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September 1993

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Superfund Record of Decision:

USDOE Oak Ridge Reservation (Operable Unit 16), TN

50272-101

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15. Supplementary Notes

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16. Abstract (Limit: 200 words)

The USDOE Oak Ridge Reservation (Operable Unit 16) site is part of the former uranium enrichment K-25 facility located in Oak Ridge, Roane County, Tennessee. Land use in the area is mixed agricultural, recreational, residential, and industrial. Site features include Poplar Creek, Clinch River, Mitchell Branch, and two former waste disposal ponds. From 1945 to 1985, the K-25 facility operated as part of the Manhattan Project and was the world's first large-scale uranium enrichment facility. In 1943, the K-1407-B Pond was constructed as a settling and holding pond to receive metal hydroxide precipitates generated during neutralization and precipitation of metal-laden solutions treated in the K-1407-A Neutralization Unit. The pond also received discharges from the K-1420 Metals Decontamination Building and waste from the K-1501 Steam Plant. In 1973, the K-1407-C Pond was constructed to store the potassium hydroxide scrubber sludge generated at K-25 and to receive sludge discharges from the K-1407-B Pond. Once the K-1407-B Pond reached maximum sludge capacity, it was dredged, and the sludge was transferred to the K-1407-C Pond. In 1985, sampling was conducted to characterize the waste in the pond sludge and subsurface soil. In 1987 and 1988, DOE removed sludge from the K-1407-C and K-1407-B Ponds to comply with RCRA clean closure requirements. Subsequent sampling confirmed the presence of residual

(See Attached Page)

17. Document Analysis a. Descriptors

Record of Decision - USDOE Oak Ridge Reservation (Operable Unit 16), TN
Eighth Remedial Action
Contaminated Medium: soil
Key Contaminants: VOCs (PCE, TCE), metals (arsenic, chromium), radioactive materials

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report) None	21. No. of Pages 122
	20. Security Class (This Page) None	22. Price

(See ANSI-Z39.18) *See Instructions on Reverse* OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce

Abstract (Continued)

radionuclide contamination in the pond soil. As a result, RCRA closure activities were halted until a new strategy could be developed to integrate RCRA/CERCLA requirements. Previous 1991 and 1992 RODs addressed contaminated soil, sludge, and debris at the United Nuclear Corporation disposal site; contaminated sediment at the Y-12 Plant; contaminated sludge at the K-25 facility; contaminated surface water at the K-25 facility; and contaminated soil at the Y-12 Plant, as OUs 2, 3, 4, 6, and 18, respectively. Other 1993 RODs address contaminated surface debris and soil at the Oak Ridge National Laboratory, as OUs 8 and 17, respectively. This ROD addresses the contaminated K-1407-B and K-1407-C Ponds at the K-25 facility, as OU16. A future ROD will address onsite contaminated ground water. The primary contaminants of concern affecting the soil are VOCs, including PCE and TCE; metals, including arsenic and chromium; and radioactive materials.

The selected remedial action for this site includes implementing stormwater runoff controls and fugitive dust controls; filling K-1407-B Pond, which contains 21,000 yd^3 of soil with residual contamination with approximately 14,000 yd^3 of crushed rock and K-1407-C Pond with approximately 63,000 yd^3 of engineered compacted soil; placing a soil cover over the filled ponds; regrading and revegetating the pond areas to control erosion and stabilize the soil covers; monitoring ground water; and maintaining existing institutional controls and site access restrictions. The estimated present worth cost for this remedial action is $5,000,000, which includes an estimated annual O&M cost of $33,000.

PERFORMANCE STANDARDS OR GOALS:

Chemical-specific soil cleanup goals are based on a health-risk level of 10^{-6}, EPA-recommended equations for calculating preliminary remediation goals for radionuclides in soil, and RCRA clean closure requirements, and include americium^{-241} 0.002 pCi/g; cadmium 1 mg/kg; cesium^{-137} 0.004 pCi/g; chromium 0.000002 mg/m^3; cobalt^{-60} 0.002 pCi/g; europium^{-154} 0.004 pCi/g; manganese 156 mg/kg; mercury 0.1 mg/kg; neptunium^{-237} 0.002 pCi/g; nickel 130 mg/kg; potassium^{-40} 0.033 pCi/g; technetium^{-99} 1.8 pCi/g; thorium^{-230} 0.003 pCi/g; uranium^{-234} 0.003 pCi/g; uranium^{-235} 0.007 pCi/g; uranium^{-238} 0.001 pCi/g; and zinc 52 mg/kg.

DOE/OR/02-1125&D3

Record of Decision for the K-1407-B/C Ponds at the Oak Ridge K-25 Site Oak Ridge, Tennessee

September 1993

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September 1993

Prepared for
U.S. Department of Energy
Office of Environmental Restoration
and Waste Management

Prepared by
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under contract DE-AC05-90OR21851

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ACRONYMS AND INITIALISMS

ARAR	applicable or relevant and appropriate requirement
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
CNF	Central Neutralization Facility
COC	contaminant of concern
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FFA	*Federal Facility Agreement for the Oak Ridge Reservation*
FR	*Federal Register*
FS	Feasibility Study
HSWA	Hazardous and Solid Waste Amendments
IRC	Information Resource Center
MCL	maximum contaminant level
NCP	National Oil and Hazardous Substance Contingency Plan
NPDWS	National Primary Drinking Water Standards
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
NSDWS	National Secondary Drinking Water Standards
O&M	operation and maintenance
ORR	Oak Ridge Reservation
OU	operable unit
PPE	personal protective equipment
PRG	preliminary remediation goal
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RI	Remedial Investigation
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act of 1986
SF	slope factor
SWMU	solid waste management unit
TBC	to be considered
TCA	Tennessee Code Annotated
TCE	trichloroethene
TDEC	Tennessee Department of Environment and Conservation
USACE	U.S. Army Corps of Engineers
VOC	volatile organic compound

PART 1. DECLARATION

SITE NAME AND LOCATION

K-1407-B Holding Pond and K-1407-C Retention Basin (also known as K-1407-B/C Ponds)
Oak Ridge K-25 Site; K-1407 Operable Unit (OU)
Oak Ridge Reservation (ORR)
Oak Ridge, Tennessee

STATEMENT OF BASIS AND PURPOSE

This decision document presents the selected remedial action for the K-1407-B Holding Pond and the K-1407-C Retention Basin, which are part of the K-1407 OU of the U.S. Department of Energy (DOE) K-25 Site in Oak Ridge, Tennessee. This action was chosen in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) and, to the extent practicable, with the National Oil and Hazardous Substance Contingency Plan (NCP). This decision is based on the Administrative Record file for this site.

The state of Tennessee and the U.S. Environmental Protection Agency (EPA), after review of relevant documentation, concur with the selected remedy for the K-1407-B/C Ponds.

ASSESSMENT OF THE SITE

Actual or threatened releases of hazardous substances from this site, if not addressed by implementing the response action selected in this Record of Decision (ROD), may present an imminent and substantial endangerment to public health, welfare, or the environment.

DESCRIPTION OF SELECTED REMEDY

The selected remedy addresses residual contamination in the K-1407-B/C Pond soils. The K-1407-B/C Ponds are part of the K-1407 OU, which is in the K-25 main plant area. Other designated waste management units within the K-1407 OU will be evaluated under a separate CERCLA remedial investigation (RI)/feasibility study (FS). In addition, the groundwater contamination in the vicinity of K-1407-B/C Ponds will be addressed as part of the sitewide K-25 Groundwater OU RI/FS.

This final source control action is intended to reduce the potential threats to human health and the environment posed by residual metal, radiological, and volatile organic compound (VOC) contamination within the K-1407-B/C Ponds.

The major components of the selected remedy for the K-1407-B/C Ponds include:

- placement of clean soil and rock fill for isolation and shielding,
- maintenance of institutional controls, and
- groundwater monitoring to assess performance of the action and to develop information for use in reviewing the effectiveness of this remedy.

The principal threats to human health at the K-1407-B/C Ponds are to the hypothetical future on-site resident for baseline conditions. These threats are posed primarily by ^{137}Cs via direct exposure to ionizing radiation, ^{99}Tc via ingestion of homegrown produce, and trichloroethene (TCE) via groundwater ingestion. The alternative chosen for the K-1407-B/C Ponds will provide a reduction in the potential threats from cancer risks posed by ^{137}Cs and ^{99}Tc, but will not address groundwater contaminants.

The threat of ^{137}Cs, ^{99}Tc, and other soil-bound residual contaminants will be addressed by eliminating the exposure pathways for external exposure to ionizing radiation and ingestion of homegrown produce routes, as well as the exposure pathways for ingestion of soil, dermal contact with soil, and inhalation of wind-generated dust. This action will isolate the residual contaminants whose risks have been identified from the surface environment, as well as those for which excess cancer risks cannot be quantified.

The future K-25 Groundwater OU CERCLA RI/FS will address the potential risk posed to the hypothetical future on-site resident by TCE through groundwater ingestion and the potential risks posed by other groundwater contaminants and groundwater pathways. Meanwhile, the maintenance of institutional controls at the K-25 Site will preclude the completion of groundwater pathways and the associated risks to human health.

Although engineering controls will effectively deactivate all direct exposure and soil pathways of exposure identified in the baseline risk assessment, the continued presence of residual soil contamination on-site represents a potential threat. The purpose of institutional controls at the K-1407-B/C Ponds is to prevent the inadvertent exhumation of the residual soil contamination buried under the soil cover. If at any point in the future an unconditional release of the site becomes a possibility, DOE or its successor shall conduct a review of the remedy and current site conditions prior to transfer of the K-25 Site from DOE or its successor to another person or entity.

STATUTORY DETERMINATIONS

The selected remedy is protective of human health and the environment, complies with federal and state requirements that are legally applicable or relevant and appropriate to the remedial action, and is cost-effective. This remedy utilizes permanent solutions and alternative treatment or resource recovery technologies to the maximum extent practicable. However, because treatment of the principal threats of the site was not found to be practicable, this remedy does not satisfy the statutory preference for treatment as a principal element. Current technology does not offer means to effectively treat residual radiological contamination such as that found at the K-1407-B/C Ponds site. Therefore, management of in situ residues is a more appropriate remedy at this site.

Because this remedy will result in hazardous substances remaining on-site above health-based levels, a review will be conducted every 5 years, beginning within 5 years after commencement of the remedial action, to ensure that the remedy continues to provide adequate protection of human health and the environment, as required by CERCLA 121(c).

