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Voluntary Corrective Action Report for a Solid Waste Management Unit at TA-33

33-007(c)

Field Unit 3

Environmental Restoration Project

October 1996

A Department of Energy
Environmental Cleanup Program

DRAFT

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1.0 INTRODUCTION

Solid waste management unit (SWMU) 33-007(c) is located at Area 6 of Technical Area (TA) 33. During Phase I investigation of the SWMU, uranium was detected above screening action levels (SALs) and retained as a chemical of potential concern (COPC). SWMU 33-007(c) is identified in the Los Alamos National Laboratory's (LANL's) Hazardous Waste Facility Permit, Module VIII, as requiring a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI). An accelerated cleanup was proposed in the TA-33 September 1995 RFI report (Environmental Restoration Project 1995, 1265). Although uranium is not a RCRA, concern, this VCA report is provided for completion of the SWMU.

In 1996 a pilot project was initiated to determine the effectiveness of two methods to remove uranium from soil. Initial results suggested that the pilot project methods were effective. Therefore, a plan was developed to collect confirmatory samples, calculate cleanup levels, and investigate the SWMU as a voluntary corrective action (VCA), (Environmental Restoration Project 1996, 02-117).

Because results of confirmatory sampling, discussed in Section 3.3 of this VCA report, indicate that uranium concentrations have been reduced to acceptable levels, SWMU 33-007(c) is proposed for no further action (NFA) under Criterion 5 of the document of understanding between LANL, the New Mexico Environment Department (NMED), and the Environmental Protection Agency (EPA) (New Mexico Environment Department et al. 1995,1328). A Class III permit modification will be requested to remove this site from the HSWA Module of the Laboratory's RCRA operating permit.

2.0 SITE CHARACTERIZATION PRIOR TO CLEANUP ACTIVITY

2.1 History

Between 1947 and 1972 TA-33 was used to develop initiators, a component of nuclear weapons. Area 6 at TA-33 was a small firing site where gun-type studies were performed between 1949 and 1955. No high explosives were detonated. SWMU 33-007(c) encompasses firing activities at Area 6. Following abandonment as a firing site, the site was used for occasional experiments and office facilities. Additional historical information on Area 6 is included in the RFI Work Plan for Operable Unit 1122 (LANL 1992, 0784).

2.2 Description

SWMU 33-007(c) consists of three firing pads and a pair of catcher boxes at Area 6. One concrete firing pad lies immediately west of TA-33-16. The area surrounding the building is level and paved. Three 6-ft-square catcher boxes were approximately 20 ft south of the building and firing pad. Removal of the catcher boxes and surrounding soil revealed that a concrete pad was located under the boxes.

2.3 Previous Investigation

RFI Phase I sampling was performed at Area 6 during the 1993 and 1994 sampling campaigns at TA-33. Sections 2.4–2.7 of this VCA report summarize results from those campaigns.

2.4 Field Investigation

The 1993 and 1994 field investigations are discussed in the January and September 1995 RFI reports for TA-33 (LANL 1995, 1212; Environmental Restoration Project 1995, 1265). All samples collected were analyzed for inorganics, high explosives, uranium, and gamma emitters. A subset of samples was analyzed for pesticides, herbicides, and polychlorinated biphenyls. During the TA-33 sampling campaign in 1994, trenches were dug into catcher boxes located in the SWMU. Eight samples were collected and analyzed for uranium and inorganics.

2.5 Evaluation of Inorganic Chemicals and Radionuclides

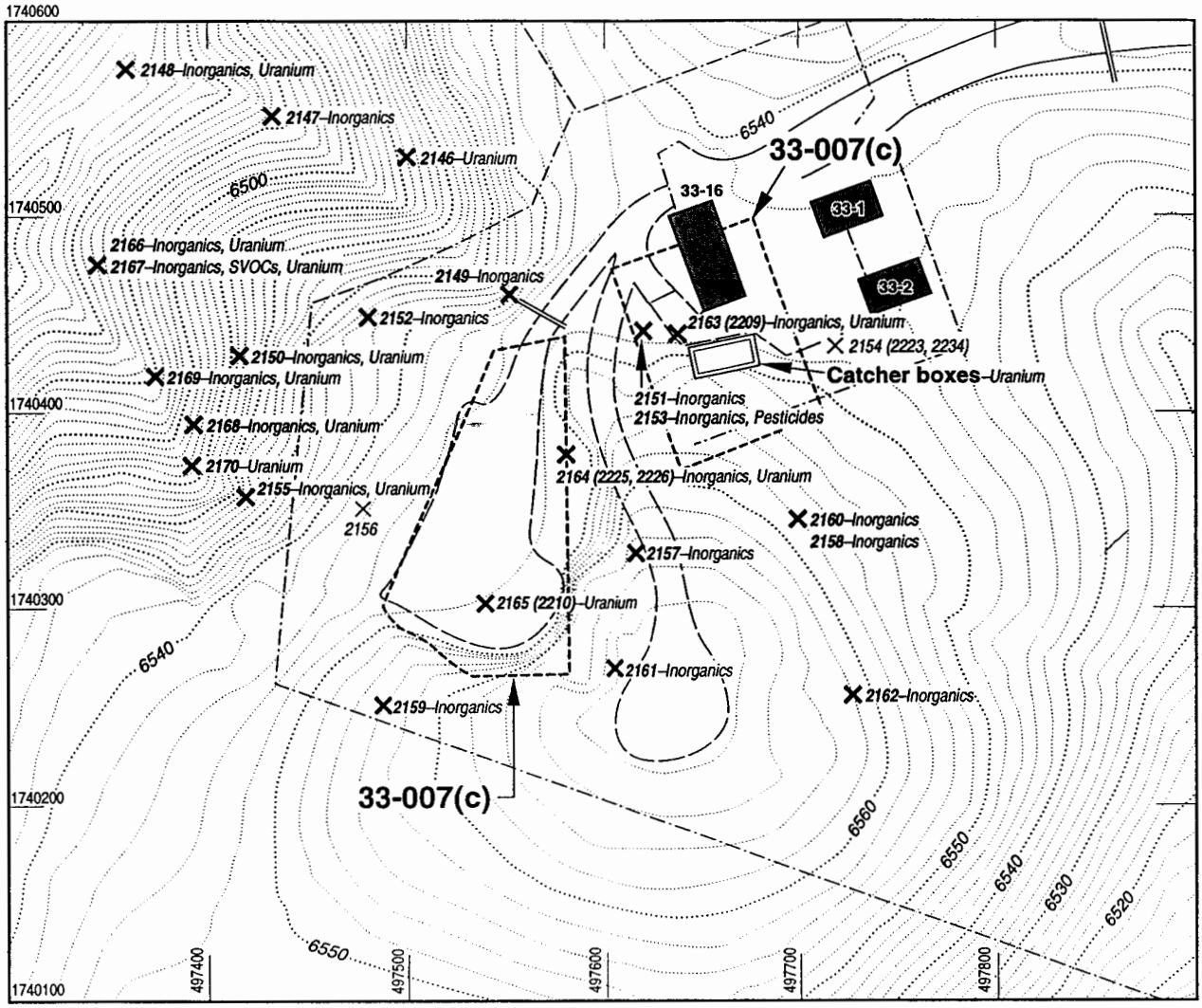
Inorganic chemicals. Analyses from the 1993 sampling campaign indicated that arsenic and beryllium were above background in two samples. Lead, nickel, and zinc were detected in many samples above background but below SALs. Sample AAA2164 and its two field splits contained elevated levels of cadmium, chromium, nickel, lead, antimony, and zinc. Table 2.5-1 lists inorganic contaminants found above background upper tolerance limits (UTLs) and Fig. 2.2-1 shows sample locations from the 1993 sampling campaign (LANL 1995, 1212).

