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Relative Risk Site Evaluation for Buildings 7740 and 7741 Fort Campbell, Kentucky

January 1998

Prepared for the
U.S. Department of the Army
Environmental Division
Fort Campbell, Kentucky

Under Contract DE-AC06-76RLO 1830
to the U. S. Department of Energy

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for Buildings 7740 and 7741
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G. V. Last
T. J. Gilmore
F. J. Bronson

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MASTER

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Summary

Buildings 7740 and 7741 are a part of a former nuclear weapon's storage and maintenance facility located in the southeastern portion of Fort Campbell, Kentucky. This underground tunnel complex was originally used as a classified storage area beginning in 1949 and continuing until 1969. Staff from the Pacific Northwest National Laboratory recently completed a detailed Relative Risk Site Evaluation of the facility. This evaluation included 1) obtaining engineering drawings of the facility and associated structures, 2) conducting detailed radiological surveys, 3) air sampling, 4) sampling drainage systems (including floor drains), and 5) sampling the underground wastewater storage tank. Ten samples were submitted for laboratory analysis of radionuclides and priority pollutant metals, and two samples submitted for analysis of volatile organic compounds.

No volatile organic contaminants were detected using field instruments or laboratory analyses. However, several radionuclides and metals were detected in water and/or soil/sediment samples collected from this facility. Of the radionuclides detected, only ^{226}Ra may have come from facility operations; however, its concentration is at least one order of magnitude below the relative-risk comparison value. Several metals (arsenic, beryllium, cadmium, copper, mercury, lead, and antimony) were found to exceed the relative-risk comparison values for water, while only arsenic, cadmium, and lead were found to exceed the relative risk comparison values for soil. Of these constituents, it is believed that only arsenic, beryllium, mercury, and lead may have come from facility operations.

Other significant hazards posed by the tunnel complex include radon exposure and potentially low oxygen concentrations (<19.5% in atmosphere) if the tunnel complex is not allowed to vent to the outside air. Asbestos-wrapped pipes, lead-based paint, rat poison, and possibly a selenium rectifier are also present within the tunnel complex.

A relative-risk site evaluation of this facility resulted in an overall relative risk rating of medium, primarily because of the surface water/sediment-ecological endpoint pathway. Potential management alternatives for the site include no action, the use of engineering and administrative controls, modification and reuse of the facility, abandonment in place, and/or destruction/removal of the facility. A review of the historic eligibility of the facility, the regulatory requirements governing the continued management of this facility (e.g., underground storage tank regulations, asbestos abatement, etc.), and the possible future uses/needs for this facility should be weighed against the feasibility, implementability, and cost of these different actions.

Acknowledgments

Sincere appreciation is extended to James H. Dudley and Glyn Gordon of the Environmental Division of the Directorate of Public Works at Fort Campbell for their technical support in performing this site investigation and Relative Risk Site Evaluation. Their intimate knowledge of the facility helped facilitate the evaluation. Appreciation is also extended to William D. Sales, who was instrumental in locating and making copies of engineering drawings of the facilities.

The authors would like to acknowledge the contributions of David W. Harvey, David C. Lanigan, Elisabeth S. Barrows, and Wayne C. Cosby of Pacific Northwest National Laboratory. David Harvey reviewed the history and engineering drawings of the tunnel complex and drafted recommendations for conducting a cultural resources review of the facility. David Lanigan was instrumental in preparing many of the graphics used in this document. Elisabeth (Betsy) Barrows provided much of the analytical support and drafted the discussion on analytical methods. Wayne Cosby conducted the final editing and document production support.

The authors would also like to thank James G. Bush, Peter J. Mellinger, and Gene Whelan for providing programmatic support; John C. Evans, Khris B. Olsen, and Michael L. Blanton for providing technical guidance and/or review, Patrick A. Wright for providing Health and Safety support; and Nancy Kelly-Girvin) for providing subcontracting support.

Finally, we would like to thank the subcontractors that provided technical support to this investigation. True Line Coring and Cutting, Nashville, Tennessee, provided all the concrete coring support both inside and outside of the tunnel complex. SPATCO Environmental, Inc., Nashville, Tennessee, provided the excavation and tank sampling support. Analytical Resources Incorporated, Seattle, Washington, provided analytical support for volatile organic analyses.

Glossary

Abbreviations of Elements

Ag	silver	Pb	lead
As	arsenic	Pu	plutonium
Ba	barium	Ra	radium
Be	beryllium	Rn	radon
C	carbon	Sb	antimony
Cd	cadmium	Se	selenium
Cr	chromium	Sn	tin
Cs	cesium	Sr	strontium
Cu	copper	Th	thorium
³ H	tritium	Tl	thallium
Hg	mercury	U	uranium
K	potassium	Zn	zinc
Ni	nickel		

Acronyms

ACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
ACOE	U.S. Army Corps of Engineers
AEC	U.S. Atomic Energy Commission
AEHA	U.S. Army Environmental Hygiene Agency
AOC-E	area of concern "E"
ARI	Analytical Resources Incorporated
CVAF	cold vapor atomic fluorescence
DoD	U.S. Department of Defense
EPA	U.S. Environmental Protection Agency
ICP/MS	inductively coupled plasma/mass spectrometry
MEDDAC	Medical Department Activity
MDA	minimum detectable activity
MSL	mean sea level
NCRP	National Council on Radiation Protection and Measurement
NHPA	National Historic Preservation Act
PID	photo ionizing detector
PMS	Preventive Medicine Service
PNNL	Pacific Northwest National Laboratory
PPE	personal protective equipment
PRG	preliminary remediation goals
RRSE	relative risk site evaluation
SHPO	State Historic Preservation Officer
SNL	Sandia National Laboratory
SWMU	solid waste management unit
TCE	trichloroethylene

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1.0 Introduction

Building 7740 is a tunnel complex located in the southeastern portion of Fort Campbell at the site of the old Clarksville Base (Figure 1.1). This facility was used as a nuclear weapons storage and maintenance area from 1949 to 1966. Building 7741 is an associated underground wastewater storage tank located just outside the tunnel complex. The *1996 Installation Action Plan* lists this site as area of concern "E" (AOC-E) (ACOE 1996).

Fort Campbell staff requested the assistance of the Pacific Northwest National Laboratory (PNNL) in conducting a relative risk site evaluation (RRSE) of several facilities. Documentation and results of the RRSE process applied to these facilities are included in the report *Relative Risk Site Evaluations for Fort Campbell* (Whelan et al. 1997). Because of the unique nature of the AOC-E site, however, this separate and more detailed report was compiled to capture the pertinent information required to support a determination on future uses of the facility and make recommendations on possible corrective actions.

The site was evaluated in two steps due to the uncertainties and complexities associated with the site. On May 7-8, 1997, PNNL staff conducted a records search and reconnaissance survey of the tunnel complex (excluding Structure A that remained locked)¹ to support the development of a field sampling plan to acquire the data necessary to complete the RRSE². The second step of this evaluation was to obtain access to all areas of the facility and to collect the necessary environmental samples. This field sampling effort was conducted from August 25-28, 1997, and was directed at collecting samples considered to be representative of the worst case levels of contamination expected to be found in these facilities.

This report provides a synopsis of the site's background (including its history, previous environmental investigations, and environmental setting) and a detailed description of the facility. Then the sampling and analytical methodologies used in this study and their results are described. Finally, some conclusions and recommendations are provided.

¹ G. V. Last and T. J. Gilmore. 1997. "Fort Campbell AOC-E (7740 Tunnel Complex) Trip Report for May 7 and 8, 1997" in Letter from George V. Last to Jim Dudley, dated June 11, 1997.

² G. V. Last, T. J. Gilmore, and F. J. Bronson. 1997. Field Sampling Plan for Relative Risk Site Evaluation of AOC-E Building 7740 Tunnel Complex, Fort Campbell, Kentucky. Dated 13 August 1997. Pacific Northwest National Laboratory, Richland, Washington.

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2.0 Background

This section briefly describes the history of the site as we currently understand it, previous environmental investigations, potential contaminants of concern, and the environmental setting.

2.1 Site History

Building 7740 (formerly designated as building 318) is one of seven underground tunnel complexes previously used to store and maintain nuclear capsules (warheads). Building 7741 (formerly designated as Building 358) is an associated underground wastewater storage tank located just outside the tunnel complex. These buildings are located along the southern boundary of Fort Campbell, Kentucky, in an area once designated as the Clarksville Base. Clarksville Base was established in 1948 as part of the Armed Forces Special Weapons Project. Classified storage began in 1949 and continued until 1969 (AEHA 1986). The Defense Atomic Support Agency assumed control of the base in the late 1950's. Sandia Corporation, Albuquerque, New Mexico, was the principal Atomic Energy Commission (AEC) contractor for the base from February 1948 to August 1965. In August 1965, the AEC and its contractors vacated Clarksville Base, and in October 1969, the Defense Atomic Support Agency turned the base over to Fort Campbell.

The Building 7740 tunnel complex consists of three wings or structures (Figure 2.1). Structure A contained the nuclear capsule storage area that was secured behind a bank-type locking vault door at the end of a 600 ft-long tunnel. This vault door had reportedly been locked since the 1960s and the combination was unknown. Structure B and Structure C were "maintenance" wings. Maintenance activities reportedly conducted in Structure C involved dismantling the nuclear assembly system, checking the activity of the fissile material, and replacing the polonium/beryllium initiators³. Structure B was originally designated as a back-up for Structure C; however, it appears to have most recently been set up as a "Medical Wing."

The wastewater tank (Building 7741) and its associated influent wastewater system were designed to capture potentially contaminated wastewaters from the tunnel complex. The 10,000-gallon tank is located outside the tunnel complex and across the road from the main portal entrance. This wastewater drainage system was installed to contain decontamination water that may be generated if an accident occurred in either the maintenance wings or in the vault storage area. This system drained both the emergency (deluge) showers in the maintenance areas and the vault room floor drains.

³ L. A. Dawson. December 1, 1994. "Trip Report - Fort Campbell (Clarksville Base), Kentucky/Tennessee, Former Weapons Storage Area". Letter to John C. Gould, Department of Energy, Albuquerque, New Mexico, from L. A. Dawson, Sandia National Laboratory, Albuquerque, New Mexico.

Figure 2.1. General Site Layout

The *1996 Installation Action Plan* (ACOE 1996) lists this site as AOC-E and lists the contaminants of concern as radiation (radium, plutonium and beryllium). The media of concern was listed as soil and groundwater.

2.2 Previous Environmental Investigations

Several environmental investigations have previously been conducted at the Building 7740 tunnel complex. These have included 1) a 1970 closeout radiological survey, 2) several radon studies conducted from 1971 to 1986, 3) site tours and historical records reviews in 1994, and 4) an asbestos assessment survey in 1996. These studies are briefly discussed below.

2.2.1 Closeout Radiological Survey (1970)

The Defense Atomic Support Agency conducted a closeout radiological study in July 1970 to determine if Clarksville Base had any radioactive contamination. This study found elevated levels of indoor radon, but concluded that "No radiological health hazards existed in Building 318 (now designated Building 7740) at the time of the survey," and that "The contamination found there was probably due to natural radioactivity and Rn daughter products dispersed in air" (AEHA 1986).

2.2.2 Radon Studies (1971 To 1986)

M. F. Vaeth⁴, with the Preventive Medicine Service at Fort Campbell reviewed ²²²Rn accumulation in Clarksville Base facilities. Vaeth reported that Sandia Corporation had experienced problems with ²²²Rn accumulation during their operation of the base from 1948 to 1965. Sandia had noted that without mechanical ventilation, ²²²Rn accumulated beyond recommended health criteria in the Building 7740 tunnel complex. A special radiation protection study conducted by the U.S. Army Environmental Hygiene Agency (AEHA) in 1971 indicated that several structures experienced ²²²Rn accumulation problems. They attributed the accumulation to a combination of poor ventilation and naturally occurring U deposits. Follow-up evaluations were conducted in 1976 by AEHA and in 1981 by the Preventive Medicine Service (PMS). Table 2.1 provides the sample results for Building 7740. The results from all other facilities ranged from 0.05 to 58.69 pCi/L, with a median value of 2.45 pCi/L. The maximum permissible air concentration (MPC_{air}) of ²²²Rn in unrestricted areas of occupancy is 3.0 pCi/L (10 CFR 20)⁵. Based on these surveys, the facility was then (before 16 March 1984) apparently sealed by welding the main portal doors shut using a metal strap. The facility reportedly remained sealed until about 1994.

⁴ M. F. Veath. 27 March 1984. "Evaluation and Control of Radon-222 in Soil Covered or Subsurface Structures at Fort Campbell." Memorandum for Deputy Post Commander from Mary F. Veath, Chief, Preventive Medicine Service, Headquarters Medical Department Activity, Fort Campbell, Kentucky.

Table 2.1. Radon-222 Sampling in Building 7740

Date Sampled	Agency Performing Sampling	Sample Results (pCi/L)	MPC _{air} (pCi/L)
7-17 June 1971	AEHA	152.48	3.0
5-6 April 1976	AEHA	14.6 43.4	3.0
20 November 1981	PMS	21.4 33.4	3.0

After Vaeth⁵

In 1986, the AEHA (1986) analyzed indoor Rn concentrations inside occupied Fort Campbell buildings. While this study did not specifically address Building 7740, it did collect air and soil samples from other Clarksville Base facilities, which can provide an indication of background concentrations. The air grab sample taken outside the MEDDAC facility produced a radon concentration of 0.12 pCi/L. This is within the 0.1 to 0.15 pCi/L range of outdoor Rn concentrations found throughout the United States (NCRP 1984). Results of grab air samples from inside Building 7811 found Rn concentrations of 8.9 ± 0.33 pCi/L and 10 ± 0.4 pCi/L. Grab samples from inside three other facilities ranged from 1.3 ± 0.1 to 1.9 ± 0.2 pCi/L. The results of the working-level-monitor measurements taken inside the "Gravel Gertie" area of Building 7811, found that personnel who work there could be exposed to concentrations that greatly exceed the occupational standard for Rn daughters. The results from the working level monitor at five other indoor locations had radon daughter concentrations significantly below the occupational standard. Analytical results of soil samples collected from outside the "Gravel Gertie" and the MEDDAC facility are provided in Table 2.2.

Table 2.2. Results of Soil Samples from the 1986 AEHA Study

Sample Identification	²¹⁰ Pb (pCi/g $\pm 2\sigma$)	²¹⁰ Bi (pCi/g $\pm 2\sigma$)
Adjacent to "Gravel Gertie"	1.5 ± 0.4	1.2 ± 0.3
Adjacent to "Gravel Gertie"	1.5 ± 0.3	1.4 ± 0.3
Above MEDDAC "Crawl Space"	1.7 ± 0.4	1.3 ± 0.4
Above MEDDAC "Crawl Space"	1.4 ± 0.4	0.94 ± 0.19

After AEHA (1986)

2.2.3 Site Reconnaissance and Records Review (1994)

In 1994, staff from the Sandia National Laboratory (SNL) visited the former nuclear weapons storage area at Fort Campbell⁴. The U.S. Army Center for Health Promotion and Preventive

⁵ M. F. Veath. 27 March 1984. "Evaluation and Control of Radon-222 in Soil Covered or Subsurface Structures at Fort Campbell." Memorandum for Deputy Post Commander from Mary F. Veath, Chief, Preventive Medicine Service, Headquarters Medical Department Activity, Fort Campbell, Kentucky.

Medicine (ACHPPM) also toured the site in 1994 and searched available records (ACHPPM 1994). ACHPPM provided recommendations on radiological surveys that would be required to declare the Clarksville Base safe for unrestricted use. They reported that a close-out radiation survey was supposedly made of the base right after the nuclear weapons were removed (i.e., 1962-1966), but that no documentation could be found to substantiate this. They further suggested that survey techniques used at that time might not be acceptable by today's standards. They concluded that several areas may be potentially contaminated and would require verification surveys. In particular they suggested that the Structures A, B, and C should be treated as affected areas and should undergo alpha, beta, and low-energy gamma radiation measurements as well as gross alpha-beta wipe tests. Corridors should be treated as unaffected areas with a maximum 10%, but not less than 1% of the area surveyed. Biased sampling was recommended for all floor drains, floor cavities (e.g., source storage pits), and ventilation systems. Special evaluations were recommended for the wastewater storage tank, including techniques to locate the tank, sampling the inside of the tank for radioactivity, and/or depth discrete soil sampling. Recommended analyses included gross alpha-beta and spectral gamma. They also recommended that if any contamination is found either at the floor drains or at the wastewater tank then an extensive survey of all drain lines should be undertaken.

2.2.4 Asbestos Assessment Survey (1996)

In 1996, Gobbell Hays Partners, Inc. conducted an Asbestos Assessment Survey (Gobbell Hays Partners, Inc. 1996) of the tunnel complex. They report asbestos to be present in the insulation around some pipes, duct systems, and fire door insulation.

2.3 Potential Contaminants Of Concern

Based on the available information, the potential contaminants of concern include

- Metals - Pb, Be
- Volatile Organic Compounds - trichloroethylene (TCE), alcohol, acetone
- Radionuclides - U (fissionable ^{235}U and daughter products), Ra, Pu

2.4 Environmental Setting

Fort Campbell is located in the geomorphic regions known as the Mississippian Plateau (in Kentucky) and the western Highland Rim (in Tennessee). Much of the installation is underlain by fractured and karstified carbonate rock of the Mississippian-age St. Louis and Ste. Genevieve Limestones⁵. The old Clarksville Base area is relatively remote, and access to the tunnel complex

⁴ L. A. Dawson. December 1, 1994. "Trip Report - Fort Campbell (Clarksville Base), Kentucky/Tennessee, Former Weapons Storage Area". Letter to John E. Gould, Department of Energy, Albuquerque, New Mexico, from L. A. Dawson, Sandia National Laboratory, Albuquerque, New Mexico.

⁵ C. J. Taylor. 1995. *Results of Dye-Tracing Tests in the Little West Fork Basin, Fort Campbell Military Reservation, Tennessee*. DRAFT. Prepared by the U.S. Geological Survey for the U.S. Department of the Army, Fort Campbell, Directorate of Public Works, Environmental Division. Fort Campbell, Kentucky.

is restricted by a locked door. The topography of the site ranges from 420 to 500 ft above mean sea-level (MSL).

2.4.1 Groundwater

Groundwater beneath Fort Campbell occurs generally in the residual soil and underlying limestone bedrock (Metcalf & Eddy 1995). A. D. Little (1996) notes that the saturated overburden aquifer consists of groundwater in the residuum and epikarst that has a piezometric surface distinct (higher) from that in the underlying regional bedrock aquifer. The overburden aquifer is limited spatially and is not continuous across the installation. This upper aquifer is considered a recharge source to the regional aquifer with vertical flow pathways being highly localized. In areas of deep overburden, groundwater sometimes has a similar elevation to that in the bedrock wells; in these areas, the deep overburden and the bedrock aquifers are likely to be hydraulically connected and are, therefore, both considered part of the regional aquifer. A. D. Little (1996) notes that a potentiometric map of the overburden aquifer has not been developed. Fort Campbell's overburden aquifers are small, laterally discontinuous, and potentially perched, and thus do not lend themselves to contouring on a large scale.