APPROVALS

W. W. Adams — 9-24-93

Assistant Manager for Environmental Restoration
and Waste Management
U.S. Department of Energy
Oak Ridge Operations
— Date

Earl C. Leming — 9-28-93

Director, DOE Oversight Division
State of Tennessee
Tennessee Department of Environment and Conservation
— Date

Patrick M Tobin — 9-30-93

Regional Administrator
U.S. Environmental Protection Agency, Region IV
— Date

PART 2. DECISION SUMMARY

SITE NAME, LOCATION, AND DESCRIPTION

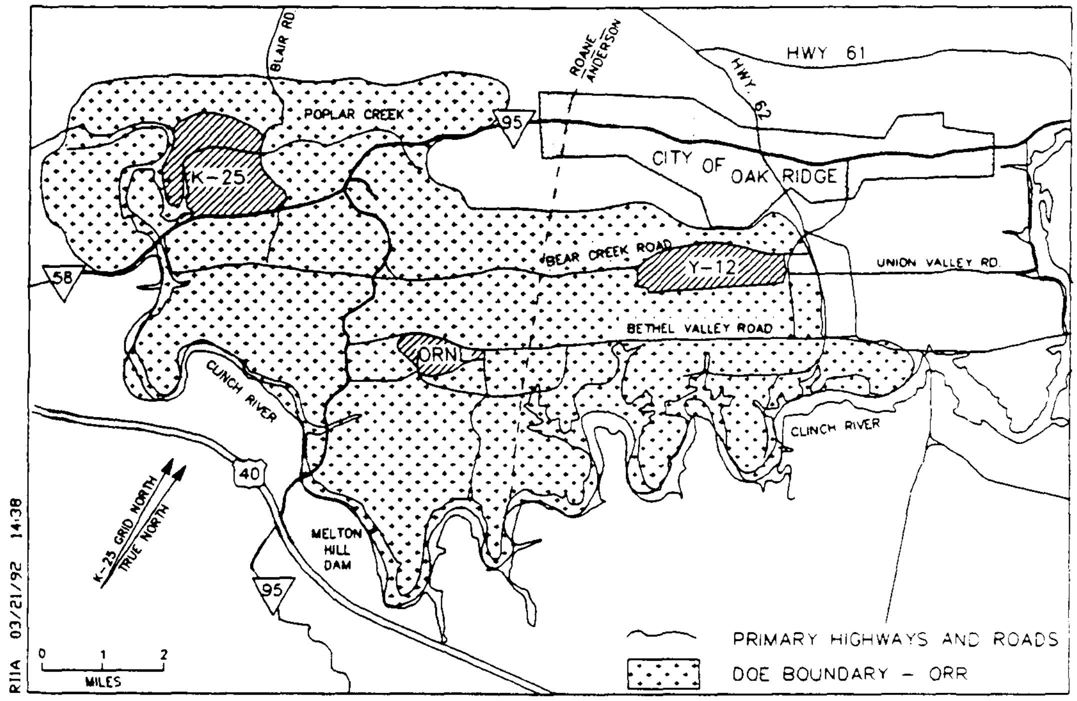
The Oak Ridge K-25 Site, formerly known as the Oak Ridge Gaseous Diffusion Plant, was built as part of the Manhattan Project during World War II and was the world's first large-scale uranium enrichment facility. The K-25 Site is in Roane County, approximately 20 miles west of Knoxville, Tennessee, and 10 miles southwest of the city of Oak Ridge. The facility is accessible from the northeast and southwest by U.S. Interstate 40 to Tennessee Highway 58 and by Blair Road from the north. It is situated in the northwest portion of the ORR at the confluence of Poplar Creek and the Clinch River (Fig. 2.1).

The K-25 Site is bordered by five counties (Anderson, Knox, Loudon, Morgan, and Roane) that have a combined population of greater than 500,000 (1990 census). Knoxville and Oak Ridge are the two largest metropolitan areas within a 50-mile radius of K-25. Knoxville has a population of approximately 165,000, and Oak Ridge has a population of approximately 27,000. Other smaller municipalities (and their populations) lying within the surrounding counties include Clinton (8,000), Harriman (8,000), Rockwood (6,000), Lenoir City (5,500), Kingston (4,500), and Oliver Springs (4,000) (Energy Systems 1989).

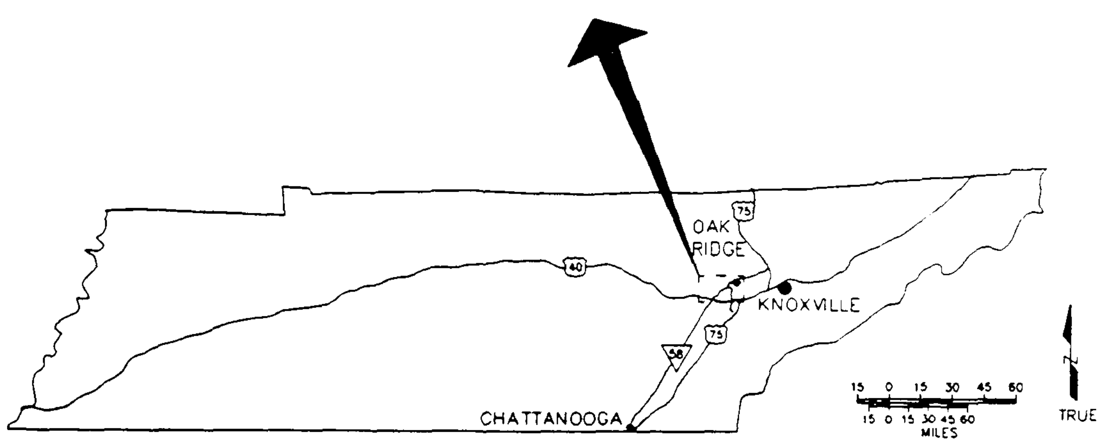
The nearest privately owned residential properties are approximately 1.5 miles north of the K-25 Site in the Poplar Creek/Sugar Grove Valley area. This northeast-southwest trending valley extends for several miles in either direction from K-25 and is primarily devoted to agricultural use. It is lightly to moderately populated. Similar population densities occur approximately 2 miles southwest of K-25 across the Clinch River and along Highway 58 and in the Poplar Springs community 2 miles south-southeast of K-25. Employees at K-25 constitute an additional part-time population of approximately 2,400 people. Because of the small areal extent of the K-1407-B/C Ponds and the relatively large distance to any local residence, regional groundwater and the quality of groundwater used by local residents are not considered to be affected by conditions at the ponds. There is currently no use of groundwater at the K-1407-B/C Ponds site.

Although access to ORR and the K-25 Site is restricted to authorized personnel, deer hunting is permitted in some areas of the reservation. Area recreational activities include hunting, fishing, and pleasure boating on the nearby Watts Bar Lake/Clinch River waterways. Since the land surrounding K-25 is part of the ORR, it is mostly undeveloped. However, there are residential, industrial, recreational, and light agricultural sites in adjacent areas. Aside from light agriculture, there is currently no commercial development of natural resources in the area.

The K-1407-B/C Ponds are in the northeast quadrant of the K-25 Site within the perimeter fence (Fig. 2.2). The pond area is relatively flat except for the levee around the K-1407-C Pond,

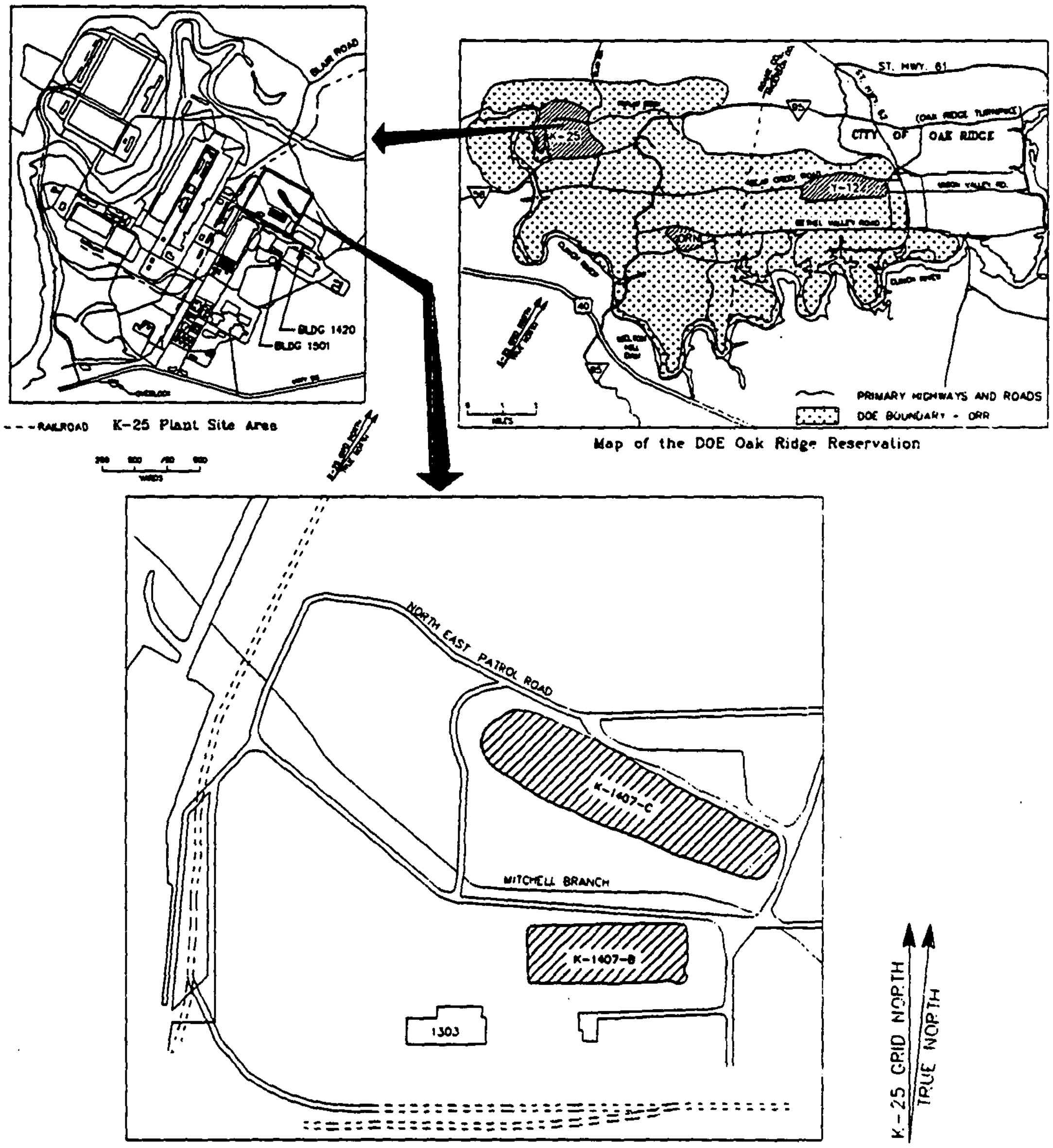


Map of the DOE Oak Ridge Reservation



Regional Location of Y-12, ORNL, and K-25 Plant Sites

RADIAN Source: Radian Date: 1992	Regional map of Oak Ridge area showing the Oak Ridge Reservation
Environmental Restoration Program	Fig. 2.1



K-1407-B/C PONDS

::::::: RAILROAD

0 125 250 375
FEET

(SOURCE; CLOSURE PLAN K1407-B HOLDING POND
K/ER-26 - K/HS-216/R1 APRIL 1990)

RADIAN Source: Radian Date: 1992	Location of K-1407-B/C Ponds.
Environmental Restoration Program	Fig. 2.2

and the site is readily accessible from inside the K-25 boundaries. There is no obtrusive vegetation next to the ponds, and well-kept access ways exist. The impoundments are separated by about 100 ft of flat terrain and by Mitchell Branch. This naturally occurring intermittent stream, also known as the K-1700 stream, flows between the K-1407-B Pond and the K-1407-C Pond and converges with Poplar Creek in the northwest portion of the K-25 Site (DOE 1992a).

