4. Nature and Extent of Contamination

CONTENTS

FIGURES

TABLES

4. NATURE AND EXTENT OF CONTAMINATION

The investigations conducted to determine the nature and extent of the contamination at the sites in the WAG 5 comprehensive RI/BRA are summarized in this section. The contaminants detected at WAG 5 sites, and the source-term estimates for the WAG 5 BRA are presented.

4.1 Site Groupings

Waste Area Group 5 comprises the ARA and PBF, two geographically separate facilities as shown in Figures 4-1 and 4-2. To define the nature and extent of contamination and to estimate the cumulative baseline occupational and residential risks at WAG 5, the potential release sites were grouped for the air and groundwater pathways. For all other exposure pathways, each potential release site was evaluated independently.

Grouping of the sites for the air and groundwater pathways was implemented based on the following logic. A single radiation field encompasses both the ARA-I and ARA-II facilities. Another radiation field encompasses ARA-III, but the facility is physically removed from ARA-I and -II. Similarly, the five PBF operational areas are several kilometers from the ARA area, and removed from each other by distances ranging from 0.5 to 2.0 km (0.3 to 1.2 mi). Cumulative groundwater concentrations from the separate facilities, except for ARA-I and -II, are not likely because of the locations of the facilities relative to each other and the hydraulic gradient. Remediation activities at any given site could impact the other sites nearby. Therefore, the following six groups of sites were defined for the air and groundwater pathway evaluations for the 15 sites retained for the BRA:

Group 1—Six sites at the ARA-I and ARA-II facilities

- ARA-01: Chemical/Evaporation Pond
- ARA-02: ARA-I Sanitary Waste Leach Field and Seepage Pit (two sources)
  - Seepage pit
  - Septic tank soils
- ARA-03: ARA-I Pad near ARA-627
- ARA-16: ARA-I Radionuclide Tank
- ARA-23: Radiologically contaminated soils and subsurface structures in and around ARA-I and ARA-II
- ARA-25: ARA-I soils beneath the ARA-626 hot cells

Group 2—Two sites at the ARA-III facility

- ARA-12: ARA-III Radioactive Waste Leach Pond
- ARA-24: Surface soils around ARA-III

Group 3—Three sites at the PBF Reactor Area

- PBF-05: PBF Reactor Area Warm Waste Injection Well
- PBF-10: PBF Reactor Area Evaporation Pond
- PBF 12: Special Power Excursion Reactor Test (SPERT) -I Leach Pond

Group 4—One site at the PBF Waste Engineering Development Facility (WEDF)

- PBF-16: SPERT-II Leach Pond

Group 5—One site at the PBF Waste Experimental Reduction Facility (WERF)

- PBF-21: PBF SPERT-III Large Leach Pond

Group 6—Two sites at the PBF Mixed Waste Storage Facility (MWSF)

- PBF-22: PBF SPERT-IV Leach Pond
- PBF-26: PBF SPERT-IV Lake.

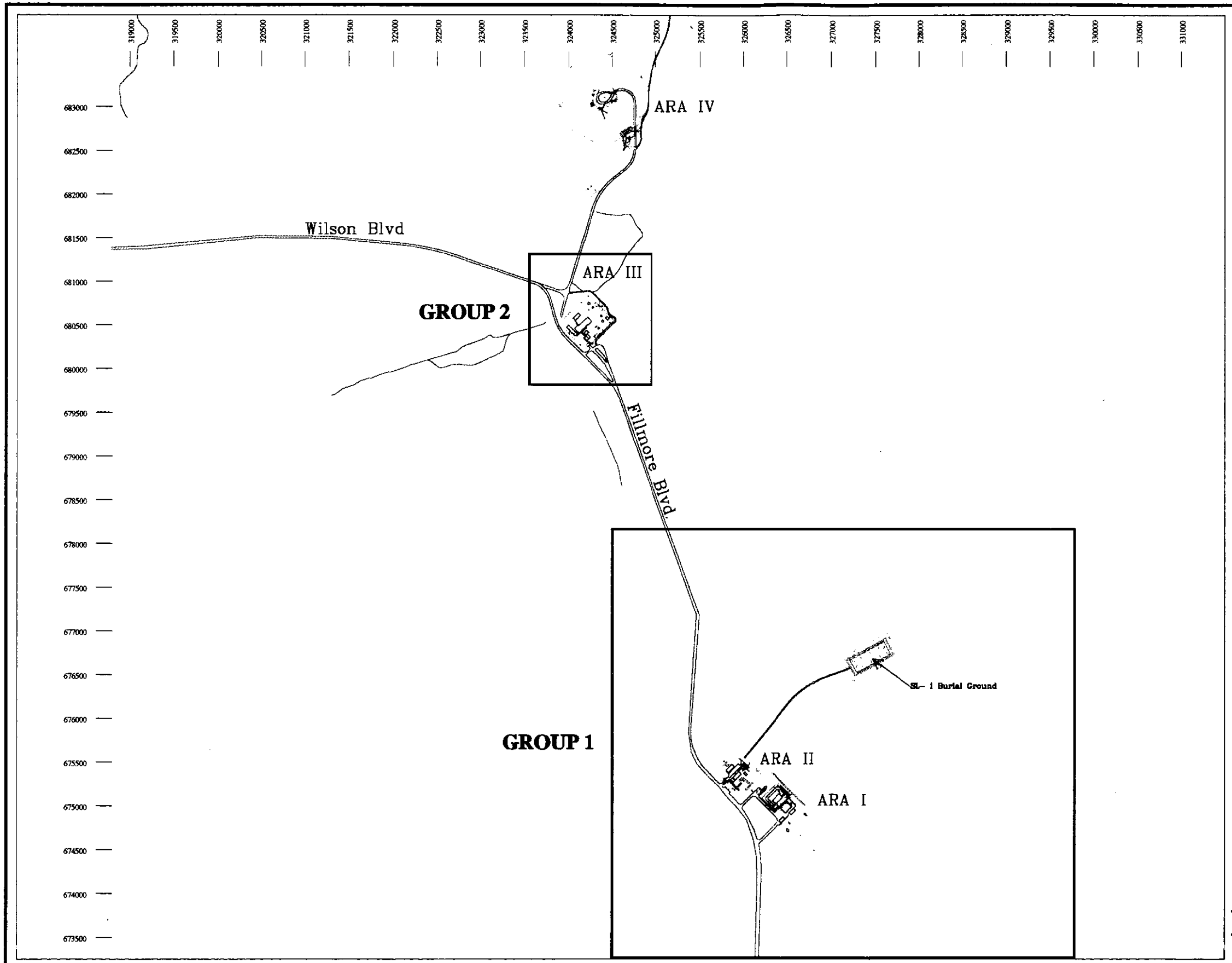
Figures 4-3 through 4-8 show the site groups and the location of each retained site in the ARA and PBF areas. A site group was not assigned for either the PBF Control Area or ARA-IV because no sites within the facilities were retained for quantitative evaluation in the baseline risk assessment. A radiation field is not associated with either area, and both facilities are distant from the other operational areas.

The ARA-IV facility was built to accommodate the Mobile Low Power Reactor 1, an active project from 1957 to 1964. The Nuclear Effects Reactor was operated at ARA-IV from 1967 to 1970. The area was closed down until 1975, at which time it was used temporarily for some welding qualification work. Decontamination and dismantlement was performed in 1984 and 1985. Since 1985, the area has been used on an occasional basis for explosive-initiated, powdered-metal manufacture experiments. A small control building, a bunker, the buried remains of two leach pits, and a sanitary waste system are all that remain.

The PBF Control Area was originally built in the late 1950s for remote control of the SPERT experiments. The facility was greatly expanded for the PBF program, but its primary function as a support facility has not changed. The facility provides raw water storage and distribution, administrative offices, instrument and mechanical work areas, and data acquisition resources.

4.2 Summaries of Sites Retained for the Baseline Risk Assessment

A description of each site retained for quantified evaluation in the BRA is given below. A more detailed summary of the history of each site is included in Section 3.1. The discussions below focus on the characteristics that support the risk assessment. Each site summary includes three parts: a site description, a summary of the investigations conducted at the site, and the nature and extent of contamination associated with the site. The site descriptions include information necessary to support



Auxiliary Reactor Area

Legend

Roads & Buildings
Fences

N

0 500 1000 1500 Feet

Date Drawn: September 28, 1998

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Figure 4-1. WAG 5 site groups at the Auxiliary Reactor Area.

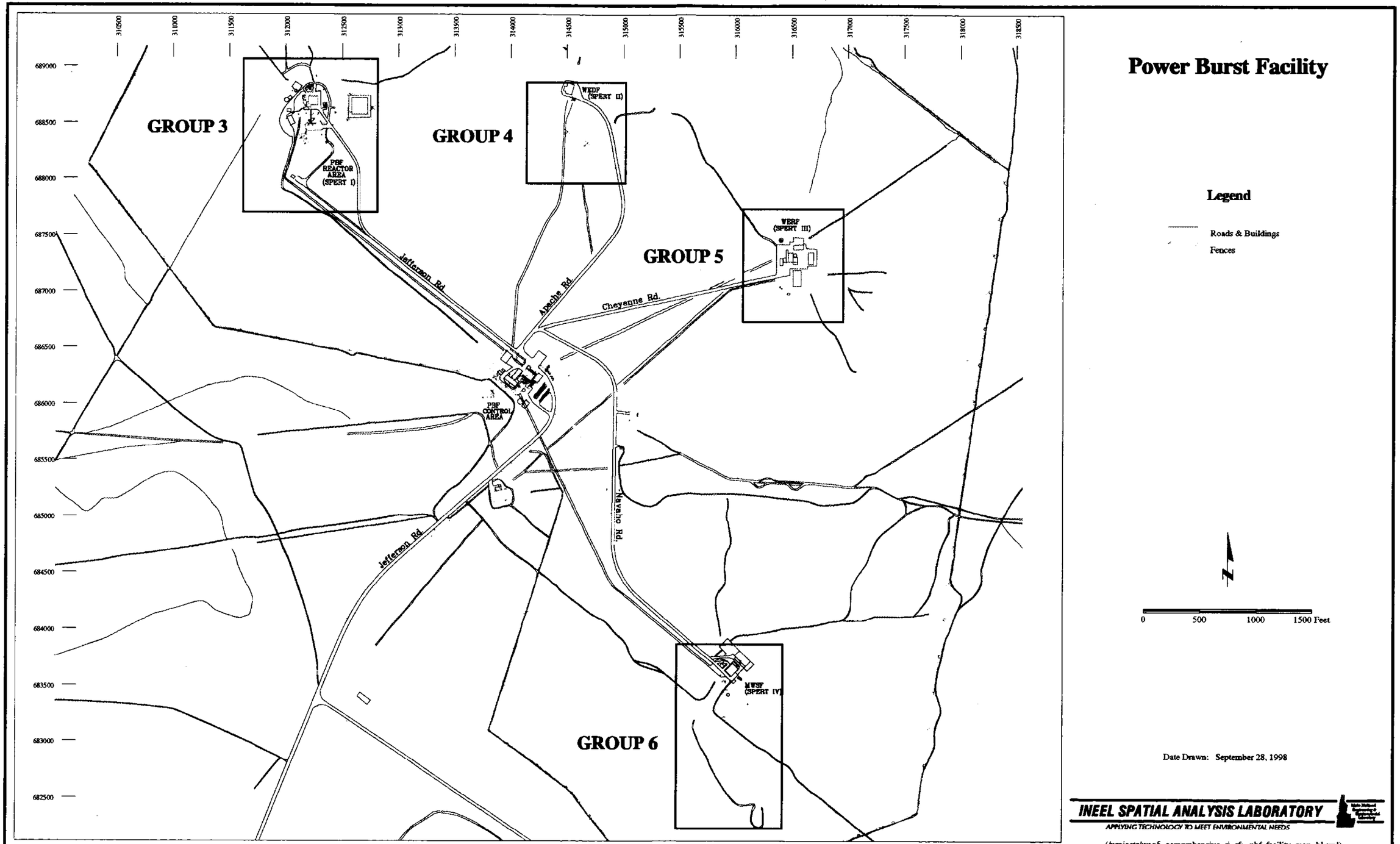


Figure 4-2. WAG 5 site groups at the Power Burst Facility.

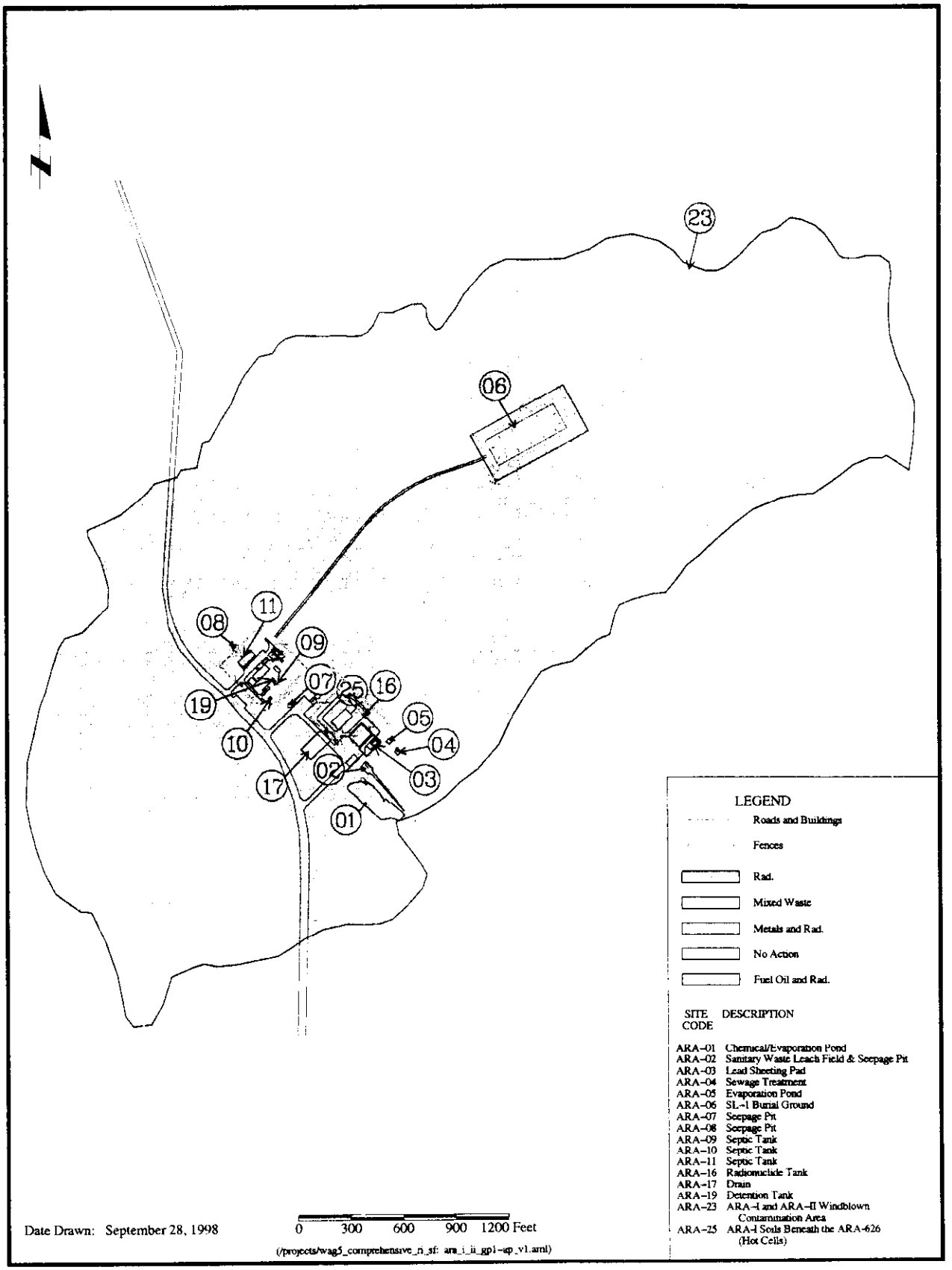


Figure 4-3. Site Group 1 (ARA–I and ARA–II).