Webber (1996) notes that, based on 29 observation wells, the regolith beneath Fort Campbell varies in thickness from approximately 20 to 100 ft with most of the wells being west of the cantonment area. For the wells closest to the cantonment area and not directly in the flood plain, the depth to the water table is on the order of 50 to 80 ft. The residual soil tends to consist of sandy to silty clays with moderate to high plasticity and possibly reddish, sticky clay derived from weathering (Metcalf & Eddy 1995; A. D. Little 1996; Hileman 1996). In two different samples, the saturated hydraulic conductivities of the residual soil was determined as $4.9\text{E-}08$ and $7.2\text{E-}06$ cm/s (Metcalf & Eddy 1995). This type of soil could impede the mobility of contaminants to the water table if conduits for flow from the surface to the water table do not exist. Fractured carbonate bedrock underlies the regolith and is visible where the regolith is thin or eroded.

The underlying bedrock at Fort Campbell consists principally of two limestone formations: Ste. Genevieve (formerly known as Monteagle) Limestone and the underlying St. Louis Limestone (Metcalf & Eddy 1995). The Ste. Genevieve Limestone is up to 100 ft thick, and the St. Louis Limestone is similar in appearance and general composition to the Ste. Genevieve Limestone with a thickness of over 300 ft in the eastern part of the installation (Metcalf & Eddy 1995). At Fort Campbell, the Ste. Genevieve Limestone appears to have weathered into residuum, and, therefore, the limestone is largely the St. Louis Limestone, especially in regions of the drainage ways (A. D. Little 1996; Metcalf & Eddy 1995). A. D. Little (1996) also notes that vertical recharge through these limestones may be generally diffuse with the limestone acting as an aquitard. During the drilling of monitoring wells through this formation, the groundwater was often observed to rise rapidly indicating that groundwater was under pressure. Figure 2.2 presents A. D. Little's conceptualization of the hydrogeology of the region.

Figure 2.2. Schematic of Fort Campbell Geohydrology (After A. D. Little 1996)

Hileman (1996) goes on to note that the potentiometric surface in the bedrock aquifer indicates that the directions of groundwater flow in the area generally mimic the directions of surface water flow from uplands toward and along perennial stream valleys. The residents and workers at Fort Campbell and numerous nearby rural residents use the bedrock aquifer as a source of drinking water.

A. D. Little (1996) does provide a potentiometric map that was based on wells chosen for piezometric levels that included bedrock wells that were screened at depths comparable to the springs and to Little West Fork Creek. A few deep overburden wells were also included in the construction of this potentiometric map. These wells encountered between 50 to 100 ft of overburden. The precise placement of contours, potential flow paths, and basin boundaries was subject to interpretation and should be regarded as approximate. However, based on this information, groundwater beneath the Building 7740 Tunnel Complex likely flows towards Little West Fork Creek at a depth consistent with this stream's base flow (~420 ft MSL).

In accordance with the Federal Safe Drinking Water Act Amendments and Tennessee law, a wellhead protection plan must be developed for public water supplies withdrawing water from wells or springs (Fort Campbell 1996). Because Fort Campbell has identified contaminant sources and obtains all of its water from Boiling Spring, a proposed wellhead protection area has

been designated. This wellhead protection area for Boiling Spring involves most of the area associated with Fort Campbell.

2.4.2 Surface Water

Effluent from the wastewater storage tank (Building 7741) was potentially discharged to an old channel of Little West Fork Creek. Most of the watershed for Little West Fork Creek lies within the boundaries of Fort Campbell (Ladd 1996). The major tributaries of the Little West Fork Creek include Noah Spring Branch, Dry Fork Creek, Piney Fork, and Fletchers Fork. The cantonment area is included in three of the watersheds: Dry Fork Creek to the north, Little West Fork, which forms the main drainage stem, and Fletchers Fork in the south. During a 2-year period, base-flow discharges ranged from 18.4 to 419 ft³/s at the mouth of Little West Fork Creek as it left the installation.

Boiling Spring, which supplies the army base with its potable water, is located along Little West Fork Creek, upstream from the Tunnel Complex. Taylor⁶ notes that Boiling Spring does not normally contribute flow to Little West Fork Creek because the discharge of the spring is captured by withdrawal of approximately 45 million gal/d of water, which is piped to the Fort Campbell water treatment plant. Under some extreme flood conditions, discharge from Boiling Spring may discharge through an overflow gate and drain to Little West Fork Creek by way of a short runoff channel on the east side of the pumping station.

⁶ C. J. Taylor. 1995. *Results of Dye-Tracing Tests in the Little West Fork Basin, Fort Campbell Military Reservation, Tennessee*. DRAFT. Prepared by the U.S. Geological Survey for the U.S. Department of the Army, Fort Campbell, Directorate of Public Works, Environmental Division. Fort Campbell, Kentucky.

3.0 Facility Design

A number of pertinent drawings were found in a search of engineering/architectural drawing files at Fort Campbell's Facility Engineers' Office. Appendix A provides a comprehensive listing of the available drawings. The drawing numbers were identified by cross referencing the current building numbers (7740 for the tunnel complex, and 7741 for the wastewater tank) with the old building numbers (Buildings 318 and 358, respectively). The curator of the files, Mr. William (Bill) D. Sale, helped to locate and obtain copies of the drawings. Several of the engineering drawings were compiled into a computer graphics package to generate composite maps and detailed drawings of the facility.

The facility consists of three main underground structures connected by a system of tunnels (Figure 2.1). This facility was excavated into the side of a hill composed of unconsolidated soil overlying limestone bedrock. The main portal entrance is secured by a large steel double door (i.e., a blast door) (Figure 3.1). The main structural components of the tunnel complex consist of approximately 18-in.-thick reinforced concrete walls with arched ceilings. Ventilation ductwork runs down the center of the tunnel corridors on the ceiling. The floors of the corridors are edged with a gutter system designed to drain any natural seepage and/or condensation to a main sump and/or to an exterior drainage system. The tunnel corridors are approximately 9 ft wide and 12 ft high. These corridors connect the three main structures of the facility, designated as Structures A, B, and C. Structure A is located at the end of an approximately 600-ft-long corridor. The entrance to Structure A was protected by a bank-type vault door. This structure was used to store nuclear capsules. Structures B and C are located at the end of short (~50 ft long) corridors that extend perpendicular to the main tunnel near the main portal entrance. The tunnel corridors connecting Structures A, B, and C all come together in a main corridor area that housed the utilities for operating the complex. This main area, referred to as the utility room, contains two small rooms (a wash room and compressor room) located along its eastern wall. In the main corridor is a sump (not shown on the engineering drawings), the main electrical panels, ventilation system monitors, and a steel frame that once supported a bank of emergency backup batteries.

3.1 Structure A

Structure A was mined into the limestone bedrock and is located approximately 60 ft below ground surface. The entrance to this structure was secured by a bank vault door that had remained locked since the mid to late 1960s. Attempts by U.S. Army personnel to open the vault door were unsuccessful. Access to this structure was gained by cutting two 24-in.-diameter holes (one above the other) through the reinforced concrete wall just to the left of the door (Figure 3.2). Contrary to the engineering drawings, this vault door was found to be located within the tunnel corridor. Two additional doors were found behind the vault door defining three small rooms within the corridor (Figure 3.3). Structure A itself originally consisted of four small rooms, each connected to a main corridor area by a short tunnel (Figures 3.3 and 3.4).

Figure 3.1. Photograph of Main Portal Entrance to Tunnel Complex

Figure 3.2. Photograph of Main Vault Door to Structure A, and Location of Access Holes

BUILDING 7740 - STRUCTURE A **FORT CAMPBELL, KENTUCKY**

0 5 10
 Scale (ft)

Figure 3.3. Plan View of Structure A

BUILDING 7740 - STRUCTURE A
FORT CAMPBELL, KENTUCKY

Figure 3.4. Cross Sectional View Through Structure A

This structure also appears to have been modified from the engineering drawings and now contains two larger rooms along the eastern wall of the main corridor area. Each room is secured by its own vault door except the last two small rooms, which are secured by a single vault door at the entrance to their connecting tunnel. The metal liners inside each small vault room on the original engineering drawings have been replaced by steel shelving. The roof vents inside each of the small vault rooms also appear to have been modified and are now covered by a steel plate with a small copper drain line running to the floor drain.

3.2 Structure B

Structure B (also referred to as "B Wing") was identified as the "Medical Wing" on a sign near the utility room area where the two tunnels connecting Structures B and C are located. Structure B consists of three small rooms (Figure 3.5) that are tile lined and had an unusual large high-intensity light in each room. Visual inspection of these unusual light fixtures found the manufacture's nameplate and serial number. These identified the lights as 550 watt, Operay Multibeam "Explosion Proof Lights," manufactured by the Ohio Chemical and Surgical Equipment, Co., Madison, Wisconsin, Catalog No. A32893 (Figure 3.6). An emergency (deluge) shower is located in the corridor between two of the rooms.

3.3 Structure C

Structure C (Figure 3.6) contains one small room and two large rooms, one with an overhead crane or pulley system on a track. The second large room contains what appears to be an anti-static mat covering the floor with a copper grounding rod around the walls. These rooms were apparently designed to conduct maintenance activities on the nuclear capsules. It is believed that both rooms were similar in design, but that the southernmost room was later converted into a communications room (i.e., the sink and overhead crane had been removed and a large coaxial antenna wire installed).

3.4 Sewer and Drainage Systems

The tunnel complex was supported by three separate sewer/drainage systems: one for natural drainage water, one for sanitary wastewater, and one for potentially contaminated wastewater. These drainage systems are considered the most likely collection points for any contamination resulting from operations inside the tunnel complex. An underground wastewater storage tank located in the tank farm area (designated Building 7741) just outside the tunnel complex received outflow from the potentially contaminated wastewater sewer system. The sanitary sewer system drained to a septic tank and drainfield reportedly located just east of the tank farm boundary. Natural drainage water drained to the graded topography and other surface water runoff controls outside the tunnel complex.

**BUILDING 7740
STRUCTURE B, C, & UTILITY ROOM
FORT CAMPBELL, KENTUCKY**

Sanitary Sewer System

- 2" Cast Iron Soil Pipe
- 3" Cast Iron Soil Pipe
- 4" Cast Iron Soil Pipe

Waste Water Sewer System

- 3" Cast Iron Soil Pipe
- 4" Cast Iron Soil Pipe

Drainage Water Sewer System

- 4" Drain Tile

Figure 3.5. Plan View of Structures B and C and the Utility Room Area

Figure 3.6. Light Fixture in B Structure

3.4.1 Wastewater Sewer System

The wastewater sewer system drained areas of the complex that were considered to have the potential for producing contaminated wastewater. This sewer system received wastewater from five floor drains within Structure A and two floor drains within each of Structures B and C, including those under the deluge showers. Each of these areas could be isolated from the rest of the wastewater sewer system using the gate valves.

Wastewater received by this sewer system was discharged into a 10,000-gallon wastewater tank outside the facility. The tank is located under an earthen mound directly across the road opposite the entrance to the tunnel complex (Figure 2.1). The mound covering the tank was found to be overgrown with vegetation. Flow into the wastewater storage tank was controlled by a gate valve. Three valves are located between the service road and the tank, although only the center valve leads to the tank. The two additional valves were installed to support potential expansion of the tank farm to include two additional waste tanks. However, these additional tanks were never installed.

The wastewater tank also has an outlet or effluent valve located on the downgradient side of the tank to the north. A small excavation was observed on the north end of the mound, approximately where a manhole and effluent valve were originally located (Figures 3.7 and 3.8),

and it appears that the valve control has been removed. The outfall from the tank was located approximately 115 ft north of the mound where it would discharge to the old creek bed of Little West Fork Creek. The two risers shown to extend from the top of the tank (Figures 3.7 and 3.8) also appear to have been at least partially removed, with their debris located on the north side of the earthen mound. Thus, it appears that some efforts had been made to isolate this tank.

3.4.2 Sanitary Sewer System

The sanitary sewer system was used to drain the lavatory stools, urinals, and sinks in the utility room as well as the sinks in both Structures B and C. According to the engineering drawings, this system drained into a septic tank and associated drainfield located outside the tunnel complex (Figure 3.7). Drawings show the septic tank and drainfield to be located approximately 67 ft east of the wastewater storage tank, with a minimum of 8 in. of cover overlying the septic tank and 1.5 to 2 ft of soil overlying the drainfield.

Attempts to locate the septic tank and/or drainfield were unsuccessful. An area of approximately 40 by 60 ft was excavated using a backhoe to a depth of approximately 3 ft. However, no indications of the septic tank or drainfield were found. It is hypothesized that the engineering drawings are inaccurate and that the septic tank and drainfield are located elsewhere.

3.4.3 Natural Drainage

Four-in.-diameter drain tile was placed in gravel fill beneath the floors of all structures and tunnel corridors, and along the outside walls of Structures B and C, and the utility room. This drainage system was used to drain waters that infiltrated into the tunnel complex through the overlying soil and rock formations. This drainage system also received condensation waters from inside the tunnel complex via a gutter system located along the walls of the tunnel corridors. These drainage waters were then discharged outside the tunnel complex to local topographic and surface water controls.

3.5 Ventilation Systems

The tunnel complex received fresh air from a main vent and blower system in the utility room area. A system of duct work distributed this air throughout the complex. Of primary importance to this study were the exhaust vents in Structures B and C (Figure 3.5) and the external vents in Structure A (Figure 3.4).

3.5.1 Structures B and C Exhaust Vents

Exhaust vents for Structures B and C are centrally located at the far ends of each structure. A blower system in each of the far rooms of both structures pulled air from these rooms and exhausted it through these outside vents. Airborne contamination potentially present in these rooms would most likely build up on the exhaust filters and other portions of these vent systems.

BUILDING 7741 WASTE WATER STORAGE TANK FORT CAMPBELL, KENTUCKY

0 5 10 20
Scale (ft)

Figure 3.7. Plan View of the Wastewater Storage Tank (Building 7741)

BUILDING 7741 WASTE WATER STORAGE TANK FORT CAMPBELL, KENTUCKY

0 5 10 20
Scale (ft)

Figure 3.8. Cross Sectional View Through the Wastewater Storage Tank

3.5.2 Structure A Vents

Four vents extend from each of the four original vault rooms. These 8-in.-diameter vents extend from the roof of each vault room to the ground surface located approximately 60 ft above (Figure 3.4). These vents terminate inside separate baffled ventilation structures located on the hillside above the complex. These vents were important to this study because they could potentially provide remote access to the vault rooms for air monitoring before entry. One of the four vents was missing its metal ventilator, and all were found to contain municipal waste, i.e., beer cans, paper, and other trash located in the first chamber of the baffle (directly below the ventilator).

Following the discovery of poor air quality (i.e., low oxygen content and high radon) behind the main vault door to Structure A, an 8-in.-diameter hole was cut through the roof of each concrete baffle box to permit direct access into the ventilation shafts leading to the vault rooms. Field screening measurements found no abnormal (above background) readings from these systems. However, it was discovered that access to the vault rooms was blocked, and that standing water was present in two of the shafts. Table 3.1 lists the depth to bottom and depth to water measured in each ventilation shaft.

Table 3.1. Depth to Water and Depth to Bottom in Structure A Vent Shafts.

Vent/Vault Room Number (location)	Depth to Water (in ft from top of concrete)	Depth to Bottom (in ft from top of concrete)	Depth of Standing Water (in ft)
1 (Northwest)	48.58	49.33	0.75
2 (Northeast)	32.17	44.42	12.25
3 (Southwest)	NA	52.67	NA
4 (Southeast)	NA	49.33	NA

NA = Not Applicable

Later observation of the vent shafts from inside the vault rooms revealed that the bottom of the shafts had been covered by a metal plate, preventing access to the vault rooms from above. A small drain tube was connected to the bottom plate and plumbed into the floor drains, which would eventually drain into the wastewater tank outside the facility. Two of these drain tubes are obviously obstructed, leading to the standing water inside the vent shafts.

4.0 Site Investigation

A detailed field sampling plan³ was prepared, based on a review of the previous environmental data, engineered drawings, and the field reconnaissance conducted in May 1997. This plan called for

- sampling the contents of the wastewater storage tank and septic tanks
- sampling the soils at the outfall from the wastewater tank and beneath the septic drain field
- radiological surveying, wipe testing, and air monitoring inside the tunnel complex
- sampling floor drains, sinks, and sumps within the tunnel complex.

This field investigation was conducted August 25-27, 1997. A discussion of the sampling and analytical results from each component of the facility is presented after a brief discussion of the sampling and analytical methodologies used.

4.1 Methodologies

A number of field and laboratory analytical tools were used throughout this study to monitor air quality, determine if radiological controls were necessary, and determine the presence and concentration of contaminants of concern (both radiological and non-radiological).

4.1.1 Field Instruments

The following field survey instruments were used in monitoring the tunnel complex. Air samples were counted on a Ludlum Model 2929 with a beta efficiency of 47% using a ⁹⁰Sr source and an alpha efficiency of 34% using a ²³⁹Pu source. Surveys for fixed and removable contamination were performed using the Victoreen Model 190 radiation meter with a Victoreen Model RP1 probe. Volatile organic compounds were measured with a Photovac 2020 photo-ionizing detector (PID). Oxygen, combustibles, and carbon monoxide were measured with the Industrial Scientific Corporation LTX310 three gas monitor.

4.1.2 Contamination Determinations

The criteria for using field survey instruments to determine if an area or material was radiologically contaminated were taken from the U.S. Department of Energy Radiological Control Manual, Table 2-2, *Summary of Contamination Values*. The alpha release level for U-natural, ²³⁵U, ²³⁸U and associated decay products are 1,000 dpm/100 cm² for removable and 5,000 dpm/100 cm² total (fixed and removable) contamination. The beta-gamma emitters release

³ G. V. Last, T. J. Gilmore, and F. J. Bronson. 1997. *Field Sampling Plan for Relative Risk Site Evaluation of AOC-E Building 7740 Tunnel Complex, Fort Campbell, Kentucky*. Dated 13 August 1997. Pacific Northwest National Laboratory, Richland, Washington.

levels including mixed fission products containing ^{90}Sr are 1,000 dpm/100 cm² for removable and 5,000 dpm/100 cm² total (fixed and removable) contamination.

The determination for volatile organic contamination was a measurable amount in parts per million above background for the site. The background concentration of volatile organics was 0 to 5 ppm outside the tunnel complex and 0 ppm inside.