The K-1407-B Pond is a rectangular surface impoundment approximately 400 ft long and 150 ft wide. It covers 1.3 acres and has a 2.5 million-gal storage capacity and a maximum depth of approximately 8 ft. The K-1407-C Pond is an elongated impoundment approximately 720 ft long and averages about 75 ft in width. It covers approximately 2.2 acres and averages about 8 ft deep. When in use, this unit had a storage volume capacity of approximately 4 million gal (DOE 1992a).

SITE HISTORY AND ENFORCEMENT ACTIVITIES

The K-25 Site was built as part of the Manhattan Project during World War II and was the world's first large-scale uranium enrichment facility. K-25 operated in this capacity for both defense and nuclear energy applications from the time of its completion in 1945 until enrichment operations ceased in 1985. The K-1407-B/C Ponds were built as settling and holding ponds primarily for the secondary treatment of metal-laden wastes generated at K-25. The wastes consisted of coal pile runoff water, steam plant boiler blowdown solution, steam plant fly ash, raffinate from equipment, plating/stripping process wastes, and cleaning/decontamination and metal-bearing wastes generated from processes at the K-1420 metals decontamination building. The K-1407-B/C Ponds also received purge cascade and laboratory waste solutions (Energy Systems 1989).

The K-1407-B Pond, constructed in 1943, was primarily used for settling metal hydroxide precipitates generated during neutralization and precipitation of metal-laden solutions treated in the K-1407-A Neutralization Unit. It also received discharge from the K-1420 Metals Decontamination Building and wastes from the K-1501 Steam Plant. The K-1407-C Pond, constructed in 1973, was primarily used to store potassium hydroxide scrubber sludge generated at K-25. It also received sludge from the K-1407-B Pond. When the K-1407-B Pond reached maximum sludge capacity, it was dredged, and the sludge was transferred to the K-1407-C Pond (Energy Systems 1989).

The K-1407-B/C Ponds are regulated as Resource Conservation and Recovery Act (RCRA) interim status units and were in operation before RCRA was impacted by the Hazardous and Solid Waste Amendments (HSWA) issued by EPA in November 1984. HSWA [Sect. 3005(j)] required that hazardous waste surface impoundments either comply with Sect. 3004(o)(1)(a) or be closed by November 1988. To satisfy the closure requirement, the discharge of all wastes into the ponds ceased before the November 1988 mandate. DOE was in the process of complying with RCRA regulations when the ORR was placed on the CERCLA National Priorities List (NPL) in November 1989.

In 1985, a sampling and analysis strategy of the ponds was developed for the waste characterization of the pond sludges and subsurface soils. RCRA constituents, as identified in 40 Code of Federal Regulations (CFR) 261 Subpart C, were characterized. Closure plans for the removal of sludge from the K-1407-B/C Ponds were submitted to the regulators in May 1988. Sludge removal from the K-1407-C Pond began in February 1987 and was completed in October 1988. Sludge removal from the K-1407-B Pond began in November 1988 and was completed in August 1989. Sampling to evaluate the effectiveness of sludge removal procedures was subsequently performed and confirmed the removal of RCRA constituents and the presence of residual radionuclide contamination in the pond soils (DOE 1992a).

Because source, special nuclear, and by-product materials as defined by the Atomic Energy Act are not regulated under RCRA and because the ORR had been placed on the NPL, RCRA closure activities were halted until a strategy could be developed to integrate CERCLA/RCRA requirements. Pursuant to a tentative agreement among DOE, the Tennessee Department of Environment and Conservation (TDEC), and EPA (Region IV), the temporary delay in the closure of the surface impoundments was resolved by declaring that the sites would satisfy RCRA clean closure criteria and that the CERCLA process would address radiological contaminants at the ponds (DOE 1992b). Certification of clean closure will be completed before remedial activities are implemented at the site.

HIGHLIGHTS OF COMMUNITY PARTICIPATION

The Proposed Plan for the K-25 K-1407-B/C Ponds (DOE 1992c) was released to the public in February 1993 by inclusion in the Administrative Record file maintained at the DOE Information Resource Center (IRC) at 106 Broadway, Oak Ridge, Tennessee. The Notice of Availability of the Proposed Plan was published in the *Oak Ridger* on February 2, 1993; in the *Knoxville News-Sentinel* on January 31, 1993; and in the *Roane County News* on February 2, 1993.

A public comment period was held from February 3 through March 4, 1993. No public meeting was scheduled, but an opportunity for a meeting was offered in the Notice of Availability of the Proposed Plan for K-1407-B/C Ponds.

Responses to comments received during the public comment period would normally be included in the Responsiveness Summary (Part 3 of this ROD); however, no public comments were received. This decision document presents the selected remedial action for the K-25 K-1407-B/C Ponds chosen in accordance with CERCLA as amended by the SARA and, to the extent practicable, the NCP. The remedial action decision for this site is based on the Administrative Record.

SCOPE AND ROLE OF THE SITE

The selected alternative presented in this ROD represents the final remedial action for the K-1407-B/C Ponds only. Source control actions addressing the remediation of other designated waste management units within the K-1407 OU will be evaluated under a separate, future CERCLA RI/FS(s). Groundwater contamination in the vicinity of the ponds will be addressed as part of the sitewide K-25 Groundwater OU RI/FS (Energy Systems 1990). These remedial actions are intended to meet DOE's goal of reducing current threats to human health and the environment. The selected remedy for the K-1407-B/C Ponds is consistent with planned future remedial activities at the K-1407 OU and the K-25 Site. Data generated under post-remediation groundwater monitoring to assess the performance of the remedial action at the K-1407-B/C Ponds may also be used in the future K-1407 OU and K-25 Groundwater OU investigations.

The final action for the K-1407-B/C Ponds is intended to reduce the potential threats to human health and the environment posed by residual metal, radiological, and VOC contamination within the pond soils. The principal threats to human health at the site are to the hypothetical future on-site resident for baseline conditions. These threats are posed primarily by ^{137}Cs via direct exposure to ionizing radiation, ^{99}Tc, via ingestion of homegrown produce, and TCE via groundwater ingestion. The remedial alternative chosen for the K-1407-B/C Ponds will provide a reduction in the potential threats from cancer risks posed by ^{137}Cs and ^{99}Tc but will not address groundwater contaminants.

The threat of ^{137}Cs, ^{99}Tc, and other soil-bound residual contaminants will be addressed by eliminating the exposure pathways for the external exposure to ionizing radiation and ingestion of homegrown produce routes; ingestion of soil, dermal contact with soil, and inhalation of wind-generated dust pathways will also be eliminated. This action will isolate the surface environment from the residual contaminants for which risks have been identified and those for which excess cancer risks cannot be quantified.

The future K-25 Groundwater OU CERCLA RI/FS will address the potential risk posed by TCE through groundwater ingestion, as well as the potential risks posed by other groundwater contaminants and groundwater pathways. Meanwhile, the maintenance of institutional controls at the K-25 Site will preclude the completion of groundwater pathways and the associated risks to human health at the K-1407-B/C Ponds.

SITE CHARACTERISTICS

As settling and holding ponds for secondary treatment of metal-laden wastes generated at K-25, the K-1407-B/C Ponds received wastes consisting of coal pile runoff water, steam plant boiler blowdown solution, steam plant fly ash, raffinate from equipment, plating/stripping process wastes, cleaning/decontamination and metal-bearing wastes generated from processes at the K-1420 metals decontamination building, and purge cascade and laboratory waste solutions.

The K-1407-B/C Ponds are in the northeast quadrant of the K-25 Site, within the perimeter fence (Fig. 2.2). The impoundments are separated by about 100 ft of flat terrain and by Mitchell Branch. This naturally occurring intermittent stream, also known as the K-1700 stream, flows between the K-1407-B Pond and the K-1407-C Pond and converges with Poplar Creek in the northwest portion of the K-25 Site. Mitchell Branch is the receiving stream for both surface and groundwater discharge for the northeastern portion of K-25 and represents the main surface water feature in the K-1407-B/C Pond area. Small portions of the ponds site, including the south, west, and northeast sides, lie within the 100-year flood zone, including the K-1407-B Pond area. A field survey was conducted at the K-1407-B/C Ponds site to determine the presence of wetlands. Based on this survey, neither pond meets the criteria for wetlands as defined in the *Corps of Engineers Wetlands Delineation Manual* (U.S. Army 1987).

Soil Contamination

To comply with the original RCRA closure plans for the units, sludge removal from the K-1407-B/C Ponds began in 1987 and was completed in 1989. In an effort to demonstrate that all RCRA-regulated contaminants had been removed, soil verification sampling was performed. After all visible traces of sludge were removed, soil samples were collected from the bottom of each pond. These samples were analyzed for metals, VOCs, and radionuclides known or suspected to be present at the site.

Analyses indicated that no metals were present above Extraction Procedure toxicity present; technetium and uranium were found to have the highest concentrations. Because radionuclide contamination was detected in the K-1407-B/C Ponds, a CERCLA sampling event was conducted to gather additional data during 1989 (K-1407-C Pond) and 1990 (K-1407-B Pond). An RI/FS was conducted for the site based on this and other pre-existing soil data and on groundwater data previously collected from monitoring at the ponds (DOE 1992a).

Soil samples were collected to a total depth of 18 in. and analyzed at 6-in. increments (0 to 6 in., 6 to 12 in., and 12 to 18 in.) for gross alpha and beta activity, radionuclides, and metals. Because VOCs were detected in previous sampling events and in groundwater samples from monitoring wells, analyses for organic compounds were also conducted for K-1407-B Pond soil samples.

Analyses of soil samples collected during the 1989/1990 sampling event indicate that radionuclide contamination exists in both K-1407-B/C Ponds. Multiple sampling points revealed elevated alpha and beta activities. Residual metal contamination was also further defined for both ponds, along with additional assessment of organic contamination for the K-1407-B Pond. Although no organic constituents were found at significantly elevated levels, the VOCs 1,1,1-trichloroethane; 1,2-dichloroethene; 1,1-dichloroethane; chloroform; tetrachloroethene; and TCE were detected in the K-1407-B Pond soil.

The radionuclide contaminants detected in the K-1407-B/C Pond soils were ^{241}Am, ^{137}Cs,^{60}Co,^{244}Cm, ^{154}Eu, ^{155}Eu, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{40}K, ^{99}Tc, ^{228}Th, ^{230}Th, ^{232}Th, ^{234}U, ^{235}U, ^{238}U, and Sr (total). However, some of these radionuclides were detected at negligible concentrations, and ^{40}K is a naturally occurring radionuclide. The radionuclides with the highest average alpha activity are ^{238}U and ^{234}U; the predominant beta-emitting radionuclide is ^{99}Tc. The half-lives (the amount of time required for a given radioactive species to decrease to half its initial value due to radioactive decay) for the primary radiological contaminants of concern at the site range from 30 years for ^{137}Cs to 4.5 billion years for ^{238}U.