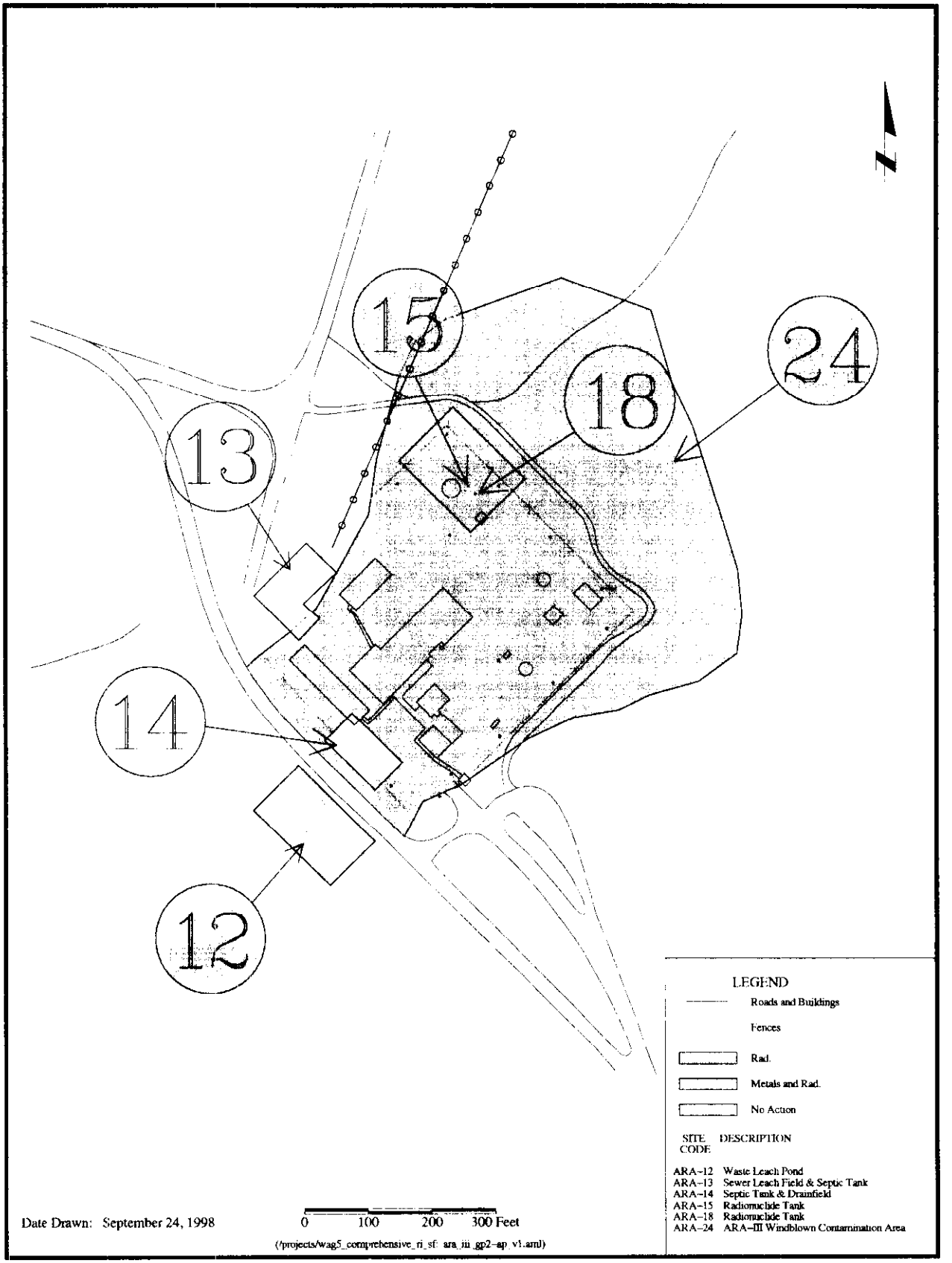


Figure 4-4. Site Group 2 (ARA–III).

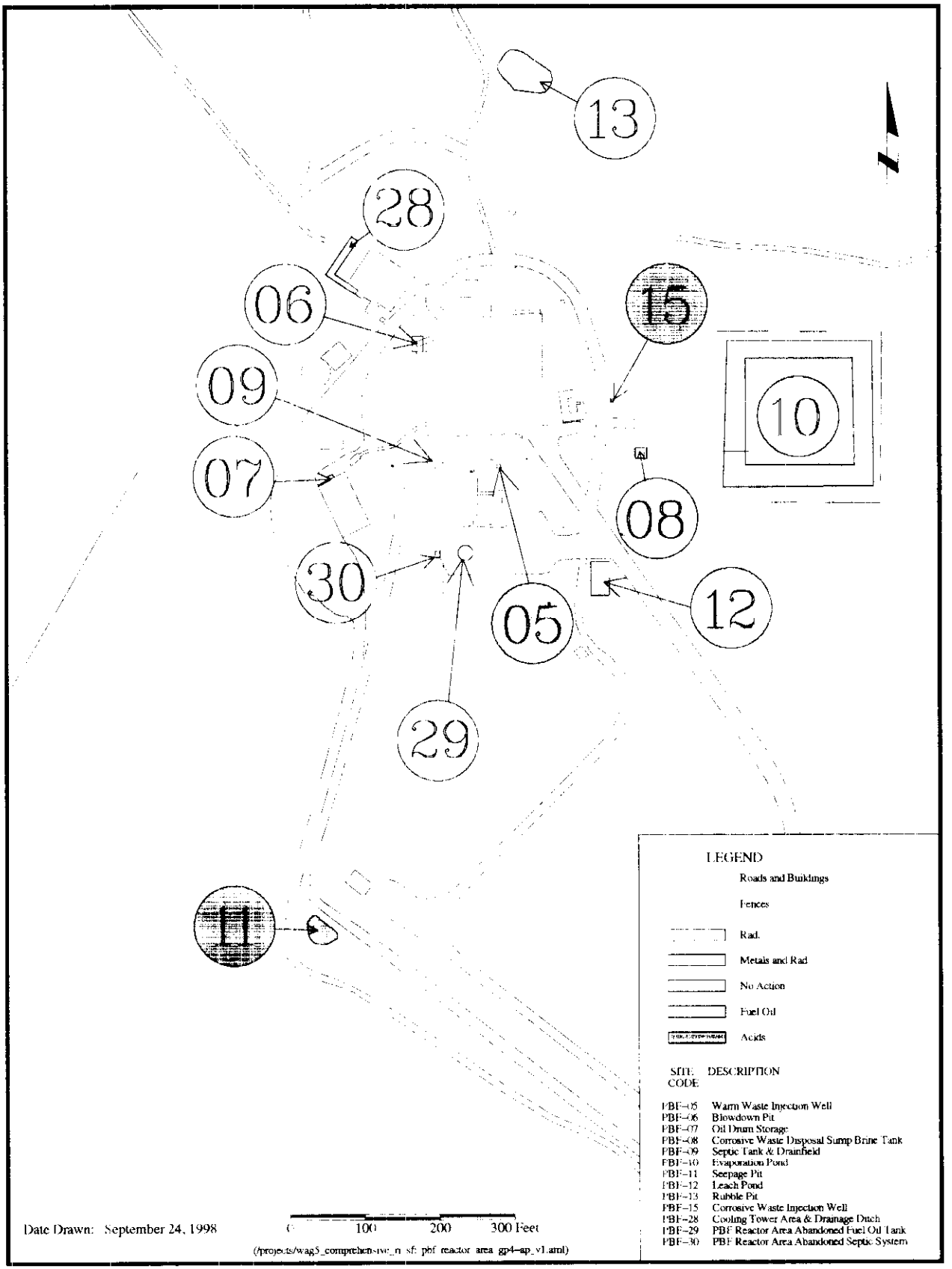


Figure 4-5. Site Group 3 (PBF Reactor Area [SPERT I]).

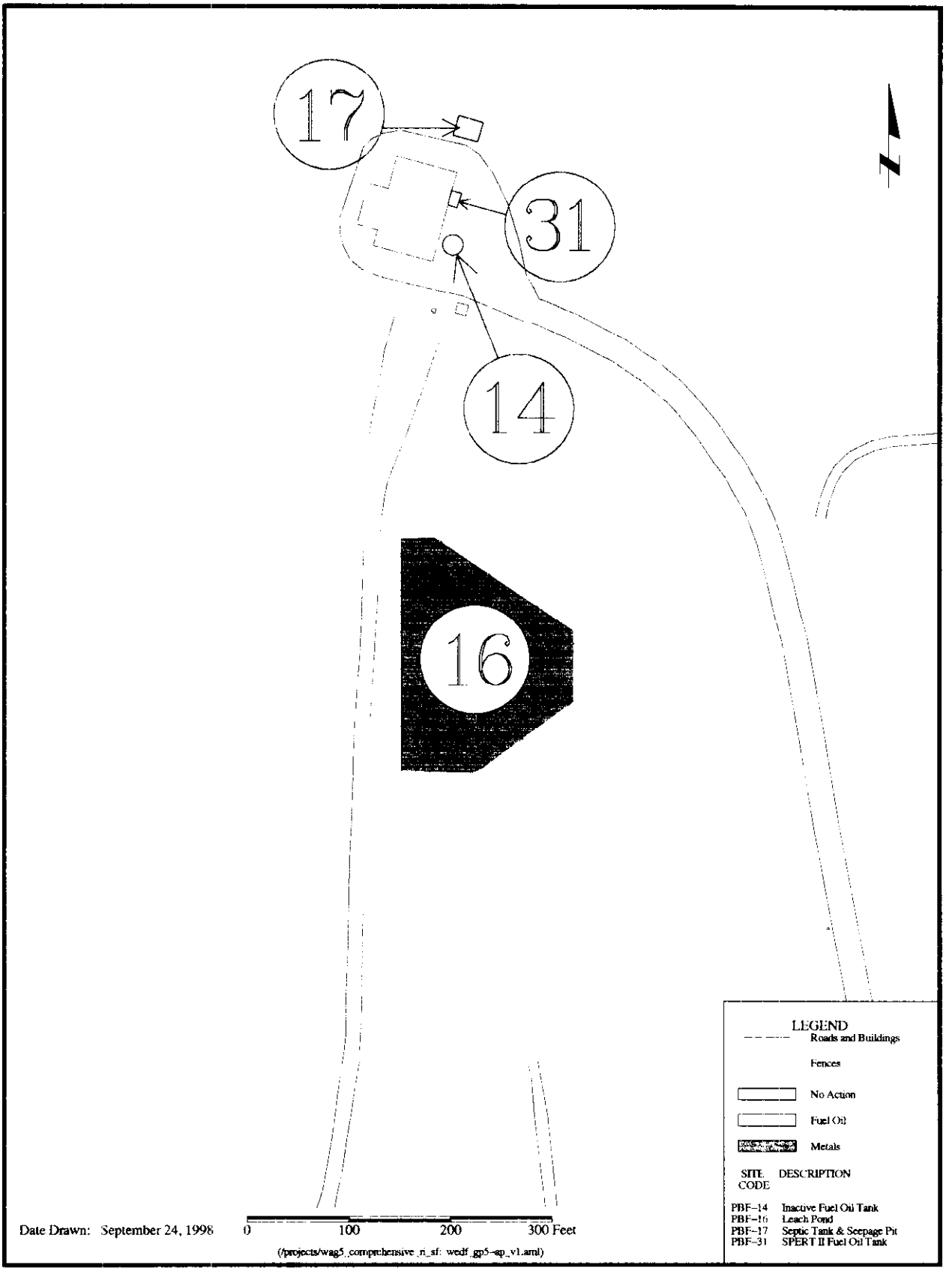


Figure 4-6. Site Group 4 (PBF WEDF [SPERT II]).

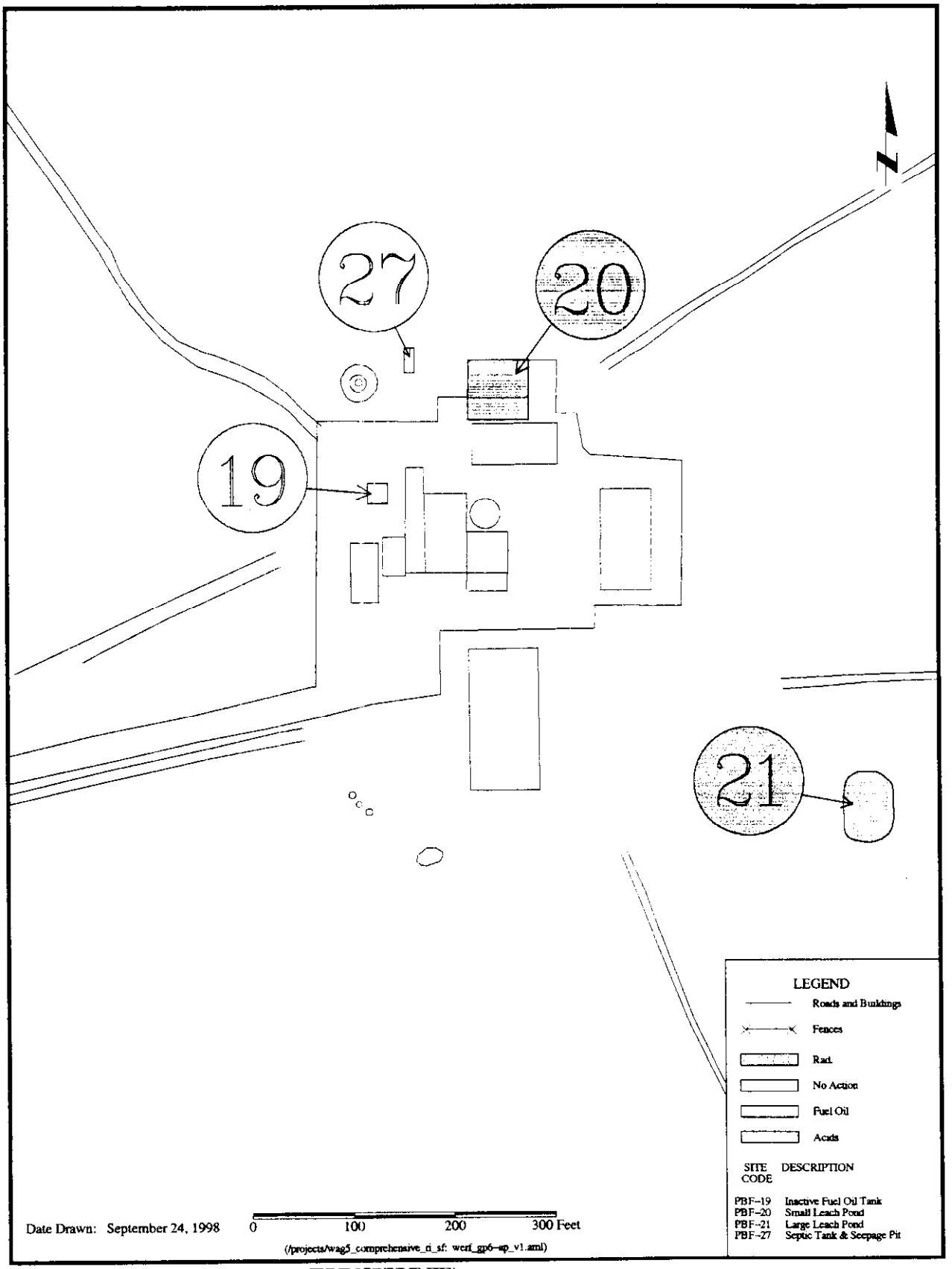


Figure 4-7. Site Group 5 (PBF WERF [SPERT III]).