4.1.3 Sample Collection

A number of environmental samples were collected from the floor drains, the sumps within the tunnel complex, and the wastewater storage tank. Where standing water was present a polyethylene suction sampler was used to withdraw water from the floor drain or sump. A coliwasa was used to collect the sample from the wastewater storage tank. Where standing water was not present, a stainless steel spatula was used to recover sediment from the drains. Table 4.1 provides a list of the samples collected and the laboratory analyses requested.

Table 4.1. Sample Locations and Requested Analyses.

Sample Location	Sample Number	Matrix	Analyzed Constituent		
			Radionuclides	Metals	Volatile Organics
Wastewater Tank	-082797-Tank1 -082797-Tank2 (dup)	water	X	X	X
Tank Outfall	-082797-OUTFALL	soil	X	X	
Septic Tank	None	N/A			
Drain Field Composite	None	N/A			
B wing wastewater system	-flr-B	water	X	X	
B wing sanitary system	-flr-B2	water	X	X	
B and C wing composite wastewater system	-comp-BC	sediment	X	X	
Main corridor/utility room flr drain	-flr-UTIL	water	X	X	
Pipe chase and sump in main corridor	-comp-UTIL	water	X	X	
Lavatory drain	-util-SEWER	sediment	X	X	
A wing composite (back vault room)	-082797-VAULT	water	X	X	

4.1.4 Laboratory Analyses

Three analytical laboratories were used to analyze the environmental samples collected from the tunnel complex; PNNL's laboratory in Richland, Washington, Analytical Resources Incorporated (ARI) of Seattle, Washington, and Battelle's Marine Science Laboratory (MSL) in Sequim, Washington.

PNNL conducted all radiological analyses. Gamma counting was conducted using Intrinsic Germanium detectors with Genie PC analysis software per PNNL's procedure PNL-ALO-464. Alpha/beta counting was conducted using a Wallac 1415 Liquid Scintillation Counter following procedures PNL-ALO-106.4 and PNL-ALO-474. The results of these analyses are presented in Appendix B.

ARI was contracted to analyze water samples for volatile organic compounds by gas chromatography per the U.S. Environmental Protection Agency's (EPA's) method 8010/8020 (EPA 1986). The results of these analyses are presented in Appendix C.

The MSL conducted all metals analyses. Aqueous samples submitted for analyses were not filtered before digestion. The total recoverable metals procedure in EPA Method 1638 was used for digestion, with the exception of substituting nitric acid only for the nitric and hydrochloric acid mixture recommended. Soil samples were digested according to EPA Method 200.3 (EPA 1991). Metals (Ag, As, Ba, Be, Cd, Cr, Cu, Ni, Pb, Sb, Se, Tl, and Zn) were analyzed by inductively coupled plasma mass spectrometry (ICP/MS) following EPA Method 200.8 (EPA 1991). Water samples for total Hg analysis were digested using a BrCl procedure and analyzed by cold vapor atomic fluorescence (CVAf) spectrometry following EPA Method 1631 (EPA 1995). Soil samples for Hg analysis were analyzed by CVAA following EPA Method 245.5 (EPA 1991). The results of these analyses are presented in Appendix D.

4.2 Investigation of the Tunnel Complex (Building 7740)

Investigation of the tunnel complex included 1) air monitoring, entry, and mapping of Structure A, 2) radiological and volatile organic field screening of floors, ventilation systems, and equipment inside each of the structural components of the complex, and 3) biased sampling of all floor drains and sumps. A discussion of the field investigations and analytical results from each structural component of the tunnel complex is provided below

4.2.1 Structure A

Particulate air sampling was performed at the end of the tunnel corridor leading to Structure A and inside the room immediately behind the main vault door. Using field instruments, the tunnel corridor and all vault rooms, corridors, and shelving within Structure A were surveyed for fixed and removable radiological contamination. The areas selected for surveying were biased towards areas where radioactive contamination would likely collect in the event of an accident or from routine storage of the nuclear capsules. A composite water sample was collected from all five floor drains and analyzed for gamma, alpha, and beta activity, and priority pollutant metals.

4.2.1.1 Air Sampling

High volumes of air were sampled for radioactive particulates near the main vault door and just inside the first chamber immediately after a 4-in.-diameter access hole was drilled through the concrete wall next to the main vault door. The initial results for air particulates showed a high concentration of Rn in the area. The initial particulate concentrations were $2.44\text{E-}7$ mCi/cc for alpha contamination and $6.54\text{E-}8$ mCi/cc for beta-gamma contamination. After a 24-hour decay of the air samples, the results were less than the minimal detectable activity (MDA). The MDA for alpha contamination on the Ludlum Model 2929 was $1.31\text{E-}11$ mCi/cc and $2.56\text{E-}11$ mCi/cc for beta-gamma contamination.

Radon-222 is a direct daughter of ^{226}Ra and is thus part of the natural U decay series. Radium is usually found in association with other alkaline earth metals and is present in plasters and gypsum bearing materials as well as in concrete and rock. Previous studies have shown that Rn tends to collect in this tunnel complex as well as other enclosed facilities at Fort Campbell, with concentrations increasing over time if the areas are not vented (See Section 2.2.2).

Air was monitored for volatile organics, O_2 , combustibles, and carbon monoxide during all aspects of accessing, surveying, and sampling inside the vault area. The O_2 content inside each newly opened room inside Structure A was found to be below 17%, presenting an unsafe atmosphere. No volatile organics, combustibles, or carbon monoxide were detected. The main vault door to Structure A is reported to have been closed since the mid-to-late 1960s, and the vents in this structure are also sealed, leaving the vault rooms sealed from the outside atmosphere for over 30 years.

Because the initial Rn concentrations were high and the O_2 content low, each newly opened room was left to equilibrate for several hours before entering to allow the Rn to dissipate and the O_2 levels to increase back to normal atmospheric conditions.

4.2.1.2 Radiological Surveys

Each of the floor drains and the metal storage racks (used for storage of the nuclear capsules) were surveyed for fixed and removable contamination. Random floor smears were collected through Structure A and surveyed for removable contamination. The vent baffle chambers and shafts were also surveyed for fixed contamination. No removable or fixed contamination was found above the release levels indicated in Section 4.1.2.

4.2.1.3 Floor Drain Samples

A composite water sample was collected from all five floor drains located within Structure A. A dark oily substance was observed near some of the floor drains and particularly in the floor drain in the southeast vault room (referred to as room No. 4) (Figure 3.3). However, no volatile organics were detected with the PID. This composite sample was submitted for determination of gamma, alpha, and beta activity, and for priority metals analysis. The results are provided in Table 4.2 and Appendices B and D.

Table 4.2. Analytical Results from Structure A Floor Drains

Analysis/Constituent	Maximum Detection Activity	Relative Risk Comparison Values ^(a)		Structure A
		Soil	Water	Floor Drains
				(Water Sample No. 082797-vault)
Radionuclides	(pCi/mL)	(pCi/g)	(pCi/mL)	(pCi/mL)
Gamma Activity				
⁴⁰ K	1.89E-01	NR	NR	2.68E+00
¹³⁷ Cs	1.64E-02	NR	NR	ND
²¹² Pb	3.15E-02	NR	NR	ND
²²⁸ Ra	3.84E-01	6.60E+02	4.00E-02	ND
²³⁴ U	2.43E+01	5.00E+03	3.00E-01	ND
²³⁵ U	1.17E-01	5.00E+03	3.00E-01	ND
²³⁸ U	2.07E-01	NR	NR	ND
²³⁸ Pu	1.44E+02	3.60E+02	2.20E-02	ND
²³⁹ Pu	1.64E+02	3.50E+02	2.10E-02	ND
²⁴⁰ Pu	1.34E+02	3.50E+02	2.10E-02	ND
²⁴¹ Pu	4.79E+02	2.20E+04	1.30E+00	ND
²⁴² Pu	1.33E+00	3.60E+02	2.20E-02	ND
Alpha/Beta Activity				
³ H	2.00E+00	NR	NR	ND
¹⁴ C	4.00E+00	NR	NR	ND
⁹⁰ Sr	4.00E+00	NR	NR	ND
Gross Alpha	2.00E+00	NR	NR	ND
Gross Beta	6.00E+00	NR	NR	ND
Metals		(mg/kg)	(ug/L)	(ug/L)
Ag		3.80E+02	1.80E+02	2.67E-01
As		2.20E+01	4.50E+00	7.01E+01
Ba		5.30E+03	2.60E+03	5.53E+01
Be		1.40E+01	1.60E+00	1.16E-01
Cd		3.80E+01	1.80E+01	3.15E+01
Cr		3.00E+03	1.80E+02	3.70E+01
Cu		2.80E+03	1.40E+03	4.76E+03
Hg - total		2.30E+01	1.10E+01	6.48E+01
Ni - soluble salts		1.50E+03	7.30E+02	6.94E+01
Pb		4.00E+02	4.00E+00	4.11E+02
Sb		3.10E+01	1.50E+01	1.27E+01
Se		3.80E+02	1.80E+02	1.15E+02
Sn		4.60E+04	2.20E+04	5.01E+00
Tl - chloride		6.10E+00	2.90E+00	1.13E-01
Zn		2.30E+04	1.10E+04	1.61E+03
Volatile Organic Compounds		(mg/kg)	(ug/L)	
TCE		7.10E+02	1.60E+02	NA
alcohol		NR	NR	NA
acetone		2.00E+03	6.10E+02	NA

NA = Not Analyzed

ND = Not Detected

NR = Not Reported

U = Not Detected at or above DL shown

J = Value is reported below the MDL

^(a) From DOD (1997). Note that comparison values for water are less than the maximum detection activity for radionuclides.

Constituents in BOLD are the primary contaminants of concern potentially attributable to the facility.

Shaded concentrations exceed the Relative Risk Comparison Value

No anthropogenic radiological contamination was detected. However, several metals (As, Cd, Cu, Hg, and Pb) were found to exceed the relative risk comparison values for water. Of these, only As and Pb are attributable to the facility, As from the use of rodenticides, and Pb from the presence of Pb-based paint and/or Pb solder. Potential sources of Hg may be from the use of thermometers and/or manometers in regulating the atmosphere inside the tunnel complex. A potential source of Cu could be from the Cu tubing used to drain condensation from the vent shafts into the floor drains. Potential anthropogenic sources of Cd are left unexplained at this time.

4.2.2 Structures B and C

Using field instruments, Structures B and C were surveyed for fixed and removable radiological contamination, and samples were collected from each of the floor drains. Samples were analyzed for gamma, alpha, and beta activity and priority pollutant metals.

4.2.2.1 Radiological Surveys

Structures B and C were both surveyed for fixed and removable contamination. The following areas selected for surveying were biased towards areas where radioactive contamination would have likely collected in the event of an accident or from routine operation of these facilities:

- air exhaust vents located in the main maintenance bays and medical rooms
- vents in the first room of each structure located above the floor drains
- in and around the sink and sink drain in the left maintenance bay of Structure B
- in and around the sink and sink drain in the first medical room
- all floor drains.

Random floor smears were collected and surveyed throughout Structures B and C. No fixed or removable radiological contamination was found above release levels (see Section 4.1.2).

4.2.2.2 Sampling of Floor Drains

Separate water samples were collected from the two floor drains in Structure B and one composite sample was collected of the debris and sediment from the two floor drains in Structure C. It should be noted that partially burned paper (e.g., old manuals, phone book) surrounded and overlaid the central floor drain in Structure B and that the debris and sediments from Structure C were very rusty and contained cigarette butts. All samples were submitted for gamma, alpha, and beta activity, and priority pollutant metals (see Table 4.3 and Appendices B and D).

No radionuclides of clear anthropogenic origin were detected. Lead-212 was detected in two of the samples, and ²²⁶Ra was detected in one sample. However, these radionuclides are in the natural decay chains of Th and U, respectively, and both were found in concentrations below the relative risk comparison values.

Table 4.3. Analytical Results from Structure B and Structure C Floor Drains

Analysis/Constituent	Maximum Detection Activity	Relative Risk Comparison Values ^(a)		Structure B		Structure C
		Soil	Water	Deluge Shower Drain	Center Floor Drain	Floor Drain Composite (Sediment Sample No. 082697-Comp-B,C)
				(Water Sample No. 082697-Flr-B)	(Water Sample No. 082697-Flr-B2)	
Radionuclides	(pCi/mL)	(pCi/g)	(pCi/mL)	(pCi/mL)	(pCi/mL)	(pCi/g)
Gamma Activity						
⁴⁰ K	1.89E-01	NR	NR	2.91E-02	4.64E-01	ND
¹³⁷ Cs	1.64E-02	NR	NR	ND	ND	ND
²¹² Pb	3.15E-02	NR	NR	ND	9.11E+00	8.00E-02
²²⁶ Ra	3.84E-01	6.60E+02	4.00E-02	ND	ND	1.68E+01
²³⁴ U	2.43E+01	5.00E+03	3.00E-01	ND	ND	ND
²³⁵ U	1.17E-01	5.00E+03	3.00E-01	ND	ND	ND
²³⁸ U	2.07E-01	NR	NR	ND	ND	ND
²³⁸ Pu	1.44E+02	3.60E+02	2.20E-02	ND	ND	ND
²³⁹ Pu	1.64E+02	3.50E+02	2.10E-02	ND	ND	ND
²⁴⁰ Pu	1.34E+02	3.50E+02	2.10E-02	ND	ND	ND
²⁴¹ Pu	4.79E+02	2.20E+04	1.30E+00	ND	ND	ND
²⁴² Pu	1.33E+00	3.60E+02	2.20E-02	ND	ND	ND
Alpha/Beta Activity						
³ H	2.00E+00	NR	NR	ND	ND	ND
¹⁴ C	4.00E+00	NR	NR	ND	ND	ND
⁹⁰ Sr	4.00E+00	NR	NR	ND	ND	ND
Gross Alpha	2.00E+00	NR	NR	1.46E+00	ND	ND
Gross Beta	6.00E+00	NR	NR	ND	ND	ND
Metals		(mg/kg)	(ug/L)	(ug/L)	(ug/L)	(mg/kg)
Ag		3.80E+02	1.80E+02	2.63E-01	3.50E+00	1.05E+00
As		2.20E+01	4.50E+00	3.43E+00	4.47E+01	7.94E+01
Ba		5.30E+03	2.60E+03	8.04E+01	5.43E+01	6.64E+02
Be		1.40E+01	1.60E+00	1.29E-01	2.63E-01	4.00E-01 U
Cd		3.80E+01	1.80E+01	3.96E+00	8.16E+00	9.43E+01
Cr		3.00E+03	1.80E+02	5.23E+00	2.29E+01	2.70E+02
Cu		2.80E+03	1.40E+03	6.34E+01	3.02E+03	5.07E+02
Hg - total		2.30E+01	1.10E+01	2.57E+00	4.64E+02	1.15E+01
Ni - soluble salts		1.50E+03	7.30E+02	1.45E+01	3.77E+02	6.40E+01
Pb		4.00E+02	4.00E+00	1.47E+02	2.31E+01	6.86E+02
Sb		3.10E+01	1.50E+01	7.99E+00	4.30E+02	8.46E+00
Se		3.80E+02	1.80E+02	5.66E+00	1.22E+01	2.00E+00 U
Sn		4.60E+04	2.20E+04	1.97E+00	1.12E+01	NR
Ti - chloride		6.10E+00	2.90E+00	3.00E-02	1.89E-02	9.76E-01
Zn		2.30E+04	1.10E+04	6.11E+02	3.78E+02	3.11E+03
Volatile Organic Compounds		(mg/kg)	(ug/L)			
TCE		7.10E+02	1.60E+02	NA	NA	NA
alcohol		NR	NR	NA	NA	NA
acetone		2.00E+03	6.10E+02	NA	NA	NA

NA = Not Analyzed

ND = Not Detected

NR = Not Reported

U = Not Detected at or above DL shown

J = Value is reported below the MDL

^(a) From DOD (1997). Note that comparison values for water are less than the maximum detection activity for radionuclides.

Constituents in BOLD are the primary contaminants of concern potentially attributable to the facility.

Shaded concentrations exceed the Relative Risk Comparison Value

Several metals (As, Cu, Hg, Pb, and Sb) were found to exceed the relative risk comparison values for water. Arsenic, Cd, and Pb were also found to exceed the relative risk comparison values for soil. Of these, only As and Pb are attributable to the facility: As from the use of rodenticides and Pb from the use of Pb-based paint and/or Pb solder. Potential sources of mercury may be from the use of thermometers and/or manometers in regulating the atmosphere inside the tunnel complex. The only sample to contain Sb above the relative risk comparison values was a water sample taken from the central floor drain in Structure B, which was covered with partially burned papers. Potential anthropogenic sources of Cu and Cd are left unexplained at this time.

4.2.3 Central Corridor and Utility Room

Using field instruments, the central corridors and utility room areas were surveyed for fixed and removable radiological contamination. Water and/or sediment samples were collected from the sump, the restroom pipe chase, and floor drains in the restroom and furnace room. These samples were analyzed for gamma, alpha, and beta activity and priority pollutant metals.

4.2.3.1 Radiological Surveys

Radiological surveys were conducted throughout the central corridors and utility room area for fixed and removable contamination. This included the air vent in the furnace room, in and around the sink and sink drains in the restroom, in the floor drains, and in the sump located in the central corridor. Random floor smears for removable contamination were collected throughout the area. No fixed or removable contamination was detected above the release limits (see Section 4.1.2).

4.2.3.2 Sampling of Sump, Pipe Chase and Floor Drains

One composite water sample was collected from the sump in the central corridor, the pipe chase in the restroom, and the floor drain in the restroom. Since the floor drain in the restroom was part of the sanitary sewer system while the sump and pipe chase were more representative of the natural drainage system, a second separate sample from the restroom floor drain was also collected to allow some distinction between the two drainage/sewer systems. A debris/sediment sample was collected from the floor drain in the furnace room (also connected to the sanitary sewer system). It should be noted that the debris and sediment from the furnace room floor drain contained a lot of rust. All samples were submitted for gamma, alpha, and beta activity and priority pollutant metals (see Table 4.4 and Appendices B and D).

Both tritium (^3H) and ^{90}Sr were detected in the water samples while ^{137}Cs and ^{212}Pb were detected in the sediment sample. Tritium, ^{90}Sr , and ^{137}Cs are anthropogenic radionuclides commonly found in low (pCi/g or pCi/L) concentrations throughout the northern hemisphere as a result of nuclear testing (Eisenbud and Gesell 1997). Since the concentrations detected are low (i.e., in the $1\text{E-}01$ pCi/g or pCi/mL range) and there is no record of these radionuclides having been used in this facility, it is likely that the presence of these radionuclides is due to nuclear fallout rather than from facility operations.