The soil depth interval with the highest average activity for all radionuclides was the 0- to 6-in. interval. Since soil samples have not been collected below the 18-in. zone, complete characterization of radionuclides below this depth is not possible. However, a general reduction of radionuclide concentrations occurs with depth. This trend of decreasing concentrations with depth, along with other factors at the site, indicates that significant vertical or lateral migration of contaminants from the pond soils is unlikely. This inference is supported by computer modeling conducted during the RI/FS to assess the potential for migration of these constituents from the pond soils.

Metals detected during sampling activities within the ponds considered potential contaminants of concern (COCs) include As, Ba, Be, B, Cd, Cr, Co, Pb, Mn, Hg, Mo, Ni, Ag, Sr, V, and Zn. Since background samples are not available for the K-1407-B/C Pond site, it is difficult to eliminate detected metals by screening evaluation. Because beryllium concentrations in the K-1407-B/C Pond soils are above guidance levels, these concentrations were compared to background concentrations from sites with soils representative of those found at the K-1407-B/C Ponds in the vicinity of the ORR (DOE 1992a).

The statistical analysis of these sampling results indicate that the concentrations of beryllium in the K-1407-B/C Pond soils are comparable to the background samples to which they were compared. Therefore, the concentrations of beryllium in the ponds are attributable to normal background levels and not to pond operations. Based on comparison of total concentrations of RCRA-regulated metals and organics in the K-1407-B/C Pond soils to RCRA guidance levels and on the statistical analysis that shows beryllium concentrations in the pond soils to be consistent with background concentrations at ORR, it has been demonstrated that RCRA-regulated metals are not present in the pond soils above regulatory criteria as a result of pond operations. Accordingly, EPA and TDEC tentatively agreed at the June 16, 1992, Working Group Meeting held among EPA Region IV, TDEC, and DOE at the TDEC Oversight office in Oak Ridge, Tennessee, that the requirements have been satisfied for RCRA clean closure at the K-1407-B/C Ponds (DOE 1992b).

The potential for migration of metal contaminants from the pond soils below the 18-in. depth was assessed by computer modeling. Computer modeling indicates minimal migration of metal contaminants from the K-1407-B/C Pond soils. These results, combined with the general decrease of metals concentrations with depth, indicate a lack of significant vertical and lateral migration of metals contaminants from the pond soils (1992a).

Since results from previous sampling events indicated that the K-1407-C Pond is not contaminated with organic compounds, analyses for organic constituents were conducted only for the K-1407-B Pond soil samples during the 1989/1990 sampling event. No guidance levels were exceeded for any of the RCRA-regulated VOCs in the pond soils.

All radionuclides detected in the pond soils were included for consideration in the baseline risk assessment. Metals detected at elevated levels during sampling activities were included in the RI/FS baseline risk assessment without regard to the possible influence of background concentrations. Because of the lack of background data for site contaminants, some naturally occurring metals were included in the risk evaluation. Likewise, although the K-1407-B Pond is not considered to be the source of organic contamination found in the groundwater at the site, some organic compounds were evaluated in the baseline risk assessment based on their presence in the soils.

It is estimated that there are approximately 21,000 yd^3 of subgrade soils with residual contamination at the bottom of the ponds.

Groundwater Contamination

Although groundwater remediation is beyond the scope of the remedial action proposed by this ROD, an evaluation of groundwater contamination at the ponds site was conducted during the RI/FS for the K-1407-B/C Ponds. The purpose of this evaluation was to determine the extent to which contaminants from pond soils may have migrated into groundwater in the past and the future potential for such cross-contamination. An understanding of the potential for cross-contamination from the soil to groundwater is necessary to choose a remedial alternative consistent with the long-term remedial goals for the K-1407 OU. Furthermore, this information is necessary to choose an alternative for the K-1407-B/C Pond soils that is consistent with future groundwater remediation at the site.

Radiochemical contamination of groundwater in the vicinity of the K-1407-B/C Ponds is evidenced by elevated measurements of alpha and beta activity in area monitoring wells. However, only one downgradient monitoring well at the site has been consistently contaminated. This monitoring well, located downgradient of the K-1407-B Pond, has shown elevated beta activity for all sampling events. Radiological contamination of groundwater at the site is concentrated to the north and east of the K-1407-B Pond.

Based on data from monitoring wells to the west of the K-1407-B/C Ponds, alpha activity detected in monitoring wells downgradient from the ponds may be primarily attributable to upgradient sources. However, the elevated levels of beta activity downgradient of the K-1407-B Pond are probably due in part to beta-emitting radionuclides (primarily ^{99}Tc) that have migrated from the K-1407-B Pond.

Historical operations at the K-1407-B/C Ponds and the presence of radionuclides identified in the K-1407-B/C Pond soils indicate alpha and beta emitters that might potentially be found in the groundwater. Alpha emitters potentially present in area groundwater include ^{234}U, ^{235}U, ^{238}U, ^{228}Th, ^{230}Th, ^{232}Th, ^{238}Pu, ^{239}Pu, ^{241}Am, and ^{237}Np. Potential beta emitters are ^{99}Tc, ^{90}Sr, ^{137}Cs, ^{40}K, ^{154}Eu, ^{234}Th, and ^{234}Pa. The predominance of ^{234}U, ^{238}U, and ^{230}Th in K-1407-B/C Pond soils indicate that one or all of these three radionuclides could be the alpha emitters detected in the groundwater. Because it is the beta emitter with the highest level of activity in the pond soils and it is much more mobile than the other beta-emitting radionuclides in the soil, ^{99}Tc was believed to be the source of elevated beta activity detected in downgradient monitoring wells at the K-1407-B Pond. Isotope-specific groundwater data for ^{99}Tc for first quarter 1992 confirmed that this radionuclide is present in the groundwater at a sufficient concentration to account for all beta activity detected in site monitoring wells (DOE 1992a).

Subsequent to removal of the sludge from the K-1407-B Pond, beta activity has decreased in downgradient monitoring wells; results of groundwater sampling show steadily decreasing levels of beta activity. Removal of the sludge from the K-1407-B Pond resulted in removal of the primary source of ^{99}Tc that could be leached and cause cross-contamination of the groundwater. Accordingly, beta activity in downgradient wells should continue to decrease commensurate with contamination presently migrating from the pond soils or other upgradient sources (DOE 1992a).

Assessment of the migration of pond contaminants to soils and groundwater beneath and downgradient of the K-1407-B/C Ponds shows that, although a few metals have sporadically exceeded maximum contaminant levels (MCLs) in groundwater monitoring wells at the site, none have done so consistently. For those metals with established National Primary Drinking Water Standards (NPDWS), only cadmium exceeded NPDWS in one monitoring well downgradient of the K-1407-B/C Ponds for a single sampling event. No monitoring wells have exceeded regulatory limits in filtered samples for As, Ba, Cr, Hg, Se, or Ag for any sampling event. Computer modeling simulation of metal contaminant migration is compatible with site data, indicating that none of the metals exhibit a significant tendency to migrate into the groundwater from pond soils (DOE 1992a).

For metals with National Secondary Drinking Water Standards (NSDWS), manganese and iron have exceeded guidance levels for most of the monitoring wells at the ponds for several sampling events. Manganese has exceeded NSDWS limits for all monitoring wells for at least one sampling event. Iron has exceeded NSDWS limits for most monitoring wells. However, iron and manganese are present at elevated levels in monitoring wells upgradient of the K-1407-B/C Ponds and are present at naturally elevated levels in area soils and groundwater. The high concentrations of these metals are considered to reflect natural groundwater conditions at the site rather than migration of contaminants from the K-1407-B/C Ponds (DOE 1992a).

Organic constituents, primarily VOCs, have been detected in both unconsolidated and bedrock monitoring wells throughout the K-1407-B Pond area. TCE is the predominant VOC in the K-1407-B/C Pond groundwater; also abundant is trans-1,2-dichloroethene. However, a false-positive assessment, initiated in 1987 and approved by the TDEC in March 1989, concluded that the K-1407-B Pond was not the source of halogenated organics present in the groundwater (Haymore 1988). This conclusion is supported by analyses showing low VOC contaminant concentrations in the K-1407-B Pond sludge and soil, the proximity of K-1407-B Pond to numerous Solid Waste Management Units (SWMUs), and hydrogeologic conditions at the site (Geraghty & Miller, 1989a). Infiltration of groundwater contaminated with VOCs may also occur by upgradient flow from the bedrock zone (Forstrom 1990). For the most part, groundwater in the vicinity of the K-1407-C Pond has not been found to be contaminated with VOCs.

Although guidance values for alpha activity are exceeded in some of the K-1407-B/C Pond monitoring wells, activity has not been detected at levels considered to pose a risk to human health. Therefore, alpha-emitting radionuclides are not considered to be COCs in groundwater at the site. Of the beta emitters present in the groundwater, ^{99}Tc is believed to be the predominant contributor to beta activity.

Hydrogeology characteristics and groundwater pathways of migration

Analysis of the hydraulic relationship between groundwater in the bedrock zone and the unconsolidated zone at the K-1407-B Pond reveals that hydraulic heads can be greater in bedrock than in the unconsolidated zone (Forstrom 1990). The higher piezometric levels in the bedrock zone indicate confined or semiconfined flow conditions within the bedrock and the potential for upward groundwater flow from the bedrock to the unconsolidated zone. This condition is important to migration of contamination at the K-1407-B Pond. Upward flow can retard the downward migration of dissolved contaminants from the unconsolidated zone to the bedrock zone. Conversely, contaminants could be introduced from the bedrock zone into the unconsolidated zone, as indicated for organic contaminants at the site.

Water has been continually present in the K-1407-B Pond since discharge operations ceased prior to 1988. Comparison of the surveyed ground elevation at the bottom of K-1407-B Pond with seasonal water table elevations recorded for monitoring wells in the vicinity of the pond shows that the bottom of the K-1407-B Pond is several feet below the groundwater table, indicating that groundwater in the unconsolidated zone is discharging directly into the surface impoundment. Conversely, the K-1407-C Pond is situated several feet above the water table.

Because the residual contamination in the K-1407-B/C Ponds could be subject to leaching by infiltration of meteoric waters and because the K-1407-B Pond's bottom is further affected by groundwater flow through the unit, groundwater transport of contamination is considered a potential pathway of migration at the site. Differing hydrogeological conditions at the K-1407-B and K-1407-C Ponds represent different implications for contaminant transport from the ponds. Analysis of the migration of contamination at the K-1407-B Pond is complicated by the existence of contaminant sources upgradient of the unit and by upward groundwater flow from the bedrock zone into the unconsolidated zone.

The mobility of radionuclides and metals in groundwater within the K-1407-B/C Pond soils is related to the properties of the individual constituents and to the properties of the soils in which they are found. Since the pH of groundwater in K-1407-B monitoring wells is neutral to only slightly acidic, the solubilities of the radionuclides and metals are generally expected to be moderate. Soil and groundwater characteristics at the site are not expected to promote migration of most constituents.

Technetium-99 represents an exception to this general trend. While cationic substances are strongly adsorbed by the clays typically found in area soils, the ability of ^{99}Tc to form complexes and behave in an anionic nature allows it to migrate relatively freely. The high potential for the migration of ^{99}Tc is indicated by the elevated levels detected in monitoring wells downgradient of the K-1407-B Pond.