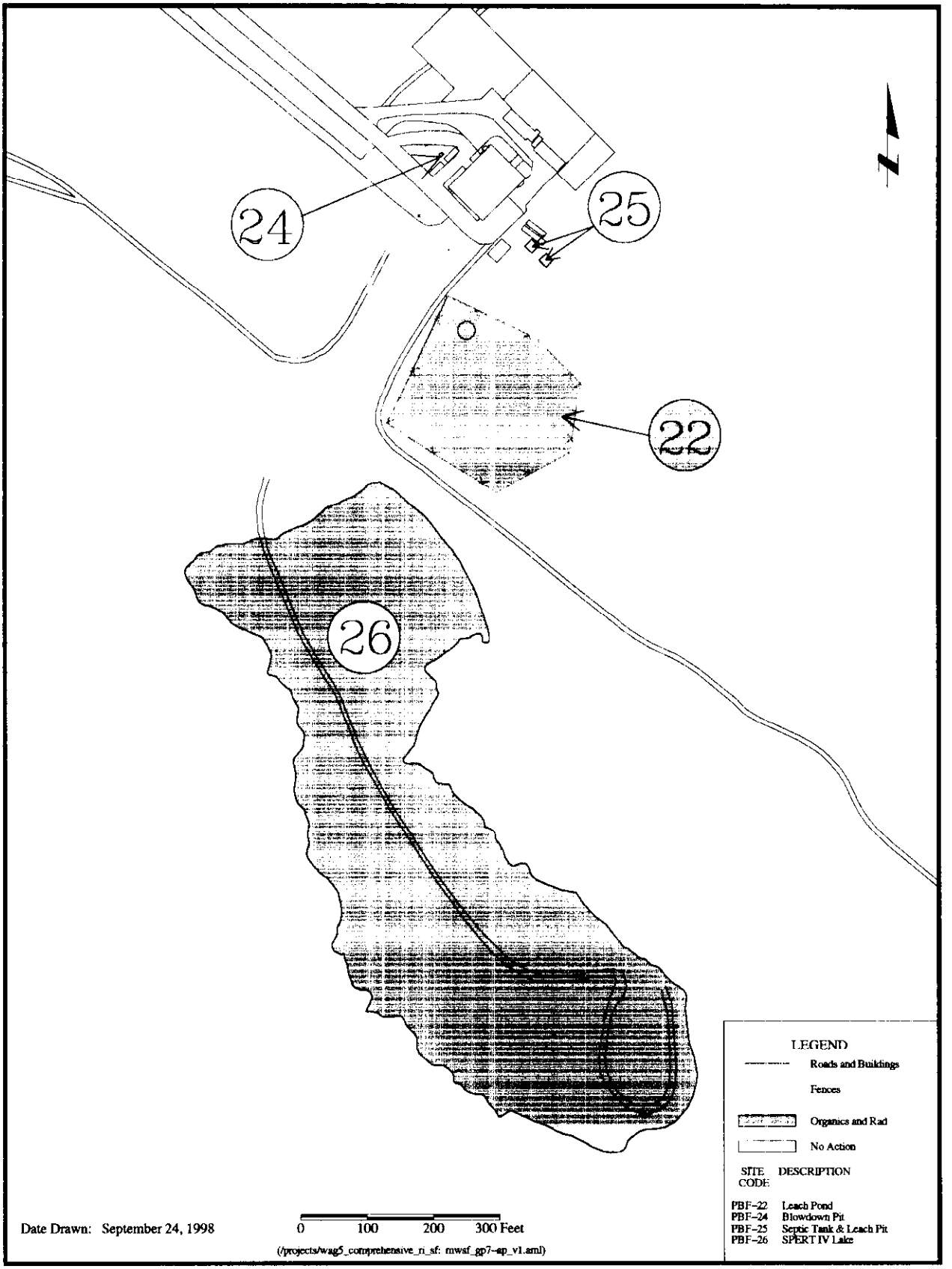


Figure 4-8. Site Group 6 (PBF MWSF [SPERT–IV]).

the conceptual site models developed in Section 6. The synopses of site investigations focus on the data applied to define the nature and extent of contamination and to develop risk estimates. The sections on the nature and extent of contamination at each site include descriptions of the site area for each contaminant source and the depths of contamination associated with each contaminant used to develop the source term dimensions and volumes for the BRA. Only those contaminants retained for the risk assessment are discussed (see Section 3.4 for site screening).

Two figures are presented for each site evaluated quantitatively in the BRA. The first figure illustrates the location of the individual site. The second figure presents the source term and assumptions for the risk assessment in four parts: a contaminant depth profile for each contaminant retained for evaluation, a three-dimensional diagram of the contaminant source simulated in the risk assessment, tables of contaminant concentrations simulated in the risk assessment, and the assumptions applied in the risk assessment with notes relative to the site. The data used to develop the contaminant concentrations are provided in Appendix A. Only those contaminants retained in the contaminant screening (see Section 3.4 and Appendix B, Tables B-1 through B-18 [and Appendix L for ARA-25]) are illustrated.

4.2.1 Group 1—Auxiliary Reactor Area I and II

The ARA-I and ARA-II facilities were constructed in 1957. The ARA-I facility was built to support the Stationary Low-Power Reactor 1 (SL-1) located in the adjacent ARA-II facility and was the staging area for the emergency response to the 1961 SL-1 reactor accident and cleanup. The SL-1 reactor at ARA-II was operated intermittently from August 1958 until it was destroyed by a nuclear accident in January 1961 (Holdren, Filemyr, and Vetter 1995). Subsequent to decontamination following the SL-1 accident, activities at ARA-I included hot cell operations, materials research, and a laboratory for sample preparation and inspection. The three main buildings at ARA-II were converted to offices and welding shops. The ARA-II facility also housed numerous minor structures such as a guardhouse, well house, chlorination building, decontamination and laydown building, power extrapolation building, electrical substation, and several storage tanks. The ARA-I and ARA-II facilities were formally shut down in 1988 and 1986, respectively. The human health risk from six sites in Group 1, ARA-01, ARA-02, ARA-03, ARA-16, ARA-23, and ARA-25, were quantified in the BRA.

4.2.1.1 ARA-01—Chemical Evaporation Pond.

4.2.1.1.1 Site Description—The ARA-01 site is a shallow, unlined surface impoundment that was used to dispose of wastewater from the ARA-I Shop and Maintenance Building (ARA-627). The pond, shown in Figure 4-9, is located about 80 m (260 ft) southeast of the building, was excavated in 1971, and received process discharges until 1988. Process discharges included small quantities of radioactive substances, acids, bases, and VOCs. The pond has a surface area of 2,987 m^2 (32,155 ft^2) and is now dry except during spring runoff and heavy precipitation.

4.2.1.1.2 Site Investigation—An RI/FS was completed for the Chemical Evaporation Pond in 1992 (Stanisich et al. 1992). New data collected in the RI/FS sampling program were combined with existing data and summarized to assess the risks associated with the site. A single composite surficial sediment sample was collected in 1982. Organic constituents above the minimum detection limit (MDL) and metals above background concentrations were not detected. Between 1986 and 1988, quarterly waste stream effluent monitoring detected arsenic, silver, lead, nickel and selenium. In 1990, 58 samples were taken at the surface to the soil/basalt interface at depths ranging from 0.2 to 1.8 m (0.8 to 6 ft). Arsenic, barium, chromium, lead, mercury, selenium, and silver were detected at concentrations above background. Cesium-137, Co-60, methylene chloride, acetone, and toluene also were detected. These

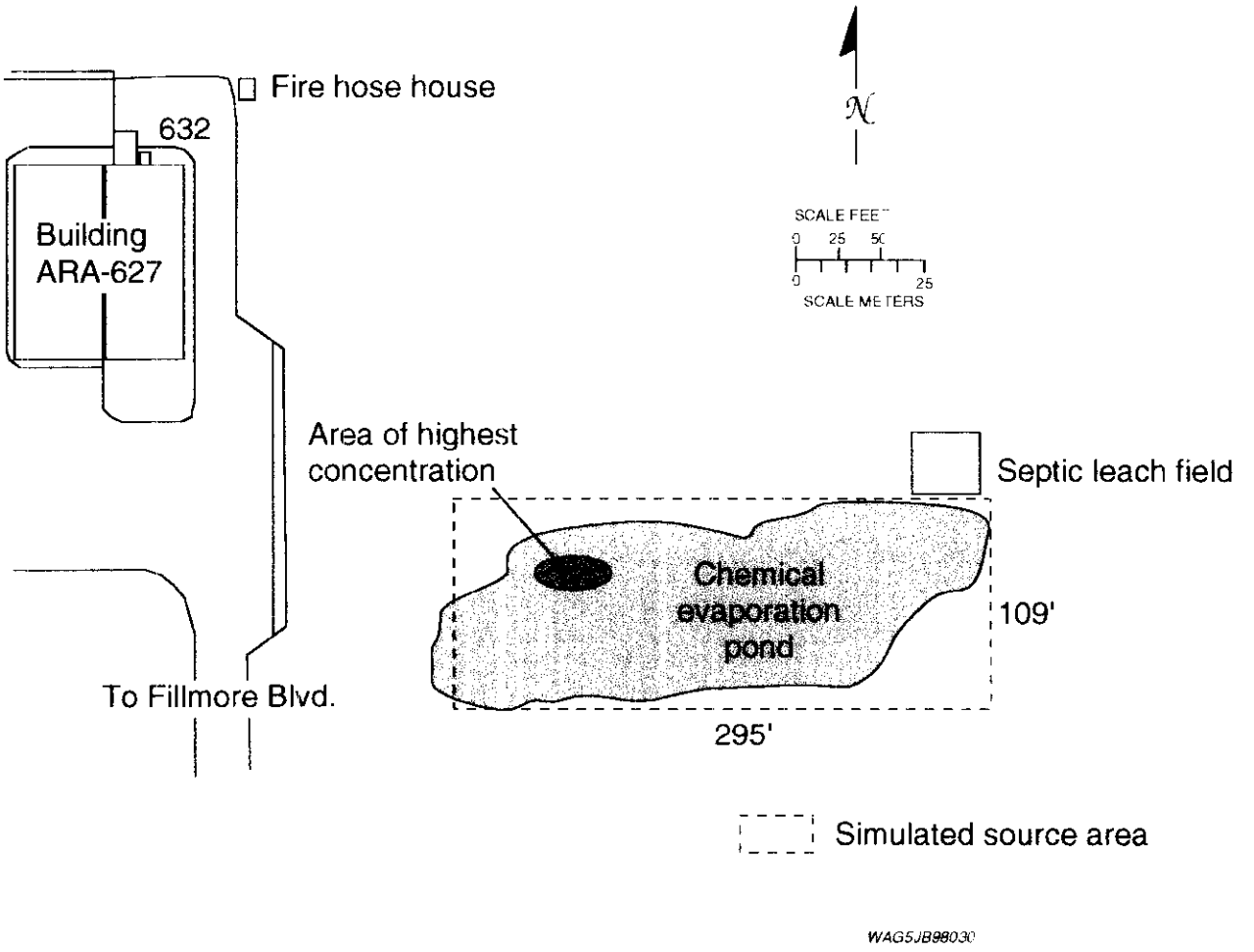


Figure 4-9. ARA-I evaporation pond, Site ARA-01.

data were considered in the ARA-01 RI/FS (Stanisich et al. 1992) and no unacceptable risks were identified for surface pathways. However, the groundwater pathway was not evaluated.

The ROD for the RI/FS (DOE-ID 1992) determined that no remedial action was necessary at the site, but that additional evaluation of subsurface conditions and the groundwater pathway would be conducted in another OU within WAG 5. Sampling was conducted for the OU 5-12 comprehensive RI/FS in 1997 (DOE-ID 1997) to determine the vertical extent of contamination and the presence and concentrations of alpha-emitting isotopes and Sr-90. Two boreholes were drilled at biased locations, and samples were collected from surficial sediments. Nineteen additional sampling locations were selected at random from a grid that was overlain on the pond area. Arsenic, lead, thallium, Pu-238, Pu-239/240, Ra-226, Sr-90, and U-235 were detected (see Appendix E) in concentrations above the contaminant screening levels given in Appendix B.

4.2.1.1.3 Nature and Extent of Contamination—The diagram in Figure 4-10 shows the contaminant concentrations at depths below the surface. Surface sediments are shallow at ARA-01, with a maximum thickness of 0.6 m (2 ft). Two boreholes were drilled at the site, one to a depth of 94 ft and one to a depth of 118 ft, without encountering a sedimentary interbed. In situ gamma and beta measurements of the boreholes indicated that the media underlying the surficial sediments are not radiologically contaminated. Therefore, the contamination was assumed to be limited to the surficial sediments.

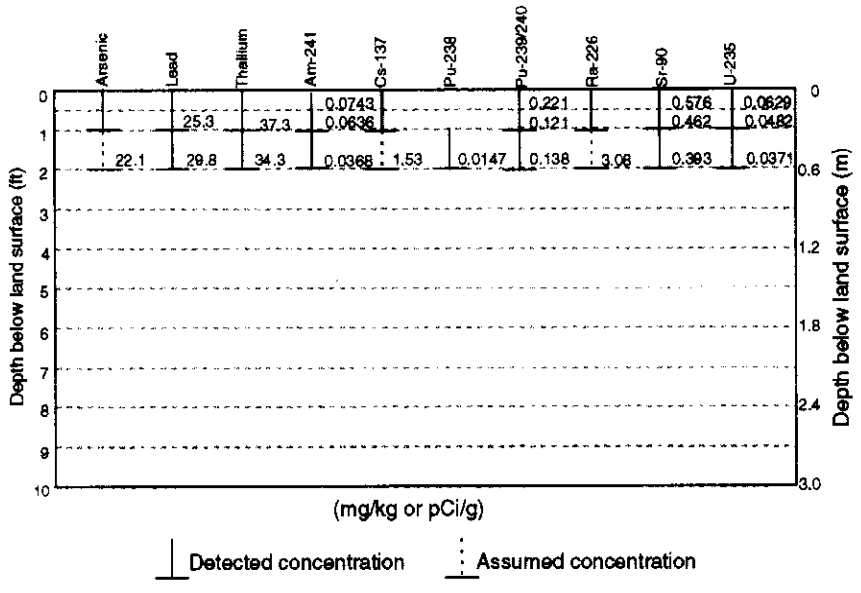
4.2.1.2 ARA-02—Sanitary Waste Leach Field and Seepage Pit.

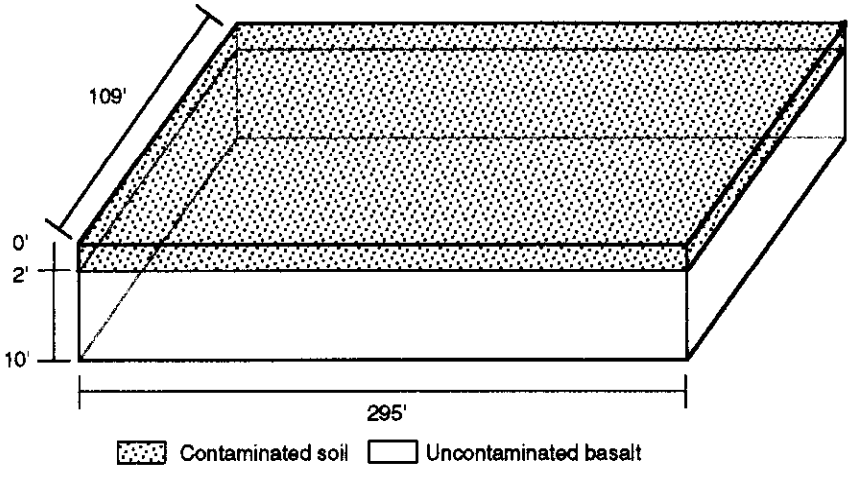
4.2.1.2.1 Site Description—The ARA-02 site is a sanitary septic system area including three septic tanks in series, a seepage pit, and piping. The bottoms of the three concrete septic tanks are approximately 8 ft below the surface. The 8-in. mainline between the tanks and the seepage pit lies approximately 4 in. below the surface. The contaminated soils surrounding the septic tanks and piping compose an area of approximately 139 m^2, and the seepage pit composes an area of approximately 84 m^2. The system was built in 1960 and serviced permanent and temporary ARA-I buildings until 1988 when ARA-I was inactivated. The configuration of ARA-02 is shown in Figure 4-11. Though no spills are recorded or incidents documented that would have resulted in contamination of the septic system, periodic radiological control surveys indicated radioactive contamination from an unknown source. Two contaminant sources, the seepage pit and contaminated soils around the septic tanks, were evaluated individually in the BRA.

4.2.1.2.2 Site Investigations—During January 1992, Cs-137, Co-60, and U-235 were detected in two samples collected from manholes above the septic tanks. During August 1992, sampling was performed interior and exterior to the septic tanks, and interior and exterior to the seepage pit, and exterior to the mainline,. Arsenic, barium, beryllium, cadmium, chromium, lead, mercury, nickel, selenium, silver, vanadium, zinc, Am-241, Co-60, Cs-137, Eu-152, Eu-154, Eu-155, Pu-239/240, Sr-90, U-235, and U-238 were detected (Pickett et al. 1993) in concentrations above current background values.