TABLE 2.5-1

INORGANICS DETECTED ABOVE BACKGROUND UTLs IN THE 1993 SAMPLING CAMPAIGN

SAMPLE ID	ARSENIC (mg/kg)	BARIUM (mg/kg)	BERYLLIUM (mg/kg)	CADMIUM (mg/kg)	CHROMIUM (mg/kg)	NICKEL (mg/kg)	LEAD (mg/kg)	ANTIMONY (mg/kg)	ZINC (mg/kg)
SAL	Background	5 300	Background	38	210	1 500	400	31	23 000
LANL UTL	7.82	315	1.95	2.7	19.3	15.2	23.3	1	50.8
AAA2150	2.7	240	0.81	<0.4	6.3	*44*[a]	13	<0.07	*67*
AAA2151	1.9	100	0.35	<0.4	4.6	8	*80*	0.25	47
AAA2152	5.0	*330*	1.2	<0.4	12	*60*	15	<0.07	*57*
AAA2153	2.6	110	0.51	<0.4	5.9	14	*57*	<0.07	44
AAA2154	3.4	150	0.86	<0.4	9	*25*	17	0.22	*56*
AAA2223	2.7	130	0.75	0.5	10	*21*	13	<0.1	*64*
AAA2224	3.2	150	0.9	0.5	11	*22*	14	0.27	*70*
AAA2155	3.0	250	0.65	0.9	8.5	*67*	*39*	0.13	*75*
AAA2156	1.5	74	0.75	<0.4	6.2	5	*36*	<0.07	38
AAA2157	*10.9*	*370*	*2.3*	<0.4	30	*41*	21	<0.1	*61*
AAA2158	5.5	290	1.2	0.5	14	*39*	20	<0.07	46
AAA2159	4.7	*320*	1.4	<0.4	27	*50*	19	<0.07	46
AAA2160	5.0	280	1.4	<0.4	17	*38*	16	<0.07	50
AAA2161	*11.2*	*700*	*2.4*	0.4	25	*53*	16	0.105	*60*
AAA2162	3.5	310	1.5	<0.4	15	*47*	14	0.13	47
AAA2163	4.9	210	1	0.5	18	*33*	21	0.15	50
AAA2209	5.2	230	1.2	<0.4	13	*32*	*26*	<0.1	*51*
AAA2164	4.0	230	1.3	*4.4*	*52*	*850*	*150*	*2.6*	*210*
AAA2225	4.6	260	1.3	*3.8*	*62*	*530*	*130*	0.34	*220*
AAA2226	3.6	200	1.1	*3.6*	*54*	*440*	*120*	2.2	*190*
AAA2165	1.6	100	0.23	<0.4	6.3	8	*24*	0.15	26
AAA2210	1.8	200	0.34	0.5	7.7	11	*33*	<0.1	41
AAA2146	1.2	133	0.9	<0.8	6.8	11	12	<11.2	46.8
AAA2147	1.0	204	0.76	1.8	10.3	*46*	14	<11.2	*108*
AAA2148	4.0	210	0.93	<0.4	8	*38*	14	<0.07	*51*
AAA2149	1.1	291	0.74	1.5	7.4	*52*	16	<11.2	*78.5*
AAA2166	2.4	220	0.84	<0.4	7	*46*	13	<0.1	39
AAA2167	1.7	160	0.52	<0.4	4.4	*32*	10	<0.04	27
AAA2168	2.5	220	0.74	1.1	6.6	*45*	*38*	0.15	*130*
AAA2169	1.3	130	0.63	<0.4	4.3	*34*	7	<0.04	30
AAA2081	2.9	260	1.1	<0.4	19	*32*	16	<0.06	*57*

[a] Italicized results are above LANL background UTLs



Sources: FIMAD 1993, G101009, G101010, G101476
Modified by: cARTography by A. Kron 1/26/95

Permanent structure
Paved road
Unimproved road/trail
Fence
Storm drain/culvert
PRS boundary

X 2154 Sample location and number—no elevated levels found
X 2164 Sample with PCOCs detected above LANL background levels
(2223, 2234) Duplicate samples are shown in parentheses

0 50 100 ft

Contour interval = 2 ft

N

Fig. 2.5-1. SWMU 33-007(c) showing 1993 sampling locations.

Catcher box sampling in 1994 indicated that lead, nickel, silver, and zinc were above LANL background levels but below SALs (Environmental Restoration Project 1995, 1265).

Uranium. Sample AAA2164 and its field splits in the cinder cone contained elevated levels of uranium in addition to the inorganics listed above.

During 1994 trenching in the catcher boxes, a pocket of corroded uranium was uncovered. Two soil samples taken near the pocket contained elevated uranium, one in excess of 6 000 mg/kg. Samples collected elsewhere in the catcher box soil contained uranium at background levels.

2.6 Evaluation of Organic Chemicals

Organic analyses are discussed in the January 1995 RFI report (LANL 1995, 1212). PCBs detected in SWMU 33-007(c) samples were assigned to SWMU 33-009, an overlapping canyonside disposal area where a VCA is planned.

2.7 Human Health Assessment

2.7.1 Screening Assessment

Inorganic analyses for 31 samples collected across SWMU 33-007(c) are presented in the January 1995 RFI report for TA-33 (LANL 1995, 1212). Results for inorganics above LANL background UTLs are reproduced from that report in Table 2.5-1 of this VCA report. Results for samples collected in the catcher boxes are presented in the September 1995 RFI report (Environmental Restoration Project 1995, 1265).

Inorganic chemicals. As discussed in the January 1995 RFI report, beryllium and arsenic were found above LANL background (95%, 0.95) UTLs in two samples (AAA2157 and AAA2161) collected at the top of the cinder cone in a relatively undisturbed area above the Area 6 developed sites. Only these two samples contained arsenic and beryllium above the UTLs, but in the remaining samples both elements also tended to be elevated relative to TA-33 background. In general, samples from this area include material derived from an unusual (for LANL) matrix of basaltic cinders, which are high in iron and in elements that tend to be associated with iron in soils. For example, several samples from SWMU 33-007(c) were above LANL background levels for chromium and nickel, elements that are positively correlated with iron in LANL background samples, as discussed in Section 3.2.2.1 of the RFI report (Environmental Restoration Project 1995, 1212). These observations are summarized in Table 2.7-1. Consequently, arsenic and beryllium are judged not to be associated with programmatic activities at Area 6, but rather to represent the high end of natural background concentrations in this area.

TABLE 2.7-1

COMPARISON OF ARSENIC AND BERYLLIUM CONCENTRATIONS WITH LANL BACKGROUND VALUES

STATISTIC	AAA2157	AAA2161
Arsenic concentration (mg/kg)	10.9	11.2
Arsenic LANL (95%,0.95) UTL[a] (mg/kg)	7.82	7.82
Arsenic framework maximum (mg/kg)	11.2	11.2
Beryllium concentration (mg/kg)	2.3	2.4
Beryllium LANL (95%,0.95) UTL (mg/kg)	1.95	1.95
Beryllium framework maximum (mg/kg)	4	4

[a] UTL = Upper tolerance limit.

Another sample (AAA2164 with two field splits), collected from a location in the cinder cone adjacent to one of the gun mounts, contained cadmium, chromium, nickel, lead, antimony, and zinc, as well as uranium, at levels well above both LANL-wide and local background levels. Table 2.7-2 shows the results of a multiple constituent evaluation (MCE) for the elevated inorganic chemicals at the location of sample AAA2164. Lead is excluded from this calculation because its toxicity is based on lead uptake in children (EPA 1994, 1178). Uranium, as a radioactive carcinogen, is handled separately (see below). Because the SALs for cadmium and chromium have been approximately halved since January 1995, the result shown in Table 2.7-2 (1.1) is different than the result shown in Table 4-16 (0.8) of the original RFI report (LANL 1995, 1212).

TABLE 2.7-2

MULTIPLE CONSTITUENT EVALUATION FOR NONCARCINOGENIC EFFECTS OF INORGANICS DETECTED IN SAMPLE AAA2164 AND ITS FIELD SPLITS

ANALYTE	SAMPLE ID	MAXIMUM SOIL CONCENTRATION (mg/kg)	SOIL SAL (mg/kg)	CONCENTRATION NORMALIZED TO SAL
Antimony	AAA2164	2.6	31	0.08
Cadmium	AAA2164	4.4	38	0.1
Chromium	AAA2225	62	210	0.3
Nickel	AAA2164	850	1 500	0.6
Zinc	AAA2225	220	23 000	0.005
TOTAL				1.1

The MCE for noncarcinogenic effects slightly exceeds the target value of 1. However the concentrations of these elements in the 1993 data set of contaminants exceeding UTLs (Table 2.5-1 of this VCA report) does not suggest a significant contaminant release. Any area of inorganic contamination at SWMU 33-007(c) is projected to be limited. The potential human health concern that would be evaluated with a recreational exposure scenario at this site is considered low. Risk calculations using the shorter exposure duration and smaller exposure frequency associated with the recreational land use assumed for TA-33 reduce the possibility of realizing adverse health impacts from soil exposure. Therefore, additional evaluation of metals for human health risk will not be pursued at this SWMU and these inorganics will not be carried forward through the screening level process as COPCs.

For inorganics detected in the catcher boxes during the 1994 sampling campaign, an MCE for noncarcinogenic effects indicated that inorganics were not present in catcher box soil at levels of concern. Catcher box inorganics were not carried forward through the screening process as COPCs (Environmental Restoration Project 1995, 1265).

Uranium: The only chemical of concern at SWMU 33-007(c) was uranium, observed at high levels in two samples during the RFI investigation of the catcher boxes (Environmental Restoration Project 1995, 1265), and at levels above both background and SAL in AAA2164 and its field splits (LANL 1995, 1212).

Because uranium results for sample AAA2164 and its field splits (72, 91, and 84 mg/kg) are above SAL (LANL 1995, 1212), they are compared with the cleanup levels discussed in Section 3.1 of this VCA report. A total uranium concentration of 374 mg/kg is necessary to deliver the EPA-allowable maximum dose of 15 mrem per year under a recreational scenario, assuming the isotopic distribution of natural uranium. The maximum concentration of uranium (91 mg/kg) measured at this point is less than 25% of the 374 mg/kg limit. Based on these calculations, the total dose associated with uranium isotopes in sample AAA2164 and its field splits, considered as a source of exposure in the recreational scenario and used to calculate the cleanup levels, is well within EPA limits. Therefore, uranium is not considered a COPC at SWMU 33-007(c) outside of the catcher boxes.

2.7.2 Risk Assessment

No risk assessment was performed for SWMU 33-007(c) because a cleanup was planned.

2.8 Preliminary Ecological Assessment

In cooperation with the NMED and EPA Region 6, the Laboratory Environmental Restoration (ER) Project is developing an approach for ecological risk assessment. Further ecological risk assessment at this site will be deferred until the site can be assessed as part of the ecological exposure unit methodology currently being developed.

2.9 Extent of Contamination

Elevated uranium concentrations of concern were confined to localized spots in the catcher boxes. Total volume of the catcher boxes was approximately 200 yd^3. Subsequent soil separation indicated that 9 yd^3 of that volume were contaminated (Section 4.1 of this VCA report).