Soil pathways of migration for baseline conditions

The soil pathway for contaminant migration at the K-1407-B/C Ponds site is closely associated with the groundwater pathway. The clay residuum found at the site typically has a low hydraulic conductivity and a relatively high capacity for adsorption of cations and filtering of particulates (Lee, et al., 1988; Baes, et al., 1984). These characteristics indicate that the majority of the radionuclides and metals present at the units would tend to be bound in the soil.

Since the probable mode of migration of these constituents is leaching by infiltration of surface water, movement is expected to be minimal. With the exception of ^{99}Tc, which is highly mobile in the soil column, the migration of most of the metals and radionuclides is likely to be minimal. Surface runoff is possible for the K-1407-B/C Ponds site but is expected to be attenuated by site conditions. Because surface water runoff at the ponds is limited, the associated transport of soil is also limited. Furthermore, vegetation at the site inhibits soil runoff during storm events. Thus, the physicochemical properties of the COCs and of the surrounding soil suggests that overall transport of contaminants from the soil will be low.

Surface water pathways of migration for baseline conditions

Analyses of sediment samples from Mitchell Branch have shown it to be contaminated with metals, radionuclides, and organic compounds indicating historical discharge of contaminants into the stream (Ashwood 1986). Since K-25 encompasses many sites of contaminant discharge, it is not possible to determine the extent to which historical discharges from the K-1407-B/C Ponds may have contributed to the contamination of Mitchell Branch. Current site conditions and operations preclude significant erosion of contaminated soils or direct discharge from the ponds into Mitchell Branch.

Analysis of soil and groundwater data indicates that COCs would not migrate to Mitchell Branch from the pond soils. Although it cannot be completely eliminated as a possible pathway of migration, groundwater from these units is not likely to be a measurable contributor to surface water contamination because of the low concentrations of contaminants in the groundwater migrating from the units. Therefore, based on current site conditions and operations, the contaminants found in the K-1407-B/C Pond soils do not represent a significant potential for contamination of surface waters (i.e., Mitchell Branch) at the site.

Air pathways of migration for baseline conditions

Suspension of contaminated soil as airborne fugitive dust is considered a potential migration and exposure pathway for alpha- and beta-emitting radionuclides and toxic metals. The potential volatilization of organics from the soil surface is not considered a major pathway of migration since only low concentrations of organic contaminants were detected in K-1407-B Pond soil.

Current conditions at the K-1407-B/C Ponds are not conducive to the airborne migration of contamination. Site conditions, such as the presence of standing water in the K-1407-B Pond and vegetation at both units, would serve to inhibit the formation of significant amounts of wind-generated dust. However, these conditions are relatively ephemeral and largely dependent on levels of precipitation. Extended drought conditions could drastically alter site conditions. Therefore, generation of airborne constituents found at the pond sites should be considered a potential migration pathway for contamination from the site. Contaminant concentrations in air and associated risks to human health in the baseline risk assessment were based on fate and transport modeling.

Biota pathways of migration for baseline conditions

The ingestion and transportation of contaminated plants to off-site areas by herbivores represents a potential migration route for site-related contaminants. Since vegetation is the basic foundation of the terrestrial food chain, accumulation of site-related contaminants in plants can transport contaminants throughout the system. Plants growing in contaminated soils can accumulate radionuclide, metal, and organic contaminants. This would lead to the ingestion and assimilation of contaminated media by small herbivores and subsequent transport of these contaminants off-site. Similarly, aquatic biota in Mitchell Branch could accumulate contaminants directly from the water or by ingesting contaminated prey.

Due to the low concentrations of organic contaminants detected in the K-1407-B Pond's soils, air-to-leaf transfer is not expected to be a major pathway of vegetative contamination. Ingestion of contaminated vegetation by herbivores or other links in the food chain is considered negligible.

Exposure routes for baseline conditions

Current exposure routes to the general public are limited by institutional controls. Although operations at the K-1407-B/C Ponds have ceased, it is conceivable that an on-site worker could go onto these sites. There is also a potential that employees in the K-25 vicinity could be exposed to wind-generated dust contamination from the ponds. In addition, travelers on a public road outside the facility boundary could also be exposed to wind-generated dust. If institutional controls were removed from the K-25 Site in the future, human receptors entering the site could be adversely affected by existing contamination. The greatest potential risk would exist for the on-site resident.

Potential exposure pathways for both the general plant employee and the on-site worker are ingestion of, dermal contact with, and inhalation of wind-generated dust. The general plant employee is additionally considered to be exposed to radiation in dust; the on-site worker is additionally considered to be exposed to ionizing radiation.

Assuming that contaminant concentrations in the soil remain constant, the potential pathways affecting the on-site resident include ingestion of and dermal contact with contaminated soil, external exposure to ionizing radiation, and inhalation of wind-generated dust. Because groundwater in the vicinity of K-25 is sufficient to support household activities, it is also assumed that the on-site resident could be exposed to contaminants in groundwater via ingestion, dermal contact during bathing, and inhalation of volatiles during bathing. It is also assumed that the on-site resident could consume contaminated homegrown vegetables.

Site conditions affecting remedial action

The K-1407-B/C Ponds are readily accessible from inside the K-25 Site area and amenable to remedial construction activities at the site. The emplacement of rock fill to a level above the normal water table should eliminate any complications that standing water in the K-1407-B Pond might present. However, if water in the pond does not equilibrate quickly enough with the water table to allow continued construction activity, water will be pumped from the pond to the K-25 Central Neutralization Facility (CNF) and processed.

SUMMARY OF SITE RISKS

Human health risks

As part of the CERCLA RI/FS process, a human health risk assessment was performed for the K-1407-B/C Ponds following the *Risk Assessment Guidance for Superfund* (EPA 1989a) and the *Superfund Exposure Assessment Manual* (EPA 1988a). The complete baseline risk assessment is contained in Sect. 5 of the *Remedial Investigation/Feasibility Study (RI/FS) for the K-1407-B/C Ponds K-25 Site, Oak Ridge, Tennessee*, DOE/OR-1012&D3 (DOE 1992a). Risks from contamination exposure from the K-1407-B and K-1407-C Ponds were evaluated separately; however, because of the physical similarity and proximity of the sites, the evaluations used similar assumptions.

Data evaluation

Sampling data were obtained as part of earlier studies to characterize the nature and extent of contamination present in the various media at the K-1407-B/C Ponds. EPA-certified laboratory methods were followed during the analysis of soil samples from the ponds. Although the data were not initially independently validated, laboratory personnel conducted a data review before the risk assessor received the data. Additionally, the risk assessment personnel scrutinized the data before using them in the risk assessment. A representative portion of the data was validated at a later date to confirm the usefulness of the data for use in the baseline risk assessment. Based on this evaluation, not all laboratory data were appropriate for use in a quantitative manner. Instead, some of the data were incorporated into a qualitative assessment or eliminated from the assessment process altogether. Validation of data for use in the risk assessment was conducted in accordance with the procedures outlined in the *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual* (EPA 1989b) and the *Remedial Facility Investigation Guidance Volume I* (EPA 1989c).

Contaminants of concern

As a result of the data evaluation process, a list of potential COCs in soil was developed, which was then divided into those contaminants to be quantitatively evaluated and those to be qualitatively evaluated in the baseline risk assessment. The concentrations for COCs evaluated quantitatively for the K-1407-B and K-1407-C pond soils are shown in Tables 2.1 and 2.2, respectively. The concentrations for COCs evaluated qualitatively are shown in Table 2.3. The risk from exposure to some contaminants detected in the pond soils cannot be quantified because no current EPA-approved slope factor (SF) or reference dose (RfD) is available; these contaminants were evaluated qualitatively.

Table 2.1. Potential contaminants of concern in the K-1407-B Pond soil evaluated quantitatively and their representative concentrations

Analyte	Frequency of detection	Range of detected concentrations	Representative concentration[a]
Organics (mg/kg)			
1,2-Dichloroethene (total)	3/40	0.027 - 0.033	0.033
1,1,1-Trichloroethane	1/40	0.001 - 0.001	0.001[b]
Chloroform	4/40	0.006 - 0.024	0.024
Tetrachloroethene	8/40	0.005 - 0.069	0.069
Trichloroethene	11/40	0.009 - 0.130	0.130
Metals (mg/kg)			
Arsenic	6/17	6.8 - 32.0	16.2
Barium	17/17	33.0 - 250.0	133.1
Beryllium	17/17	0.37 - 1.8	1.3
Boron	10/17	2.0 - 19.0	9.9
Cadmium	17/17	0.82 - 4.1	3.2
Chromium	17/17	26.0 - 240.0	114.6
Manganese	17/17	86.0 - 1,800.0	867.5
Mercury	4/8	2.9 - 13.0	6.6
Molybdenum	1/17	2.3 - 2.3	2.3[b]
Nickel	17/17	20.0 - 1,100.0	324.2
Vanadium	17/17	14.0 - 43.0	35.4
Zinc	17/17	26.0 - 98.0	72.5
Radionuclides (pCi/g)			
Americium-241	19/19	-0.51 - 0.32	0.13
Cesium-137	48/48	0.02 - 62.10	6.42
Neptunium-237	48/49	-0.04 - 15.12	1.97
Plutonium-238	48/49	-5.94 - 0.21	0.40
Plutonium-239	48/49	-1.97 - 25.65	3.24
Potassium-40	49/49	5.94 - 35.10	18.64
Technetium-99	49/49	2.05 - 1,107.0	1,239.6
Thorium-228	44/45	-99.90 - 43.20	5.08
Thorium-230	48/49	0.27 - 432.0	72.12
Thorium-232	48/49	-0.59 - 22.68	3.53
Uranium-234	49/49	1.27 - 4,050.0	470.5
Uranium-235	48/49	-0.05 - 180.9	20.52
Uranium-238	49/49	0.68 - 26,190.0	1,674.2

[a]Except where indicated, all representative concentrations are either the maximum detected concentration or the 95% upper confidence limit on the arithmetical average of 0- to 6-in. samples, whichever is lower.
[b]Only detected value.

Table 2.2. Potential contaminants of concern in the K-1407-C Pond soil evaluated quantitatively and their representative concentrations

Analyte	Frequency of detection	Range of detected concentrations	Representative concentration[a]
Metals (mg/kg)			
Arsenic	6/16	7.0 - 30.0	20.7
Barium	16/16	59.0 - 160.0	116.5
Beryllium	16/16	0.48 - 1.6	1.0
Boron	8/16	3.5 - 34.0	13.7
Cadmium	12/16	0.57 - 7.4	2.3
Chromium	16/16	25.0 - 160.0	86.0
Manganese	16/16	550.0 - 2,700.0	1,563.7
Mercury	12/17	1.1 - 29.0	10.4
Molybdenum	8/16	1.0 - 4.3	3.7
Nickel	16/16	20.0 - 1,400.0	507.4
Silver	1/16	0.9 - 0.9	0.9[b]
Vanadium	16/16	28.0 - 61.0	50.2
Zinc	16/16	37.0 - 120.0	87.9
Radionuclides (pCi/g)			
Americium-241	78/78	-1.08 - 32.40	4.04
Cesium-137	78/78	0.24 - 178.2	22.28
Cobalt-60	75/75	-0.20 - 0.35	0.04
Curium-244	25/25	-0.35 - 0.06	-0.01
Europium-154	1/1	2.13 - 2.13	2.13[b]
Neptunium-237	78/78	4.6×10^{-3} - 143.1	13.12
Plutonium-238	78/78	-2.43 - 16.20	1.56
Plutonium-239	78/78	2.7×10^{-3} - 162.0	20.48
Potassium-40	76/76	3.24 - 23.76	11.77
Technetium-99	78/78	0.04 - 4,320.0	586.8
Uranium-234	78/78	1.32 - 2,673.0	348.0
Uranium-235	78/78	0.06 - 62.10	12.39
Uranium-238	78/78	0.81 - 1,620.0	186.6

[a]Except where indicated, all representative concentrations are either the maximum detected concentration or the 95% upper confidence limit on the arithmetical average of 0- to 6-in. samples, whichever is lower.
[b]Only detected value.