During the summer of 1997 (DOE-ID 1997), samples were collected from a borehole drilled next to the seepage pit at depths of 2.5 to 5 ft and 7.5 to 10 ft. Samples also were collected from depths of about 4 and 10 ft near the septic tanks.

4.2.1.2.3 Nature and Extent of Contamination—The ARA-02 site was treated as two individual sources in the BRA: (1) the seepage pit and (2) the soils around the septic tanks.





Assumptions:

- The area of the site is the area of contamination: 295 ft × 109 ft = 32,155 ft².
- The depth of the site is the depth of the surficial sediments down to the first basalt interface: 2 ft.
- The simulated source term volume is the area times the depth of the surficial sediments: 32,155 ft² × 2 ft = 64,310 ft³.
- Basalt underlying the 2-ft-thick layer of surface sediment is uncontaminated. Therefore, simulated occupational and residential exposures are limited to the 0 to 2-ft depth-weighted average concentrations.

Notes:

- Concentrations in the top 6 in. (0 to 0.5-ft interval) are either the 95% lognormal UCL or the maximum detected concentration, whichever is less.
- Simulated source term concentrations below the 0 to 0.5-ft surficial sediments are depth-weighted averages calculated as follows:

$$C_I = \frac{\sum_{i=1}^{I} C_i}{I}$$

where:

C_I = depth-weighted average concentration over the entire interval I
C_i = 95% UCL or maximum detected concentration, whichever is less, for the ith 1-ft increment
i = specific 1-ft increment (i.e., 0 to 1 ft, 1 to 2 ft, ..., I-1 to I ft)
I = the number of 1-ft increments.

- For ARA-01, I = 2.

Source Term Concentrations

Nonradionuclides (mg/kg)

Depth (ft)	Arsenic	Lead	Thallium
0-0.5	2.21E+01	2.53E+01	3.73E+01
0-2	2.21E+01	2.76E+01	3.58E+01

Radionuclides (pCi/g)

Depth (ft)	Am-241	Cs-137	Pu-238	Pu-239/240	Ra-226	Sr-90	U-235
0-0.5	7.43E-02	1.53E+00	0.00E+00	2.21E-01	3.08E+00	5.76E-01	6.29E-02
0-2	5.02E-02	1.53E+00	7.35E-03	1.29E-01	3.08E+00	4.28E-01	4.27E-02

Figure 4-10. ARA-I Chemical Evaporation Pond, Site ARA-01, source term concentrations and assumptions for risk assessment.

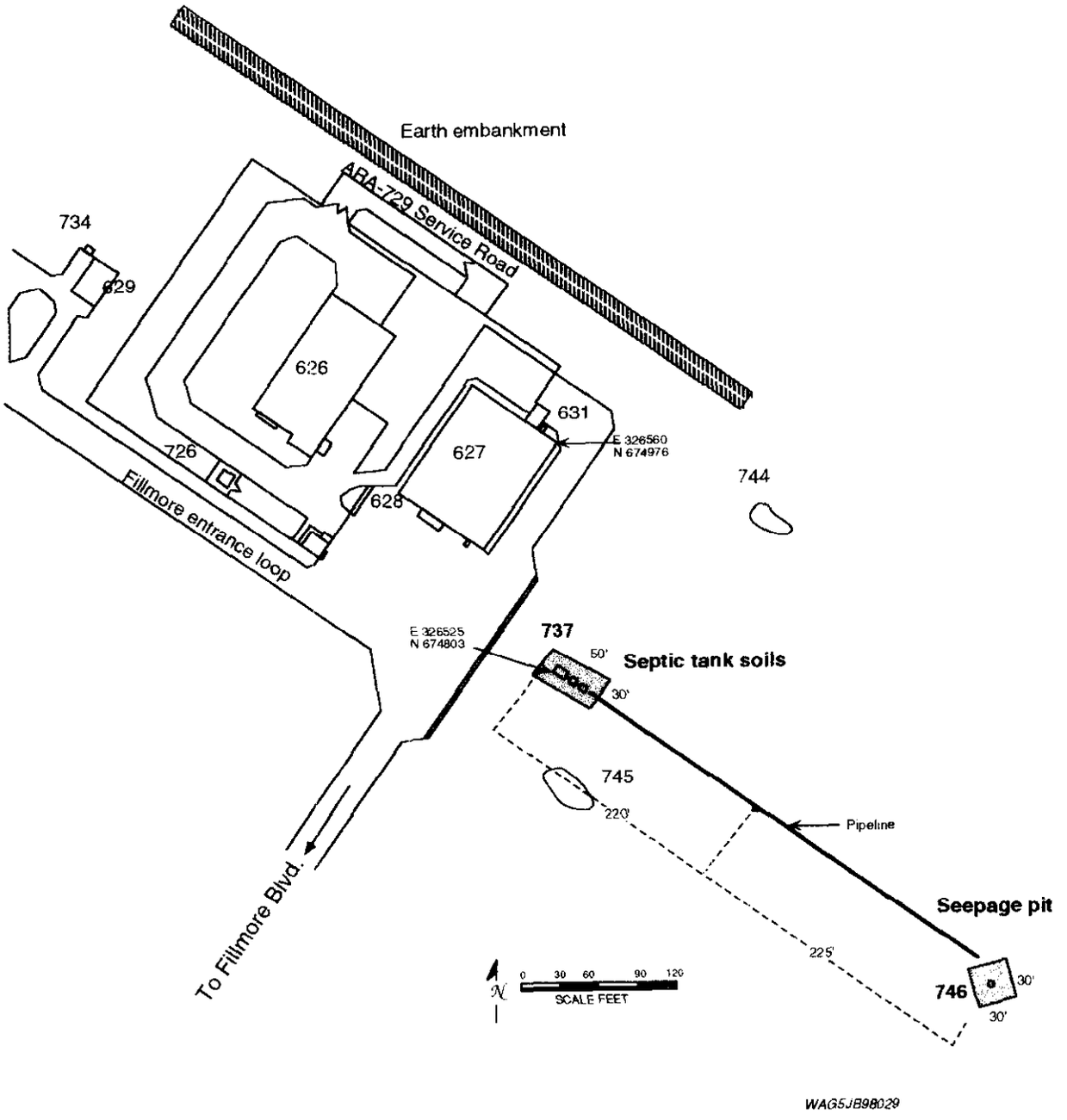


Figure 4-11. ARA-I sanitary waste leach field and seepage pit, Site ARA-02.

Contaminants detected in the seepage pit sludge are displayed in Figure 4-12 as the depth interval from 9 to 10 ft. The area above 9 ft is void space in the seepage pit. The 2 to 5-ft and 7 to 9-ft concentrations were detected in the soils outside of the seepage pit. The highest concentrations were detected between 2 and 3 ft below the surface.

Figure 4-13 illustrates the profiles of contaminants detected in the soils around the septic tanks. Concentrations were detected throughout the soil profile from 2 to 10 ft.

4.2.1.3 ARA-03—Pad Near ARA-627 (Lead Sheeting).

4.2.1.3.1 Site Description—The ARA-03 site is a 669-m^2 (7,198-ft^2) contaminated soil area located east of ARA-I building ARA-627, as shown in Figure 4-14. The area was identified as contaminated in 1979 during a routine radiation survey. The source of the contamination is uncertain, but may have originated either from a tank truck parked at the facility or from SL-1 cleanup operations. Lead sheeting was placed over the site for shielding. The sheeting was removed in 1991. In 1994, soil to a depth of approximately 3 ft was removed and disposed of.

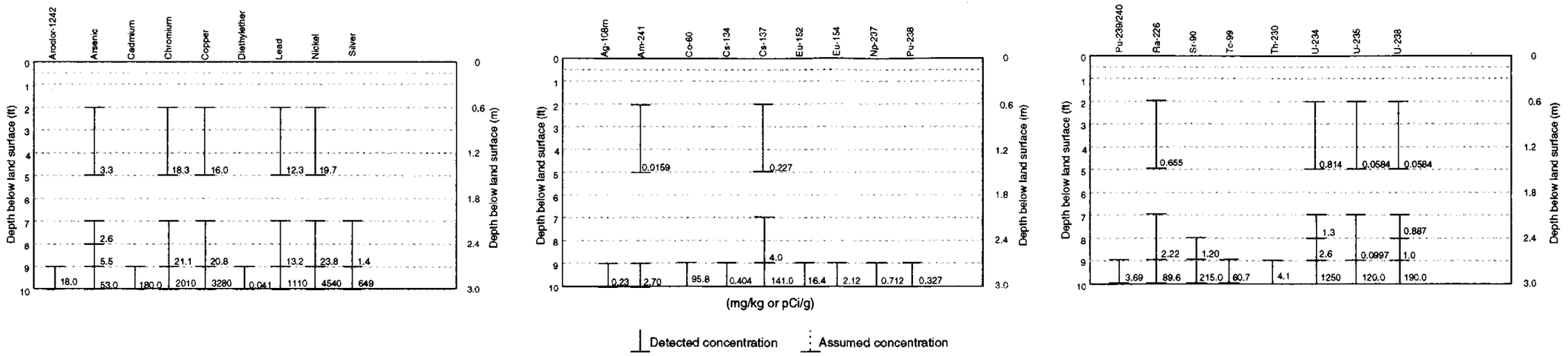
4.2.1.3.2 Site Investigations—In 1991, before the soil removal was implemented, Co-60, Cs-137, and Eu-154 were detected in the top 6 in. of soil. Only Cs-137 was detected at 2 ft. Volatile organic compounds, SVOCs, herbicides, pesticides, metals, and inorganics were below regulatory levels for the toxicity characteristic leaching procedure (Pickett et al. 1993). After excavation at the site in 1994, sampling showed Cs-137 slightly above background and metals below background (DOE-ID 1997).

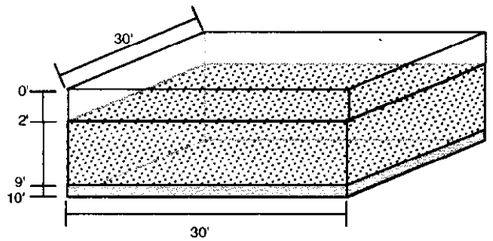
4.2.1.3.3 Nature and Extent of Contamination—The contaminant profile in the soil is shown in Figure 4-15. The only contaminant analyzed in the BRA was the Cs-137 detected in the post-soil removal verification sampling. Because the site was backfilled to a depth of 0.9 m (3 ft) with clean soils following the soil removal, the maximum detected concentration was assigned to the 3 to 6-ft interval below the surface for risk assessment purposes.

4.2.1.4 ARA-16—ARA-I Radionuclide Tank.

4.2.1.4.1 Site Description—The ARA-16 site is a 1,000-gal stainless steel underground holding tank within a lidless concrete vault. The tank and vault are covered by approximately 1.1 m (4 ft) of soil. The area of the site is 61.3 m^2. From 1959 to 1988, the tank received radioactive liquid waste from the ARA-I hot cells and mixed acids containing methanol, acetone, and chlorinated paraffin from materials testing and research and metal-etching processes. The contents of the tank were emptied into a tank truck and transported to the INTEC for disposal on an as-needed basis as defined by the level in the tank. The ARA-I facility was formally shut down in 1988. During the shutdown procedure, the tank was partially excavated. All lines into and out of the tank were cut and capped, and the contents of the tank were agitated and pumped out, leaving approximately 8 cm, or 109 L (29 gal), of liquid and sludge. The location of ARA-16 is shown in Figure 4-16.

4.2.1.4.2 Site Investigations—In 1988, the ARA-I radionuclide tank contents were sampled and found to contain metals, VOCs, and sulfate. Field surveys indicated radiological contamination in subsurface soils alongside the outlet pump line, the inlet lines, and the manhole cover. Field readings at the manhole opening were 2 R/hour of beta/gamma radiation. A radiological surface survey above the 1.1 m (4 ft) soil cover was performed in 1991. Readings were 1 mR/hour (see EG&G 1993 in Appendix J).





Source Term Concentrations

Nonradionuclides (mg/kg)

Depth (ft)	Aroclor-1242	Arsenic	Cadmium	Chromium	Copper	Diethylether	Lead	Nickel	Silver
0-0.5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0-4	0.00E+00	1.65E+00	0.00E+00	9.15E+00	8.00E+00	0.00E+00	6.15E+00	9.85E+00	0.00E+00
0-10	1.80E+00	7.10E+00	1.30E+01	2.11E+02	3.37E+02	4.10E-03	1.17E+02	4.64E+02	6.52E+01

Radionuclides (pCi/g)

Depth (ft)	Ag-108m	Am-241	Co-60	Cs-134	Cs-137	Eu-152	Eu-154	Np-237	Pu-238
0-0.5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0-4	0.00E+00	7.95E-03	0.00E+00	0.00E+00	1.14E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0-10	2.30E-02	2.75E-01	9.58E+00	4.04E-02	1.50E+01	1.64E+00	2.12E-01	7.12E-02	3.27E-02

Radionuclides (pCi/g)

Depth (ft)	Pu-239/240	Ra-226	Sr-90	Tc-99	Th-230	U-234	U-235	U-238
0-0.5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0-4	0.00E+00	3.28E-01	0.00E+00	0.00E+00	0.00E+00	4.07E-01	2.92E-02	3.44E-01
0-10	3.69E-01	9.60E+00	2.16E+01	6.07E+00	4.10E-01	1.06E+02	8.04E+00	1.94E+01

Assumptions:

- The area of the site is the area of contamination: 30 ft × 30 ft = 900 ft².
- The site is covered to a depth of 3 ft with clean soil.
- The vertical interval for the site, 7 ft, is the depth of the surficial sediments down to 10 ft less the 3 ft of clean soil overlying the site.
- The simulated source term volume is the area times the vertical interval: 900ft² × 10 ft = 9,000 ft³.
- The pipeline between the seepage pit and the septic tanks is intact and has not released contaminants into the environment.
- Compared to the contaminants in the seepage pit sludge, releases to the subsurface are negligible.
- All detections at 3 ft were assigned to the 2 to 3-ft interval for the purposes of calculating depth-weighted average concentrations.

Notes:

- ARA-02 is subdivided into two separate sources for risk evaluation: the seepage pit and contaminated soils around the septic tanks.
- Simulated source term concentrations are depth-weighted averages calculated as follows:

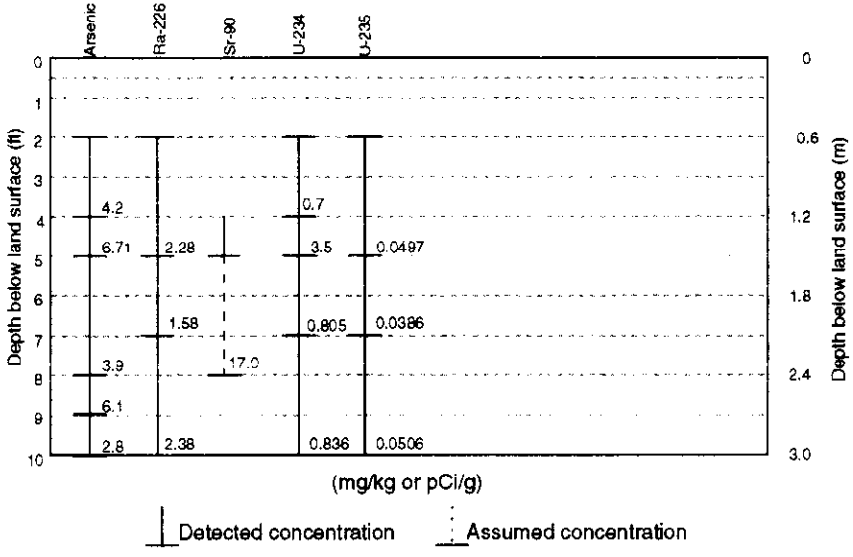
$$C_I = \frac{\sum_{i=k}^{I} C_i}{I}$$

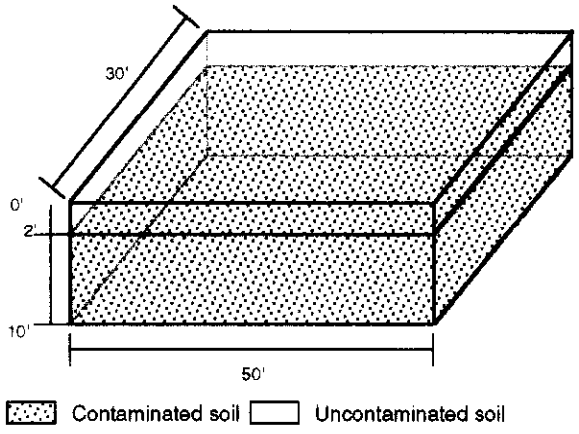
where:

C_I = depth-weighted average concentration over the entire interval I
C_i = 95% UCL or maximum detected concentration, whichever is less, for the *i*th 1-ft increment
i = specific 1-ft increment (i.e., 0 to 1 ft, 1 to 2 ft, ..., I-1 to I ft)
I = the number of 1 ft increments.