2.10 Conclusions and Recommendations

The MCE calculations in Section 2.7 of this VCA report indicate that inorganics are not a concern at SWMU 33-007(c) under a recreational scenario. As a result of the analyses discussed in the original RFI reports and summarized above, uranium was the only COPC identified at SWMU 33-007(c) (LANL 1995, 1212; Environmental Restoration Project 1995, 1265). Uranium was found to be above levels of concern only in the catcher boxes south of TA-33-16, where limited RFI data suggested that it might be confined to small pockets surrounded by uncontaminated soil.

A pilot study was conducted in 1996 to separate uranium-contaminated soil from clean soil. Initial data collected during the cleanup campaign indicated satisfactory separation. A VCA plan was developed to describe the objectives of the pilot study and define the cleanup objectives. A VCA was appropriate at this site because the following criteria were met.

- The contaminant of concern (uranium) was defined, as well as its nature and extent.
- Removal time was less than six months and waste facilities were available.
- Remedy was obvious and final.
- Land-use assumptions were straightforward.
- Cleanup costs were reasonable for the planned action.

As discussed in Section 3.3 of this VCA report, uranium concentrations were reduced below levels of concern during soil separation. Soil returned to the site of the catcher boxes is below cleanup levels.

Only radioactive contamination, subject to DOE regulatory authority, was found at SWMU 33-007(c). For nonradioactive contaminants, five criteria have been agreed upon under which a SWMU may be proposed for NFA (New Mexico Environment Department et al. 1995, 1328). The appropriate criterion for the NFA proposed for SWMU 33-007(c) is Criterion 5: the SWMU has been characterized or remediated in accordance with current applicable state or federal regulations, and the available data indicate that contaminants of concern are either not present or are present in concentrations that would pose an acceptable level of risk under the projected future land use.

Based on the radiological cleanup and NFA Criterion 5, SWMU 33-007(c) is recommended for NFA.

3.0 REMEDIAL ACTIVITIES AND RESULTS OF CONFIRMATORY SAMPLING

Because high concentrations of uranium occurred in distinct pockets and the remaining soil was known to be at background levels, a pilot study was performed to reduce uranium concentrations below levels of concern. The study included mechanically separating clean soil from radioactively contaminated soil. Contaminated soil was leached to remove uranium.

3.1 Cleanup Level Derivation

Derivation of cleanup levels was presented in the VCA plan for SWMU 33-007(c). Modeling calculations using the Residual Radioactive (RESRAD) computer code determined concentrations of residual uranium acceptable to meet regulatory requirements of the proposed EPA dose limit of 15 mrem/yr. RESRAD calculations assumed a recreational scenario exposure for typical recreational time periods for picnickers and trail users. Table 3.1-1 lists several key assumptions used to calculate the maximum total allowed dose.

TABLE 3.1-1

RECREATIONAL SCENARIO RESRAD INPUT PARAMETERS FOR SWMU 33-007(c)

PARAMETER	ASSUMPTIONS
Allowed dose/year	15 mrem
Area of contaminated zone	1 960 yd^3, 9 ft deep
Time spent on site	9 days/year, 3 hr/day
Inhalation rate (recreational)	50.4 yd^3/day of air inhaled
Dust mass loading	0.00045 g/yd3
Soil Ingestion Rate	0.2 g/day (Approximately 0.003 ounces)

In order for the picnicker not to exceed the proposed EPA dose limit (the most conservative case), the total dose from all uranium isotopes in the soil must be reduced below 15 mrem/yr. Single radionuclide soil guidelines were calculated for uranium-234, -235, and -238 assuming the picnicker scenario. A basic radiation dose limit of 15 mrem/year was set for each isotope. Results are shown in Table 3.1-2. These activities are equivalent to a concentration of 374 mg/kg, assuming the isotopic distribution of natural uranium.

TABLE 3.1-2

SINGLE RADIOACTIVE SOIL GUIDELINES CALCULATED BY RESRAD TO PRODUCE A DOSE OF 15 mrem/YR

ISOTOPE	GUIDELINE
Uranium-234	114 pCi/g
Uranium-235	72 pCi/g
Uranium-238	116 pCi/g

To determine if residual uranium at the site meets EPA guidelines, the 0.95 upper confidence bound (UCB) for the mean concentration of each isotope in the clean soil will be calculated. The reasonable maximum dose based on these UCBs will be calculated as

$$15 \sum Ui/U_{gi} ,$$

where U_i is the UCB for the ith isotope and U_{gi} is the guideline for the ith isotope from Table 3.1-1. If this reasonable maximum dose is less than 15 mrem/year, the site will meet EPA guidelines. See Section 3.3 of this RFI report for results of confirmatory sampling.

3.2 Remedial Implementation

A total of 202 yd^3 of soil was processed· Soil separation was performed by the Thermo Nuclean Segmented Gate System™ (SGS) in April/May 1996. Soil from the catcher boxes was delivered to a hopper on the SGS plant where large rocks and other debris were caught by a mesh and rejected. Soil was delivered at a uniform thickness to a conveyor belt that passed under a set of gamma radiation detectors. A series of gates on the conveyor belt diverted contaminated soil to collection bags; clean soil was deposited in separate piles. At the conclusion of the campaign, discarded rocks were hand screened for radioactivity and returned to the catcher box area, together with the clean soil. A description of the SGS is given in Attachment A.

During removal of large pieces in the SGS hopper, 56 experimental projectiles were discovered. These were non-exploding containers for experimental devices. The projectiles were 2.5 in.-diameter cylinders varying from 5 to 22 in. long. Radiography indicated that they were solid metal except for small cavities. The cavities appeared to be empty. Most projectiles appeared to be steel or metal alloys; some were made of uranium. They were removed to locked storage pending investigation to determine proper management and disposal methods.

Bags containing contaminated soil were leached by the LANL-developed containerized vat leaching (CVL) system using a solution of sodium bicarbonate, that preferentially dissolves uranyl hydroxides, the form of uranium present. Uranyl carbonate was collected on resin columns and the carbonate

solution reused. This process is described in the VCA plan. Details of the pilot study are given in Attachment B. The CVL study is continuing. Uranium-contaminated soil separated by the SGS plant has been retained as experimental material.

3.3 Confirmatory Sampling

To determine if the soil and area of the catcher boxes met cleanup goals, a total of 20 confirmatory soil samples were collected (Table 3.3-1). All samples were analyzed for isotopic uranium.

- Eight samples represented the material remaining at the back and bottom of the area of excavation.
- Twelve samples, including two field duplicates, represented the SGS clean pile material that was returned to the excavated area.

The eight samples collected at the back and bottom of the excavation were biased toward locations around and below areas where projectiles were found during excavation (Fig. 3.3-1). All isotopic uranium measurements on these samples were below the (.95,.95) UTLs for background (Table 3.3-1).

TABLE 3.3-1

CONFIRMATORY SAMPLES FROM THE EXCAVATION

SAMPLE ID	REQUEST NUMBER	LOCATION	URANIUM-234 (pCi/g)	URANIUM-235 (pCi/g)	URANIUM-238 (pCi/g)
Cleanup level	N/A [a]	N/A	114	72	116
UTL	N/A	N/A	1.94	0.084	1.82
33-96-0181	2136	Bottom of east box, beneath projectile location	0.75	0.05	0.81
33-96-0182	2136	Bottom of west box, beneath projectile location	0.93	0.04	0.93
33-96-0183	2136	Bottom of west box, beneath projectile location	1.02	0.05	1.00
33-96-0184	2136	Bottom of excavation, beneath hot spot	1.83	0.07	1.34
33-96-0185	2136	Back of east box, beneath projectile	0.86	0.04	0.88
33-96-0186	2136	Back of box near excavated projectiles	0.82 (R) [b]	0.04 (R)	0.88 (R)
33-96-0187	2136	Back of box near excavated projectiles	1.13	0.06	1.14
33-96-0188	2136	Back of box near excavated projectiles	1.25	0.07	1.16

[a] N/A = Not applicable.
[b] R = Results are rejected because of sample preparation irregularities.