Table 4.4. Analytical Results from the Utility Room Area

Analysis/Constituent	Maximum Detection Activity	Relative Risk Comparison Values ^(a)		Utility Room Area		
				Composite Sump, Pipe Chase, and	Restroom Floor Drain	Fumance Room Floor Drain
				(Water Sample No. 082697-Comp-Utl)	(Water Sample No. 082697-Fir-Utl)	(Sediment Sample No. 082697-utility sewer)
Radionuclides	(pCi/mL)	Soil (pCi/g)	Water (pCi/mL)	(pCi/mL)	(pCi/mL)	(pCi/g)
Gamma Activity						
⁴⁰ K	1.89E-01	NR	NR	4.21E-01	5.08E-01	2.00E-01
¹³⁷ Cs	1.64E-02	NR	NR	ND	ND	3.40E-01
²¹² Pb	3.15E-02	NR	NR	ND	ND	3.20E-01
²²⁶ Ra	3.84E-01	6.60E+02	4.00E-02	ND	ND	ND
²³⁴ U	2.43E+01	5.00E+03	3.00E-01	ND	ND	ND
²³⁵ U	1.17E-01	5.00E+03	3.00E-01	ND	ND	ND
²³⁸ U	2.07E-01	NR	NR	ND	ND	ND
²³⁸ Pu	1.44E+02	3.60E+02	2.20E-02	ND	ND	ND
²³⁹ Pu	1.64E+02	3.50E+02	2.10E-02	ND	ND	ND
²⁴⁰ Pu	1.34E+02	3.50E+02	2.10E-02	ND	ND	ND
²⁴¹ Pu	4.79E+02	2.20E+04	1.30E+00	ND	ND	ND
²⁴² Pu	1.33E+00	3.60E+02	2.20E-02	ND	ND	ND
Alpha/Beta Activity						
³ H	2.00E+00	NR	NR	2.40E+00	ND	ND
¹⁴ C	4.00E+00	NR	NR	ND	ND	ND
⁹⁰ Sr	4.00E+00	NR	NR	1.30E+00	8.80E-01	ND
Gross Alpha	2.00E+00	NR	NR	ND	ND	ND
Gross Beta	6.00E+00	NR	NR	4.38E+00	3.89E+00	ND
Metals						
		(mg/kg)	(ug/L)	(ug/L)	(ug/L)	(mg/kg)
Ag		3.80E+02	1.80E+02	3.66E-01	1.15E-01	1.03E+01
As		2.20E+01	4.50E+00	2.67E+00	1.01E+00	1.25E+02
Ba		5.30E+03	2.60E+03	1.45E+02	1.87E+02	6.59E+02
Be		1.40E+01	1.80E+00	5.34E-02	1.10E-01	4.00E-01
Cd		3.80E+01	1.80E+01	6.45E+00	1.92E+00	3.11E+01
Cr		3.00E+03	1.80E+02	6.44E+00	2.26E+00	9.52E+01
Cu		2.80E+03	1.40E+03	1.04E+02	1.54E+01	7.70E+02
Hg - total		2.30E+01	1.10E+01	8.52E-01	1.19E-01	5.56E+00
Ni - soluble salts		1.50E+03	7.30E+02	1.43E+01	3.63E+00	7.55E+01
Pb		4.00E+02	4.00E+00	2.09E+02	1.25E+01	3.20E+02
Sb		3.10E+01	1.50E+01	2.04E+00	2.52E+00	1.68E+01
Se		3.80E+02	1.80E+02	3.75E+00	3.82E+00	1.66E+00
Sn		4.60E+04	2.20E+04	6.70E-01	2.52E+00	NR
Ti - chloride		6.10E+00	2.90E+00	5.62E-02	5.00E-03	1.87E-01
Zn		2.30E+04	1.10E+04	1.88E+03	2.05E+02	4.87E+03
Volatile Organic Compounds						
		(mg/kg)	(ug/L)			
TCE		7.10E+02	1.60E+02	NA	NA	NA
alcohol		NR	NR	NA	NA	NA
acetone		2.00E+03	6.10E+02	NA	NA	NA

NA = Not Analyzed

ND = Not Detected

NR = Not Reported

U = Not Detected at or above DL shown

J = Value is reported below the MDL

^(a) From DOD (1997). Note that comparison values for water are less than the maximum detection activity for radionuclides.

Constituents in BOLD are the primary contaminants of concern potentially attributable to the facility.

Shaded concentrations exceed the Relative Risk Comparison Value

Only Pb was found in concentrations above the relative risk comparison values for water, while As was the only metal found to exceed the relative risk comparison values for soil. Both these metals may have come from the facility, As from the use of rodenticides, and Pb from the use of Pb-based paint and/or Pb solder.

4.2.4 Other Areas of Concern

Other potential areas of concern observed within the tunnel complex included asbestos wrapped pipes, potential Pb-based paint, rodent control boxes labeled "poison," and a Se rectifier. All were observed in the main portions of the tunnel complex (i.e., Structures B and C, and the Utility Room area).

4.3 Investigation of Wastewater Storage Tank

Investigation of the wastewater storage tank included radiological and volatile organic field screening and sampling of both the tank and its outfall.

4.3.1 Sampling of the Wastewater Storage Tank

The wastewater storage tank was accessed through the northernmost vent riser, which had been partially removed. A backhoe was used to locate and access the riser pipe. It was located approximately 4.5 ft below ground where it appears to have been cut off. A rock was evidently placed over the pipe stub to retard dirt from entering the tank. Some soil did, however, enter the tank during our excavation efforts.

The tank was sampled through the riser pipe using a coliwasa (i.e., a long sampling tube). Water from the tank was very clear with a little sludge/sediment on the bottom. The sediment collected in the bottom of the coliwasa was about 1 in. thick and was a red soil color. Much of this sediment was likely from the soil that dropped through the riser during excavation. Duplicate water samples were submitted to the laboratories for determination of gamma and alpha/beta activities, priority pollutant metals, and volatile organic analyses (Table 4.5 and Appendices B, C, and D).

Tritium and ^{90}Sr were detected in both water samples while ^{212}Pb was detected in just one. Both ^3H and ^{90}Sr are common nuclear fallout constituents (Eisenbud and Gesell 1997) and since there is no record of these radionuclides having been used in this facility, it is most likely that the presence of these radionuclides is due to nuclear fallout rather than from facility operations.

Comparison between metal analyses from the duplicate water samples is not very good. Field records show that the water samples collected for metals analyses were the last samples to be collected from the coliwasa and that the last metals sample (082797-Tank-1) consisted of what was left in the coliwasa. This last metals sample was described as a "very small sample" and "very dirty." Laboratory records confirm that sample 082797-Tank-1 was very dirty and had to be

Table 4.5. Analytical Results from the Wastewater Storage Tank and Outfall

Analysis/Constituent	Maximum Detection Activity	Relative Risk Comparison Values ^(a)		Waste Water Storage Tank		
		Soil	Water	Waste Water Tank	Waste Water Tank Duplicate	Tank Outfall
				(Water Sample No. 082797-Tank-1)	(Water Sample No. 082797-Tank-2)	(Sediment Sample No. 082797-outfall)
Radionuclides	(pCi/mL)	(pCi/g)	(pCi/mL)	(pCi/mL)	(pCi/mL)	(pCi/g)
Gamma Activity						
⁴⁰ K	1.89E-01	NR	NR	2.70E-01	7.23E-01	4.03E+00
¹³⁷ Cs	1.64E-02	NR	NR	ND	ND	2.90E-01
²¹² Pb	3.15E-02	NR	NR	1.19E+01	ND	5.20E-01
²²⁶ Ra	3.84E-01	6.60E+02	4.00E-02	ND	ND	1.95E+00
²³⁴ U	2.43E+01	5.00E+03	3.00E-01	ND	ND	ND
²³⁵ U	1.17E-01	5.00E+03	3.00E-01	ND	ND	ND
²³⁸ U	2.07E-01	NR	NR	ND	ND	ND
²³⁸ Pu	1.44E+02	3.60E+02	2.20E-02	ND	ND	ND
²³⁹ Pu	1.64E+02	3.60E+02	2.10E-02	ND	ND	ND
²⁴⁰ Pu	1.34E+02	3.60E+02	2.10E-02	ND	ND	ND
²⁴¹ Pu	4.79E+02	2.20E+04	1.30E+00	ND	ND	ND
²⁴² Pu	1.33E+00	3.60E+02	2.20E-02	ND	ND	ND
Alpha/Beta Activity						
³ H	2.00E+00	NR	NR	9.50E-01	1.65E+00	ND
¹⁴ C	4.00E+00	NR	NR	ND	ND	1.66E+01
⁹⁰ Sr	4.00E+00	NR	NR	3.40E-01	5.00E-01	1.72E+01
Gross Alpha	2.00E+00	NR	NR	ND	ND	1.21E+00
Gross Beta	6.00E+00	NR	NR	4.27E+00	4.36E+00	1.45E+01
Metals		(mg/kg)	(ug/L)	(ug/L)	(ug/L)	(mg/kg)
Ag		3.80E+02	1.80E+02	9.20E-01	2.05E-01	1.10E-01
As		2.20E+01	4.50E+00	1.23E+01	4.31E+00	6.58E+00
Ba		5.30E+03	2.60E+03	5.17E+03	5.70E+02	1.47E+02
Be		1.40E+01	1.60E+00	3.19E+01	2.39E+00	8.40E-01
Cd		3.80E+01	1.80E+01	1.34E+01	9.39E-01	5.62E-01
Cr		3.00E+03	1.80E+02	4.31E+02	4.26E+01	3.59E+01
Cu		2.80E+03	1.40E+03	3.32E+02	3.73E+01	1.88E+01
Hg - total		2.30E+01	1.10E+01	4.78E+00	4.73E-02	1.03E-01
Ni - soluble salts		1.50E+03	7.30E+02	4.17E+02	4.52E+01	3.64E+01
Pb		4.00E+02	4.00E+00	7.70E+03	6.02E+01	2.75E+01
Sb		3.10E+01	1.50E+01	1.51E+00	8.60E-01	1.49E-01
Se		3.80E+02	1.80E+02	4.90E+01	7.55E+00	9.17E-01
Sn		4.60E+04	2.20E+04	3.33E+00	6.36E+00	NR
Tl - chloride		6.10E+00	2.90E+00	4.44E+00	5.80E-01	4.36E-01
Zn		2.30E+04	1.10E+04	1.21E+03	1.47E+02	1.51E+02
Volatile Organic Compounds		(mg/kg)	(ug/L)			
TCE		7.10E+02	1.60E+02	<1ug/L	<1ug/L	NA
alcohol		NR	NR	NA	NA	NA
acetone		2.00E+03	6.10E+02	<5 ug/L	<5 ug/L	NA

NA = Not Analyzed

ND = Not Detected

NR = Not Reported

U = Not Detected at or above DL shown

J = Value is reported below the MDL

^(a) From DOD (1997). Note that comparison values for water are less than the maximum detection activity for radionuclides.

Constituents in BOLD are the primary contaminants of concern potentially attributable to the facility.

Shaded concentrations exceed the Relative Risk Comparison Value

diluted with a large amount of deionized water⁷. Hence, the high concentration of metals in this sample is not considered to be very representative of the water in the tank. However, the metals analyses from sample 082797-Tank-2 still indicate that both Be and Pb exceed the relative risk comparison values for water.

The depth of water in the tank was approximately 55 in. Based on the geometry of the tank, this was estimated to equate to approximately 5,200 gallons, or about half of the tank's capacity. It is speculated that much of this water is the result of condensation and/or leakage into the tunnel complex and then entered the wastewater sewer system. (Note that over 12 ft of water was found in one of the ventilation shafts into Structure A).

4.3.2 Soil Sampling at the Tank Outfall

Using field instrumentation, the soil at the outfall from the wastewater storage tank was surveyed and then sampled. Samples were submitted for determination of gamma, alpha/beta activities, and priority pollutant metals. The results of these analyses are presented in Table 4.5 and Appendices B and D.

Cesium-137, ²¹²Pb, ²²⁶Ra, ¹⁴C, and ⁹⁰Sr were detected at relatively low (10^{-1} to 10^{+1} pCi/g) concentrations. These concentrations are consistent with naturally occurring and nuclear fallout levels (Eisenbud and Gesell 1997). Of these radionuclides, only ²²⁶Ra is known to have been used in this facility, and its concentration is two orders of magnitude below the relative risk comparison value for soil. Metals also did not exceed the relative risk comparison values, and except for Zn, were within the range of natural soil concentrations for soils overlying limestone and calcareous bedrock (Kabata-Perdias and Pendias 1985).

⁷ Personal communication with E. S. Barrows, 12/15/97.

5.0 Relative Risk Site Evaluation

The Department of Defense (DoD) has implemented the RRSE process as a way to categorize sites based on their relative risk to human health and the environment. Limited funds can then be allocated to individual bases in accordance with the relative hazard of each site. This section describes the process by which AOC-E (Buildings 7740 and 7741) was evaluated and the results of that evaluation.

5.1 Evaluation Process

The RRSE process results in an assessment of risk for a given site that is based on individual assessments for each specific medium and exposure pathway. These individual pathway assessments could range from qualitative to very quantitative, depending on the data available. A quantitative assessment was performed for those specific pathways in which medium-specific contaminant concentrations were available. Contaminant concentrations were compared to the relative risk comparison values derived from the EPA Region IX Preliminary Remediation Goals (PRG) for groundwater and soils (DoD 1996). A contaminant hazard factor was assigned for the specific medium and exposure endpoint, based on the ratio of the contaminant concentration divided by the relative risk comparison value for that contaminant. The qualitative assessments involved no specific contaminant data, but through the use of conservative assumptions about facility operations and physical and chemical behaviors of constituents of concern, judgments were made about the completeness of specific exposure pathways. In this way, if a specific exposure pathway was considered incomplete, the health risk through that pathway would be zero. The most recently compiled RRSE guidance (DoD 1996), obtained from the Internet on February 20, 1997, was used in this report. Because this guidance is revised annually, some relative risk comparison values can change.

The assessment process is a risk assessment approach of defining exposure pathways. An exposure pathway describes how a contaminant may move from its source to a receptor. An exposure pathway is important only if it is complete. A complete exposure pathway has five primary elements:

- a chemical source
- a mechanism of release
- an environmental medium
- an exposure point
- a feasible route of exposure (e.g., ingestion).

An exposure pathway is complete if there is a reasonable likelihood that a receptor may take in contaminants through inhalation, ingestion, or dermal contact with contaminated media. There will be no exposure, and thus no risk, if the exposure pathway is incomplete. For this RRSE, contaminant sources, release mechanisms, and migration pathways were assessed using

information from this recent site investigation, operations history, and physical and chemical properties of the constituents of concern as related to their environmental behavior.

The specific approach used in performing the RRSE is presented in DoD guidance (DoD 1996). Adherence to the guidance was followed except in cases where no contamination data were available for a specific media (e.g., groundwater or surfacewater). In those cases, conservative assumptions about site history, operating conditions, and physical and chemical properties of the constituents of concern were applied to provide a quantifiable rationale for any conclusion about possible contaminant releases and their environmental behavior.

The evaluations involved completing relative risk evaluation worksheets for soils, surface water/sediment, and groundwater; calculating contaminant hazard factors, migration pathway factors, and receptor factors for each medium; determining media-specific risk ratings; and finally, determining the overall site relative risk category. The RRSE worksheets are presented in Appendix E.

5.2 Relative Risk Site Evaluation Results

Results of the RRSE evaluation are summarized in Table 5.1. Detailed discussions of site data and rationale for the ratings are presented in the RRSE worksheets in Appendix E. The results presented in Table 5.1 indicate that AOC-E received a LOW rating for the groundwater, surfacewater/sediment-human endpoint, and soil pathways, but received a MEDIUM rating for surfacewater/sediment-ecological endpoint pathways. These ratings resulted in an overall site relative risk rating of MEDIUM.

Table 5.1. Summary of Relative Risks.

Media/Exposure Endpoint	Contaminant Hazard Factor	Migration Pathway Factor	Receptor Factor	Relative Risk Rating
Groundwater	Moderate	Confined	Limited	LOW
Surfacewater/Sediment - Human Endpoint	Minimal	Potential	Limited	LOW
Surfacewater/Sediment - Ecological Endpoint	Moderate	Potential	Potential	MEDIUM
Soil	Minimal	Potential	Limited	LOW
Overall				MEDIUM

No downgradient monitoring wells are located at this site, so no groundwater data are available. Using analytical data from the wastewater storage tank and other water samples as a maximum indicator of potential groundwater concentrations resulted in a moderate contaminant hazard factor. The only plausible release scenarios to the soil column that could impact the groundwater are via the sanitary sewer drainfield and/or a leak in the wastewater storage tank. However, failure to locate the sanitary sewer suggests that subsurface contamination from this facility must be very limited. Sampling of the wastewater storage tank also suggested that the tank has retained its integrity and that no significant release was likely to have occurred.

Additionally, the properties of the subsurface soils are such that they would impede the mobility of contaminants, and groundwater flow is unlikely to impact water-supply areas. Thus, the groundwater pathway was assigned a LOW relative risk.

No surfacewater or sediment analytical data are directly available for this site. However, using analytical data from the soil sample at the wastewater tank outfall as a conservative estimate yielded a minimal contaminant hazard factor for the human endpoint, and a moderate contaminant hazard factor for the ecological endpoint. With the outfall of the wastewater storage tank located adjacent to Little West Fork Creek and the lack of information to the contrary, it is conservatively assumed that there is a potential for surface water (particularly during flood events) to intersect and transport potentially contaminated sediment away from the source. Little West Fork Creek is reported to be used for recreational fishing, which is limited to onbase personnel and their families. Thus, the surfacewater/sediment exposure pathway for the human endpoint was assigned a relative risk rating of LOW.

Analytical results from soil at the wastewater tank outfall resulted in a minimal contaminant hazard factor for the soil pathway. Together with a conservation assumption that there could be a potential for soil migration, but that human exposure would be limited, this resulted in a low relative risk for the soil exposure pathway. However, the potential for surface runoff and migration, and the potential for human exposure, resulted in a MEDIUM relative risk.

6.0 Conclusions

An environmental investigation was conducted to support the preparation of a RRSE of the Building 7740 Tunnel Complex and Building 7741 Wastewater Storage Tank. Access was gained to all portions of the tunnel complex, and radiological and volatile organic surveys conducted throughout. Large volume air sampling was conducted within the main tunnel corridor and a portion of Structure A, and other air quality parameters were monitored throughout all aspects of the investigation. Environmental samples were collected from portions of the three sewer/drainage systems that supported the facility. All surveys and sampling efforts were biased towards portions of the facility considered most likely to accumulate contamination and thus to represent the worst case levels of contamination within the facility. A synopsis of the findings from each major component of the facility and the relative risk of the site is provided below.

6.1 Tunnel Structure

Access and visual inspection of Structure A revealed that this portion of the facility had been modified from the available engineering drawings. Air monitoring and large volume particulate air sampling found this portion of the facility (which had been sealed since the mid- to late-1960s) was initially very low in O₂ content (<17%) and high in Rn. The O₂ content and Rn concentrations were shown to reach or approach acceptable levels within a few hours after the structure was allowed to vent. No fixed or removable radiological contamination nor volatile organic compounds were detected throughout any portion of the tunnel complex. However, other potential hazards were observed, including the presence of asbestos wrapped pipes, Pb-based paint, rat poison, and a Se rectifier.