- For the ARA-02 seepage pit, I = 10.
- Sampled intervals that yielded results below detection limits were assigned a zero concentration for depth-weighted averaging
- Concentrations detected in the seepage pit sludge (9 to 10 ft data) and in exterior soils (2 to 5 ft and 7 to 9 ft data) were combined to develop estimates for the source term concentrations.

Figure 4-12. ARA-02 ARA-I Sanitary Waste System Seepage Pit source term concentrations and assumptions for risk assessment.





Source Term Concentrations

Nonradionuclides (mg/kg)

Depth (ft)	Arsenic
0-0.5	0.00E+00
0-4	2.10E+00
0-10	3.57E+00

Radionuclides (pCi/g)

Depth (ft)	Ra-226	Sr-90	U-234	U-235
0-0.5	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0-4	1.14E+00	0.00E+00	3.50E-01	2.49E-02
0-10	1.71E+00	6.80E+00	9.02E-01	3.78E-02

Assumptions:

- The area of the site is the area of contamination: 30 ft × 50 ft = 1,500 ft².
- The site is covered to a depth of 2 ft with clean soil.
- The vertical interval for the site, 8 ft, is the depth of the surficial sediments down to 10 ft less the 2 ft of clean soil overlying the site.
- The simulated source term volume is the area times the vertical interval: 1,500 ft² × 10 ft = 15,000 ft³.
- The pipeline between the seepage pit and the septic tanks is intact and has not released contaminants into the environment.
- Basalt underlies the septic tanks at a depth of 10 ft and is not contaminated.
- All detections at 2 ft were assigned to the 2 to 3-ft interval for the purposes of calculating depth-weighted average concentrations.

Notes:

- ARA-02 is subdivided into two separate sources for risk evaluation: the seepage pit and contaminated soils around the septic tanks.
- Simulated source term concentrations are depth-weighted averages calculated as follows:

$$C_I = \frac{\sum_{i=k}^{I} C_i}{I}$$

where:

C_I = depth-weighted average concentration over the entire interval I
C_i = 95% UCL or maximum detected concentration, whichever is less, for the *i*th 1-ft increment
i = specific 1-ft increment (i.e., 0 to 1 ft, 1 to 2 ft, ..., I-1 to I ft)
I = the number of 1 ft increments.

- For the ARA-02 septic tanks soils, I = 10.
- Sampled intervals that yielded results below detection limits were assigned a zero concentration for depth-weighted averaging.
- Intervals that were not sampled were assigned concentrations equal to the neighboring interval for depth-weighted averaging.

Figure 4-13. ARA-02 ARA-I Sanitary Waste System septic tank soils source term concentrations and assumptions for risk assessment.

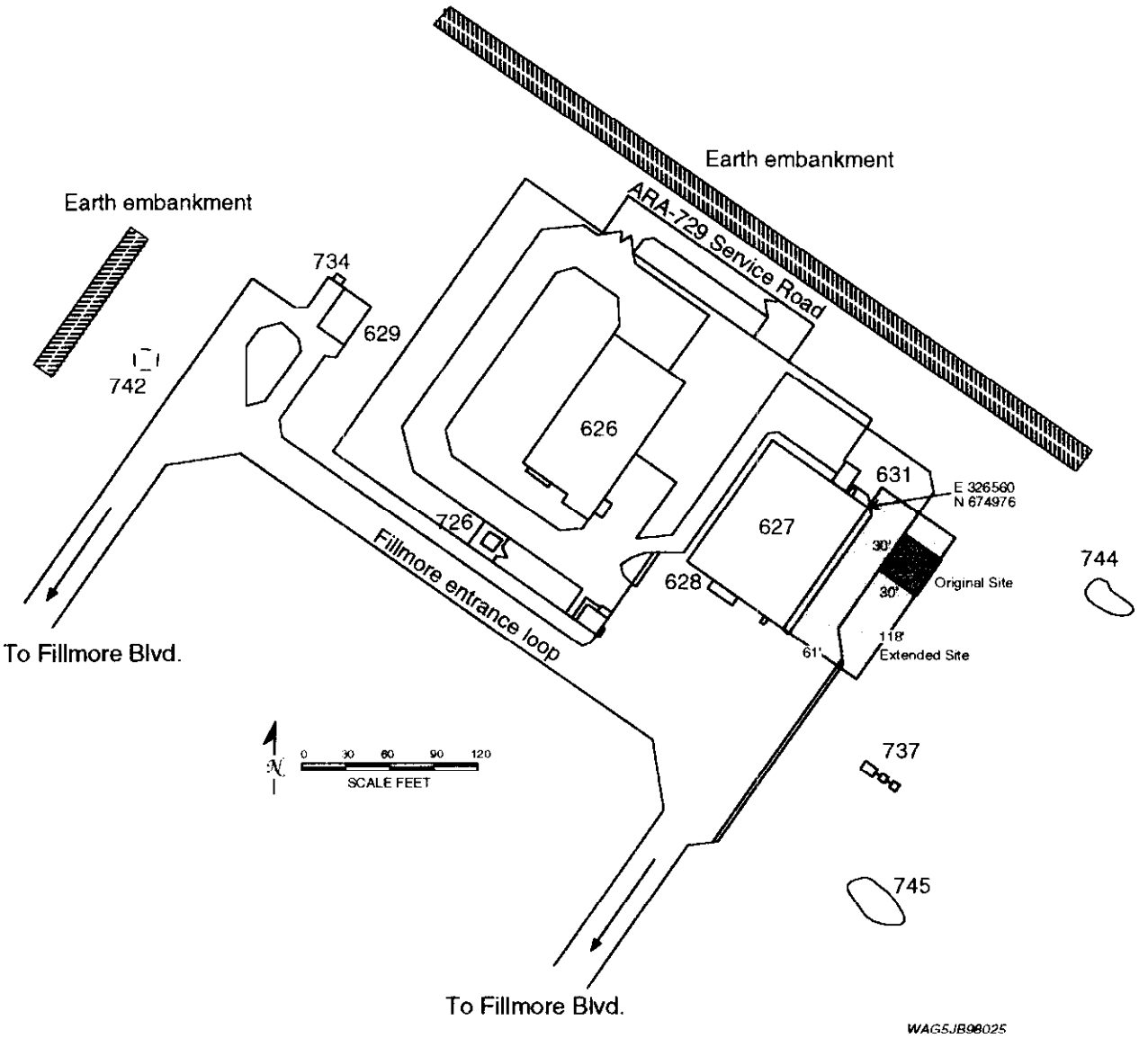
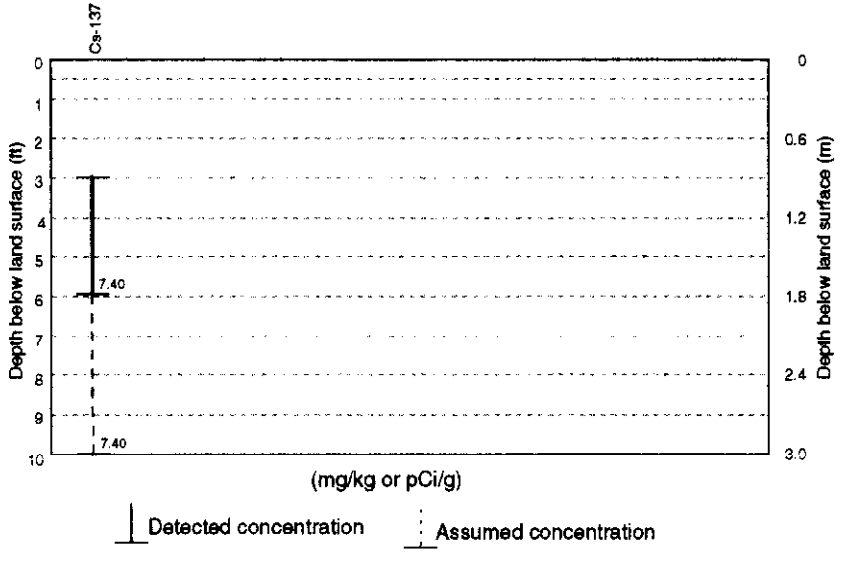
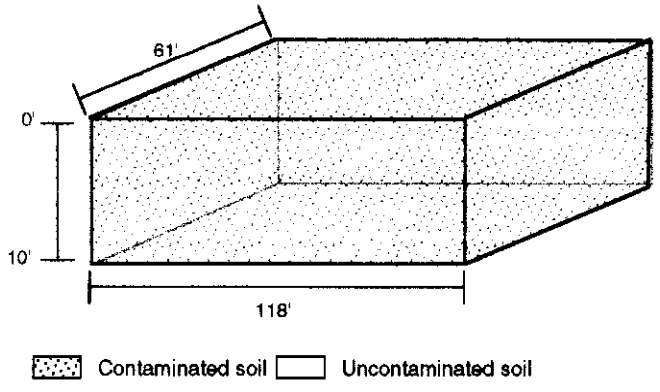


Figure 4-14. ARA-I pad near ARA-627, Site ARA-03.





Source Term Concentrations	
Radionuclides (pCi/g)	
Depth (ft)	Cs-137
0-0.5	0.00E+00
0-4	5.55E+00
0-10	5.18E+00

Assumptions:

- The area of the site is the area of contamination: 118 ft x 61 ft = 7200 ft^2.
- The site is covered to a depth of 3 ft with clean soil.
- The simulated source term volume is the area times the vertical interval: 7200 ft^2 × 10 ft = 72,000 ft^3.
- The entire 0 to 10 ft interval is contaminated at the same concentration as detected in the 3 to 6 ft interval.

Notes:

- Simulated source term concentrations are depth-weighted averages calculated as follows:

$$C_I = \frac{\sum_{i=k}^{I} C_i}{I}$$

where:

C_I = depth-weighted average concentration over the entire interval I
C_i = 95% UCL or maximum detected concentration, whichever is less, for the *i*th 1-ft increment
i = specific 1-ft increment (i.e., 0 to 1 ft, 1 to 2 ft, ..., I-1 to I ft)
I = the number of 1 ft increments.

- For ARA-03, I = 10.

Figure 4-15. ARA-03 ARA-I lead sheeting pad source term concentrations and assumptions for risk assessment.

During the summer of 1997, two boreholes were drilled within the concrete vault to the bottom at an approximate depth of 2.9 m (9.5 ft) to evaluate the contamination of the surface and subsurface soil and gravel inside the concrete vault. Samples were collected at the top and bottom of each borehole. In addition, a surface sample was collected above the center of the tank. The surface samples were analyzed for metals, radionuclides, VOCs, SVOCs, and PCBs. Only Co-60, Cs-137, and Sr-90 were detected in concentrations above background. The sampling was performed in the surface and subsurface soil outside of the concrete vault to estimate the extent of the contamination. Three boreholes were drilled to a depth of 4.6 m or to basalt beside the exterior of the concrete vault. Borehole samples were collected at two depths and analyzed for metals, radionuclides, VOCs, SVOCs, and PCBs (DOE-ID 1997). Cesium-137 and Sr-90 were detected in concentrations above background. Chloride, sulfate, Ag-108m, Co-60, Cs-134, Eu-152, Eu-154, and Ra-226 also were detected. Because background values have not been established for the above isotopes, any positive detections are considered above a supposed background value of zero.

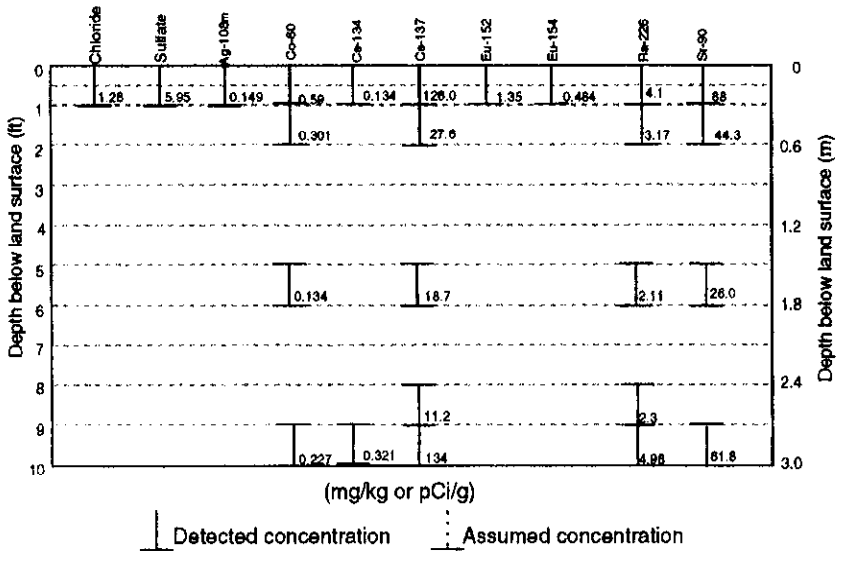
4.2.1.4.3 Nature and Extent of Contamination—The distributions of retained contaminants in the upper 3 m (10 ft) of soil at ARA-16 are illustrated in Figure 4-17. Cobalt-60, Cs-137, Ra-226, and Sr-90 were detected at most depths with the largest concentrations occurring at the surface and at the 9 to 10-ft depth below the surface. Cesium-134 was detected in surface soils and at the 9 to 10-ft depth. Other contaminants (chloride, sulfate, Ag-108m, Eu-152, and Eu-154) were detected only in surface soils.

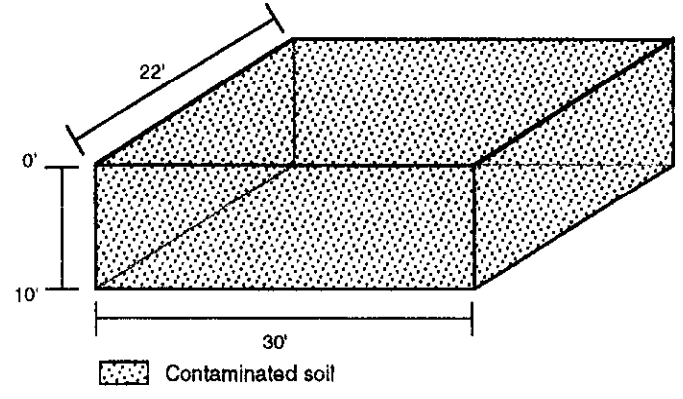
4.2.1.5 ARA-23—Radiologically Contaminated Soils and Subsurface Structures in and Around ARA-I and ARA-II.

4.2.1.5.1 Site Description—The ARA-23 site is defined as the subsurface structures including the SL-1 reactor building foundation and underground utilities, contaminated soils within the ARA-I and ARA-II facility fences, and all surface soils contaminated during the SL-1 accident and cleanup activities. The area of ARA-23 is about 169,000 m^2 as shown in Figure 4-18.

4.2.1.5.2 Site Investigations—An aerial radiological survey was performed in 1990. Based on detected counts per second, inner (35,000 to 110,000 cps) and outer (1,100 to 2,400 cps) gamma survey isopleths were defined. In 1977, 1985, and 1991, surface soil samples were taken from 1 to 2-in. and 2 to 4-in. depths. From 1973 to 1990, surface radiation surveys were performed every 3 to 5 years. The highest readings ranged from 1 to 3 mrem/hour in 1984. Readings ranged from 0.05 to 11.0 mrem/hour in 1987 and 0.04 to 4.42 mrem/hour in 1990. Four soil samples were collected in 1993, and five soil samples were collected in 1994. The detected contaminants included Am-241, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Pu-238, Pu-239/240, Sr-90, U-233, and U-235. The Radiological and Environmental Science Laboratory collected soil data from the area surrounding ARA-I and –II in 1977, 1985, and 1991. Because the contamination is a result of windblown deposition, the majority of the contamination is believed to be restricted to the upper 4 in. of soil (Jorgensen 1995).