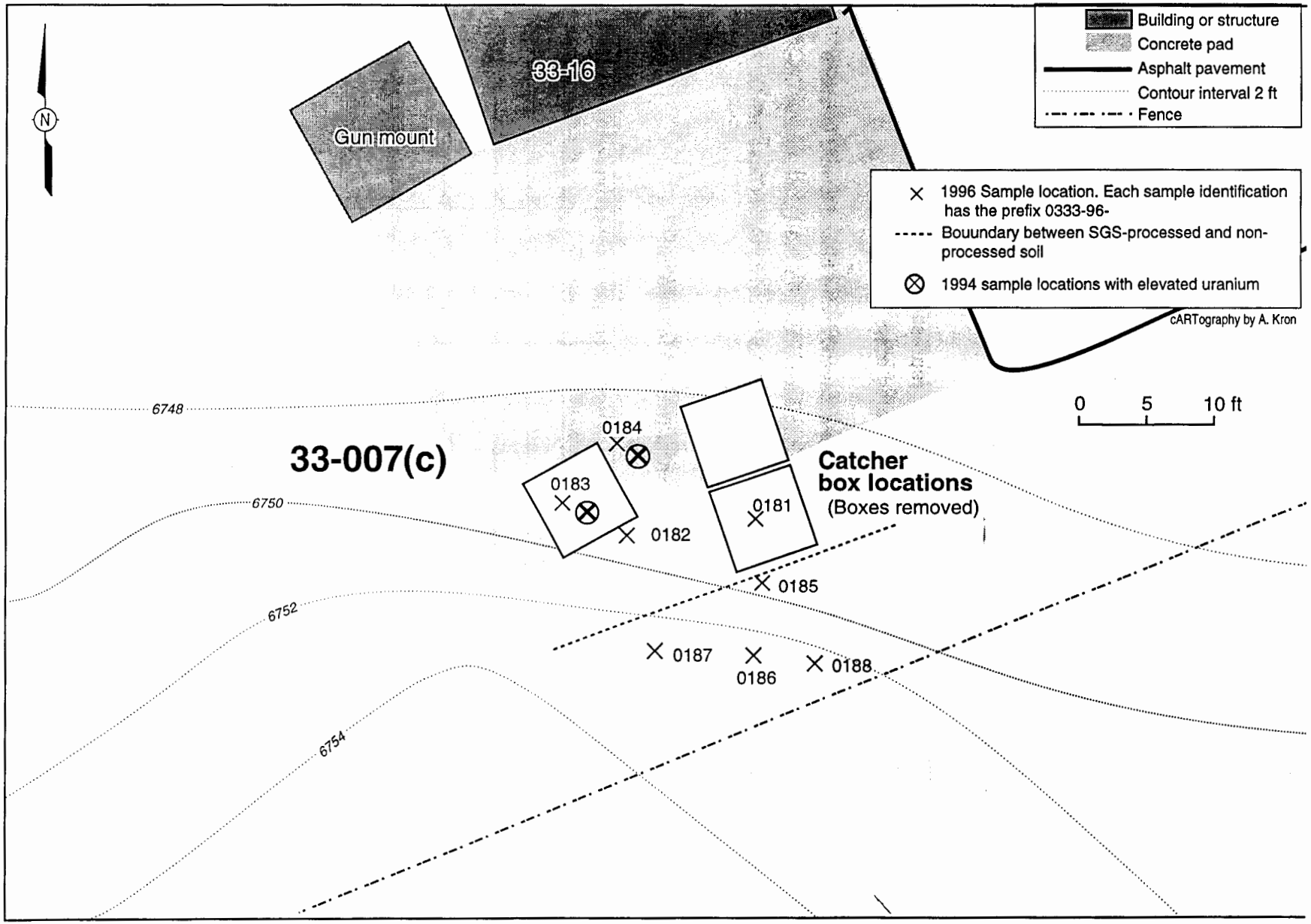


Fig. 3.3-1. Confirmatory sampling locations at SWMU 33-007(c) catcher box location.

Samples collected from the SGS clean pile were distributed across seven processing days. Results were generally above background, and the data indicate considerable heterogeneity in this material (Table 3.3-2). However, the highest isotopic uranium results, obtained for sample 33-96-0170 on day 5, were less than 25% of the cleanup levels.

TABLE 3.3-2

CONFIRMATORY SAMPLES FROM THE SGS CLEAN PILE

SAMPLE ID	REQUEST NUMBER	LOCATION	URANIUM-234 (pCi/g)	URANIUM-235 (pCi/g)	URANIUM-238 (pCi/g)
Cleanup level	N/A [a]	N/A	114	72	116
UTL	N/A	N/A	1.94	0.084	1.82
33-96-0166	96-06-199	SGS clean pile, day 1	16.73	0.67	16.57
33-96-0167	96-06-199	SGS clean pile, day 2	3.16	0.10	3.13
33-96-0168	96-06-199	SGS clean pile, day 3	2.47	0.08	2.69
33-96-0169	96-06-199	SGS clean pile, day 4	14.55	0.68	13.94
33-96-0179	96-06-199	Duplicate of 33-96-0169	11.2	0.42	11.1
33-96-0170	96-06-199	SGS clean pile, day 5	26.96	1.14	27.34
33-96-0171	96-06-199	SGS clean pile, day 6	2.01	0.07	1.87
33-96-0172	96-06-199	SGS clean pile, day 7	1.56	0.07	1.53
33-96-0173	96-06-199	SGS clean pile, day 7	1.75	0.07	1.81
33-96-0174	96-06-199	SGS clean pile, after rerun of day 1 clean pile with lower settings	7.3	0.26	7.51
33-96-0180	2136	Duplicate of 33-96-0174	3.3	0.13	3.22
33-96-0175	96-06-199	SGS clean pile, after rerun of day 6 clean pile	16.02	0.06	15.96

[a] N/A = Not applicable.

Data from the SGS clean pile can be used to estimate the exposure of a recreational user of the site, assuming (very conservatively) that his total exposure while at the site comes from the material in this pile. For this purpose, results from 10 of the 12 samples shown in Table 3.3-2 are used. The field duplicate results, obtained by splitting homogenized samples, were not considered to be independent measurements. Because the data are skewed to the right, calculations were made using lognormal assumptions following the method described by Gilbert (1987, 0506). Results are shown in Table 3.3-3.

TABLE 3.3-3

STATISTICS FOR MATERIAL IN SGS CLEAN PILE[a]

STATISTIC	URANIUM-234	URANIUM-235	URANIUM-238
Cleanup level (pCi/g)[U_{gi}]	114	72	116
Estimate for mean activity (pCi/g)	9.34	0.302	9.44
95% UCB[a] for mean activity (pCi/g)U_i]	15.8	0.515	15.7
Fraction of PRG [U_i/U_{gi}]	0.136	0.007	0.138
Reasonable maximum dose (mrem/year)	$15 \sum U_i/U_{gi} = 4.2$		

[a] UCB = upper confidence bound.

Based on the calculations shown in Table 3.3-3, the total dose of 4.2 mrem/yr associated with all uranium isotopes in the SGS clean pile material, considered as the source of exposure for the picnicker used to calculate the PRGs, is less than 30% of the EPA dose limit of 15 mrem/yr. Therefore the SGS clean pile material will be left on the site, and SWMU 33-007(c) is recommended for NFA.

4.0 WASTE MANAGEMENT

4.1 Waste Minimization, Recycling, and Waste Avoidance

Three samples were collected to represent material diverted by the SGS for the CVL process. Results are shown in Table 4.1-1. Results for sample 33-96-0189 shown in Table 4.1-1 are from a CVL bag after leaching. All contaminated material diverted from the SGS has been retained as experimental material for further experiments using the CVL process. See Attachment B of this VCA report for a description of the CVL pilot study.

Leached soil that meets the cleanup criteria described in Section 3.1 of this VCA report will be returned to the catcher box site. Material failing the criteria will be disposed at LANL TA-54, Area G, as radioactive waste.

TABLE 4.1-1

CVL CHARACTERIZATION SAMPLES

SAMPLE ID	REQUEST NUMBER	LOCATION	URANIUM-234 (pCi/g)	URANIUM-235 (pCi/g)	URANIUM-238 (pCi/g)
33-96-0176	96-06-199	Clean pile after SGS rerun of a "hot" pile (material then leached).	205.82	8.05	210.23
33-96-0177	96-06-199	CVL bag #3 prior to leaching, sample included a piece of oxidized uranium	930	36	943
33-96-0178	96-06-199	CVL bag #3 prior to leaching	73.24	2.74	72.85
33-96-0189	2476	CVL bag #1 after leaching	45.5	2.02	45.7
33-96-0189D	2476	Laboratory duplicate	42.1	1.85	42.9

Chunks of uranium removed from the CVL bags by hand or mechanical screening prior to leaching and uranium uranium-contaminated material generated by leaching will be sent to LANL TA-54, Area G as radioactive waste,.

Projectiles were radiographed to identify uranium-containing and nonradioactive items. They will be segregated and disposed of appropriately.

- Projectiles free of uranium will be sectioned to determine if hazardous metals are present. If no such metals are found, the projectiles will be sent to a contract recycle firm.
- Projectiles containing both hazardous metals and uranium will be disassembled and segregated into hazardous and radioactive components for disposal.
- Projectiles containing hazardous metals will be sent to an approved RCRA facility for disposal.
- Projectiles containing uranium will be disposed of as radioactive waste.

4.2 Comparisons with VCA Plan

Table 4.2-1 compares the estimated actual volumes of generated VCA waste with projected waste volumes estimated in the VCA Plan (Environmental Restoration Project 1996, 02-117). Discrepancies are due to the following:

- Catcher box timbers and associated municipal wastes were not included in the projected waste volume estimate.
- Projectile disassembly is anticipated to successfully separate recyclable industrial waste from hazardous and radioactive components.
- Uranium was found to be a larger component of several projectiles than expected.

Because of continuing experimentation with the CVL system, actual waste volumes are not known at this time. The objective of the CVL pilot is maximum waste reduction.

TABLE 4.2-1

ESTIMATED ACTUAL VOLUMES COMPARED WITH PROJECTED WASTE VOLUMES

SWMU ID	WASTE TYPE	PROJECTED BULK VOLUME	ESTIMATED ACTUAL BULK VOLUME
33-007(c)	Municipal refuse	1 yd^3	4 yd^3
	Radioactive liquid (CVL)	15 gal.	30 gal.[a]
	Radioactive solid (CVL)	15 gal.	15 gal.[a]
	Recyclable metals (projectiles)	0.10 yd^3	0.8 yd^3 [b]
	Radioactive (projectiles)	0.05 yd^3	0.1 yd^3 [b]
	Mixed	0.01 yd^3	0 yd^3 [b]
	Hazardous (projectiles)	0.01 yd^3	<0.1 yd^3 [b]

4.3. Type of Waste and Waste Characterization Methods

Natural uranium, the principal contaminant, was characterized by beta/gamma Geiger counters and fixed laboratory isotopic uranium analysis. Radiography of projectiles was performed in September 1996 by LANL radiography group ESA-MT. Analysis of radiographic data will be used to determine appropriate disposal. Disassembly and further analysis of the metal composition by x-ray fluorescence may be needed.