Table 2.3. **Potential contaminants of concern in the K-1407-B/C Pond soils evaluated qualitatively and their range of concentrations**

Analyte	Frequency of detection	Range of detected concentrations[a]
K-1407-B Pond Organics (mg/kg)		
1,1-Dichloroethane	1/40	0.003 - 0.003[b]
K-1407-B Pond Metals (mg/kg)		
Cobalt	17/17	2.5 - 26.0
Lead	17/17	6.6 - 58.0
Strontium	17/17	8.2 - 38.0
K-1407-C Pond Metals (mg/kg)		
Cobalt	16/16	8.5 - 29.0
Lead	15/16	16.0 - 59.0
Strontium	16/16	8.4 - 64.0
K-1407-B Pond Radionuclides (pCi/g)		
Europium-155	3/3	1.11 - 7.83

[a]Reported concentrations represent the samples taken from the top 6 in. of soil only.
[b]Only detected value.

The potential for migration of soil contaminants to groundwater at the ponds site made the evaluation of risks posed by exposure to groundwater pathways necessary. By considering groundwater contamination in the risk assessment, the risk contribution of soil contamination to the groundwater pathway was evaluated.

Radioisotopes are present in the soils of both ponds, and a potential exists for migration to groundwater. The risk associated with exposure to beta activity in K-1407-B Pond's groundwater was determined quantitatively by assuming that the source of all beta activity is ^{99}Tc, a mobile beta-emitting radioisotope that has been found in K-1407-B Pond soil. The complete list of COCs for groundwater and their concentrations is found in Table 2.4.

Exposure assessment

The original primary contamination source in the K-1407-B/C Ponds was sludge. Prior to sludge removal in 1988, contamination had apparently transferred to the underlying soil; consequently, the soil is now a potential contamination source. Currently, the contaminated clay soil of the ponds is exposed to atmospheric conditions, and some vegetation exists to prevent erosion. Although precipitation is occasionally retained in K-1407-C Pond, the bottom of the pond is usually dry. The K-1407-B Pond typically contains water because it is below the local water table. But because the K-1407-B Pond could become dry during periods of drought and would then represent a potential for wind-generated dust, the pond was assumed to be dry for the

Table 2.4. Representative concentrations for K-1407-B/C Ponds potential contaminants of concern in groundwater

Analyte	Frequency of detection	Range of detected concentrations	Representative concentration[a]
		K-1407-B Pond	
Organics (mg/L)			
1,1-Dichloroethane	14/14	0.11-1.0	1.0
1,2-Dichloroethene (total)	13/13	0.05-1.9	1.9
1,1,1-Trichloroethane	13/13	0.031-0.29	0.29
Chloroform	5/13	0.0008-0.006	0.006
Tetrachloroethene	12/12	0.038-0.93	0.93
Trichloroethene	13/13	0.87-10.0	10.0
Metals (mg/L)			
Boron	17/17	0.13-0.21	0.21
Strontium	16/16	0.27-0.65	0.65
Radionuclides (pCi/L)			
Beta Activity as technetium-99	NA	-32.0-1137.6	1137.6
		K-1407-C Pond	
Metals (mg/L)			
Arsenic	10/17	0.005-0.009	0.009
Cadmium	8/21	0.003-0.017	0.017
Cobalt	10/20	0.0078-0.21	0.21
Manganese	30/30	0.014-33.0	33.0
Mercury	2/17	0.003-0.0051	0.005
Molybdenum	2/20	0.012-0.013	0.013
Strontium	20/20	0.055-0.27	0.27

[a]Maximum concentrations detected in monitoring wells nearest the ponds.
NA=Not Applicable

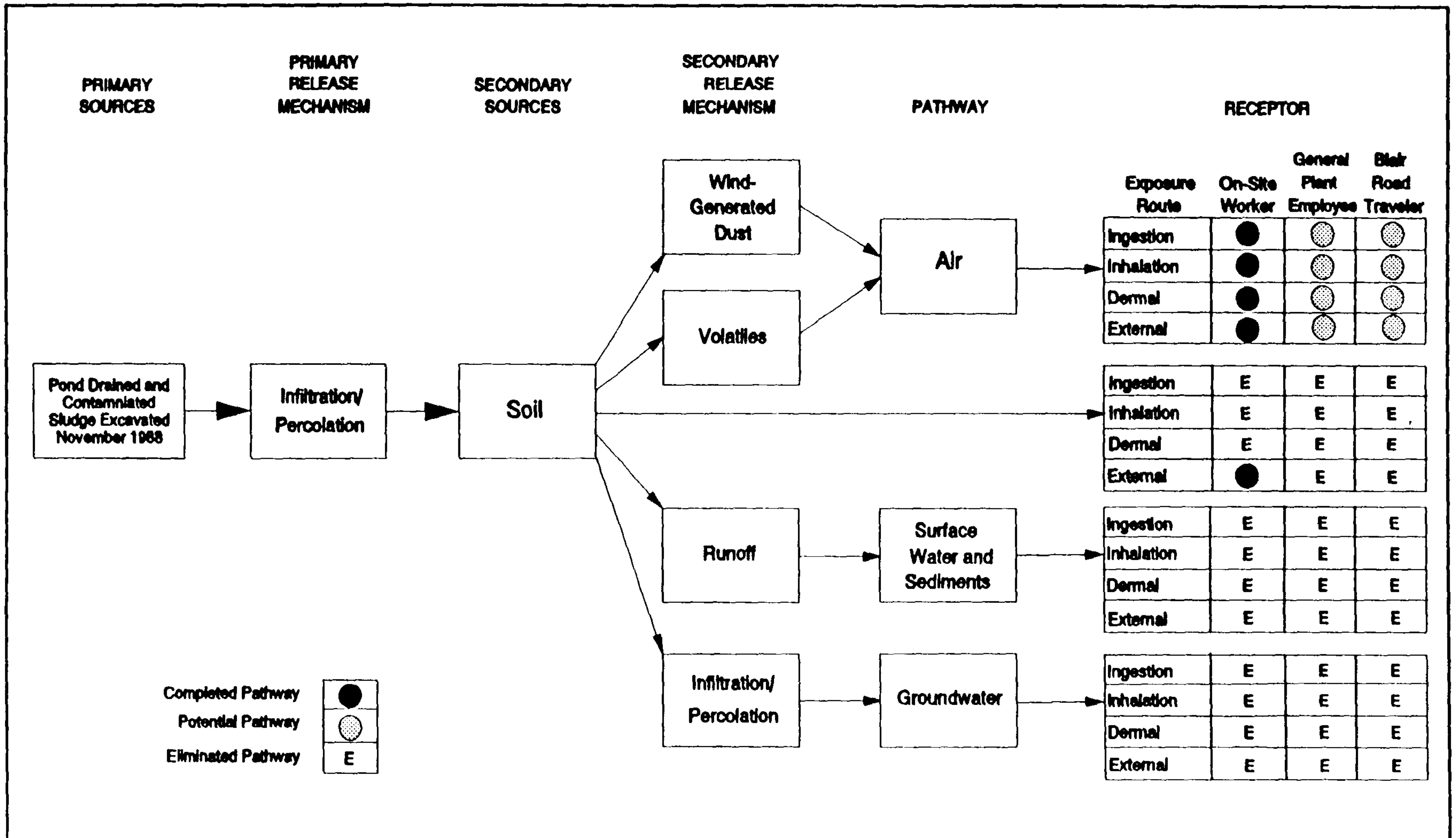
purpose of the risk assessment. This assumption likely resulted in an overestimation of actual risks from wind-generated dust.

Figure 2.3 illustrates the site conceptual model that represents baseline exposure pathways related to contamination at the ponds, including potentially exposed populations, exposure scenarios, transport media, and routes of exposure. Since the K-1407-B/C Ponds are within the perimeter security fence, no recreational activity occurs there (i.e., no boating, swimming, fishing). The ponds are not fenced within the main plant area, but are posted; access by plant employees and visitors is restricted. Although operations at the ponds have been curtailed, it is assumed that on-site workers will be exposed to risks while conducting occasional site inspections. Potential also exists for general K-25 Site employees at some distance from the ponds to be exposed to airborne contaminants originating from the pond soils. Although no residents live along Blair Road in proximity to the K-1407-B/C Ponds, this public road is just outside the K-25 Site boundary approximately 700 ft from the ponds. Travelers on the road may potentially be exposed to wind-transported particulate contamination from the ponds. In summary, the receptors who under current conditions may be exposed to K-1407-B/C Ponds contamination are an on-site worker, a general plant employee working in other areas of the K-25 Site, and an individual traveling on Blair Road.

If institutional controls were removed from the K-25 Site, future receptors could be adversely affected by existing contamination. Because residential land use is most often associated with the greatest exposures, future exposure was evaluated within the context of a residential scenario. The environmental media responsible for transport and the potential exposure pathways considered in the residential scenario are shown in the future land use site conceptual model in Fig. 2.4. Environmental concentrations were assumed to be constant for the baseline risk assessment (i.e., concentrations were not reduced by loss due to removal processes such as volatilization, leaching, and biodegradation). Thus, exposure concentrations were based on 100% of the measured or estimated concentrations in air, soil, and groundwater.

The on-site resident scenario assumes that the K-1407-B Pond is dewatered, and all activities related with residency take place in the soils at the bottom of the pond. Therefore, the surface water pathway for the K-1407-B Pond was not considered in the baseline risk assessment. Because the groundwater in the vicinity of the K-1407-B/C Ponds is sufficient to support household activities, it was assumed that on-site residents would use groundwater for domestic purposes.