During the summer of 1997, sampling was performed at 19 approximately equally spaced locations along the 10 pCi/g Cs-137 isopleth. Samples were collected from 1 to 15 cm (0.4 to 6 in.) and 15 cm to 0.6 m (0.5 to 2 ft) for a total of 38 samples (DOE-ID 1997). Cesium-137 was detected in concentrations up to 2,140 pCi/g. Other radionuclides detected in concentrations greater than contaminant screening levels include Am-241, Ra-226, Sr-90, Th-230, and U-235. An in situ radiation survey also was conducted with a vehicle-mounted scintillator to measure and determine the detailed distribution and concentration of Cs-137 in the surface soil. More than 69,000 measurements were collected, and the data were converted to estimates of in situ Cs-137 concentrations. The highest Cs-137 concentration measured with the GPRS was 2,530 pCi/g (see Josten 1997 in Appendix J).





Source Term Concentrations

Nonradionuclides (mg/kg)

Depth (ft)	Chloride	Sulfate
0-0.5	1.28E+00	5.95E+00
0-4	3.20E-01	1.49E+00
0-10	1.28E-01	5.95E-00

Radionuclides (pCi/g)

Depth (ft)	Ag-108m	Co-60	Cs-134	Cs-137	Eu-152	Eu-154	Ra-226	Sr-90
0-0.5	1.49E-01	5.90E-01	1.90E-01	1.26E+02	1.35E+00	4.84E-01	4.01E+00	8.80E+01
0-4	3.73E-02	2.23E-01	4.75E-02	3.85E+01	3.38E-01	1.21E-01	1.79E+00	3.31E+01
0-10	1.49E-02	1.25E-01	5.11E-02	3.18E+01	1.35E-00	4.84E-02	1.66E+00	2.20E+01

Assumptions:

- The area of the site is the area of contamination: 30 ft × 22 ft = 660 ft².
- The vertical interval for the site is 10 ft.
- The simulated source term volume is the area times the vertical interval: 660 ft² × 10 ft = 6,600 ft³.
- Results from samples collected from within the tank vault and outside of the tank vault are representative of the same simulated source term (i.e., the two regions of contamination are not differentiated).

Notes:

- Concentrations in the top 6 in. (0 to 0.5-ft interval) are either the 95% lognormal UCL or the maximum detected concentration, whichever is less.
- Simulated source term concentrations below the 0 to 0.5-ft surficial sediments are depth-weighted averages calculated as follows:

$$C_I = \frac{\sum_{i=k}^{I} C_i}{I}$$

where:

C_I = depth-weighted average concentration over the entire interval I
C_i = 95% UCL or maximum detected concentration, whichever is less, for the *i*th 1-ft increment
i = specific 1-ft increment (i.e., 0 to 1 ft, 1 to 2 ft, ..., I-1 to I ft)
I = the number of 1-ft increments.

- For ARA-16, I = 10.

Figure 4-17. ARA-16 ARA-I radionuclide tank soils source term concentrations and assumptions for risk assessment.

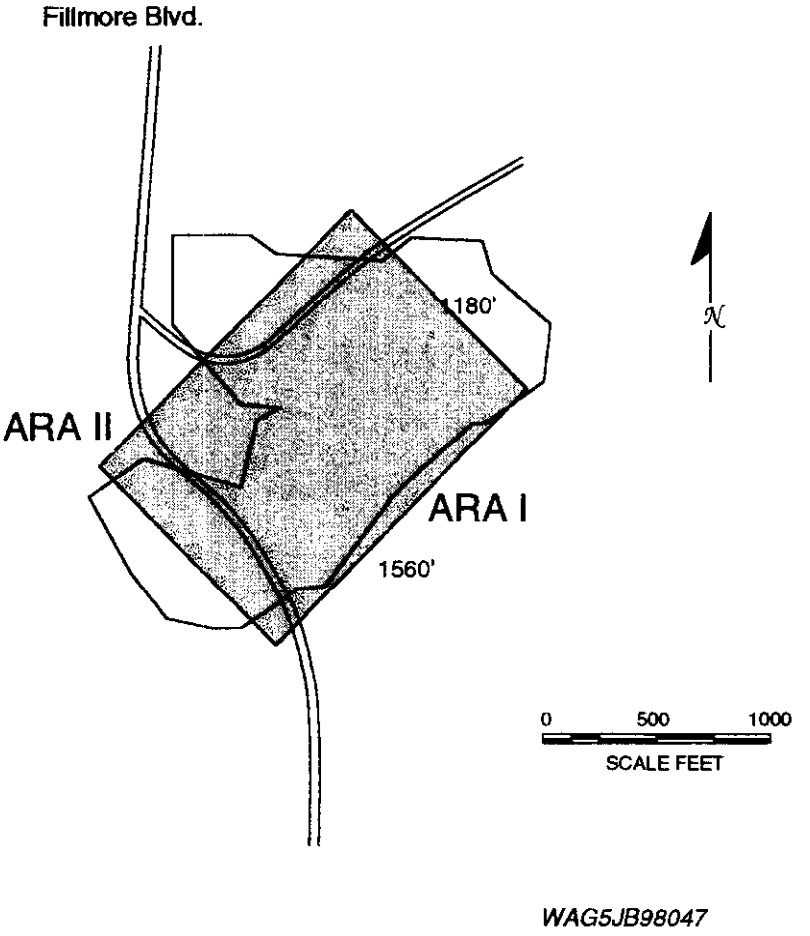


Figure 4-18. ARA-I and ARA-II contaminated soils and subsurface structures, Site ARA-23.

4.2.1.5.3 Nature and Extent of Contamination—During the summer 1997 investigation (DOE-ID 1997), Am-241, Cs-137, Ra-226, Sr-90, Th-230, and U-235 were detected above background in the upper 2 ft of soil as illustrated in Figure 4-19. Converted data from the 1997 in situ investigation were compiled into maps showing the quantitative distribution of Cs-137 across ARA-23. In Figure 4-20, a map is provided of these concentrations based on the assumption that the contamination is limited to the top 1 in. of soil.

4.2.1.6 ARA-25: ARA-I Soils Beneath the ARA-626 Hot Cells.

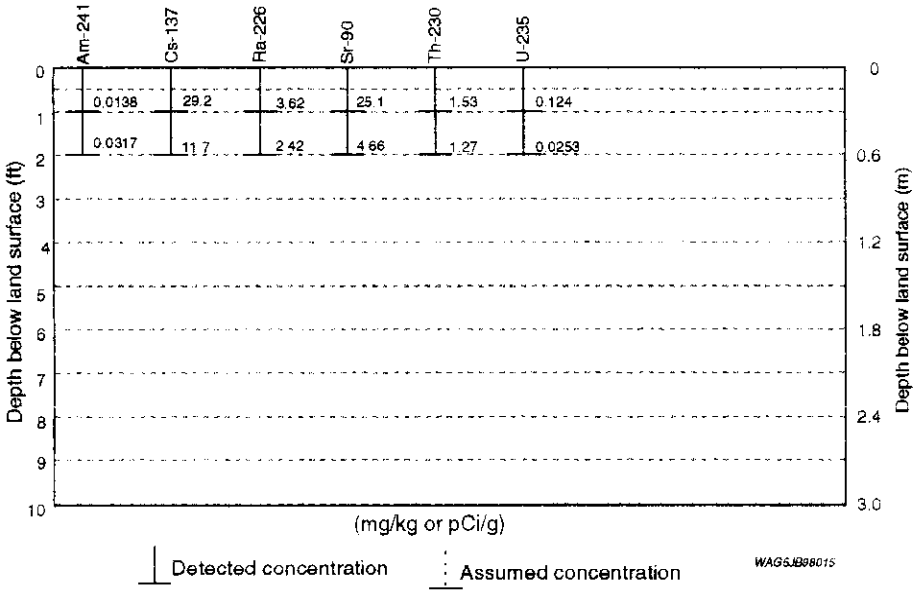
4.2.1.6.1 Site Description—The ARA-25 site, shown in Figure 4-21, was discovered during the late stages of the development of the WAG 5 comprehensive RI/FS during the D&D of the ARA-I facility. The site comprises contaminated soils discovered beneath the two hot cells (Hot Cells No. 1 and No. 2) in building ARA-626. The area of the site is approximately 35 m^2. At one time, stainless steel piping connected these drains to the ARA-729 radionuclide tank (site ARA-16), which contains PCB-contaminated, listed mixed waste and transuranic radionuclides. Six other drain lines from buildings ARA-626 were connected to the ARA-16 tank. These lines were from the decontamination room, the service area, the hot metallurgy area, a hot laboratory, and two isolation areas located immediately behind the hot cells and used for repair and modification of equipment and for initial decontamination of equipment removed from the hot cells (Vega 1995). The lines were disconnected from the ARA-16 tank and capped in 1988 (see Holdren 1998 in Appendix J).

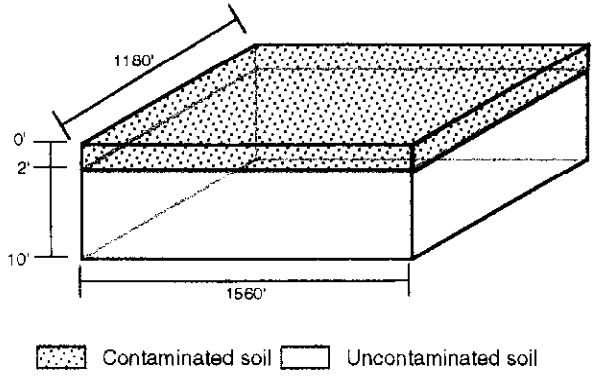
4.2.1.6.2 Site Investigations—As part of the ongoing D&D activities at ARA-I, the steel-clad concrete floor slabs of the ARA-626 building were cut out of the hot cells. In a radiological evaluation of the soils that sloughed off the underside of the concrete slabs and of the rebar protruding from the concrete, contamination levels of 50,000 disintegrations per minute were identified. However, the level of radioactivity in the soil was difficult to verify because of the radiological interference generated by the floor slabs.

During subsequent radiological surveys performed in June 1998, soil immediately adjacent to the Hot Cell No. 1 floor drain showed radioactivity greater than 500,000 disintegrations per minute beta/gamma as determined with a Ludlum 2A gamma detector, and greater than 15 mR/hour as determined with an Eberline RO 20 ion chamber. Radiological surveys of soils further from the drain area beneath the slab yielded readings of 8,000 to 12,000 disintegrations per minute. Contamination levels of soils beneath Hot Cell No. 2 were not as high as the levels found beneath Hot Cell No. 1. Soil surveys at the base of the floor drain yielded 10,000 disintegrations per minute, and contamination readings of the soils away from the Hot Cell No. 2 floor drain were 5,000 disintegrations per minute.

The hot cells were removed by D&D in 1998 and the soils below the concrete were collected for laboratory analysis. Three surface soil samples were collected from depths of 0 to 6-in. where the floor drains had been located. Three other samples were taken of the concrete floor slab. Concentrations of arsenic, copper, lead, manganese, Cs-134, Cs-137, Co-60, Eu-152, Eu-154, Ra-226, Sr-90, and U-235 were detected in soil and concrete above risk screening levels.

4.2.1.6.3 Nature and Extent of Contamination—Based on the contaminant screening in Appendix L, twelve contaminants detected in soil were retained for quantitative risk assessment: arsenic, copper, lead, manganese, Cs-134, Cs-137, Co-60, Eu-152, Eu-154, Ra-226, Sr-90, and U-235. Because sampling was limited to the surface of the soil, the risk assessment incorporated the assumption that the maximum detected concentrations extend from the surface down to the basalt interface at a depth of 5 ft. The contaminant profiles are illustrated in Figure 4-22.





Assumptions:

- The area of the site is the area of contamination: 1,560 ft × 1,180 ft = 1,840,800 ft².
- The contamination at the site was caused by windblown deposition and is limited to the top 2 ft of soil, and the underlying soils are not contaminated (i.e., intervals below the 1 to 2-ft interval were assigned zero concentrations for the depth-weighted average concentration calculations).
- The vertical interval for the site is 2 ft.
- The simulated source term volume is the area times the vertical interval: 1,840,800 ft² × 2 ft = 3,681,600 ft³.
- Radioisotopes are the only contaminants of potential concern at the site.

Notes:

- Concentrations in the top 6 in. (0 to 0.5-ft interval) are either the 95% lognormal UCL or the maximum detected concentration, whichever is less.
- Simulated source term concentrations below the 0 to 0.5-ft surficial sediments are depth-weighted averages calculated as follows:

$$C_I = \frac{\sum_{i=k}^{I} C_i}{I}$$

where:

C_I = depth-weighted average concentration over the entire interval I
C_i = 95% UCL or maximum detected concentration, whichever is less, for the ith 1-ft increment
i = specific 1-ft increment (i.e., 0 to 1 ft, 1 to 2 ft, ..., I-1 to I ft)
I = the number of 1-ft increments.

- For ARA-23, I = 2.
- Only soil sample data were considered. Data from GPRS surveys were not included in the concentrations. See Section 6.5.1 for a qualitative sensitivity analysis based on the GPRS data.

Source Term Concentrations

	Radionuclides (pCi/g)					
Depth (ft)	**Am-241**	**Cs-137**	**Ra-226**	**Sr-90**	**Th-230**	**U-235**
0-0.5	138E-02	2.92E+01	3.62E+00	2.51E+01	1.53E+00	1.24E-01
0-4	1.14E-02	1.02E+01	1.51E+00	7.44E+00	7.00E-01	3.73E-02
0-10	4.55E-03	4.09E+00	6.04E+00	2.98E+00	2.80E-01	1.49E-02

Figure 4-19. ARA-23 ARA-I and ARA-II radiologically contaminated soils source term concentrations and assumptions for risk assessment.

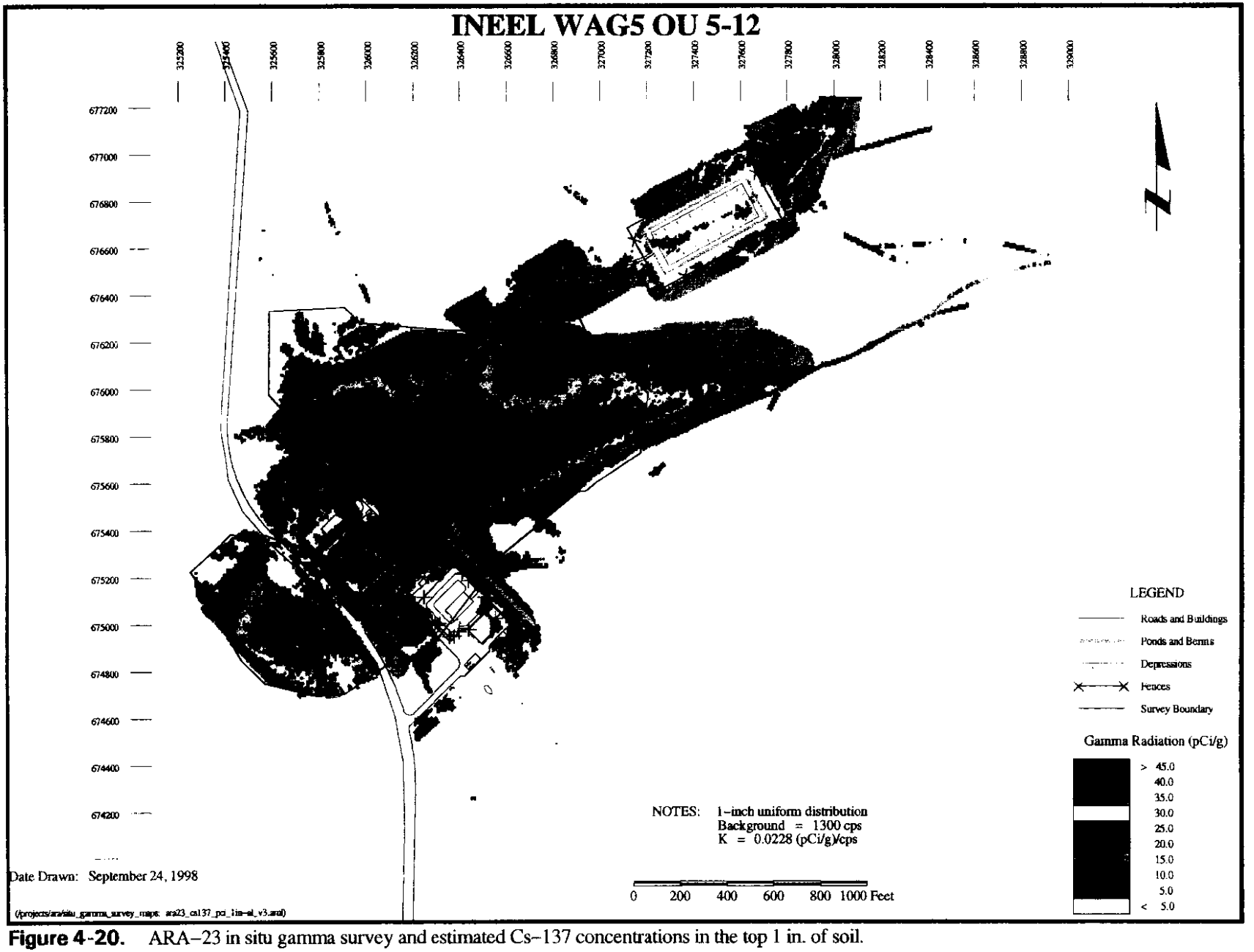


Figure 4-20. ARA-23 in situ gamma survey and estimated Cs-137 concentrations in the top 1 in. of soil.