Review of the engineering drawings revealed that three separate sewer/drainage systems supported the tunnel complex, one for natural drainage water, one for sanitary wastewater, and one for potentially contaminated wastewater. Environmental samples were collected from each of these systems and submitted for laboratory analysis of radionuclides and priority pollutant metals. Samples from the wastewater storage tank were also submitted for analysis of volatile organic compounds.

6.2 Natural Drainage System

This system was sampled at the sump and pipe chase in the utility room in the main corridor (Section 4.2.3). No significant levels of contamination (radioactivity or volatile organic compounds) were detected on field instruments. Low (pCi/mL) concentrations of ³H and ⁹⁰Sr were detected in the water samples, and are most likely due to nuclear fallout rather than from facility operations. Lead was the only constituent, potentially attributable to the facility, that exceeded the relative risk comparison values.

6.3 Sanitary Sewer System

This system was sampled at the floor drains in the lavatory and in the furnace room (Section 4.2.3). Efforts to find and sample the septic tank and drainfield were unsuccessful, suggesting that the location of these structures is not consistent with the engineering drawings. No significant levels of radioactivity or volatile organic compounds were detected on field instruments. However, ^{90}Sr was detected in the water sample from the restroom floor drain, while ^{137}Cs and ^{212}Pb were detected in the sediment sample from the furnace room floor drain. The low concentrations of these radionuclides is consistent with natural and nuclear fallout levels, rather than from facility operations. Lead was found in concentrations above the relative risk comparison values for water, while As exceeded the relative risk comparison values for soil. Both these metals may have come from the facility; As from the use of rodenticides, and Pb from the use of Pb-based paint and/or Pb solder.

6.4 Wastewater Sewer System

The wastewater sewer system was designed to receive potentially contaminated wastewater from the maintenance bays and storage areas of the facility. This system was sampled at several locations within the tunnel complex, including the floor drains of Structure A (Section 4.2.1) and the floor drains in both Structures B and C (Section 4.2.2) and directly from the wastewater storage tank and its outfall (Section 4.3). No significant levels of radioactivity or volatile organic compounds were detected on field instruments.

Several radionuclides were detected in either the water samples and/or soil/sediment samples from this wastewater system. However, of the detected radionuclides, only ^{226}Ra is potentially attributable to this facility, and its concentration is at least an order of magnitude below the relative risk comparison value for soil.

Several metals (As, Be, Cd, Cu, Hg, Pb, and Sb) were found to exceed the relative risk comparison values for water in at least one sample. Arsenic, Cd, and Pb were also found to exceed the relative risk comparison values for soil. Of these constituents, As, Be, Hg, and Pb all potentially may have come from the facility.

6.5 Relative Risk

Results from the RRSE indicate that AOC-E has a LOW relative risk rating for the groundwater pathway but MEDIUM relative risk ratings for the surfacewater/sediment and soil pathways. These ratings resulted in an overall site relative risk rating of MEDIUM.

7.0 Recommendations

Potential alternatives for short- and long-term management of this site include no action, the use of engineering and administrative controls, modification and reuse of the facility, abandonment in place, and/or destruction/removal of the facility. Additional sampling (particularly to address background issues) and/or formal risk assessments should be conducted to ascertain the need for environmental response actions at the site. A review of the historic eligibility of the facility, the regulatory requirements governing the continued management of this facility (e.g., underground storage tank regulations, asbestos abatement, etc.), and the possible future uses/needs for this facility should also be conducted to help balance the feasibility, implementability, and cost of the different site management alternatives.

7.1 Short-Term Management Alternatives

Alternatives for short-term management of the facility include no action, the use of improved engineering and administrative controls, removal of the wastewater storage tank, and/or isolation/sealing of the tunnel complex. It is also recommended that a cultural resource review be conducted to determine the eligibility of the facility for the National Register of Historic Places.

7.1.1 No Action

This alternative would consist of maintaining the status quo of limiting access to the facility. Of particular concern is limiting exposure of personnel to high Rn concentrations, potentially low O₂ levels, and other potentially hazardous materials within the facility (asbestos, Pb paint, rat poison, etc.).

7.1.2 Improved Engineering and Administrative Controls

This alternative would include implementing improved access controls to the facility. These controls would include proper posting of hazard signs on the portal entrance and near the underground storage tank and improved administrative controls to restrict and monitor access to the facility. It would also be important to open the main vault door and to disable all vault doors to prevent their closure and potential safety problems. Some housekeeping activities (i.e., removal of all debris, old personal protective equipment (PPE), etc.) are also recommended.

Other potential engineering controls would include either sealing the tunnel complex and/or improving the natural ventilation of the facility.

7.1.2.1 Seal Tunnel Complex

Sealing the tunnel complex would likely include placing a top seal over the four vents to Structure A to prevent condensation and/or rain water from entering the complex and/or sealing the main portal entrance (via welded metal straps) to eliminate personnel access completely.

7.1.2.2 Improve Natural Ventilation of the Tunnel Complex

Natural ventilation appears to be fairly good within Structures B and C, but is poor in Structure A. Reopening and retrofitting the vents in Structure A would likely improve the natural ventilation, resulting in reduced Rn levels and improved O₂ content. Similar retrofits to the main ventilation system (e.g., install larger exhaust stacks and/or remove restrictions from current vents) would also improve ventilation in Structures B and C.

7.1.3 Remove Wastewater Storage Tank

This alternative would include pumping the estimated 5,200 gal. of water from the tank, removing the tank, sampling the underlying soils, properly disposing of the tank and tank contents, rerouting the wastewater sewer directly to the outfall, and renovating the site.

7.1.4 Cultural Resources Review

The National Historic Preservation Act (NHPA) of 1966 directs federal agencies to assume responsibility for all cultural resources under their jurisdiction. Section 110 of the NHPA requires agencies to inventory and evaluate all their cultural resources for eligibility for the National Register of Historic Places (Register). Section 106 of the NHPA requires a Federal agency with jurisdiction over a federal, federally assisted, or federally licensed undertaking to take into account the effects of the agency's actions on properties listed, or eligible for listing, in the Register. The implementing regulations for the NHPA require agencies to consult with the State Historic Preservation Officer (SHPO) and the Federal Advisory Council on Historic Preservation (Council) to ensure that all potentially significant historic properties have been adequately identified, evaluated, and considered in planning for a proposed undertaking. Project actions may only proceed after their comments have been received and taken into account. If a particular action will have an adverse effect upon a property eligible for the Register, then the agency is required to enter into a Memorandum of Agreement with the SHPO and the Council on ways to reduce, avoid, minimize, or mitigate such effects. Mitigation usually takes the form of various levels of documentation of the property before its alteration or demolition.

Constructed in the mid- to late-1940s, the former nuclear weapons storage area (including the Building 7740 tunnel complex) at Fort Campbell meets the 50-year criteria for consideration of eligibility to the National Register of Historic Places. A preliminary review of engineering and architectural drawings and historical documentation of the tunnel complex and associated facilities suggest that the facility is unique and played an important support role at Clarksville Base and Fort Campbell. While reportedly there are few features remaining inside the tunnel complex associated with its use as a nuclear weapons storage and maintenance area, the facility is potentially significant for its important association with the nuclear weapons arsenal, a crucial national defense activity during the Cold War era. A survey and inventory of the tunnel complex and an evaluation and determination of its National Register eligibility needs to be conducted before any undertaking (modification/alteration) that would have an adverse effect on the facility.

7.2 Long-Term Management Alternatives

Long-term management alternatives would include no action, retrofit and reuse of the facility (with improved engineering and administrative controls), abandonment in place, and/or removal and disposal of the facility. A thorough evaluation of these long-term alternatives should be made with regard to the potential usefulness of the facility, its operational risks, and the implementability, feasibility, and cost of each alternative or combination of alternatives. This evaluation will aid in selecting both the long- and short-term management alternatives for the facility.

8.0 REFERENCES

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Appendix A

List Of Engineering Drawings Available From The Facilities Engineers' Office

Fort Campbell
AOC-E Building 7740 & 7741 (Nuclear Weapons Storage Tunnel Complex & Waste Water Tank)

Retrieved from the Engineering Drawings at the Facilities Engineers Office (building 876; next to building 868; Ohio and 16th street)
Personal communication with Jim Dudley, Scott Slade, and William (Bill) D. Sale. Bill has worked at the site for 31 years!

Building 7740 (former building number 318)

Building 7741 (former number 358)

<u>Copy</u> <u>Obtained</u>	<u>Drawing</u> <u>No.</u>	<u>Title/Description</u>	<u>Subtitle/Description</u>	<u>Structure</u>	<u>Date</u>	<u>Last Modified</u>
X	BM-100	CLARKSVILLE BASE	MASTER PLAN, Basic Information Map, General Site & Building Use Map, General Layout		2/2/63	5/24/72
	C-OM-2-6	A/C Schematic flow				
	C2-200	Index to Drawings, Buildings 318, 407 & 408				
	C2-200A	Index to Drawings, Buildings 318, 407 & 408				
X	C2-202	PLANT STRUCTURES	Layout	Structures A, B & C	1/16/48	4/12/62
	C2-206	Yard Facilities, Turn-out, Loading Area, Walkway				
	C2-207	Portal for Structures		A, B & C		
	C2-208	Portal for Structures		A, B & C		
X	C2-209	PLANT STRUCTURES	Door Pocket for Blast Protection Door	Structures A, B & C	1/16/48	9/24/62
	C2-210	Typical Tunnel Sections				
	C2-211	Portal for Structures		A, B & C		
	C2-212	Portal for Structures		A, B & C		
	C2-213	Portal Entrance Door				
X	C2-214	PLANT STRUCTURES	Plan & Profile, Tunnels	Structures A, B & C	?	?
X	C2-215	PLANT STRUCTURES	Drop Manhole	Structures A, B & C	1/16/48	9/24/62
X	C2-216	PLANT STRUCTURES	Ventilation - Stack Details	Structures A, B & C	1/16/48	9/24/62
X	C2-217	PLANT STRUCTURES	Plans & Sections	Structure A	1/16/48	4/17/62
X	C2-217A	FLOOR PLAN BLDG 7740			6/19/74	
X	C2-218	PLANT STRUCTURES	Reinforcing Details	Structure A	1/16/48	4/17/62
X	C2-219	PLANT STRUCTURES	Reinforcing Details	Structure A	1/16/48	4/17/62
X	C2-220	PLANT STRUCTURES	Plan	Structures B, C & Utility Room	1/16/48	4/12/62
	C2-221	Sections		Structures B, C & Utility Room		
	C2-222	Reinforcing Details		B & C		
	C2-223	Reinforcing Details		Structures Utility Room		
	C2-224	Reinforcing Details		Utility Room		
	C2-225	Portal for Structures		A, B & C		
	C2-255	Reinforcing Bill of Materials				
	C2-256	Reinforcing Bill of Materials				
	C2-257	Reinforcing Bill of Materials				
	C2-258	Reinforcing Bill of Materials				
	C2-259-B	Reinforcing Bill of Materials				
	C2-261	Elec. General Layout/Lighting, grounding, etc.				
	C2-262	Elec. General Layout/Lighting, grounding, etc.				
	C2-263	Elec. General Layout/Lighting, grounding, etc.				
	C2-264	Elec. General Layout/Lighting, grounding, etc.				
	C2-269	Lighting Details/Schematic	Plant Structure			
	C2-270	Lighting Details/Schematic	Plant Structure			
	C2-272	Elec. Power Distr. & Service Entr (Pole Assembly Details)				
	C2-278	Sliding Blast Protection Door				
	C2-279	Exhaust, air Intake & Vent Details				
	C2-288	Personnel Type Blast Protection Doors				
	C2-289	Personnel Type Blast Protection Doors				

<u>Copy Obtained</u>	<u>Drawing No.</u>	<u>Title/Description</u>	<u>Subtitle/Description</u>	<u>Structure</u>	<u>Date</u>	<u>Last Modified</u>
	C3-100	General Layout & Index to Utilities & Structural ...				
	C3-100A	General Layout & Index to Utilities & Structural ...				
X	C3-101	GENERAL LAYOUT		A, B, C & South Group	12/3/48	4/17/62
	C3-102	Water Service				
	C3-106	Water Service Misc. Details				
X	C3-110	PLANT FACILITIES	Plumbing	Structure A, B & C	12/3/48	9/28/62
X	C3-114	PLANT FACILITIES	Waste Water Storage Tank and Facilities	ABC Group	12/3/48	9/28/62
X	C3-116	PLANT FACILITIES	Sewerage Facilities	Structures A, B, & C	6/8/49	4/17/62
X	C3-150	PLANT FACILITIES	Steel Liner	Structure A	11/16/48	2/28/49
X	C3-151	PLANT FACILITIES	Steel Liner	Structure A	11/16/48	2/23/49
	C3-152	Memorall		Structure "C"		
	C3-170	Door Bulkheads		Str. A		
	C3-171	Misc. Details				
	C3-172	Misc. Details				
	C3-174	Misc. Details				
	C3-183	Flood Protection Details				
	C3-200	Index to Elec. & Mech. Installations				
	C3-201	General Layout	A/C Plant Structures			
	C3-202	Equipment Room Layout	A/C			
	C3-202A	Toilet Room Exhaust				
	C3-203	Auxiliary Cooling Installation	A/C			
	C3-204	Exhaust Fan & Hanger Details	A/C Plant Structures			
	C3-211	Schematic Flow Diagram	A/C			
	C3-239	Wall Temperature Indicating Equipment		A (Vestibule)		
	C3-239A	Wall Temperature Indicating Equipment		A (Vestibule)		
	C3-240A	Elec. Power Dist. Line, Trans. Substation				
	C3-241	Power Wiring General Layout				
	C3-242	A/C Equipment & Control Wiring				
	C3-243	Power Wiring Schematic				
	C3-255	Lighting Revisions				
	C3-257	A/C Operational Diagram		Equipment Room		
	C3-261	Telephone & Paging Systems				
	C3-269	Communications & Alarm System Service Entrance				
	C3-272	Power Supply & Power Wiring Aux. Cooling				
	C3-274	Alarm System Instal. Details				
	C3-296	Electrical Wiring for benches		Str. C-2		
	C3-400	Doors & Walls	Plant Facilities	Str. "A"		
	C3-400A	Index to Drawings	Architectural Plant Facility			
	C3-401	Doors, Walls, & Partitions	Plant Facilities	Str. "B"		
	C3-402	Doors, Walls, & Partitions	Plant Facilities	Str. "C"		
	C3-403	Doors, Walls, & Partitions	Plant Facilities	Str. "B" & "C"		
	C3-404	Doors, Walls, Partitions, & Utility Room	Plant Facilities	A, B, & C		
	C3-405	Doors, Walls, Partitions, & Utility Room	Plant Facilities	A, B, & C		
	C3-406	Doors, Walls, Partitions, & Utility Room	Plant Facilities	A, B, & C		
	C3-500	Plans, Elevation, & Sections	Equipment Building	ABC Group		
	C3-501	Plans, Elevation, & Sections	Equipment Building	ABC Group		
	C3-503	Plans, Elevation, & Sections	Equipment Building	ABC Group		
	C3-620	AC				
	C8-153	Plans & Sections	Ord. Storage Area	Str. A		
	C8-303	Revisions to light & power wiring	"A" Modification	A		
	C8-304	Revisions to alarm system & Removal of A/C Installations	Ord. Stor. Area	Str. "A"		

Appendix B
Radiological Data

FORSCOM - Fort Campbell
Samples for Radiological Analysis

All weights measured using Mettler AE240 #512-06-01-017

Sample Identification	Tare (g)	+ Sample	Sample wt (wet)	% Moisture Content	Gamma wt
Rad 082697-comp-util-W	42.2193	145.6821	103.4628	-	103.4628
Rad 082697-flr-util-W	41.3803	123.0437	81.6634	-	81.6634
Rad 0827897-vault	41.0520	183.154	142.1020	-	142.1020
Rad 082797-Tank-1	40.5187	194.6782	154.1595	-	154.1595
Rad 082797-Tank-2	40.3138	155.149	114.8352	-	114.8352
Rad082697flrBW	41.0046	126.9495	85.9449	-	85.9449
Rad 082697-Flr-B2	41.2704	144.3692	103.0988	-	103.0988
Rad 082797-Outfall	41.0140	141.0624	100.0484	67%	32.7732
Rad 082697-comp-B,C	41.4168	92.1844	50.7676	11%	45.3788
Rad 0825697-utility sewer	40.6723	116.1913	75.5190	81%	14.3118

Sample Identification	Sample for LSC - wet	Sample wt
Rad 082697-comp-util-W	-	2.5
Rad 082697-flr-util-W	-	2.5
Rad 0827897-vault	-	2.5
Rad 082797-Tank-1	-	2.5
Rad 082797-Tank-2	-	2.5
Rad082697flrBW	-	2.5
Rad 082697-Flr-B2	-	2.5
Rad 082797-Outfall	3.5300	1.1563
Rad 082697-comp-B,C	2.7300	2.4402
Rad 0825697-utility sewer	6.8700	1.3019

Sample Identification	Wet sample	Tin + dry sample	Dry Sample	% Moisture Content
Rad 082797-Outfall	96.5184	98.7256	57.7116	67.2%
Rad 082697-comp-B,C	48.0376	84.8447	43.4279	10.6%
Rad 0825697-utility sewer	68.6490	78.5897	37.9174	81.0%

Fort Campbell Samples report date 9/18/97
Gamma Activity

pCi/g					
Sample	Gamma wt	⁴⁰ K	²¹² Pb	²²⁶ Ra	¹³⁷ Cs
Rad 082697-comp-util-W	103.4628	0.41	<MDA	<MDA	<MDA
Rad 082697-flr-util-W	81.6634	0.62	<MDA	<MDA	<MDA
Rad 0827897-vault	85.9449	3.12	<MDA	<MDA	<MDA
Rad 082797-Tank-1	142.1020	0.19	8.40	<MDA	<MDA
Rad 082797-Tank-2	154.1595	0.47	<MDA	<MDA	<MDA
Rad082697flrBW	114.8352	0.03	<MDA	<MDA	<MDA
Rad 082697-Flr-B2	103.0988	0.45	8.83	<MDA	<MDA
Rad 082797-Outfall	100.0484	4.03	0.52	1.95	0.29
Rad 082697-comp-B,C	50.7676	<MDA	0.08	16.76	<MDA
Rad 0825697-utility sewer	75.519	0.20	0.32	<MDA	0.34

All samples were analyzed using Intrinsic Germanium detectors with Genie PC analysis softw
Procedure followed: PNL-ALO-464

See attached listing of radionuclide MDA

Reportable Values	pCi/mL*			
Sample	⁴⁰ K	²¹² Pb	²²⁶ Ra	¹³⁷ Cs
Rad 082697-comp-util-W	0.4208	<MDA	<MDA	<MDA
Rad 082697-flr-util-W	0.5077	<MDA	<MDA	<MDA
Rad 0827897-vault	2.683	<MDA	<MDA	<MDA
Rad 082797-Tank-1	0.2697	11.94	<MDA	<MDA
Rad 082797-Tank-2	0.7231	<MDA	<MDA	<MDA
Rad082697flrBW	2.91E-02	<MDA	<MDA	<MDA
Rad 082697-Flr-B2	0.4643	9.106	<MDA	<MDA
Rad 082797-Outfall	4.029	0.5184	1.953	0.2916
Rad 082697-comp-B,C	<MDA	3.91E-02	8.509	<MDA
Rad 0825697-utility sewer	0.154	0.2394	<MDA	0.2553

* counts list 100 mL volume rather than true wt

Fort Campbell Samples report date 9/19/97
Alpha/Beta Activity

pCi/mL

Sample	Sample wt	³ H	¹⁴ C	⁹⁰ Sr	Gross Beta	Gross Alpha
Rad 082697-comp-util-W	2.5	2.40	<MDA	1.30	4.38	<MDA
Rad 082697-flr-util-W	2.5	<MDA	<MDA	0.88	3.89	<MDA
Rad 0827897-vault	2.5	<MDA	<MDA	<MDA	<MDA	<MDA
Rad 082797-Tank-1	2.5	0.95	<MDA	0.34	4.27	<MDA
Rad 082797-Tank-2	2.5	1.64	<MDA	0.50	4.36	<MDA
Rad082697flrBW	2.5	<MDA	<MDA	<MDA	<MDA	1.46
Rad 082697-Flr-B2	2.5	<MDA	<MDA	<MDA	<MDA	<MDA
Rad 082797-Outfall	1.2	<MDA	16.59	17.18	14.53	1.21
Rad 082697-comp-B,C	2.4	<MDA	<MDA	<MDA	<MDA	<MDA
Rad 0825697-utility sewer	1.3	<MDA	<MDA	<MDA	<MDA	<MDA

MDA = Minimum Detection Limits

Alpha 2 pCi/mL

Beta 6 pCi/mL

³H 2 pCi/mL

¹⁴C 4 pCi/mL

⁹⁰Sr 4 pCi/mL

All samples were analyzed using Wallac 1415 Liquid Scintillation Counter.