4.4 DISPOSAL LOCATIONS

Nonhazardous, nonradioactive, nonmetallic waste has been sent to a sanitary landfill. Following disassembly of the projectiles, nonhazardous, nonradioactive waste will be recycled with a commercial recycle company. Radioactive and hazardous waste (if found) will be sent to LANL disposal facilities at LANL TA-54. Mixed waste is not anticipated because of planned disassembly of uranium-containing projectiles, with subsequent segregation into nonhazardous and radioactive waste. Radioactive waste generated by continuing CVL experiments will be disposed after all experimental work is completed.

5.0 REFERENCES

Environmental Restoration Project, September 29, 1995. "RFI Report for TA-33, PRSs 33-003(a), 33-004(a), 33-007(c), 33-009, 33-011(d), 33-013, 33-016, 33-017 and Revised Sampling Plans for PRSs 33-003(b), 33-004(k), 33-008(a), 33-008(b), C-33-001, C-33-002," Los Alamos National Laboratory Report LA-UR-95-3625, Los Alamos, New Mexico. **(Environmental Restoration Project 1995, 1265)**

Environmental Restoration Project, September 29, 1996. "VCA Plan for TA-33, SWMU 33-007(c)," Los Alamos National Laboratory Report LA-UR-96-2942, Los Alamos, New Mexico. **(Environmental Restoration Project 1996, 02-117)**

EPA (US Environmental Protection Agency), February 1994. "Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children," EPA 540-R-93-081, Office of Emergency and Remedial Response, Washington, DC. **(EPA 1994, 1178)**

Gilbert, R. O., 1987. *Statistical Methods for Environmental Pollution Monitoring*, Van Nostrand Reinhold, New York, New York. **(Gilbert 1987, 0506)**

LANL (Los Alamos National Laboratory), May 1992. "RFI Work Plan for Operable Unit 1122," Los Alamos National Laboratory Report LA-UR-92-925, Los Alamos, New Mexico. **(LANL 1992, 0784)**

LANL (Los Alamos National Laboratory), January 1995. "RFI Report for TA-33," Los Alamos National Laboratory Report LA-UR-95-882, Los Alamos, New Mexico. **(LANL 1995, 1212)**

New Mexico Environment Department, US Environmental Protection Agency, Los Alamos National Laboratory, Sandia National Laboratory, November 16, 1995. "Environmental Restoration Document of Understanding," Santa Fe, New Mexico. **(New Mexico Environment Department et al. 1995, 1328)**

APPENDIX A RAW RFI CHARACTERIZATION DATA

1. Screening Data. No screening data were used in decisions at this solid waste management unit.

2. Confirmatory Sampling Data. All confirmatory sampling data are shown in Tables 3.3-1 and 3.3-2. of this voluntary corrective action (VCA) report.

3. Waste Characterization Data. No samples were collected for waste characterization at this SWMU.

Chemicals that are reported by analytical laboratories that are nonhazardous, below Laboratory background levels, or as undetected have not been included in the tables of this VCA report. Nonetheless, these analytes are part of the decision-making process and it is important to note that these chemicals were analyzed for. Analytes included in the inorganic analytical suite for this VCA report are listed below.

Aluminum	Beryllium	Cobalt	Magnesium	Potassium	Thallium
Antimony	Cadmium	Copper	Manganese	Selenium	Vanadium
Arsenic	Calcium	Iron	Mercury	Silver	Zinc
Barium	Chromium	Lead	Nickel	Sodium	

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APPENDIX B QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

Validated data are available in Facility for Information, Management, Analysis and Display (FIMAD) or upon request. Table B-1 summarized data validation for confirmatory samples for SWMU 33-007(c).

Samples are submitted to analytical laboratories in batches identified by a request number. Request numbers for each sampling campaign at SWMU 33-010(b) are referenced in Tables 3.3-1, 3.3-1, and 4.4-1 and of this voluntary corrective action (VCA) report. Table B-1 summarizes the results of quality assurance/quality control (QA/QC) data validation for all inorganic and radiological analytical results used to support recommendations in this VCA report.

TABLE B-1

DATA VALIDATION TABLE FOR SWMU 33-007(c) SAMPLES

REQUEST NUMBER	ANALYTICAL SUITE*	COMMENTS
2136	Isotopic uranium	During micro-precipitation, the funnel used for sample 33-96-0186 leaked, leading to an estimated 15-20% loss. Solutions of samples 33-96-0180 and 33-96-0186 were slow in eluting from the column and the resin had to be disturbed to completely elute the sample. This may have effected recovery of the total solution. Because of these problems, results for sample 33-96-0180 is qualified as J- (result is an estimate and suspected to be low) and sample 33-96-0186 is rejected. Trace levels of uranium activity were found in the blank. This activity is attributed to uranium in sand of the blank and was expected by the laboratory. Blank and blank spike control samples were within control limits. With the exception of sample 33-96-0186 and a low bias for sample 33-96-0180, the data are accepted as valid.
2475	Isotopic uranium	No anomalies were noted during sample preparation or analysis. Trace levels of uranium activity were found in the blank. This activity is attributed to uranium in sand of the blank and was expected by the laboratory. Blank and blank spike control samples were within control limits. Data are accepted as valid.
96-06-199	Isotopic uranium	These samples were analyzed by Thermo NUtech™ laboratories and were not submitted through the LANL ER Sample Management Facility

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APPENDIX C BEFORE AND AFTER COST COMPARISON

The pilot project at Solid Waste Management Unit (SWMU) 33-007(c) was undertaken to evaluate the technique for use at similar sites at Technical Area 33 and other sites at Los Alamos National Laboratory. Table C-1 compares projected and estimated actual costs for the pilot project and the voluntary corrective action for SWMU 33-007(c).

TABLE C-1

COST COMPARISON

ACTIVITY	PROJECTED COSTS	ACTUAL COSTS PILOT PROJECT	ACTUAL COSTS VCA PLAN
Planning and field preparation	Not projected	N/A [a]	$13 461
Cleanup	$55 750	$130 930	$2 125
Post-field operations	Not projected	N/A	$31 726
Disposal	$4 856	N/A	$9 766
Develop VCA Report	Not projected	N/A	$8 678
TOTAL	$60 606	$130 930	$65 756

[a] N/A = Not applicable.
[b] Actual costs are not known because waste has not been picked up for disposal.
[c] $77 000 of $107 400 was for activity not estimated in the plan.

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APPENDIX D CONFIRMATORY SAMPLING RESULTS TABLE

All confirmatory results are shown in Tables 3.3-1 and 3.3-2 of this voluntary corrective action report.

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APPENDIX E CERTIFICATION OF COMPLETION

The certification of completion follows this page.

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ATTACHMENT A

THE THERMO NUCLEAN™ SEGMENTED GATE SYSTEM

1.0 INTRODUCTION

This attachment describes a pilot project that utilized procedures to assay and sort uranium-contaminated material from large volumes of soil. Two preliminary assaying procedures, the mower detector and the mockup unit developed by Thermo Nuclean, were used to determine the potential value of soil sorting and the parameters needed for optimal sorting at a given site. The Segmented Gate System (SGS) developed by Thermo Nuclean was used on site to assay and sort uranium-contaminated soil into contaminated and clean components.

2.0 PROJECT OBJECTIVE

The pilot project assessed the capabilities of removing radioactive contamination from large volumes of soil to remediate sites and reduce the volume of radioactive waste. The desired outcome of the pilot project was the remediation of soils at SWMU 33-007(c). Results from this work will be used to assess the cost-effectiveness of this approach for future work at similar sites.

2.1 Technical Capabilities

The effectiveness of the SGS is influenced by soil characteristics such as soil density, radioactive species, radionuclide concentrations, and contaminant distribution and sorting. Preliminary assaying techniques, a mower detector and mockup unit, were used to measure the soil characteristics to determine fine adjustments needed to operate the SGS for optimal results.

- The mower detector system is a shielded detector box on wheels pushed over the ground at estimated speeds replicating conveyer belt speeds of the SGS. Gamma ray detectors count radiation at intervals, replicating those of the SGS. The system looks at soil of thickness between 0.5 and 3 in. The system was used to determine the radioactive distribution and variability and indicated the detector sensitivity for sorting site-specific soils using the SGS.

- The SGS mockup is run in a laboratory where the system replicates the operation of the SGS plant. The SGS mockup uses the same sodium iodide gamma ray scintillators, count geometry, shielding, and count times as the SGS. It has radiation detectors and a conveyer system. The system does not have segmented gates. However, an electronic signal is generated upon detection and a signal could activate a gate if one were present.

  The SGS mockup detector signals are processed by a multichannel analyzer (MCA) that is not present in the SGS plant. The MCA is used to determine radioactive species present in a given soil. The SGS mockup system also has an adjustable speed controller for the conveyer system. This is used to determine the best belt speed to produce increased sensitivity for the SGS.

The SGS method assays and separates uranium and other radioactive contamination from soil matrices. The procedure is capable of separating contamination from large volumes (as much as 100 000 yd3) of soil. Thermo Nuclean has shown that reduction in the volume of contaminated soil is as great as 98%.

The SGS plant includes a hopper, a conveyer system, radiation detectors, and computer controls that remove radioactively contaminated soils moving on a conveyer belt. Contaminated soil is diverted to segmented gates, then to a conveyer belt that separates it from the clean soil. Figure 2.1-1 shows a schematic of the plant.