Because all soil exposure pathways considered in the risk assessment involve exposure to surface soil only, the representative soil concentrations for metals and radionuclides were determined from samples taken at a depth of 0 to 6 in. Furthermore, soil concentrations for most



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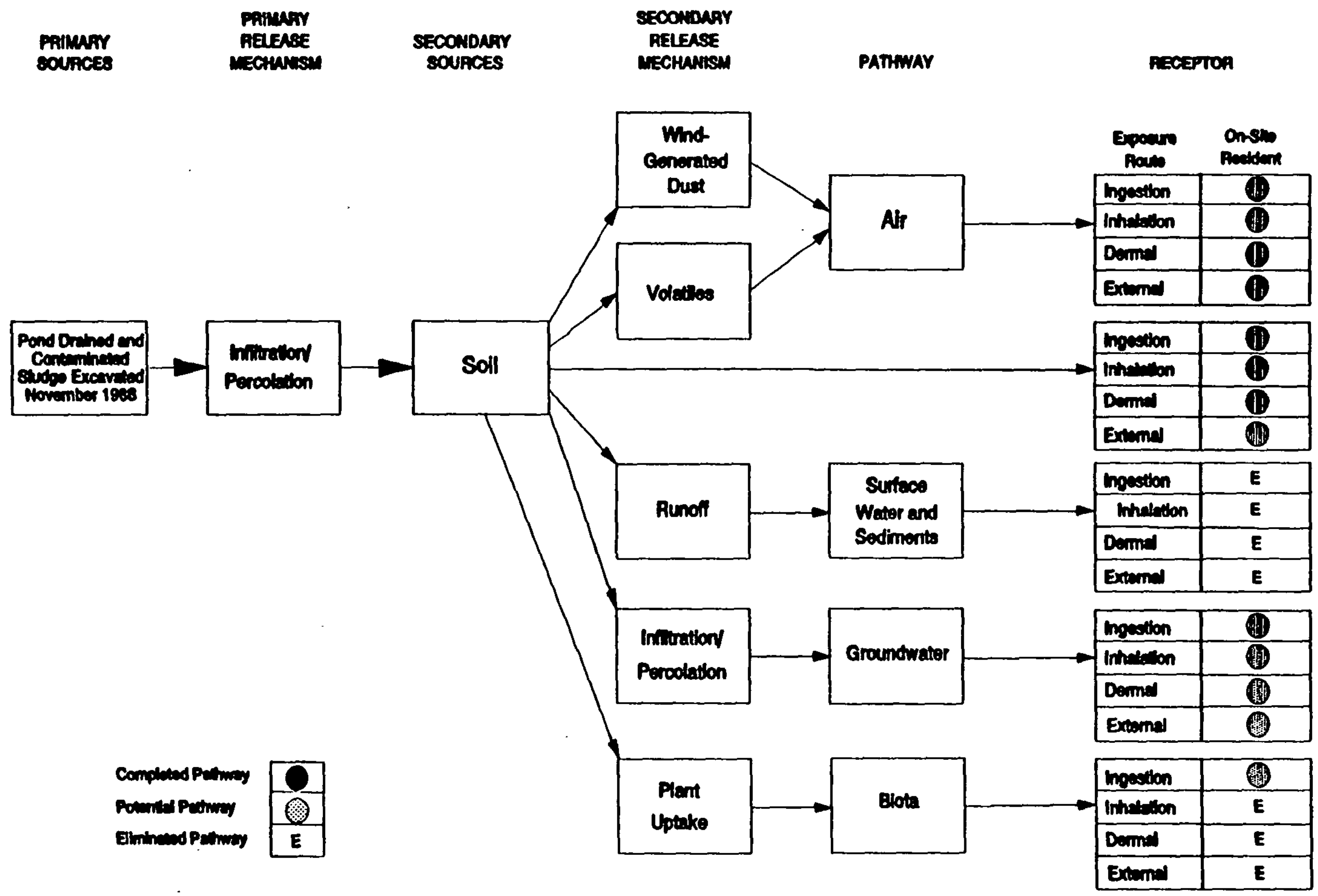
Date: 1991

Environmental Restoration Program

Present land use conceptual site model for the K-1407-B/C Ponds.

Fig. 2.3



RADIAN Source: Energy Systems Date: 1991	Future land use conceptual site model for the K-1407-B/C Ponds.
Environmental Restoration Program	Fig. 2.4

metals and radionuclides tend to decrease with depth. Conversely, VOCs have the potential for volatization, and concentrations detected in the K-1407-B Pond soil increase with depth. Therefore, the maximum concentration of organic contaminants, regardless of depth, was used as the representative concentration.

The 95% upper confidence limit on the arithmetical average was chosen as the representative concentrations for each metal and radionuclide in soil. If the computed upper-bound confidence limit was greater than the maximum detected concentration, then the maximum detected value was used as the exposure concentration. Transport equations were used to estimate the contaminant concentration in air. Elemental soil-to-plant transfer coefficients developed by Baes et al. (1984) for the edible portions of plants were used to estimate the upper-bound concentration of contaminants in plants. The transfer of organics to plants from soil was calculated using the regression equation developed by Travis and Arms (1988). There are five volatile potential COCs present in K-1407-B Pond's groundwater that could be inhaled by the resident while showering. Indoor air concentrations were estimated using an upper-bound default volatilization constant of 0.5 L/m^3 (EPA 1989d). The representative concentrations of contaminants in each medium are shown in Tables 2.1 through 2.6.

The scenario for the on-site worker assumes that an employee will be on-site for 1 h, eight times a year. The intake of contaminants was calculated using a soil ingestion rate of 50 mg/day, a body surface area of 0.394 m^2/day (arm, hands, and face), and an inhalation rate of 20 m^3/day (EPA 1989a). The variables used in each exposure equation were derived from standard intake rates, skin surface areas, and adherence factors. Variables relating to exposure frequency and duration were derived from knowledge of site conditions and assumptions regarding receptor activity. Approximately 50% of the year, the wind direction is southeast. Therefore, it was assumed that the general plant employee would be exposed to wind-generated dust half of the time, or 4 h/day, 5 days/week, 50 weeks/year for 25 years (EPA 1989a).

It was assumed that the resident would be exposed to site-related contaminants 350 days/year for 30 years. Exposure from all pathways except external radiation were divided into two sets of assumptions. First, a 6-year exposure duration was evaluated for young children, which accounts for receptors with high intake rates relative to low body weights. Second, a 24-year exposure duration was assumed for older children and adults. For example, for the soil ingestion pathway, a child ingestion rate (200 mg/day) and body weight (15 kg) was assumed for 6 years, while an adult ingestion rate (100 mg/day) and body weight (70 kg) was assumed for 24 years (EPA 1989a). The formulas used to calculate risks are provided in the baseline risk assessment of the *Remedial Investigation/Feasibility Study for the K-1407-B/C Ponds, K-25 Site Oak Ridge, Tennessee* (DOE 1992a; pp. 5-31 through 5-34, pp. 5-40 through 5-43, and pp. 5-49 through 5-56).

Table 2.5. Upper-bound concentrations of contaminants of concern in air for the K-1407-B/C Ponds on-site resident

Analyte	K-1407-B Pond	K-1407-C Pond
Organics (mg/m^3)		
1,1-Dichloroethane	9.6×10^{-12}	—[a]
1,2-Dichloroethene (total)	6.1×10^{-11}	—[a]
1,1,1-Trichloroethane	3.2×10^{-12}	—[a]
Chloroform	7.7×10^{-11}	—[a]
Tetrachloroethene	2.2×10^{-10}	—[a]
Trichloroethene	2.8×10^{-10}	—[a]
Metals (mg/m^3)		
Arsenic	5.2×10^{-8}	6.6×10^{-8}
Barium	4.3×10^{-7}	3.7×10^{-7}
Beryllium	4.2×10^{-9}	3.4×10^{-9}
Boron	3.2×10^{-8}	4.4×10^{-8}
Cadmium	1.0×10^{-8}	7.4×10^{-9}
Chromium	3.7×10^{-7}	2.8×10^{-7}
Manganese	2.8×10^{-6}	5.0×10^{-6}
Mercury	2.1×10^{-8}	3.3×10^{-8}
Molybdenum	7.4×10^{-9}	1.2×10^{-8}
Nickel	1.0×10^{-6}	1.6×10^{-6}
Silver	—[a]	2.9×10^{-9}
Vanadium	1.1×10^{-7}	1.6×10^{-7}
Zinc	2.3×10^{-7}	2.8×10^{-7}
Radionuclides (pCi/m^3)		
Americium-241	4.3×10^{-7}	1.3×10^{-5}

[a]These data are not available.

Table 2.6. Upper-bound concentrations of contaminants of concern in K-1407-B/C Ponds homegrown produce[a]

Analyte	Uptake coefficient[b]	Log K_{ow}[c]	RME concentration	
			K-1407-B produce	K-1407-C produce
Organics (mg/kg)				
1,1-Dichloroethane	3.57	1.79	0.011	—[d]
1,2-Dichloroethene	5.41	1.48	0.178	—[d]
1,1,1-Trichloroethane	1.39	2.5	0.001	—[d]
Chloroform	2.81	1.97	0.067	—[d]
Tetrachloroethene	1.22	2.6	0.084	—[d]
Trichloroethene	1.63	2.38	0.212	—[d]
Metals (mg/kg)				
Arsenic	0.006		0.097	0.124
Barium	0.015		1.996	1.748
Beryllium	0.0015		0.002	0.002
Boron	2.0		19.874	27.488
Cadmium	0.15		0.478	0.346
Chromium	0.0045		0.516	0.387
Manganese	0.050		43.374	78.185
Mercury	0.20		1.316	2.072
Molybdenum	0.060		0.086	0.224
Nickel	0.060		19.454	30.444
Silver	0.10		—[d]	0.090
Vanadium	0.003		0.106	0.151
Zinc	0.90		65.277	79.150
Radionuclides (pCi/g)				
Americium-241	2.5×10^{-4}		3.4×10^{-5}	1×10^{-3}
Cesium-137	0.030		.19	.67
Cobalt-60	0.007		—[d]	3×10^{-4}
Curium-244	1.5×10^{-5}		—[d]	-1.2×10^{-7}
Europium-154	0.004		—[d]	9×10^{-3}
Neptunium-237	0.010		0.02	0.13
Plutonium-238	4.5×10^{-5}		1.8×10^{-5}	7×10^{-5}
Plutonium-239	4.5×10^{-5}		1.4×10^{-4}	1×10^{-3}
Potassium-40	0.55		10.25	6.47
Technetium-99	1.5		1,859.5	880.2
Thorium-228	8.5×10^{-5}		4.3×10^{-4}	—[d]
Thorium-230	8.5×10^{-5}		6×10^{-3}	—[d]
Thorium-232	8.5×10^{-5}		3×10^{-4}	—[d]

Table 2.6 (continued)

Analyte	Uptake coefficient[b]	Log K_{ow}[c]	RME concentration	
			K-1407-B produce	K-1407-C produce
Uranium-234	0.004		1.88	1.39
Uranium-235	0.004		0.08	0.05
Uranium-238	0.004		6.70	0.75

[a]Produce concentrations derived from the soil concentrations given in Table 2.1 and 2.2.
[b]*Source:* Transfer coefficients for metals and radionuclides taken from C.F. Baes III, R.D. Sharp, A.L.Sjoreen, and R.W. Shor, *A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture*, ORNL-5786, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, September 1984.
[c]*Source:* Log K_{ow} values for all organics from EPA, *Superfund Public Health Evaluation Manual*, EPA/540/1-86/060, Office of Emergency and Remedial Response, Washington D.C., October 1986.
[d]These data are not available.

Toxicity assessment

The toxicity information for the carcinogenic and noncarcinogenic COCs is summarized in Tables 2.7 and 2.8, respectively.