Procedures followed: PNL-ALO-106.4, PNL-ALO-474

Reportable Values	DPM			CPM	
Sample	³ H	¹⁴ C	⁹⁰ Sr	Gross Beta	Gross Alpha
Rad 082697-comp-util-W	13.3	<MDA	7.2	24.30	<MDA
Rad 082697-flr-util-W	<MDA	<MDA	4.9	21.60	<MDA
Rad 0827897-vault	<MDA	<MDA	<MDA	<MDA	<MDA
Rad 082797-Tank-1	5.3	<MDA	1.9	23.70	<MDA
Rad 082797-Tank-2	9.1	<MDA	2.8	24.20	<MDA
Rad082697flrBW	<MDA	<MDA	<MDA	<MDA	8.10
Rad 082697-Flr-B2	<MDA	<MDA	<MDA	<MDA	<MDA
Rad 082797-Outfall	ND	42.6	44.1	37.30	3.10
Rad 082697-comp-B,C	<MDA	<MDA	<MDA	<MDA	<MDA
Rad 0825697-utility sewer	<MDA	<MDA	<MDA	<MDA	<MDA

Detector Name: ELMO
Sample Geometry: 100 mL 4oz

Sample Title: Rad-082697-Flr-B-w
Nuclide Library Used: C:\GENIEPC\CAMFILES\LILBOB.NLB

Nuclide Name	Nuclide MDA (pCi/mL)
⁴⁰ K	1.89E-01
⁵⁷ Co	1.27E-02
⁶⁰ Co	1.45E-02
⁷⁵ Se	2.15E-02
⁸⁵ Kr	3.98E+00
^{85m} Kr	1.61E-02
⁸⁵ Sr	1.72E-02
⁸⁸ Y	1.67E-02
^{108m} Ag	1.46E-02
¹⁰⁹ Cd	2.81E-01
¹¹⁰ Ag	1.49E-02
¹¹³ Sn	2.00E-02
¹³⁴ Cs	1.61E-02
¹³⁷ Cs	1.64E-02
¹³⁹ Ce	1.49E-02
¹⁵³ Gd	3.55E-02
¹⁵⁴ Eu	2.64E-02
¹⁵⁵ Eu	3.23E-02
²⁰³ Hg	1.62E-02
²⁰⁸ Tl	1.73E-02
²¹⁰ Pb	1.32E+00
²¹¹ Bi	1.18E-01
²¹¹ Pb	4.31E-01
²¹² Bi	1.37E-01
²¹² Pb	3.15E-02
²¹⁴ Bi	3.55E-02
²¹⁴ Pb	3.84E-02
²¹⁹ Rn	1.35E-01
²²⁰ Rn	1.36E+01
²²³ Fr	1.06E-01
²²³ Ra	9.50E-02
²²⁴ Ra	3.42E-01
²²⁶ Ra	3.84E-01
²²⁷ Th	1.16E-01
²²⁸ Ac	5.45E-02
²²⁸ Th	4.40E+00
²³⁰ Th	3.62E+00
²³¹ Pa	5.91E-01

²³¹ Th	2.51E+00
²³² Th	9.27E+00
²³³ Pa	3.69E-02
²³⁴ Pa	5.96E-02
^{234m} Pa	3.21E+00
²³⁴ Th	2.02E-01
²³⁴ U	2.43E+01
²³⁵ U	1.17E-01
²³⁷ Np	8.40E-02
²³⁸ Pu	1.44E+02
²³⁸ U	2.07E-01
²³⁹ Pu	1.64E+02
²⁴⁰ Pu	1.34E+02
²⁴¹ Pu	4.79E+02
^{242m} Am	4.69E+01
²⁴² Pu	1.33E+00
²⁴³ Am	2.05E-02
²⁴³ Cm	4.51E-02
²⁴⁵ Cm	3.70E-02

Appendix C

Volatile Organic Data

Analytical Resources, Incorporated
Analytical Chemists and Consultants

September 11, 1997

Mr. Tyler Gilmore
Battelle Pacific Northwest Laboratory
P. O. Box 999, M/S K6-81
Richland, WA 99352

Reference: **EMSL Tanks 1 & 2: ARI Project T616**

Dear Mr. Gilmore:

Enclosed are the original chain of custody documentation and analytical results for the referenced project. ARI received two water samples in good condition on 8/29/97.

The samples were analyzed for volatile organic compounds (VOA) using EPA Method 8260. There were no anomalies with these analyses.

Please call me if you have question or require additional information.

Sincerely,

ANALYTICAL RESOURCES INC.

Mark D. Harris
Project Manager
(206) 340-2866 ext 113

MDH:drm

cc: File T616

ORGANICS ANALYSIS DATA SHEET
Volatiles by Purge & Trap GC/MS
Page 1 of 2

ANALYTICAL
RESOURCES
INCORPORATED

Sample No: V-082797-Tank 1

Lab Sample ID: T616A

QC Report No: T616-Battelle

LIMS ID: 97-15211

Project:

Matrix: Water

Data Release Authorized: *ONB*

Date Sampled: 08/27/97

Reported: 09/10/97

Date Received: 08/29/97

Instrument: FINN3

Sample Amount: 5.00 mL

Date Analyzed: 09/05/97

Purge Volume: 5.0 mL

CAS Number	Analyte	ug/L
74-87-3	Chloromethane	2.0 U
74-83-9	Bromomethane	2.0 U
75-01-4	Vinyl Chloride	2.0 U
75-00-3	Chloroethane	2.0 U
75-09-2	Methylene Chloride	2.0 U
67-64-1	Acetone	5.0 U
75-15-0	Carbon Disulfide	1.0 U
75-35-4	1,1-Dichloroethene	1.0 U
75-34-3	1,1-Dichloroethane	1.0 U
156-60-5	trans-1,2-Dichloroethene	1.0 U
156-59-2	cis-1,2-Dichloroethene	1.0 U
67-66-3	Chloroform	1.0 U
107-06-2	1,2-Dichloroethane	1.0 U
78-93-3	2-Butanone	5.0 U
71-55-6	1,1,1-Trichloroethane	1.0 U
56-23-5	Carbon Tetrachloride	1.0 U
108-05-4	Vinyl Acetate	5.0 U
75-27-4	Bromodichloromethane	1.0 U
78-87-5	1,2-Dichloropropane	1.0 U
10061-01-5	cis-1,3-Dichloropropene	1.0 U
79-01-6	Trichloroethene	1.0 U
124-48-1	Dibromochloromethane	1.0 U
79-00-5	1,1,2-Trichloroethane	1.0 U
71-43-2	Benzene	1.0 U
10061-02-6	trans-1,3-Dichloropropene	1.0 U
110-75-8	2-Chloroethylvinylether	5.0 U
75-25-2	Bromoform	1.0 U
108-10-1	4-Methyl-2-Pentanone (MIBK)	5.0 U
591-78-6	2-Hexanone	5.0 U
127-18-4	Tetrachloroethene	1.0 U
79-34-5	1,1,2,2-Tetrachloroethane	1.0 U
108-88-3	Toluene	1.0 U
108-90-7	Chlorobenzene	1.0 U
100-41-4	Ethylbenzene	1.0 U
100-42-5	Styrene	1.0 U
75-69-4	Trichlorofluoromethane	2.0 U
76-13-1	1,1,2-Trichlorotrifluoroethane	2.0 U
1330-20-7	m,p-Xylene	1.0 U

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ANALYTICAL
RESOURCES
INCORPORATED

Sample No: V-082797-Tank 1

Lab Sample ID: T616A

QC Report No: T616-Battelle

LIMS ID: 97-15211

Project:

Matrix: Water

Data Release Authorized: *W/B*

Date Sampled: 08/27/97

Reported: 09/10/97

Date Received: 08/29/97

Instrument: FINN3

Sample Amount: 5.00 mL

Date Analyzed: 09/05/97

Purge Volume: 5.0 mL

CAS Number	Analyte	ug/L
95-47-6	o-Xylene	1.0 U
95-50-1	1,2-Dichlorobenzene	1.0 U
541-73-1	1,3-Dichlorobenzene	1.0 U
106-46-7	1,4-Dichlorobenzene	1.0 U
107-02-8	Acrolein	.50 U
74-88-4	Methyl Iodide	1.0 U
74-96-4	Bromoethane	2.0 U
107-13-1	Acrylonitrile	5.0 U
563-58-6	1,1-Dichloropropene	1.0 U
74-95-3	Dibromomethane	1.0 U
630-20-6	1,1,1,2-Tetrachloroethane	1.0 U
96-12-8	1,2-Dibromo-3-chloropropane	5.0 U
96-18-4	1,2,3-Trichloropropane	1.0 U
110-57-6	trans-1,4-Dichloro-2-butene	5.0 U
108-67-8	1,3,5-Trimethylbenzene	1.0 U
95-63-6	1,2,4-Trimethylbenzene	1.0 U
87-68-3	Hexachlorobutadiene	5.0 U
106-93-4	Ethylene Dibromide	1.0 U
74-97-5	Bromochloromethane	1.0 U
590-20-7	2,2-Dichloropropane	1.0 U
142-28-9	1,3-Dichloropropane	1.0 U
98-82-8	Isopropylbenzene	1.0 U
103-65-1	n-Propylbenzene	1.0 U
108-86-1	Bromobenzene	1.0 U
95-49-8	2-Chlorotoluene	1.0 U
106-43-4	4-Chlorotoluene	1.0 U
98-06-6	tert-Butylbenzene	1.0 U
135-98-8	sec-Butylbenzene	1.0 U
99-87-6	4-Isopropyltoluene	1.0 U
104-51-8	n-Butylbenzene	1.0 U
120-82-1	1,2,4-Trichlorobenzene	5.0 U
91-20-3	Naphthalene	5.0 U
87-61-6	1,2,3-Trichlorobenzene	5.0 U

Volatile Surrogate Recovery

d4-1,2-Dichloroethane	115%
d8-Toluene	95.4%
Bromofluorobenzene	93.0%
d4-1,2-Dichlorobenzene	99.0%

Sample No: V-082797-Tank 2

Lab Sample ID: T616B

QC Report No: T616-Battelle

LIMS ID: 97-15212

Project:

Matrix: Water

Data Release Authorized: *AWB*

Date Sampled: 08/27/97

Reported: 09/10/97

Date Received: 08/29/97

Instrument: FINN3

Sample Amount: 5.00 mL

Date Analyzed: 09/05/97

Purge Volume: 5.0 mL

CAS Number	Analyte	ug/L
74-87-3	Chloromethane	2.0 U
74-83-9	Bromomethane	2.0 U
75-01-4	Vinyl Chloride	2.0 U
75-00-3	Chloroethane	2.0 U
75-09-2	Methylene Chloride	2.0 U
67-64-1	Acetone	5.0 U
75-15-0	Carbon Disulfide	1.0 U
75-35-4	1,1-Dichloroethene	1.0 U
75-34-3	1,1-Dichloroethane	1.0 U
156-60-5	trans-1,2-Dichloroethene	1.0 U
156-59-2	cis-1,2-Dichloroethene	1.0 U
67-66-3	Chloroform	1.0 U
107-06-2	1,2-Dichloroethane	1.0 U
78-93-3	2-Butanone	5.0 U
71-55-6	1,1,1-Trichloroethane	1.0 U
56-23-5	Carbon Tetrachloride	1.0 U
108-05-4	Vinyl Acetate	5.0 U
75-27-4	Bromodichloromethane	1.0 U
78-87-5	1,2-Dichloropropane	1.0 U
10061-01-5	cis-1,3-Dichloropropene	1.0 U
79-01-6	Trichloroethene	1.0 U
124-48-1	Dibromochloromethane	1.0 U
79-00-5	1,1,2-Trichloroethane	1.0 U
71-43-2	Benzene	1.0 U
10061-02-6	trans-1,3-Dichloropropene	1.0 U
110-75-8	2-Chloroethylvinylether	5.0 U
75-25-2	Bromoform	1.0 U
108-10-1	4-Methyl-2-Pentanone (MIBK)	5.0 U
591-78-6	2-Hexanone	5.0 U
127-18-4	Tetrachloroethene	1.0 U
79-34-5	1,1,2,2-Tetrachloroethane	1.0 U
108-88-3	Toluene	1.0 U
108-90-7	Chlorobenzene	1.0 U
100-41-4	Ethylbenzene	1.0 U
100-42-5	Styrene	1.0 U
75-69-4	Trichlorofluoromethane	2.0 U
76-13-1	1,1,2-Trichlorotrifluoroethane	2.0 U
1330-20-7	m,p-Xylene	1.0 U

Sample No: V-082797-Tank 2

Lab Sample ID: T616B

QC Report No: T616-Battelle

LIMS ID: 97-15212

Project:

Matrix: Water

Data Release Authorized: *MB*

Date Sampled: 08/27/97

Reported: 09/10/97

Date Received: 08/29/97

Instrument: FINN3

Sample Amount: 5.00 mL

Date Analyzed: 09/05/97

Purge Volume: 5.0 mL

CAS Number	Analyte	ug/L
95-47-6	o-Xylene	1.0 U
95-50-1	1,2-Dichlorobenzene	1.0 U
541-73-1	1,3-Dichlorobenzene	1.0 U
106-46-7	1,4-Dichlorobenzene	1.0 U
107-02-8	Acrolein	50 U
74-88-4	Methyl Iodide	1.0 U
74-96-4	Bromoethane	2.0 U
107-13-1	Acrylonitrile	5.0 U
563-58-6	1,1-Dichloropropene	1.0 U
74-95-3	Dibromomethane	1.0 U
630-20-6	1,1,1,2-Tetrachloroethane	1.0 U
96-12-8	1,2-Dibromo-3-chloropropane	5.0 U
96-18-4	1,2,3-Trichloropropane	1.0 U
110-57-6	trans-1,4-Dichloro-2-butene	5.0 U
108-67-8	1,3,5-Trimethylbenzene	1.0 U
95-63-6	1,2,4-Trimethylbenzene	1.0 U
87-68-3	Hexachlorobutadiene	5.0 U
106-93-4	Ethylene Dibromide	1.0 U
74-97-5	Bromochloromethane	1.0 U
590-20-7	2,2-Dichloropropane	1.0 U
142-28-9	1,3-Dichloropropane	1.0 U
98-82-8	Isopropylbenzene	1.0 U
103-65-1	n-Propylbenzene	1.0 U
108-86-1	Bromobenzene	1.0 U
95-49-8	2-Chlorotoluene	1.0 U
106-43-4	4-Chlorotoluene	1.0 U
98-06-6	tert-Butylbenzene	1.0 U
135-98-8	sec-Butylbenzene	1.0 U
99-87-6	4-Isopropyltoluene	1.0 U
104-51-8	n-Butylbenzene	1.0 U
120-82-1	1,2,4-Trichlorobenzene	5.0 U
91-20-3	Naphthalene	5.0 U
87-61-6	1,2,3-Trichlorobenzene	5.0 U

Volatile Surrogate Recovery

d4-1,2-Dichloroethane	123%
d8-Toluene	94.7%
Bromofluorobenzene	99.9%
d4-1,2-Dichlorobenzene	103%

Sample No: Method Blank

Lab Sample ID: 090597MB

QC Report No: T616-Battelle

LIMS ID: 97-15211

Project:

Matrix: Water

Data Release Authorized: *MB*

Date Sampled: NA

Reported: 09/10/97

Date Received: NA

Instrument: FINN3

Sample Amount: 5.00 mL

Date Analyzed: 09/05/97

Purge Volume: 5.0 mL

CAS Number	Analyte	ug/L
74-87-3	Chloromethane	2.0 U
74-83-9	Bromomethane	2.0 U
75-01-4	Vinyl Chloride	2.0 U
75-00-3	Chloroethane	2.0 U
75-09-2	Methylene Chloride	2.0 U
67-64-1	Acetone	5.0 U
75-15-0	Carbon Disulfide	1.0 U
75-35-4	1,1-Dichloroethene	1.0 U
75-34-3	1,1-Dichloroethane	1.0 U
156-60-5	trans-1,2-Dichloroethene	1.0 U
156-59-2	cis-1,2-Dichloroethene	1.0 U
67-66-3	Chloroform	1.0 U
107-06-2	1,2-Dichloroethane	1.0 U
78-93-3	2-Butanone	5.0 U
71-55-6	1,1,1-Trichloroethane	1.0 U
56-23-5	Carbon Tetrachloride	1.0 U
108-05-4	Vinyl Acetate	5.0 U
75-27-4	Bromodichloromethane	1.0 U
78-87-5	1,2-Dichloropropane	1.0 U
10061-01-5	cis-1,3-Dichloropropene	1.0 U
79-01-6	Trichloroethene	1.0 U
124-48-1	Dibromochloromethane	1.0 U
79-00-5	1,1,2-Trichloroethane	1.0 U
71-43-2	Benzene	1.0 U
10061-02-6	trans-1,3-Dichloropropene	1.0 U
110-75-8	2-Chloroethylvinylether	5.0 U
75-25-2	Bromoform	1.0 U
108-10-1	4-Methyl-2-Pentanone (MIBK)	5.0 U
591-78-6	2-Hexanone	5.0 U
127-18-4	Tetrachloroethene	1.0 U
79-34-5	1,1,2,2-Tetrachloroethane	1.0 U
108-88-3	Toluene	1.0 U
108-90-7	Chlorobenzene	1.0 U
100-41-4	Ethylbenzene	1.0 U
100-42-5	Styrene	1.0 U
75-69-4	Trichlorofluoromethane	2.0 U
76-13-1	1,1,2-Trichlorotrifluoroethane	2.0 U
1330-20-7	m,p-Xylene	1.0 U