Processed soil is first directed through a vibrating screen plant that separates larger pieces of rock, metal, or other material from the feed material (the soil that will be directed to the SGS). The feed material is directed to the hopper at the SGS plant.

The hopper holds the feed material and directs it to a motor-driven conveyer belt that moves soil through the plant. Fifteen sodium iodide detectors are mounted over the conveyor belt and are arranged in two overlapping rows of 7 and 8 detectors, respectively. Each detector has an active area measuring 100 x 100 millimeters and is encased in an aluminum housing with a thin end window. The two rows of detectors are offset to prevent radioactive particles from passing undetected between adjacent detectors. Each detector electronically reports to an individual microprocessor board that calculates amounts of radioactivity and determines whether a radioactive particle has been detected. A master control board collects data from each detector microprocessor and determines whether dispersed radioactivity has been detected and selects and actuates the eight diversion chutes of the SGS.

Fig. 2.1-1. Schematic of the Thermo Nuclean Segmented Gate System™.

When radioactive particles or distributed contamination above release criteria are detected, one or more of the eight diversion segmented gates located at the end of the sorter conveyer diverts the contaminated material. Radioactive soil is diverted directly into a special bag or dump truck to be sent to the containerized vat leaching system. The clean soil is diverted and stacked in a pile until it is transported back to its original location.

2.2 Assaying and Sorting Procedures

Procedures for setting up and using the SGS system at SWMU 33-007(c) are presented below. Standard operating procedures developed by Thermo Nuclean and LANL were followed for all operations.

2.3 Mower Detector System

The mower detector was used at SWMU 33-007(c). A plastic cover was temporarily removed from the catcher boxes to conduct this preliminary study. Soil on the upper surface of the pile was excavated with shovels to locate contaminated soil for this study. Direct reading radiation instruments were used to guide the excavation and determine the area of interest.

Clean soil and contaminated soil were studied to determine soil background and other soil characteristics. The soil was shoveled from the pile to a 2 ft x 15 ft plank. The soil on the surface of the plank was leveled to a two-inch thickness. The mower detector was moved along this leveled surface. The detector was first driven directly on the plank, with no soil, to determine environmental and cosmic background. The mower detector was moved along the surface of the plank at estimated speeds to simulate 30 ft/min speed of the SGS conveyer belt. Gamma ray counts were recorded at 0.25-second intervals.

This study helped to define parameters needed to most effectively operate the SGS by making the following determinations:

- the distribution of the contamination,
- the background radiation in the clean soil and at the site,
- the optimal belt speed for increased sensitivity, and
- the best segmented gate setup for optimal sorting.

Because uranium contamination was exposed on the surface, there was no need to further excavate the pile. The mower detector was moved along the surface of the pile as discussed above and the optimal operating conditions were determined. Upon completion of the preliminary study, the plastic cover was replace over the contaminated soil.

2.4 SGS Mockup System

To further define operating parameters for the SGS, the following quantities and types of soil were collected from the site:

- 5 gal. of clean soil,
- 5 gal. of radioactively contaminated soil near the criteria release limit, and
- 10 gal. of bulk (clean and contaminated mixture) soil.

Thermo Nuclean transported the soil to their laboratory as environmental samples in accordance with the Nuclear Regulatory Commission and Department of Transportation guidelines for shipping environmental samples.

This study helped to define the following parameters:

- soil density,
- radioactive species,
- optimal belt speed for increased sensitivity, and
- appropriate segmented gate setup for optimal sorting.

These parameters were used to adjust the SGS plant operations for each site.

2.5 SGS Plant

The SGS plant and the screening plant were set up near building TA-33-16. Heavy plastic matting was placed under the soil processing equipment to prevent potentially contaminated soils from contacting clean ground. Planning and setup of operations are were coordinated with the facility manager at TA-33. An excavation permit was obtained prior to conducting the SGS study.

Thermo Nuclean personnel operated the SGS. ICF Kaiser personnel supervised on-site activities and collected samples for off-site analysis. A trained equipment operator with a commercial driver's license operated a front-end loader and dump truck according to Occupational Safety and Health Administration (OSHA) requirements. Setup and preliminary SGS work took approximately one week and the SGS sorting activities lasted approximately two weeks. Work was interrupted for five days because of a large forest fire in nearby Bandelier National Monument.

The SGS assayed and sorted approximately 200 yd^3 of uranium-contaminated soil. A front-end loader moved soil from the catcher boxes to the screening plant, where larger chunks of material were separated from soil. Screened soil moved by conveyor belt from the screening plant to the hopper at the SGS plant, where the soil was assayed and sorted into contaminated and clean components. The contaminated soil was directed into 1-yd^3 leaching containers. Clean soil was deposited on plastic matting until it was transported back to the original site. This material was transported in the decontaminated front-end loader at the end of the separation process. Large rocks and organic material were tested for radioactivity and returned to the original catcher box site. Extraneous material, such as metal, wood, and plastic, was not returned to the catcher box site. It will be characterized and disposed of appropriately.

Air sampling monitors were set up adjacent to the plant to measure radiation levels from dust emissions. The workers most exposed to dust wore personal air monitors to measure radiation exposure from the dust. The soil was wet down if the site safety officer and radiation control personnel determined that the dust emissions were great enough to create a health and safety problem. A 200-gal. capacity tub with a hose and sprayer provided water for dust control. The soil moisture level was monitored to assure there were no complications when moving the moistened soil along the conveyer belt system of the SGS.

ATTACHMENT B

CONTAINERIZED VAT LEACHING SYSTEM

1.0 INTRODUCTION

The objective of the containerized vat leaching (CVL) project was to demonstrate the technique of leaching uranium from soil. The effectiveness of the CVL is influenced by soil characteristics such as particle size, permeability, and organic content, as well as chemical form and concentration of the radioactive species. These characteristics were determined prior to soil leaching so that adjustments could be made to achieve optimal results.

2.0 CVL SYSTEM

The heap leach procedure involves leaching uranium-contaminated soils with a bicarbonate-carbonate solution that selectively dissolves uranium. Uranium in the oxidized state (U^{6+}) is readily soluble in carbonate solutions, but minerals containing uranium in the reduced state (U^{4+}) are not readily dissolved. The overall reaction for the dissolution of uranium oxide in bicarbonate-carbonate solution to uranyl tricarbonate is as follows:

$$UO_2^{2+} + 2HCO_3^- + CO_3^{2-} \longrightarrow UO_2(CO3)_3^{4-} + 2H^+$$

The CVL process involves using an overhead sprinkler system to spray uranium-contaminated soil with sodium bicarbonate-carbonate solution. This dissolves (leaches) uranium in the form of uranyl carbonate ion. The exact amount of uranium that can be removed depends on the characteristics of the soil and the uranium. The developers of this technology have shown that 75% to 95% of the uranium can be removed.

In situ gamma counters monitor the concentrations of uranium throughout this process. The bicarbonate solution is continually recycled through the soil and the soluble uranium is removed on ion exchange resins. During the leach, samples are taken for uranium analysis. Fig. 2.0-1 is a diagram of the CVL setup.