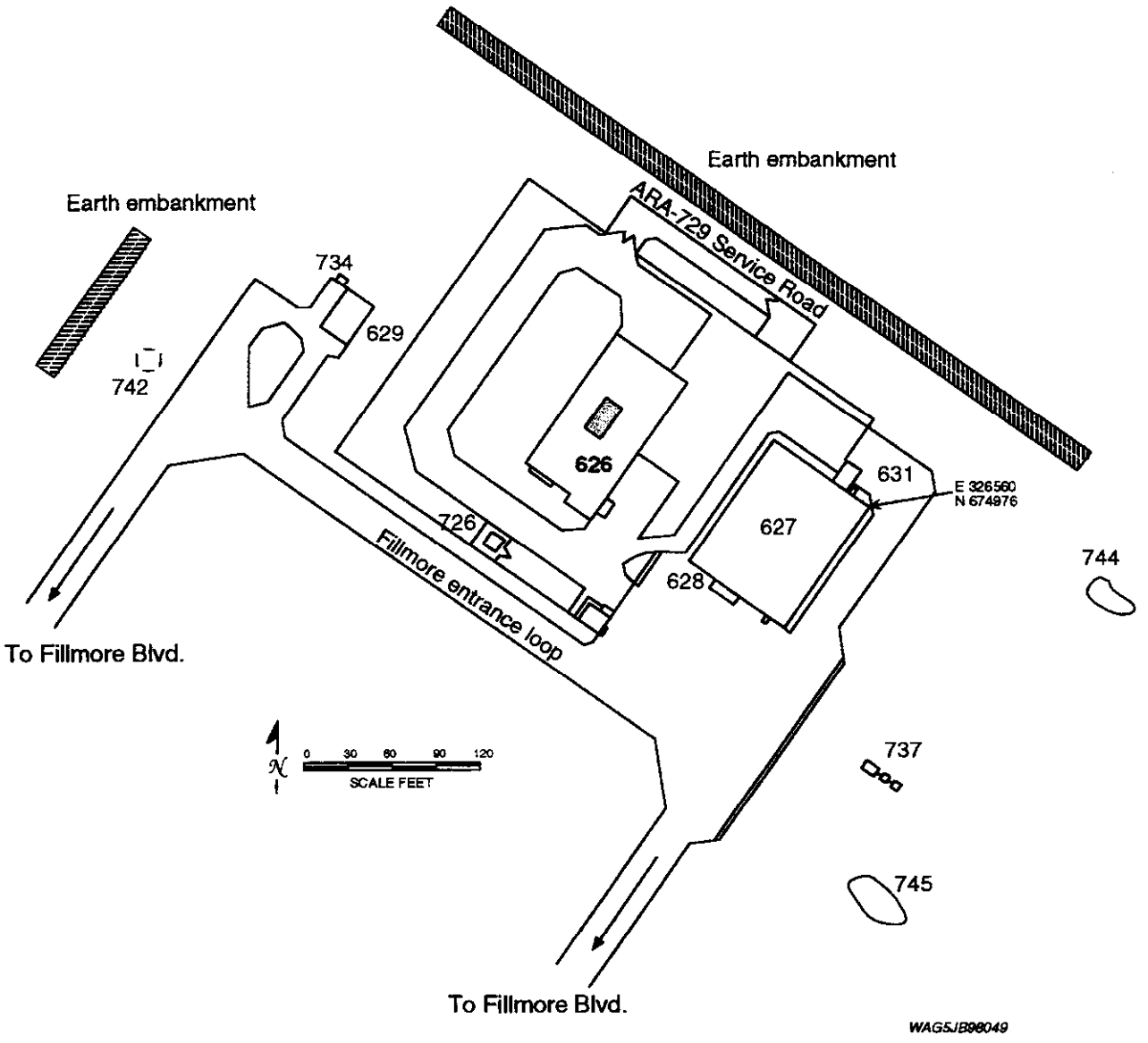
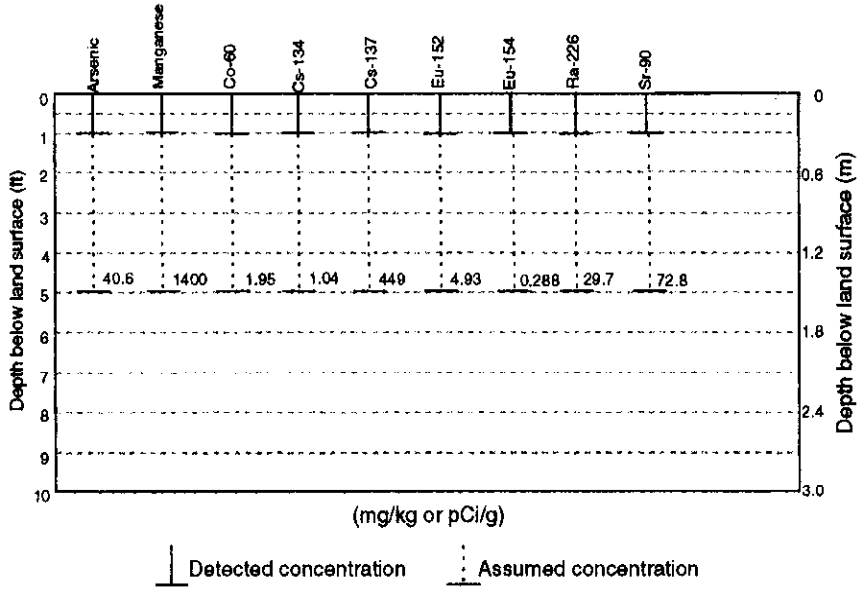
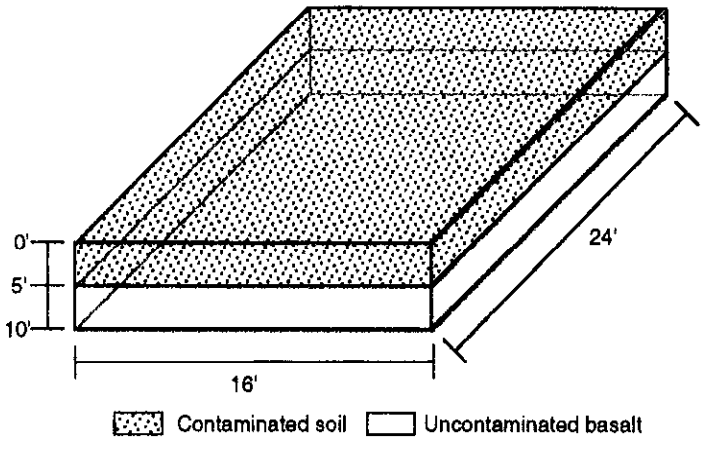


Figure 4-21. ARA-I soils beneath the ARA-626 Hot Cells, Site ARA-25.





Source Term Concentrations

Depth (ft)	Arsenic	Manganese
	Nonradionuclides (mg/kg)	
0-5	4.06E+01	1.4E+03

Depth (ft)	Co-60	Cs-134	Cs-137	Eu-152	Eu-154	Ra-226	Sr-90
	Radionuclide (pCi/g)						
0-5	1.95E+00	1.04E+00	4.49E+02	4.93E+00	0.29E+00	2.97E+01	7.28E+01

Assumptions:

- The area of the site is the area of contamination: 16 ft × 24 ft = 384 ft².
- The depth of the site is the depth of the surficial sediments down to the first basalt interface: 5 ft.
- The simulated source term volume is the area times the depth of the surficial sediments: 384 ft² × 5 ft = 1920 ft³.
- Basalt underlying the 5-ft-thick layer of surface sediment is uncontaminated. Therefore, simulated occupational and residential exposures are limited to the 0 to 5-ft depth-weighted average concentrations.

Notes:

- Concentrations are the maximum detected concentration.

Figure 4-22. ARA-25 ARA-I soils beneath the ARA-626 hot cells source term concentrations and assumptions for risk assessment.

The contaminated concrete floor slabs are not included in the risk assessment. The fixed contamination detected on the concrete would not significantly change the results of the BRA. Furthermore, the concrete will be removed and disposed of as the D&D of the ARA-I facility is completed and the comprehensive RD/RA is implemented.

4.2.2 Group 2—Auxiliary Reactor Area-III

Construction of the ARA-III facility was completed about 1959 to house the Army Gas Cooled Reactor Experiment (GCRE) research reactor. Experiments with the GCRE continued until the plant was deactivated in 1961. In 1963, the ARA-III facility was modified to support the Mobile Low Power Reactor (ML) series of tests conducted at ARA-IV and remained active until late 1965 when the Army Reactor Program was phased out. In 1969, two buildings were constructed to provide additional laboratory and office space. The facility was shut down in 1989. Two ARA-III sites, ARA-12 and ARA-24, were quantitatively evaluated in the BRA.

4.2.2.1 ARA-12—Radioactive Waste Leach Pond.

4.2.2.1.1 Site Description—The ARA-12 site is an unlined surface impoundment of a 5750-m^2 area constructed in a natural depression west of ARA-III across Fillmore Boulevard. The pond received low-level liquid waste from reactor research operations from about 1959 to 1965. Liquid waste was stored temporarily in tanks, then was transferred to the leach pond via an underground pipe. Effluent contained chromium, used in solutions to inhibit algae growth, and minute amounts of low-level radioactivity. A second separate line to the leach field originated in an uncontaminated water storage tank (ARA-709). A third source of effluent was facility runoff via a culvert. From 1966 to 1987, operations at ARA-III were limited to component and instrumentation testing, instrumentation development and fabrication, and chemical research. No waste associated with those activities was discharged to the leach pond. In 1991, the culvert was plugged in preparation for implementing D&D at ARA-III. The tanks and waste lines to the leach pond were removed in 1993 during the D&D of ARA-III. The location of ARA-12 is shown in Figure 4-23. The area of the site is approximately 5,750 m^2.

4.2.2.1.2 Site Investigations—In 1984, eight samples from the top 1 to 2 in. of surface soil and two subsurface soil samples from depths of 2 to 2.8 ft were collected. The contaminants detected included Ag-108m, Co-60, and Cs-137, but the data were not validated. Effluent sampling was performed in 1986. The pH was basic, and the water quality parameters were consistent with clean wastewater. Toxic metals were detected near the instrument detection limits. In 1993, 10 surface soil samples from the top 6 in. and 12 subsurface soil samples from depths of 2 to 7 ft were collected. The depth of sampling did not extend to 10 ft because a soil/basalt interface was encountered at a depth of 7 ft. The samples were analyzed for all suspected contaminants. Cobalt-60, Cs-137, and Ag-108m were detected above local background levels established during the sampling (Pickett et al. 1994). Americium-241, U-234, U-238, and Pu-239/240 also were detected. Metals detected above background were arsenic, beryllium, cadmium, chromium, lead, mercury, nickel, selenium, and zinc. No VOCs were detected (Pickett et al. 1994). The highest concentrations for most contaminants were detected in surface soils. In 1997, an in situ radiation survey with a vehicle-mounted scintillator was conducted to measure and determine the detailed distribution and concentrations of Cs-137 in the surface soil (see Josten 1997 in Appendix J). More than 13,000 measurements were collected at ARA-12 and ARA-24, and the data were converted to estimates of Cs-137 concentrations.

4.2.2.1.3 Nature and Extent of Contamination—Three metals and seven radionuclide contaminants were retained after contaminant screening (see Section 3.4 and Appendix B). Chromium, lead, manganese, Ag-108m, Co-60, Cs-137, U-234, and U-238 were detected throughout most of the soil

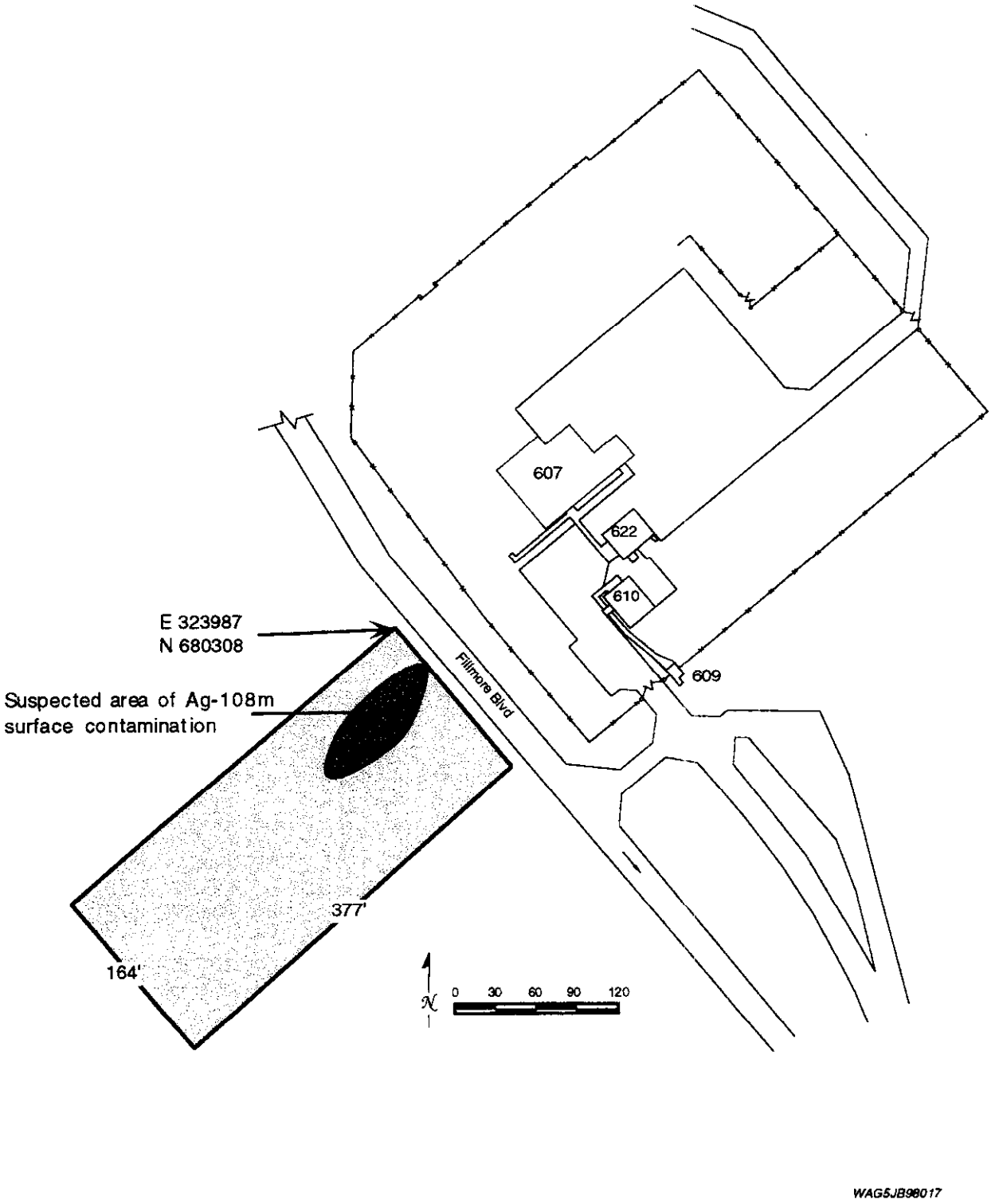


Figure 4-23. ARA-III radioactive waste leach pond, Site ARA-12.

profile to a depth of 5 to 7 ft, as shown in Figure 4-24. Americium-241 was detected in surface soils and at a depth of 2 to 3 ft, while Pu-238 was detected only in surface soils. Converted GPRS data illustrating the Cs-137 distribution across the site are discussed below with Site ARA-24. The highest Cs-137 concentration measured by the GPRS was 308 pCi/g at the southwest corner of the site outside of the pond boundary.