Sample No: Method Blank

Lab Sample ID: 090597MB

QC Report No: T616-Battelle

LIMS ID: 97-15211

Project:

Matrix: Water

Data Release Authorized: *OMP*

Date Sampled: NA

Reported: 09/10/97

Date Received: NA

Instrument: FINN3

Sample Amount: 5.00 mL

Date Analyzed: 09/05/97

Purge Volume: 5.0 mL

CAS Number	Analyte	ug/L
95-47-6	o-Xylene	1.0 U
95-50-1	1,2-Dichlorobenzene	1.0 U
541-73-1	1,3-Dichlorobenzene	1.0 U
106-46-7	1,4-Dichlorobenzene	1.0 U
107-02-8	Acrolein	50 U
74-88-4	Methyl Iodide	1.0 U
74-96-4	Bromoethane	2.0 U
107-13-1	Acrylonitrile	5.0 U
563-58-6	1,1-Dichloropropene	1.0 U
74-95-3	Dibromomethane	1.0 U
630-20-6	1,1,1,2-Tetrachloroethane	1.0 U
96-12-8	1,2-Dibromo-3-chloropropane	5.0 U
96-18-4	1,2,3-Trichloropropane	1.0 U
110-57-6	trans-1,4-Dichloro-2-butene	5.0 U
108-67-8	1,3,5-Trimethylbenzene	1.0 U
95-63-6	1,2,4-Trimethylbenzene	1.0 U
87-68-3	Hexachlorobutadiene	5.0 U
106-93-4	Ethylene Dibromide	1.0 U
74-97-5	Bromochloromethane	1.0 U
590-20-7	2,2-Dichloropropane	1.0 U
142-28-9	1,3-Dichloropropane	1.0 U
98-82-8	Isopropylbenzene	1.0 U
103-65-1	n-Propylbenzene	1.0 U
108-86-1	Bromobenzene	1.0 U
95-49-8	2-Chlorotoluene	1.0 U
106-43-4	4-Chlorotoluene	1.0 U
98-06-6	tert-Butylbenzene	1.0 U
135-98-8	sec-Butylbenzene	1.0 U
99-87-6	4-Isopropyltoluene	1.0 U
104-51-8	n-Butylbenzene	1.0 U
120-82-1	1,2,4-Trichlorobenzene	5.0 U
91-20-3	Naphthalene	5.0 U
87-61-6	1,2,3-Trichlorobenzene	5.0 U

Volatile Surrogate Recovery

d4-1,2-Dichloroethane	96.6%
d8-Toluene	90.5%
Bromofluorobenzene	95.7%
d4-1,2-Dichlorobenzene	99.3%

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ANALYTICAL
RESOURCES
INCORPORATED

Lab Sample ID: T616SB

QC Report No: T616-Battelle

LIMS ID: 97-15211

Project:

Matrix: Water

Data Release Authorized: *DMS*

Date Received: 08/29/97

Reported: 09/10/97

Date Analyzed: 09/05/97

Instrument: FINN3

LABORATORY CONTROL SAMPLE CONSTITUENT	SPIKE VALUE	SPIKE AMT	% RECOVERY
Chloromethane	31.4	50.0	62.8%
Bromomethane	37.2	50.0	74.4%
Vinyl Chloride	32.0	50.0	64.0%
Chloroethane	37.4	50.0	74.8%
Methylene Chloride	46.1	50.0	92.2%
Acetone	246.	250	98.4%
Carbon Disulfide	43.0	50.0	86.0%
1,1-Dichloroethene	39.4	50.0	78.8%
1,1-Dichloroethane	43.0	50.0	86.0%
trans-1,2-Dichloroethene	40.9	50.0	81.8%
cis-1,2-Dichloroethene	49.3	50.0	98.6%
Chloroform	44.3	50.0	88.6%
1,2-Dichloroethane	44.9	50.0	89.8%
2-Butanone	247.	250	98.8%
1,1,1-Trichloroethane	43.4	50.0	86.8%
Carbon Tetrachloride	42.5	50.0	85.0%
Vinyl Acetate	45.7	50.0	91.4%
Bromodichloromethane	45.0	50.0	90.0%
1,2-Dichloropropane	47.8	50.0	95.6%
cis-1,3-Dichloropropene	45.2	50.0	90.4%
Trichloroethene	45.3	50.0	90.6%
Dibromochloromethane	48.4	50.0	96.8%
1,1,2-Trichloroethane	46.7	50.0	93.4%
Benzene	45.0	50.0	90.0%
trans-1,3-Dichloropropene	45.7	50.0	91.4%
2-Chloroethylvinylether	32.4	50.0	64.8%
Bromoform	48.9	50.0	97.8%
4-Methyl-2-Pentanone (MIBK)	238.	250	95.2%
2-Hexanone	244.	250	97.6%
Tetrachloroethene	45.1	50.0	90.2%
1,1,2,2-Tetrachloroethane	45.4	50.0	90.8%
Toluene	44.8	50.0	89.6%
Chlorobenzene	45.0	50.0	90.0%
Ethylbenzene	44.6	50.0	89.2%
Styrene	46.3	50.0	92.6%
Trichlorofluoromethane	37.8	50.0	75.6%
1,1,2-Trichlorotrifluoroethane	45.3	50.0	90.6%
m,p-Xylene	92.3	100	92.3%
O-Xylene	45.4	50.0	90.8%

Reported in ug/L

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ANALYTICAL
RESOURCES
INCORPORATED

Lab Sample ID: T616SB

LIMS ID: 97-15211

Matrix: Water

Data Release Authorized: *WP*

Reported: 09/10/97

Date Analyzed: 09/05/97

Instrument: FINN3

QC Report No: T616-Battelle

Project:

Date Received: 08/29/97

LABORATORY CONTROL SAMPLE CONSTITUENT	SPIKE VALUE	SPIKE AMT	% RECOVERY
1,2-Dichlorobenzene	40.4	50.0	80.8%
1,3-Dichlorobenzene	41.5	50.0	83.0%
1,4-Dichlorobenzene	42.3	50.0	84.6%
Acrolein	252.	250	101%
Methyl Iodide	40.0	50.0	80.0%
Bromoethane	43.9	50.0	87.8%
Acrylonitrile	47.9	50.0	95.8%
1,1-Dichloropropene	43.7	50.0	87.4%
Dibromomethane	46.6	50.0	93.2%
1,1,1,2-Tetrachloroethane	46.2	50.0	92.4%
1,2-Dibromo-3-chloropropane	47.3	50.0	94.6%
1,2,3-Trichloropropane	45.1	50.0	90.2%
trans-1,4-Dichloro-2-butene	41.8	50.0	83.6%
1,3,5-Trimethylbenzene	41.7	50.0	83.4%
1,2,4-Trimethylbenzene	42.4	50.0	84.8%
Hexachlorobutadiene	48.1	50.0	96.2%
Ethylene Dibromide	46.9	50.0	93.8%
Bromochloromethane	46.1	50.0	92.2%
2,2-Dichloropropane	44.7	50.0	89.4%
1,3-Dichloropropane	47.2	50.0	94.4%
Isopropylbenzene	41.9	50.0	83.8%
n-Propylbenzene	41.6	50.0	83.2%
Bromobenzene	41.8	50.0	83.6%
2-Chlorotoluene	39.4	50.0	78.8%
4-Chlorotoluene	43.4	50.0	86.8%
tert-Butylbenzene	42.6	50.0	85.2%
sec-Butylbenzene	43.7	50.0	87.4%
4-Isopropyltoluene	44.4	50.0	88.8%
n-Butylbenzene	44.1	50.0	88.2%
1,2,4-Trichlorobenzene	45.8	50.0	91.6%
Naphthalene	45.7	50.0	91.4%
1,2,3-Trichlorobenzene	44.8	50.0	89.6%

Lab Control Surrogate Recovery

d4-1,2-Dichloroethane	96.9%
d8-Toluene	96.8%
Bromofluorobenzene	97.7%
d4-1,2-Dichlorobenzene	100%

Reported in ug/L

ANALYTICAL
RESOURCES
INCORPORATED

WATER VOLATILE SYSTEM MONITORING COMPOUND SUMMARY

Matrix: Water

QC Report No: T616

Lab ID	Client ID	DCE	TOL	BFB	DCB	TOT OUT
090597MB	Method Blank	97%	90%	96%	99%	0
T616A	V-082797-Tank 1	115%	95%	93%	99%	0
T616LCS	Lab Cntrl Sample	97%	97%	98%	100%	0
T616B	V-082797-Tank 2	123%	95%	100%	103%	0

	LCS/MB LIMITS	QC LIMITS
(DCE) = 1,2-Dichloroethane-d4	(80-120)	(77-123)
(TOL) = Toluene-d8	(88-110)	(87-115)
(BFB) = Bromofluorobenzene	(86-115)	(78-113)
(DCB) = 1,2-Dichlorobenzene-d4	(80-120)	(86-113)

- # Column to be used to flag recovery values
- * Values outside of required QC limits
- D System Monitoring Compound diluted out

Appendix D

Metals Data

BATTELLE MARINE SCIENCES LABORATORY

1529 W. Sequim Bay Road

Sequim, WA 98382

(360) 683-4151

**Ft. Campbell
Metals in Sediments**

(CF#1098)

MSL Code	Sponsor ID	Percent Dry Wt	(concentrations in µg/g dry wt - not blank corrected)							
			Ag	As	Ba	Be	Cd	Cr	Cu	THg
			ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	CVAF
1098TG*9	MET-082697-COMP-B,C	89.4	1.05	79.4	664	0.40 U	94.3	270	507	11.5
1098TG*11	MET-082697-UTILITY SEWER	62.9	1.03	125	659	0.40 U	31.1	95.2	770	5.56
1098TG*15	R-082797-OUTFALL	57.8	0.110	6.58	147	0.840	0.562	35.9	18.8	0.103
Blank			0.007 U	0.057 U	0.0636	0.40 U	0.21 U	0.09 U	0.040 U	0.0016 U
Achieved MDL			0.007	0.057	0.18	0.40	0.21	0.09	0.040	0.0016
BLANK SPIKE RESULTS										
Amount Spiked			10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Blank			0.01 U	0.057 U	0.0636	0.40 U	0.21 U	0.09 U	0.04 U	0.0016 U
Blank Spike			10.3	9.32	10.6	8.42	9.78	9.75	9.75	10.2
Amount Recovered			10.3	9.32	10.5	8.42	9.78	9.75	9.75	10.2
Percent Recovery			103%	93%	105%	84%	98%	98%	98%	102%
STANDARD REFERENCE MATERIAL										
SRM	mess2		0.505	22.1	401	2.18	0.221	101	40.9	NA
		certified value	0.180	20.7	NC	2.32	0.240	106	39.3	NA
		percent recovery	281% #	107%	NA	94%	92%	96%	104%	NA

U Not detected at or above DL shown

J Value is reported below the MDL

NA Not applicable

NC Not certified

r Reference value only

Outside QC criteria of 75-125% recovery

BATTELLE MARINE SCIENCES LABORATORY

1529 W. Sequim Bay Road

Sequim, WA 98382

(360) 683-4151

**Ft. Campbell
Metals in Sediments**

(CF#1098)

MSL Code	Sponsor ID	Percent Dry Wt	(concentrations in µg/g dry wt - not blank corrected)					
			Ni	Pb	Sb	Se	Tl	Zn
			ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS
1098TG*9	MET-082697-COMP-B,C	89.4	64.0	685	8.46	2.0 U	0.976	3110
1098TG*11	MET-082697-UTILITY SEWER	62.9	75.5	320	16.8	1.66 J	0.187	4870
1098TG*15	R-082797-OUTFALL	57.8	36.4	27.5	0.149	0.917 J	0.436	151
Blank			0.06 U	0.0945	0.02 U	2.0 U	0.006 U	1.38
Achieved MDL			0.06	0.016	0.02	2.0	0.006	0.065
<u>BLANK SPIKE RESULTS</u>								
Amount Spiked			10.0	10.0	10.0	10.0	10.0	10.0
Blank			0.06 U	0.0945	0.02 U	2.0 U	0.006 U	1.38
Blank Spike			10.0	10.6	10.3	10.2	10.6	9.03
Amount Recovered			10.0	10.5	10.3	10.2	10.6	7.65
Percent Recovery			100%	105%	103%	102%	106%	77%
<u>STANDARD REFERENCE MATERIAL</u>								
SRM	mess2		49.9	21.9	1.09	1.17	0.929	175
		certified value	49.3	21.9	1.09	0.72	0.98 r	172
		percent recovery	101%	100%	100%	163% #	95%	102%

U Not detected at or above DL shown

J Value is reported below the MDL

NA Not applicable

NC Not certified

r Reference value only

Outside QC criteria of 75-125% recovery

BATTELLE MARINE SCIENCES LABORATORY

1529 W. Sequim Bay Road

Sequim, WA 98382

(360) 683-4151

(CF#1098)

Ft. Campbell - Metals in Water

(concentrations in µg/L - not blank corrected)

MSL Code	Sponsor ID	Ag	As	Ba	Be	Cd	Cr	Cu	THg
		ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	CVAF
1098TG*6	MET-082997-COMP-UTIL	0.366	2.67	145	0.0534	6.45	6.44	104	0.852
1098TG*7	MET-082997-FLR-B	0.263	3.43	80.4	0.129	3.96	5.23	63.4	2.57
1098TG*8	MET-082697-FLR-UTIL	0.115	1.01	187	0.00	1.92	2.26	15.4	0.119
1098TG*10	MET-082697-FLR-B2	3.50	44.7	54.3	0.253	8.16	22.9	3020	464
1098TG*12	M-082797-TANK-1	0.920	12.3	5170	31.9	13.4	431	332	4.78
1098TG*13	M-082797-TANK-2	0.205	4.31	570	2.39	0.939	42.6	37.3	0.0473
1098TG*14	M-082797-VAULT	0.267	70.1	55.3	0.116	31.5	37.0	4760	64.8
Blank		0.008 U	0.173	0.035 U	0.11 U	0.017 U	1.5 U	0.023 U	0.009 U
Achieved MDL		0.008	0.167	0.035	0.11	0.017	1.5	0.023	0.009
<u>STANDARD REFERENCE MATERIAL</u>									
1643d		1.15	53.8	510	7.31	6.43	16.6	18.5	NA
	certified value	1.27	56.0	507	12.5	6.47	18.5	20.5	NA
	percent recovery	91%	96%	101%	58% #	99%	90%	90%	NA
1641c		NA	NA	NA	NA	NA	NA	NA	1410
	certified value	NA	NA	NA	NA	NA	NA	NA	1470
	percent recovery	NA	NA	NA	NA	NA	NA	NA	96%

U Not detected at or above DL shown

NA Not available/applicable

Outside QC criteria of 75-125% recovery

BATTELLE MARINE SCIENCES LABORATORY

1529 W. Sequim Bay Road

Sequim, WA 98382

(360) 683-4151

(CF#1098)

Ft. Campbell - Metals in Water
(concentrations in µg/L - not blank corrected)

MSL Code	Sponsor ID	Ni	Pb	Sb	Se	Sn	Tl	Zn
		ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS
1098TG*6	MET-082997-COMP-UTIL	14.3	209	2.04	3.75	0.67	0.0562	1880
1098TG*7	MET-082997-FLR-B	14.5	147	7.99	5.66	1.97	0.0300	611
1098TG*8	MET-082697-FLR-UTIL	3.63	12.5	2.52	3.82	2.52	0.005	205
1098TG*10	MET-082697-FLR-B2	377	23.1	430	12.2	11.2	0.0189	378
1098TG*12	M-082797-TANK-1	417	7700	1.51	49.0	3.33	4.44	1210
1098TG*13	M-082797-TANK-2	45.2	60.2	0.86	7.55	6.36	0.580	147
1098TG*14	M-082797-VAULT	69.4	411	12.7	115	5.01	0.113	1610
Blank		0.065 U	0.0398	0.0600	1.0 U	0.0246	0.00795	0.134
Achieved MDL		0.065	0.009	0.036	1.0	0.016	0.006	0.095
<u>STANDARD REFERENCE MATERIAL</u>								
1643d		52.9	17.3	55.5	12.0	3.16	7.19	69.2
	certified value	58.1	18.2	54.1	11.4	NC	7.28	72.5
	percent recovery	91%	95%	103%	105%	NA	99%	95%
1641c		NA	NA	NA	NA	NA	NA	NA
	certified value	NA	NA	NA	NA	NA	NA	NA
	percent recovery	NA	NA	NA	NA	NA	NA	NA

U Not detected at or above DL shown

NA Not available/applicable

Outside QC criteria of 75-125% recovery

Appendix E

Relative Risk Site Evaluation Worksheet

Appendix E

Relative Risk Site Evaluation

The comparison water and soil standard concentrations contained in this report were published in DoD (1996) and are based on the U.S. Environmental Protection Agency (EPA) Region IX Preliminary Remediation Goals, which are updated semiannually by EPA Region IX. The Region IX values are based on toxicological information documented by EPA in the Integrated Risk Information System (IRIS) and Health Effects and Assessment Summary Tables (HEAST) databases. Other reference sources, as footnoted, were used if data were not available in DoD (1996). As noted by DoD (1996), the comparison noncarcinogenic water and soil standard concentrations contained in this report are based on Reference Doses (RfDs) that are translated directly into DoD (1996). The carcinogenic values in DoD (1996) are modified to reflect a 10^{-4} computed risk value. EPA has determined that a computed risk value between 10^{-6} and 10^{-4} is acceptable, depending on prevailing circumstances. For purposes of computing relative risk the DoD Workgroup has deemed 10^{-4} to be adequate. Even though all Region IX values correspond to a risk of 10^{-6} , the values in DoD (1996) have multiplied these numbers by a factor of 100 to obtain the risk estimate to 10^{-4} .

Relative Risk Site Evaluation Worksheet

Site Background Information

Installation/Site Name for FUDS: Ft. Campbell

Location (State): Kentucky

Site (Name/RMIS ID/Project for FUDS): AOC-E

Point of Contact (Name/Phone): James H. Dudley / 502-798-9635

Date Entered (day, month, year): October, 1997

Phase of Execution (PA, SI, RI, FS, Removal, RD/RA, or equiv.