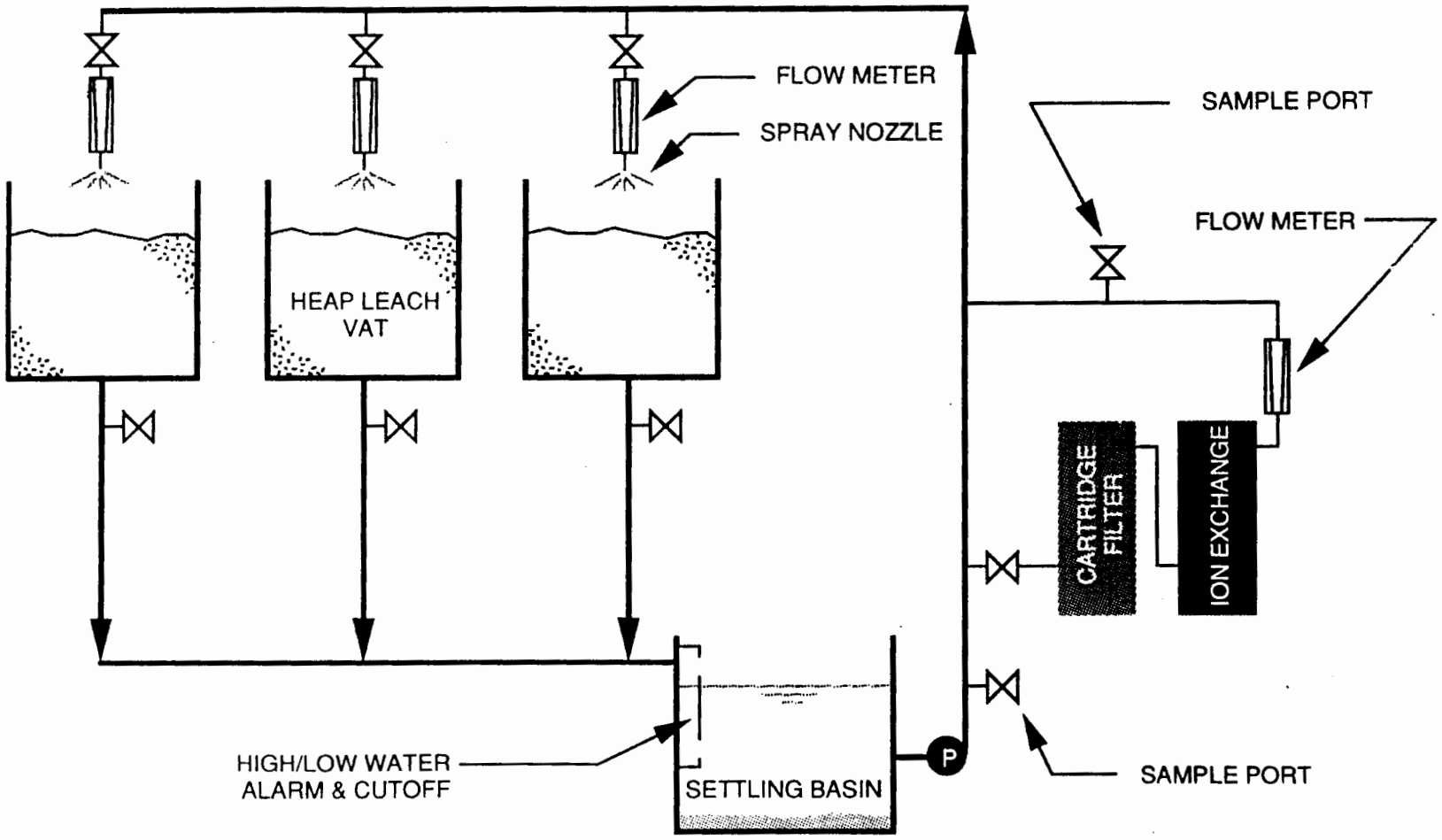

Fig. 2.0-1. Containerized Vat Leaching System flow chart.

3.0 HEAP LEACH PROCEDURES

The CVL was set up adjacent to the catcher boxes and building TA-33-16. The Los Alamos National Laboratory's Environmental Systems and Waste Characterization Group (CST-7) personnel operated CVL. ICF Kaiser personnel supervised on-site activities and collected samples for off-site analysis. Setup of the CVL lasted approximately two weeks and the leaching activities lasted approximately five months.

Prior to conducting the CVL procedure on the contaminated component (derived from the SGS separation), the following analyses were performed on the contaminated soil and were used to adjust the operation of the system:

- particle size fraction,
- organic analysis,
- speciation of radioactive constituents (by x-ray diffraction), and
- concentration of radioactivity (by LANL ER-130 method for gamma spectral analysis).

The contaminated soil was transported by conveyor belt from the SGS plant and placed into 1 yd^3 containers, then carried to the CVL setup for leaching operations. The containers are woven fabric with plastic liners and are tapered to facilitate draining liquid to the bottom of the bag. A solution of carbonate-bicarbonate reagent was sprayed on the containerized soil in a continuous, uniform fashion. The leachate drained into a settling reservoir and sediment-free solution was recycled through the system. The spent rinse may be sent to ion exchange columns where the uranium may be recovered.

The CST-7 report follows this attachment.

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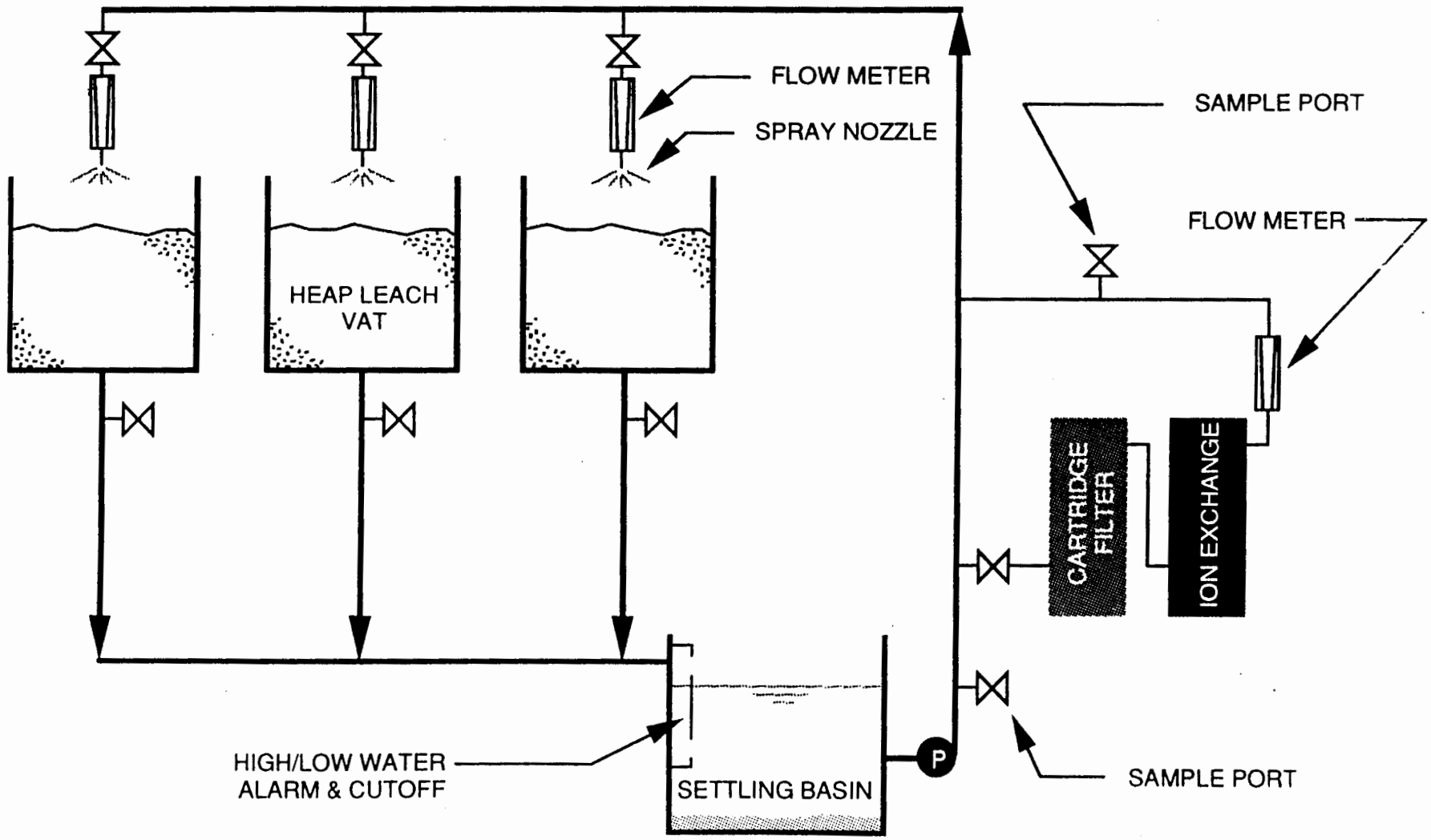
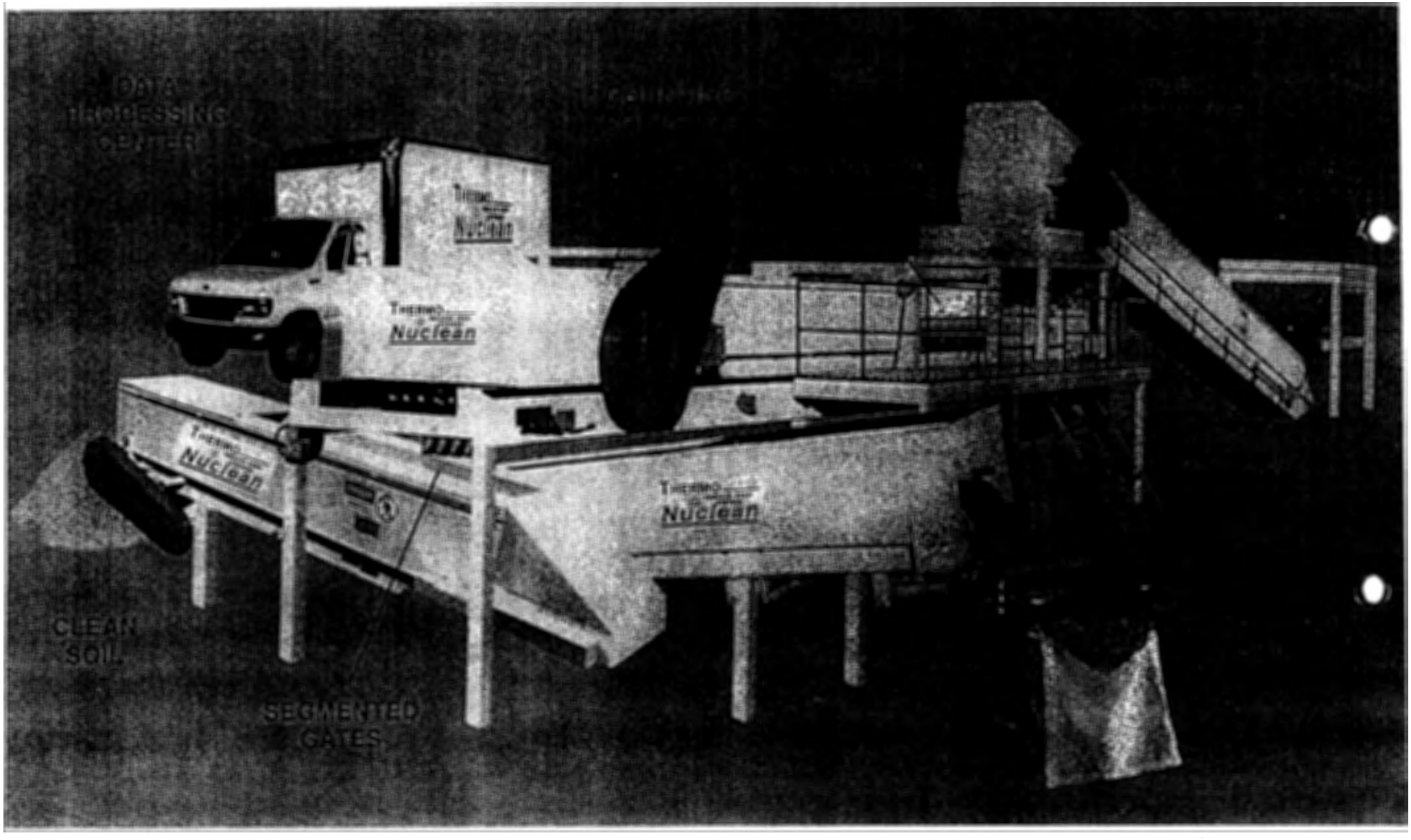
Flow Chart of Containerized Vat Leach (CVL) Process




DATA
PROCESSING
CENTER
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Nuclean
Nuclean
Nuclean
CLEAN
SOIL
SEGMENTED
GATES

ATTACHMENT H

Upper Confidence Limit(UCL) calculations for PAH Risk at PRS 33-011(a).