4.2.2.2 ARA-24—ARA-III Windblown Soils.

4.2.2.2.1 Site Description—The ARA-24 site is defined as the surface soils surrounding the ARA-III facility identified by the 1990 aerial survey, excluding ARA-12 and including the area within the ARA-III facility fence. The ARA-24 site is plotted in Figure 4-25 and has an area of about 38,200 m^2.

4.2.2.2.2 Site Investigations—An aerial radiological survey was performed in 1990. Based on detected counts per second, inner (35,000 to 110,000 cps) and outer (1,100 to 2,400 cps) isopleths were defined. In 1993, sampling was performed at a depth between 0 to 4 in. The four samples were tested by gamma spectroscopy and for alpha and Sr-90 contamination (Jorgensen 1995). Americium-241, Pu-238, Pu-239, Sr-90, U-234, U-238, and Cs-137 were detected.

In 1997, an in situ radiation survey with a vehicle-mounted scintillator was conducted to measure and determine the detailed distribution and concentration of Cs-137 in the surface soil system (see Josten 1997 in Appendix J). More than 13,000 measurements were collected at ARA-12 and ARA-24, and the data were converted to estimates of Cs-137 concentrations.

4.2.2.2.3 Nature and Extent of Contamination—Based on the contaminant screening in Appendix B, ten contaminants were retained for quantitative risk assessment. The contaminant profiles are illustrated in Figure 4-26. Contaminants detected in concentrations greater than background values include chromium, lead, manganese, Am-241, Cs-137, Pu-238, U-234, and U-238. Background values have not been established for Ag-108m, and Co-60. Therefore, all positive detections were evaluated against an assumed background value of zero.

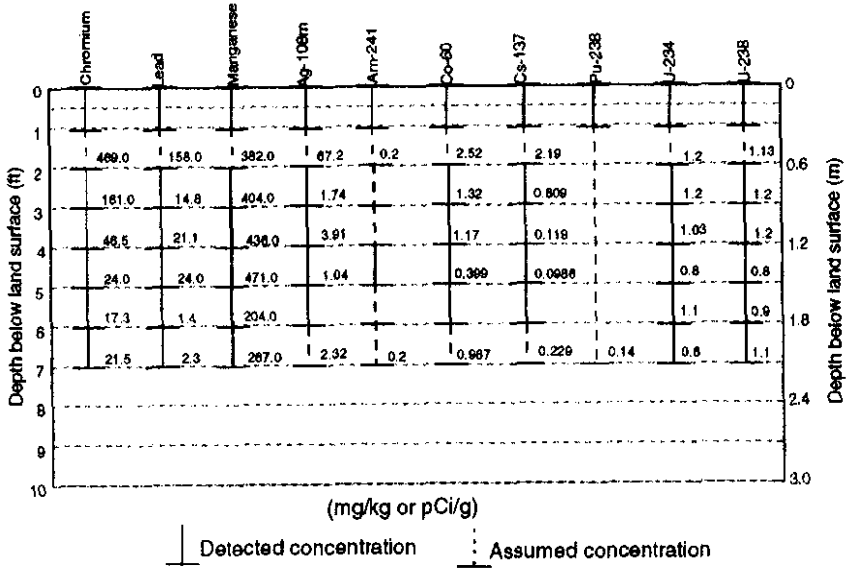
Converted data from the 1997 in situ gamma survey were compiled into maps showing the quantitative distribution of Cs-137 across the site. The concentrations are shown in Figure 4-27. All readings above local background values established during the survey were detected outside of ARA-24 near the boundary of ARA-12 (see Josten 1997 in Appendix J).

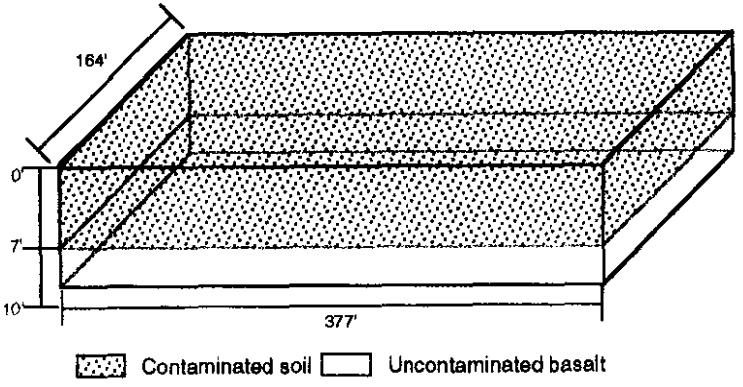
4.2.3 Group 3—Power Burst Facility Reactor Area

The PBF Reactor Area was constructed just north of the remains of the SPERT-I facility in 1972. The SPERT-I reactor was operated from 1955 to 1964, and remnants of the original SPERT-I facility, which consist of a small terminal building, a small instrument cell, some decomposing pavement, an abandoned seepage pit, and an old leach pond, remain in the vicinity of the PBF Reactor Area. The PBF Reactor Area now houses the PBF reactor, which has been on standby since 1985. Besides the reactor building, existing structures include a maintenance and storage building, cooling towers, two substations, and numerous smaller buildings and structures. Three sites, PBF-05, PBF-10, and PBF-12, were quantitatively assessed in the BRA.

4.2.3.1 PBF-05—PBF Reactor Area Warm Waste Injection Well.

4.2.3.1.1 Site Description—The PBF-05 site is a vadose zone injection well, 33.5 m (110 ft) deep, for the disposal of low-level radioactive waste and raw coolant water. No hazardous waste was discharged into the well (Hillman-Mason et al. 1994). Though the well was drilled in 1969, it did not





Assumptions:

- The area of the site is the area of contamination: 377 ft × 164 ft = 61,828 ft².
- The vertical interval for the site is the depth of the surficial sediments down to the basalt interface.
- The simulated source term volume is the area times the vertical interval: 61,828 ft² × 7 ft = 432,796 ft³.
- The 1 to 2-ft interval (for which there are no data) is contaminated with the same concentrations detected in the 0 to 1-ft interval.
- Basalt underlying the site at a depth of 7 ft is not contaminated.

Notes:

- Concentrations in the top 6 in. (0 to 0.5-ft interval) are either the 95% lognormal UCL or the maximum detected concentration, whichever is less.
- Simulated source term concentrations below the 0 to 0.5-ft surficial sediments are depth-weighted averages calculated as follows:

$$C_I = \frac{\sum_{i=k}^{I} C_i}{I}$$

where:

C_I = depth-weighted average concentration over the entire interval I
C_i = 95% UCL or maximum detected concentration, whichever is less, for the ith 1-ft increment
i = specific 1-ft increment (i.e., 0 to 1 ft, 1 to 2 ft, ..., I-1 to I ft)
I = the number of 1-ft increments.

For ARA-12, I = 7.

- Only soil sample data were considered. Data from GPRS surveys were not included in the concentrations. See Section 6.5.1 for a qualitative sensitivity analysis based on the GPRS data.

Source Term Concentrations

Nonradionuclides (mg/kg)

Depth (ft)	Chromium	Lead	Manganese
0-0.5 (1)	4.69E+02	1.58E+02	3.82E+02
0-4 (2)	2.86E+02	8.80E+01	4.01E+02
0-7 (2)	1.73E+02	5.42E+01	3.64E+02

Radionuclides (pCi/g)

Depth (ft)	Ag-108m	Am-241	Co-60	Cs-137	Pu-238	U-234	U-238
0-0.5 (1)	6.72E+01	2.00E-01	2.52E+01	2.19E+00	1.40E-01	1.20E+00	1.13E+00
0-4 (2)	3.50E+01	2.00E-01	1.32E+01	1.33E+00	1.40E-01	1.16E+00	1.16E+00
0-7 (2)	2.08E+01	2.00E-01	7.89E+00	8.37E-01	1.40E-01	1.02E+00	1.06E+00

Figure 4-24. ARA-12 ARA-III radioactive waste leach pond source term concentrations and assumptions for risk assessment.

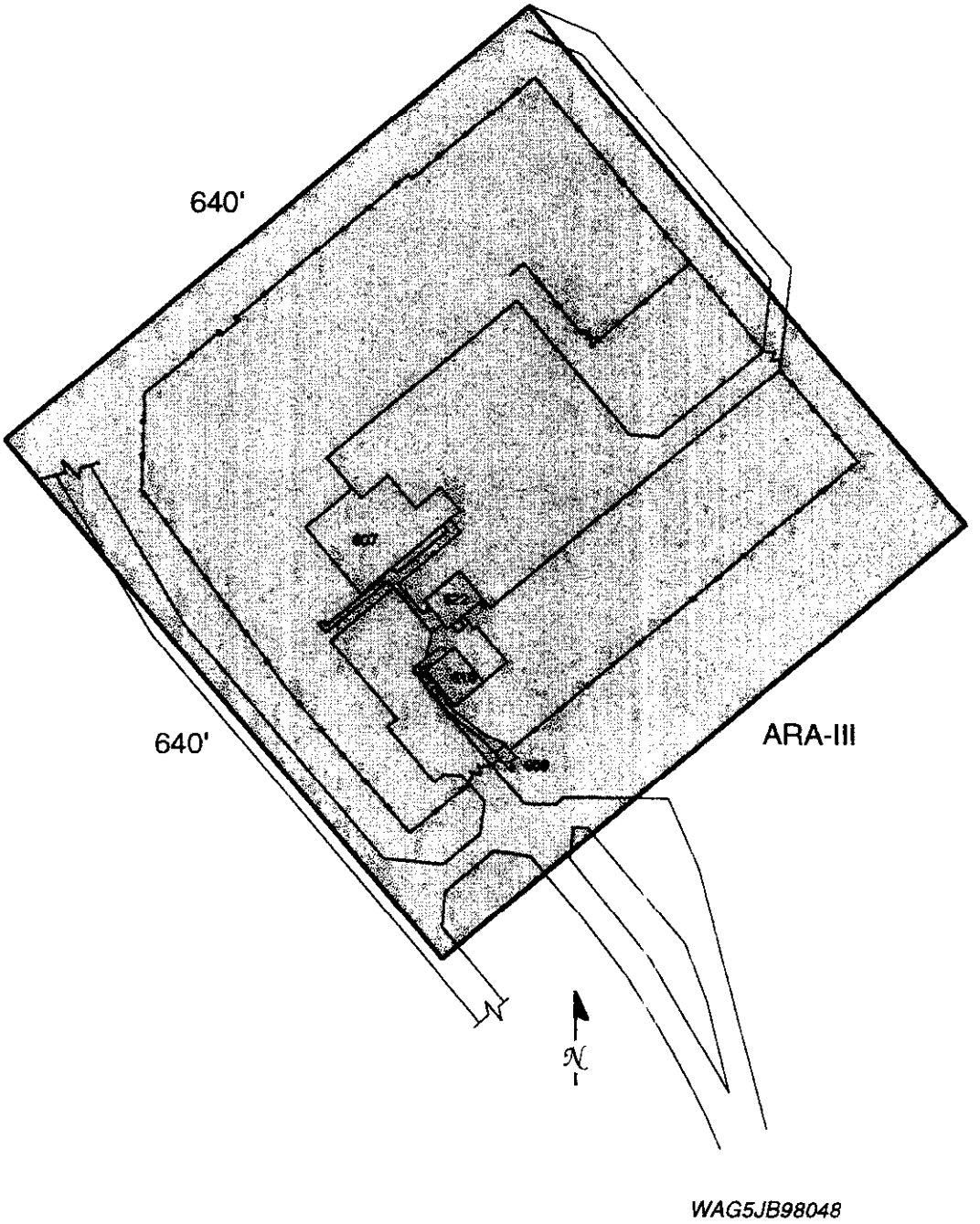
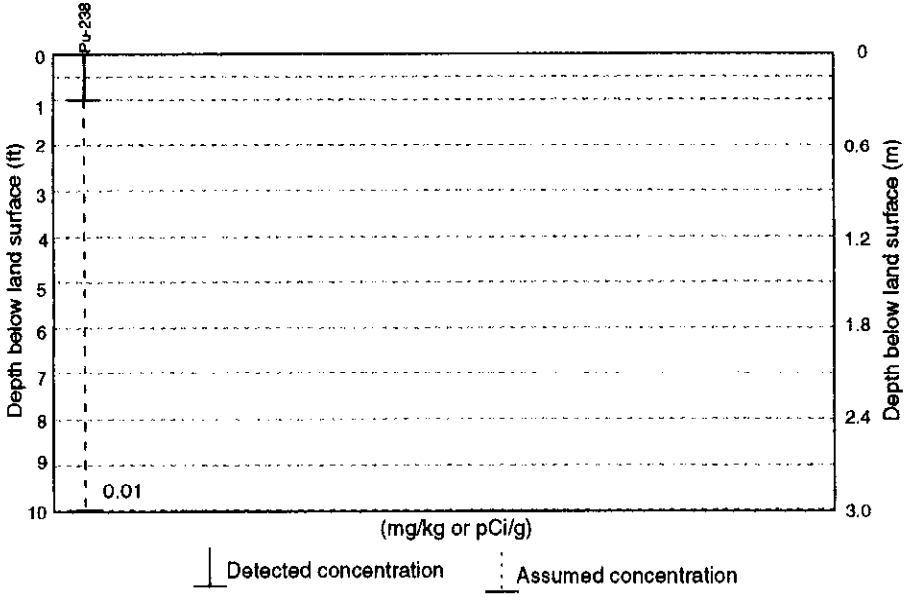
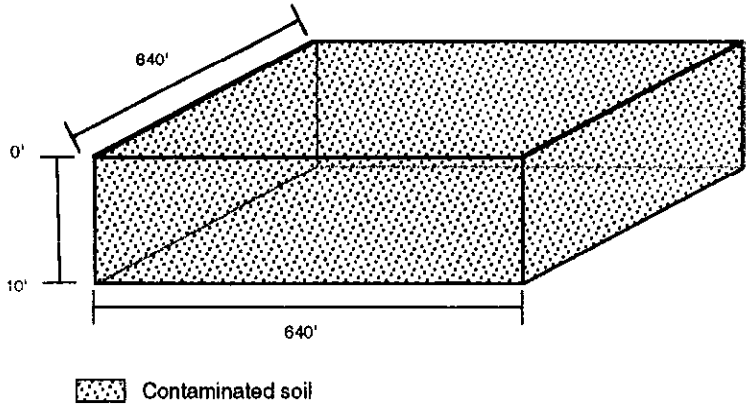


Figure 4-25. ARA-III contaminated soils area, Site ARA-24.





Source Term Concentrations	
Radionuclides (pCi/g)	
Depth (ft)	**Pu-238**
0-0.5	1.00E-02
0-4	1.00E-02
0-10	1.00E-02

Assumptions:

- The area of the site is the area of contamination: 640 ft × 640 ft = 409,600 ft².
- The vertical interval for the site is 10 ft.
- The simulated source term volume is the area times the vertical interval: 409,600 ft² × 10 ft = 4,096,000 ft³.
- The one sample collected and analyzed for the site is representative of the concentrations within each interval for the entire source volume to a depth of 10 ft.

Figure 4-26. ARA-24 ARA-III windblown soil source term concentrations and assumptions for risk assessment.