RCRA Stage, etc.): PA

Agreement Status (Y/N, if yes, type agreement e.g., FFA, Permit, Order): N

Site Summary

Brief Site Description (Include site type, materials disposed of, dates of operation, and other relevant information):

Area of Concern-E -- Buildings 7740 and 7741

This site was visually inspected on October 8, 1996, and again on May 7 and 8, 1997. A detailed site investigation was conducted on August 25-27, 1997, using radiological and organic field screening instruments and analysis of several samples collected from the sewer and drainage systems.

Building 7740 is a tunnel complex that was used as a nuclear weapons storage and maintenance area from 1949 to 1966. Building 7741 is an associated underground waste water storage tank located just outside the tunnel complex. The 1996 Installation Action Plan lists this site as area of concern "E" (AOC-E) (ACOE 1996). The tunnel complex (Building 7740) consists of three wings or structures. Structure A contained the nuclear capsule storage area that was secured behind a bank-type locking vault door. This vault door has reportedly been locked since the 1960s and the combination unknown. Structures B and C were "maintenance" wings, where required maintenance was performed on the nuclear capsules. Maintenance activities in Structure C involved dismantling the nuclear assembly system, checking the activity of fissile material, and replacing the polonium/beryllium initiators. Structure B was originally designated as a back-up for Structure C, however, it appears to have most recently been set up as a "Medical Wing."

The waste water tank (Building 7741) and associated influent waste water system were designed to capture potentially contaminated waters from the tunnel complex. The tank is a 10,000-gallon tank located outside the tunnel complex and across the road from the entrance. This "contaminated" drainage system was installed to contain decontamination water if an accident occurred in either the maintenance wings or in the vault storage area and drained the emergency (deluge) showers in the maintenance areas and the vault room floor drains. Primary contaminants of concern at the site include metals (lead and beryllium), volatile organics (TCE and Acetone), and radionuclides (uranium, radium, plutonium).

Previous investigations have included a 1970 closeout radiological survey, several radon studies conducted from 1971 to 1986, site tours and historical records reviews conducted in 1994, and an asbestos assessment survey conducted in 1996. These investigations did not reveal the presence of any residual contamination associated with past operations at the site, nor did they uncover any evidence of a past accident or release from the site. They did, however, identify the presence of some hazardous constituents (i.e., asbestos, radon) still present within the complex.

The site is located within the Old Clarksville base, which is entirely surrounded by fencing, so there is limited access to this location. The tunnel complex is an underground concrete structure that can be accessed only via a locked blast door, further limiting access to the facility. However, the sewer and drainage systems exit the facility and discharge to underground structures (i.e., waste water tank and septic system). Effluent from the waste water tank may potentially be discharged to an old surface water channel near the Little West Fork Creek. Sampling of the underground waste water tank found the tank to be half full of water, suggesting that the integrity of the tank was intact. Vegetation surrounding the site was not denuded and appeared to be very healthy.

Brief Description of Pathways (Groundwater, Surface Water/Sediment, Soil)

Groundwater: The topography of this site ranges from an elevation of 420 to 500 feet above mean sea-level (MSL). A.D. Little (1996) provides a potentiometric map that was based on wells chosen for piezometric levels that included bedrock wells that were screened at depths comparable to the springs and to Little West Fork Creek. A few deep overburden wells were also included in the construction of this potentiometric map. These wells encountered between 50 to 100 ft of overburden. The precise placement of contours, potential flow paths, and basin boundaries were subject to interpretation and should be regarded as approximate. An extrapolation of this data suggests that the piezometric head in this region is likely in the vicinity of 420 ft (consistent with the base flow of Little West Fork Creek). Groundwater occurs generally in the residual soil and the underlying limestone (Metcalf and Eddy 1995). This site is outside of the proposed wellhead protection area for Boiling Spring (Fort Campbell 1996). A.D. Little (1996) notes that the saturated overburden aquifer consists of groundwater present in the residuum and epikarst that has a piezometric surface that is distinct (higher) from that present in the underlying the regional bedrock aquifer. The overburden aquifer is limited spatially and is not continuous across the base, or, in some cases, even across Solid Waste Management Units (SWMUs). Based on its limited extent, this aquifer is considered a recharge source to the regional aquifer with vertical flow pathways being highly localized. In areas of deep overburden, groundwater sometimes has a similar elevation to the bedrock wells; in these areas, the deep overburden and the bedrock aquifers are likely to be hydraulically connected and are, therefore, both considered part of the regional aquifer. The underlying bedrock at Fort Campbell consists principally of two limestone formations: Ste. Genevieve (formerly known as Monteagle) Limestone and the underlying St. Louis Limestone (Metcalf & Eddy 1995). The Ste. Genevieve Limestone is up to 100-ft thick beneath Fort. Campbell, and the St. Louis Limestone is similar in appearance and general composition to the Ste. Genevieve Limestone with a thickness of over 300 ft (Metcalf & Eddy 1995). At Fort Campbell, the Ste. Genevieve Limestone appears to have weathered into residuum; and therefore, the limestone is largely the St. Louis Limestone, especially in regions of the drainage ways (A.D. Little 1996; Metcalf & Eddy 1995).

Surface Water/Sediment Pathway: This facility is located adjacent to Little West Fork Creek and may have discharged effluent from the waste water storage tank directly to an old creek bed of Little West Fork Creek. Sanitary sewer effluent may also have been discharged near the creek via a septic tank and drainfield located in the flood plain (although this could not be confirmed). Natural drainage water from the tunnel complex was discharged to surface drainage ways that emptied into topographic lows along the roadway and flood plain.

During a 2-year period, base-flow discharges from the mouth of Little West Fork Creek (as it left the installation) ranged from 18.4 to 419 ft³/s. Boiling Spring, which supplies the installation with its potable water, is located along Little West Fork Creek, upstream from the Tunnel Complex.

Soil Pathway: The site is an underground concrete bunker. The only plausible releases to the surface soil would be direct releases from the waste water storage tank effluent discharge pipe or discharges from the natural drainage system. Currently, the site is heavily vegetated with very little bare soil exposed.

Brief Description of Receptors (Human and Ecological)

This site is located within the Old Clarksville Base located on the southern side of the cantonment area. This area is fenced off with controlled and limited access to this area. Direct access to Building 7740 is restricted by a locked steel blast door. Direct access to the underground waste water tank is limited by several feet of soil; all vents and valve boxes have been removed to isolate the tank. There is no obvious use of groundwater in this area; however, the site is adjacent to the Little West Fork Creek, which harbors wildlife and which reportedly receives some recreational use by humans (e.g., trout fishing).

Groundwater

Contaminant Hazard Factor (CHF): MODERATE -- No downgradient monitoring wells are located at this site, so no groundwater data are available specifically for this site. While there was rumor that an accident may have occurred at the site (personal communication with Glynn Gordon), no documentation or other evidence could be found to suggest that a significant release had occurred. Thus, the only plausible release scenarios to the soil column (which could impact the groundwater) would be via direct releases from the sanitary sewer drainfield, or from a leak in the waste water storage tank. Although not directly representative of the groundwater concentrations, water concentrations from the sanitary and waste water sewer systems can be used as a surrogate for the groundwater data to calculate a contaminant hazard factor. Contaminant information directly from the sanitary drainfield is unavailable because it could not be located. However, analytical data are available for water samples taken from the floor drains inside the 7740 tunnel complex. These drains feed the sanitary sewer system. Analytical data are also available for water samples collected from the waste water storage tank. Using these values a conservative contaminant hazard factor of moderate has been assigned to this site.

Migration Pathway Factor: CONFINED -- Most of the site is confined within or beneath the concrete walls and floor of the tunnel complex under several feet of residual soil and/or limestone bedrock. The most plausible release scenarios that could impact groundwater would be via direct releases from the sanitary sewer drainfield or from a leak in the waste water storage tank. However, efforts to locate the sanitary sewer drainfield were unsuccessful, suggesting that any subsurface contamination associated with this facility must be very limited. Sampling of the waste water storage tank revealing that it still contained over 5,000 gallons of water indicated that any significant release from the tank was highly unlikely.

For contaminants to reach groundwater, they would have to be released in sufficient quantities to reach the groundwater through several feet of the residual soil. This soil consists of sandy to silty clays with moderate to high plasticity and possibly of reddish, sticky clay derived from weathering (Metcalf and Eddy 1995; A.D. Little 1996, Hileman 1996). In two different samples, the saturated hydraulic conductivities of the residual soil (albeit, not at this location) was determined as $4.9\text{E-}08$ and $7.2\text{E-}06$ cm/s (Metcalf and Eddy 1995), which contains characteristics of a soil that could impede the mobility of contaminants to the water table if preferential conduits for flow from the surface to the water table do not exist. Additionally, this location is not part of the proposed wellhead protection area for Boiling Spring (water supply area for the region), and groundwater flow patterns do not appear to flow toward water-supply areas and springs (Fort Campbell 1996; A.D. Little 1996), although there is a hydraulic link between this area and the Little West Fork Creek, which drains off of the installation. Thus, any deep soil or groundwater contamination (if present) is considered to be of limited extent and confined by either engineering structures and/or the residual soils (Table E.1).

Receptor Factor: LIMITED -- There is no potential threatened water-supply well downgradient of the source. Given the history of this site and its limited accessibility, there is no completed pathway; a rating of limited has been assigned.

Groundwater Category: LOW

Table E.1. Groundwater Contaminant Hazard Factor

Analyst/Constituent	Maximum Concentration (pCi/mL)	Comparison Values ^(a) (pCi/mL)	Ratio
Radionuclides			
Gamma Activity			
⁴⁰ K	7.23E-01	NR	NA
¹³⁷ Cs	ND	NR	NA
²¹² Pb	1.19E+01	NR	NA
²²⁶ Ra	ND	4.00E-02	NA
²³⁴ U	ND	3.00E-01	NA
²³⁵ U	ND	3.00E-01	NA
²³⁸ U	ND	NR	NA
²³⁸ Pu	ND	2.20E-02	NA
²³⁹ Pu	ND	2.10E-02	NA
²⁴⁰ Pu	ND	2.10E-02	NA
²⁴¹ Pu	ND	1.30E+00	NA
²⁴² Pu	ND	2.20E-02	NA
Alpha/Beta Activity			
³ H	2.40E+00	NR	NA
¹⁴ C	ND	NR	NA
⁹⁰ Sr	1.30E+00	NR	NA
Gross Alpha	ND	NR	NA
Gross Beta	4.38E+00	NR	NA
Metals	(ug/L)	(ug/L)	
Ag	9.20E-01	1.80E+02	0
As	1.23E+01	4.50E+00	3
Ba	5.17E+03	2.60E+03	2
Be	3.19E+01	1.60E+00	20
Cd	1.34E+01	1.80E+01	1
Cr	4.31E+02	1.80E+02	2
Cu	3.32E+02	1.40E+03	0
Hg - total	4.78E+00	1.10E+01	0
Ni - soluble salts	4.17E+02	7.30E+02	1
Pb *	6.02E+00	4.00E+00	2
Sb	2.52E+00	1.50E+01	0
Se	4.90E+01	1.80E+02	0
Sn	6.36E+00	2.20E+04	0
Tl - chloride	4.44E+00	2.90E+00	2
Zn	1.88E+03	1.10E+04	0
Volatile Organic Compounds	(ug/L)	(ug/L)	
TCE	ND	1.60E+02	NA
alcohol	NA	NR	NA
acetone	ND	6.10E+02	NA
Total			33

Note that those constituents in **BOLD** are the primary contaminants of concern potentially attributable to the facility.

(a) From DOD, 1997. Note that comparison values for water are less than the maximum detection activity for radionuclides.

NA = Not Analyzed

ND = Not Detected

NR = Not Reported

* Second highest value used since the highest value was from unfiltered sludge in the bottom of the tank, and not considered a fair surrogate for

Surface Water/Sediment - Human Endpoint

Contaminant Hazard Factor (CHF): MINIMAL -- This facility is located adjacent to Little West Fork Creek and may have discharged effluent from the waste water storage tank directly to an old creek bed of Little West Fork Creek. No surface water or sediment analytical data are available for this site. However, analytical results of soil samples collected at the discharge head wall from the underground waste water storage tank yields a minimal contaminant hazard factor for the human endpoint (Table E.2).

Migration Pathway Factor: POTENTIAL -- This facility is located adjacent to Little West Fork Creek and may have discharged effluent from the waste water storage tank directly to an old creek bed of Little West Fork Creek. Sanitary sewer effluent may also have been discharged near the creek via a septic tank and drainfield located in the flood plain (although this could not be confirmed). Natural drainage water from the tunnel complex was discharged to surface drainage ways that emptied into topographic lows along the roadway and flood plain. This information suggests that there is a potential for contamination to migrate from the source to the nearby Little West Fork Creek.

Receptor Factor: IDENTIFIED -- This site is located within the Old Clarksville Base which is fenced off with controlled and limited access to this area. There is no obvious use of surfacewater directly downgradient of this site; however, Little West Fork Creek reportedly does get some recreational use, primarily for fishing.

Surface Water/Sediment - Human Endpoint Category: MEDIUM

Table E.2. Surface Water/Sediment Contaminant Hazard Factors

Contaminant	Maximum Concentration	Comparison Values (a)		Ratio	
		Soil - Human Endpoints	Sediment - Freshwater Ecological Endpoints	Human Endpoints	Ecological Endpoints
Radionuclides	(pCi/mL)	(pCi/g)	(pCi/g)		
Gamma Activity					
⁴⁰ K	4.03E+00	NR	NR	NA	NA
¹³⁷ Cs	2.90E-01	NR	NR	NA	NA
²¹² Pb	5.20E-01	NR	NR	NA	NA
²²⁶ Ra	1.95E+00	6.60E+02	NR	0.00	NA
²³⁴ U	ND	5.00E+03	NR	NA	NA
²³⁵ U	ND	5.00E+03	NR	NA	NA
²³⁸ U	ND	NR	NR	NA	NA
²³⁹ Pu	ND	3.60E+02	NR	NA	NA
²⁴⁰ Pu	ND	3.50E+02	NR	NA	NA
²⁴¹ Pu	ND	3.50E+02	NR	NA	NA
²⁴² Pu	ND	2.20E+04	NR	NA	NA
	ND	3.60E+02	NR	NA	NA
Alpha/Beta Activity					
³ H	ND	NR	NR	NA	NA
¹⁴ C	1.66E+01	NR	NR	NA	NA
⁹⁰ Sr	1.72E+01	NR	NR	NA	NA
Gross Alpha	1.21E+00	NR	NR	NA	NA
Gross Beta	1.45E+01	NR	NR	NA	NA
Metals	(ug/L)	(mg/kg)	(mg/kg)		
Ag	1.10E-01	3.80E+02	NA	0.00	NA
As	6.58E+00	2.20E+01	6.00E+00	0.30	1.10
Ba	1.47E+02	5.30E+03	NR	0.03	NA
Be	8.40E-01	1.40E+01	NR	0.06	NA
Cd	5.62E-01	3.80E+01	6.00E-01	0.01	0.94
Cr	3.59E+01	3.00E+03	2.80E+01	0.01	1.38
Cu	1.88E+01	2.80E+03	1.60E+01	0.01	1.18
Hg - total	1.03E-01	2.30E+01	2.00E-01	0.00	0.52
Ni - soluble salts	3.64E+01	1.50E+03	1.80E+01	0.02	2.28
Pb *	2.75E+01	4.00E+02	3.10E+01	0.07	0.89
Sb	1.49E-01	3.10E+01	NA	0.00	NA
Se	9.17E-01	3.80E+02	NR	0.00	NA
Sn	0.00E+00	4.60E+04	NR	0.00	NA
Tl - chloride	4.36E-01	6.10E+00	NR	0.07	NA
Zn	1.51E+02	2.30E+04	1.20E+02	0.01	1.26
Volatile Organic Compounds	(ug/L)	(mg/kg)	(mg/kg)		
TCE	ND	7.10E+02	NR	NA	NA
alcohol	ND	NR	NR	NA	NA
acetone	ND	2.00E+03	NR	NA	NA
Total				0.61	9.62

Constituents in **BOLD** are the primary contaminants of concern potentially attributable to the facility.

(a) From DOD, 1997. Note that comparison values for water are less than the maximum detection activity for radionuclides.

NA = Not Analyzed

ND = Not Detected

Surface Water/Sediment - Ecological Endpoint

Contaminant Hazard Factor (CHF): MODERATE -- This facility is located adjacent to Little West Fork Creek and may have discharged effluent from the waste water storage tank directly to an old creek bed of Little West Fork Creek. No surface water or sediment analytical data are available for this site. However, analytical results of soil samples collected from the discharge head wall from the waste water storage tank conservatively yields a moderate contaminant hazard factor for the ecological endpoint (Table E.2).

Migration Pathway Factor: POTENTIAL -- This facility is located adjacent to Little West Fork Creek and may have discharged effluent from the waste water storage tank directly to an old creek bed of Little West Fork Creek. Sanitary sewer effluent may also have been discharged near the creek via a septic tank and drainfield located in the flood plain (although this could not be confirmed). Natural drainage water from the tunnel complex was discharged to surface drainage ways that emptied into topographic lows along the roadway and flood plain. This information suggests that there is a potential for contamination to migrate from the source to the nearby Little West Fork Creek.

Receptor Factor: POTENTIAL -- The Little West Fork Creek is reportedly used by trout and potentially other fish and wildlife. However, it is unknown whether this area is critical habitat or other critical environment.

Surface Water/Sediment - Human Endpoint Category: MEDIUM

Soil

Contaminant Hazard Factor (CHF): MINIMAL -- The only soil samples available from this site were collected at the discharge head wall from the underground waste water storage tank. These data yield a minimal contaminant hazard factor (Table E.2).

Migration Pathway Factor: POTENTIAL -- This facility may have discharged effluent from the waste water storage tank directly to the soil surface along an old creek bed of Little West Fork Creek. Natural drainage water from the tunnel complex was also discharged to surface soils in drainage ways that emptied into topographic lows along the roadway and flood plain. This information suggests that there is a potential for contamination to migrate away from the source.

Receptor Factor: POTENTIAL -- This site is located within the Old Clarksville Base, which is a fenced off area with controlled and limited access. Direct access to building 7740 is restricted by a locked steel blast door. Direct access to the underground waste water tank is limited by several feet of soil; all vents and valve boxes have been removed to isolate the tank. Little West Fork Creek reportedly does get some recreational use for fishing; thus, there is a potential for some human exposure to potentially contaminated surface soils.

Soil Category: MEDIUM

References

- Fort Campbell. 1996. *Fort Campbell Wellhead Protection Plan. Section 2. Plate I. Proposed Wellhead Protection Area for Boiling Spring.* Fort Campbell, Kentucky.
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