Calculation of Upper Confidence Limits for PAHs at PRS 33-011(a)

PAH data were collected for 27 samples from 18 locations at PRS 33-011(a). For the risk calculation, one result for each analyte for each location was used; the maximum value observed among all samples from a given location was selected for this purpose. These values are shown in Table 1.

The calculation of the mean and upper confidence limit for PAH contamination based on these data followed the method for minimum variance unbiased (MVU) estimation for lognormal populations described by Gilbert (Gilbert 1987, 0506, pp. 165-166.) Specifically, logarithms of the data in Table 1 were calculated (after replacing "<" values by one-half the reported detection limit). Then the MVU estimate of the mean is given by

$$\hat{\mu} = [\exp(\bar{y})]\Psi_n\left(\frac{s_y^2}{2}\right) \qquad (1)$$

where $\bar{y}$ is the sample mean of the logged data, s_y^2 is the sample variance, n is the sample size (18), and $\Psi_n(t)$ is a function tabled in Gilbert's book (although for our calculations we programmed this function using the series expansion given on p. 165 of that book.) An unbiased estimator of the variance of $\hat{\mu}$ is given by

$$s^2(\hat{\mu}) = \exp(2\bar{y})\left\{\left[\Psi_n\left(\frac{s_y^2}{2}\right)\right]^2 - \Psi_n\left(\frac{s_y^2(n-2)}{n-1}\right)\right\}, \qquad (2)$$

and thus a 95% upper confidence interval for the mean is computed finally as

$$\hat{\mu} + t_{n-1,0.95}s(\hat{\mu}), \qquad (3)$$

assuming approximate normality of the estimator $\hat{\mu}$ (an application of the Central Limit Theorem of probability theory) with the usual number of degrees of freedom. For n=18, the t-statistic in Equation 3 has a value of 1.74. Results are shown in Table 2.

Reference

Gilbert, R. O., 1987. Statistical Methods for Environmental Pollution Monitoring, Van Nostrand Reinhold, New York, New York. (Gilbert 1987, 0506)

Table 1. PAHs at PRS 33-011(a)

Analyte	LOCATION ID					
	33-1061	**33-1062**	**33-1063**	**33-1064**	**33-1065**	**33-1066**
Acenaphthene	<0.33	<0.33	0.49	<0.33	12.90	<0.33
Acenaphthylene	<0.33	<0.33	<0.33	<0.33	0.49	<0.33
Anthracene	0.39	<0.33	0.73	<0.33	18.60	<0.33
Benzo(a)anthracene	0.83	<0.33	1.40	<0.33	26.90	<0.33
Benzo(a)pyrene	0.79	<0.33	1.60	<0.33	28.80	0.52
Benzo(b)fluoranthene	0.60	<0.33	1.40	<0.33	28.40	0.69
Benzo(g,h,i)perylene	0.63	<0.33	0.57	<0.33	12.60	<0.33
Benzo(k)fluoranthene	0.57	<0.33	1.60	<0.33	21.40	0.47
Chrysene	0.85	<0.33	1.60	<0.33	29.20	0.54
Dibenz(a,h)anthracene	<0.33	<0.33	<0.33	<0.33	4.70	<0.33
Fluoranthene	1.70	<0.33	2.60	<0.33	54.10	0.99
Fluorene	<0.33	<0.33	0.50	<0.33	15.10	<0.33
Indeno(1,2,3-cd)pyrene	0.54	<0.33	0.60	<0.33	14.30	<0.33
Naphthalene	<0.33	<0.33	0.44	<0.33	26.60	<0.33
Phenanthrene	1.50	<0.33	2.70	<0.33	66.80	0.90
Pyrene	1.90	<0.33	2.90	<0.33	51.00	1.20
	33-1067	**33-1068**	**33-1069**	**33-1070**	**33-1072**	**33-1073**
Acenaphthene	<0.33	<0.34	<0.35	<0.35	<0.36	<0.36
Acenaphthylene	<0.33	<0.34	<0.35	<0.35	<0.36	<0.36
Anthracene	<0.33	<0.34	<0.35	<0.35	<0.36	<0.36
Benzo(a)anthracene	<0.33	<0.34	<0.35	<0.35	<0.36	<0.36
Benzo(a)pyrene	<0.33	<0.34	<0.35	<0.35	<0.36	<0.36
Benzo(b)fluoranthene	<0.33	<0.34	<0.35	<0.35	<0.36	<0.36
Benzo(g,h,i)perylene	<0.33	<0.34	<0.35	<0.35	<0.36	<0.36
Benzo(k)fluoranthene	<0.33	<0.34	<0.35	<0.35	<0.36	<0.36
Chrysene	<0.33	<0.34	<0.35	<0.35	<0.36	<0.36
Dibenz(a,h)anthracene	<0.33	<0.34	<0.35	<0.35	<0.36	<0.36
Fluoranthene	<0.33	<0.34	<0.35	<0.35	<0.36	0.46
Fluorene	<0.33	<0.34	<0.35	<0.35	<0.36	<0.36
Indeno(1,2,3-cd)pyrene	<0.33	<0.34	<0.35	<0.35	<0.36	<0.36
Naphthalene	<0.33	<0.34	<0.35	<0.35	<0.36	<0.36
Phenanthrene	<0.33	<0.34	<0.35	<0.35	<0.36	0.45
Pyrene	<0.33	<0.34	<0.35	<0.35	<0.36	0.46
	33-1076	**33-1077**	**33-1078**	**33-1147**	**33-1148**	**33-1149**
Acenaphthene	<0.33	<0.33	<0.33	<0.33	<0.33	<0.33
Acenaphthylene	<0.33	<0.33	<0.33	<0.33	<0.33	<0.33
Anthracene	0.37	<0.33	<0.33	<0.33	<0.33	<0.33
Benzo(a)anthracene	0.87	<0.33	<0.33	<0.33	<0.33	<0.33
Benzo(a)pyrene	1.10	<0.33	<0.33	<0.33	<0.33	<0.33
Benzo(b)fluoranthene	0.80	<0.33	<0.33	<0.33	<0.33	<0.33
Benzo(g,h,i)perylene	0.45	<0.33	<0.33	<0.33	<0.33	<0.33
Benzo(k)fluoranthene	1.20	<0.33	<0.33	<0.33	<0.33	<0.33
Chrysene	1.10	<0.33	<0.33	<0.33	<0.33	<0.33
Dibenz(a,h)anthracene	<0.33	<0.33	<0.33	<0.33	<0.33	<0.33
Fluoranthene	1.80	0.35	<0.33	<0.33	<0.33	<0.33
Fluorene	<0.33	<0.33	<0.33	<0.33	<0.33	<0.33
Indeno(1,2,3-cd)pyrene	0.56	<0.33	<0.33	<0.33	<0.33	<0.33
Naphthalene	<0.33	<0.33	<0.33	<0.33	<0.33	<0.33
Phenanthrene	1.70	<0.33	<0.33	<0.33	<0.33	<0.33
Pyrene	1.90	0.40	<0.33	<0.33	<0.33	<0.33

Table 2
PAHs at PRS 33-011(a)

Analyte	Mean (Eq. 1)	Standard error (Eq. 2)	95% upper confidence limit for the mean (Eq. 3)
Acenaphthene	0.37	0.10	0.55
Acenaphthylene	0.18	0.01	0.20
Anthracene	0.47	0.14	0.72
Benzo(a)anthracene	0.66	0.24	1.07
Benzo(a)pyrene	0.74	0.27	1.22
Benzo(b)fluoranthene	0.70	0.25	1.14
Benzo(g,h,i)perylene	0.44	0.12	0.66
Benzo(k)fluoranthene	0.67	0.23	1.07
Chrysene	0.75	0.28	1.24
Dibenz(a,h)anthracene	0.27	0.05	0.36
Fluoranthene	1.25	0.54	2.19
Fluorene	0.39	0.11	0.58
Indeno(1,2,3-cd)pyrene	0.46	0.13	0.69
Naphthalene	0.45	0.15	0.71
Phenanthrene	1.27	0.57	2.26
Pyrene	1.31	0.57	2.30

ADDENDUM 1

Analytical Data for PRSs in the January 1995 RFI Report for TA-33.