Risk characterization

Cancer risk from exposure to contamination is expressed as excess cancer risk—that is, the incidence of cancer incurred in addition to normally expected rates of cancer development. An excess cancer risk of 1×10^{-6} indicates one person in 1,000,000 is predicted to incur cancer from exposure to this contamination level. Excess cancer risks falling between 1×10^{-6} and 1×10^{-4} are within the EPA range of concern and require close scrutiny; cancer risks greater than 1×10^{-4} are considered unacceptable by the EPA (EPA 1989b). Excess cancer risk is estimated by multiplying intake by the contaminant-specific cancer SF published by EPA. SFs used in the evaluation of risk from exposure to contaminants in K-1407-B and K-1407-C soil are listed in Table 2.7. SFs have not been derived for several potential COCs. These contaminants may contribute to carcinogenic effects from exposure to the soil, but their effect cannot be quantified.

Noncarcinogenic effects are evaluated by comparing the exposure experienced over a specified time period with an RfD derived for a similar exposure period. RfDs available for the COCs present in K-1407-B and K-1407-C soil are given in Table 2.8. The ratio of the exposure dose to the RfD is called the hazard quotient. A hazard quotient greater than one indicates that there may be concern for potential noncarcinogenic health effects; however, the level of concern does not increase linearly as the hazard quotient approaches or exceeds one. The sum of all hazard quotients for all contaminants for a given exposure pathway is the hazard index for that pathway. SFs and RfDs have been derived from human epidemiological studies or animal studies to which uncertainty factors have been applied. These uncertainty factors help ensure that the SFs and RfDs will not underestimate the potential for adverse health effects.

For the on-site worker at the K-1407-B Pond, the excess cancer risks posed by exposure to wind-generated dust via ingestion, dermal contact, and inhalation are well below the range of concern. The total pathway risk, however, is 2×10^{-6} for external exposure to ionizing radiation, slightly above the lower limit EPA range of concern of 1×10^{-6}. Lead and strontium, also found at the site, may contribute to the carcinogenic effects from exposure to airborne soil contaminants (especially lead, given its classification as a probable B2 human carcinogen), but an SF is not available for lead. Although an SF exists for radioactive strontium, there are no isotope-specific data for strontium; consequently, the carcinogenic effects from exposure to these contaminants were not quantified. No adverse noncarcinogenic health effects are indicated for exposure to any specific contaminant at the K-1407-B Pond for the on-site worker.

Table 2.7. Toxicity information for carcinogenic potential contaminants of concern

Ingestion pathway				
Chemical	SF[a] $(mg/kg\text{-}d)^{-1}$ $(pCi)^{-1}$	Weight of evidence	Type of cancer	SF basis/ SF source[a]
Arsenic[b, c]	1.7E+00	A	Skin	Water/IRIS
Barium[b, c]	—[d]	—[d]	—[d]	—[d]
Beryllium[c]	4.3E+00	B1	—[d]	Intratracheal Instillation/IRIS
Boron[b, c]	—[d]	—[d]	—[d]	—[d]
Cadmium[b, c]	—[d]	—[d]	—[d]	IRIS
Chromium[b, c](VI)	—[d]	A	—[d]	IRIS
Cobalt[b, c]	—[d]	—[d]	—[d]	—[d]
Lead[b, c]	—[d]	B2	—[d]	IRIS
Manganese[b, c]	—[d]	D	—[d]	IRIS
Mercury[b, c]	—[d]	D	—[d]	IRIS
Molybdenum[b, c]	—[d]	—[d]	—[d]	—[d]
Nickel[b, c]	—[d]	—[d]	—[d]	—[d]
Silver[c]	—[d]	D	—[d]	IRIS
Strontium[b, c]	—[d]	—[d]	—[d]	—[d]
Vanadium[b, c]	—[d]	—[d]	—[d]	IRIS
Zinc[b, c]	—[d]	D	—[d]	IRIS
Chloroform[b]	6.1×10^{-3}	B2	Liver	Gavage/IRIS
1,1-Dichloroethane[b]	—[d]	—[d]	—[d]	—[d]
1,2-Dichloroethene (total)[b]	—[d]	—[d]	—[d]	—[d]
Tetrachloroethene[b]	5.1×10^{-2}	B2	Liver	Gavage/IRIS
1,1,1-Trichloroethane[b]	—[d]	D	Liver	Gavage/IRIS
Trichloroethene[b, c]	1.1×10^{-2}	B2	Liver	Gavage/IRIS
Americium-241[b, c]	3.1×10^{-10}	A	Many types[e]	IRIS
Cesium-137[b, c]	2.8×10^{-11}	A	Many types[e]	IRIS
Cobalt-60[c]	1.5×10^{-11}	A	Many types[e]	IRIS
Curium-244[c]	2.0×10^{-10}	A	Many types[e]	IRIS
Europium-154[c]	3.0×10^{-12}	A	Many types[e]	IRIS
Neptunium-237[b, c]	2.7×10^{-10}	A	Many types[e]	IRIS
Plutonium-238[b, c]	2.8×10^{-10}	A	Many types[e]	IRIS
Plutonium-239[b, c]	3.1×10^{-11}	A	Many types[e]	IRIS
Potassium-40[b, c]	1.1×10^{-11}	A	Many types[e]	IRIS
Technetium-99[b, c]	1.3×10^{-12}	A	Many types[e]	IRIS
Thorium-228[b]	1.5×10^{-11}	A	Many types[e]	IRIS
Thorium-230[b]	2.4×10^{-11}	A	Many types[e]	IRIS
Thorium-232[b]	2.2×10^{-11}	A	Many types[e]	IRIS
Uranium-234[b, c]	1.4×10^{-10}	A	Many types[e]	IRIS
Uranium-235[b, c]	1.3×10^{-10}	A	Many types[e]	IRIS
Uranium-238[b, c]	1.3×10^{-10}	A	Many types[e]	IRIS

Table 2.7 (continued)

Inhalation Pathway				
Chemical	SF[a] $(mg/kg\cdot d)^{-1}$ $(pCi)^{-1}$	Weight of evidence	Type of cancer	SF basis/ SF source[a]
Arsenic[b, c]	5.0×10^{1}	A	Respiratory tract	Various/IRIS
Barium[b, c]	—[d]	—[d]	—[d]	—[d]
Beryllium[c]	8.4	B2	Lung	Inhalation/IRIS
Boron[b, c]	—[d]	—[d]	—[d]	—[d]
Cadmium[b, c]	6.1	B1	Respiratory tract	Occupational/ IRIS
Chromium[b, c]	4.1×10^{1}	A	Lung	Occupational/ IRIS
Cobalt[b, c]	—[d]	—[d]	—[d]	—[d]
Lead[b, c]	—[d]	D	—[d]	IRIS
Manganese[b, c]	—[d]	D	—[d]	IRIS
Mercury[b, c]	—[d]	—[d]	—[d]	IRIS
Molybdenum[b, c]	—[d]	—[d]	—[d]	IRIS
Nickel[b, c]	8.4×10^{-1}	A	Respiratory tract	Occupational/ IRIS
Silver[c]	—[d]	—[d]	—[d]	—[d]
Strontium[b, c]	—[d]	—[d]	—[d]	—[d]
Vanadium[b, c]	—[d]	—[d]	—[d]	—[d]
Zinc[b, c]	—[d]	—[d]	—[d]	—[d]
Chloroform[b]	8.1×10^{-2}	B2	Liver	IRIS
1,1-Dichloroethane[b]	—[d]	—[d]	—[d]	—[d]
1,2-Dichloroethene(total)[b]	—[d]	—[d]	—[d]	—[d]
Tetrachloroethene[b]	1.82×10^{-3}	B2	Leukemia and Liver	Inhalation/IRIS
1,1,1-Trichloroethane[b]	—[d]	—[d]	—[d]	—[d]
Trichloroethene[b, c]	1.7×10^{-2}	B2	Lung	Inhalation/ HEAST
Americium-241[b, c]	4.0×10^{-8}	A	Many types[e]	IRIS
Cesium-137[b, c]	1.9×10^{-11}	A	Many types[e]	IRIS
Cobalt-60[c]	1.6×10^{-10}	A	Many types[e]	IRIS
Curium-244[c]	2.7×10^{-8}	A	Many types[e]	IRIS
Europium-154[c]	1.4×10^{-10}	A	Many types[e]	IRIS
Neptunium-237[b, c]	3.6×10^{-8}	A	Many types[e]	IRIS
Plutonium-238[b, c]	4.2×10^{-8}	A	Many types[e]	IRIS
Plutonium-239[b, c]	4.1×10^{-8}	A	Many types[e]	IRIS
Potassium-40[b, c]	7.6×10^{-12}	A	Many types[e]	IRIS
Technetium-99[b, c]	8.3×10^{-12}	A	Many types[e]	IRIS
Thorium-228[b]	7.7×10^{-8}	A	Many types[e]	IRIS
Thorium-230[b]	3.1×10^{-8}	A	Many types[e]	IRIS
Thorium-232[b]	3.1×10^{-8}	A	Many types[e]	IRIS
Uranium-234[b, c]	2.7×10^{-8}	A	Many types[e]	IRIS
Uranium-235[b, c]	2.5×10^{-8}	A	Many types[e]	IRIS
Uranium-238[b, c]	2.4×10^{-8}	A	Many types[e]	IRIS

Table 2.7 (continued)

External radiation exposure				
Chemical	SF[a] $(pCi/m^2/yr)^{-1}$	Weight of evidence	Type of cancer	SF basis/ SF source[a]
Americium-241[b, c]	1.6×10^{-12}	A	Many types[e]	IRIS
Cesium-137[b, c]	3.4×10^{-11}[f]	A	Many types[e]	IRIS
Cobalt-60[c]	1.3×10^{-10}	A	Many types[e]	IRIS
Curium-244[c]	5.8×10^{-14}	A	Many types[e]	IRIS
Europium-154[c]	6.8×10^{-11}	A	Many types[e]	IRIS
Neptunium-237[b, c]	1.8×10^{-12}	A	Many types[e]	IRIS
Plutonium-238[b, c]	6.1×10^{-4}	A	Many types[e]	IRIS
Plutonium-239[b, c]	2.6×10^{-14}	A	Many types[e]	IRIS
Potassium-40[b, c]	7.8×10^{-12}	A	Many types[e]	IRIS
Technetium-99[b, c]	3.4×10^{-17}	A	Many types[e]	IRIS
Thorium-228[b]	1.6×10^{-13}	A	Many types[e]	IRIS
Thorium-230[b]	5.9×10^{-14}	A	Many types[e]	IRIS
Thorium-232[b]	4.6×10^{-14}	A	Many types[e]	IRIS
Uranium-234[b, c]	5.7×10^{-14}	A	Many types[e]	IRIS
Uranium-235[b, c]	9.6×10^{-12}	A	Many types[e]	IRIS
Uranium-238[b, c]	4.6×10^{-14}	A	Many types[e]	IRIS

[a]Based on IRIS, July 1991, or HEAST, January 1991.
[b]Contaminant found in the K-1407-B Pond.
[c]Contaminant found in the K-1407-C Pond.
[d]Toxicity information not available.
[e]The type of cancer is dependent upon the organ or organs exposed.
[f]External slope factor for cesium-137 daughter product, barium-137m.

HEAST = Health Effects Assessment Summary Table
IRIS = Integrated Risk Information System
SF = Slope factor

A = sufficient evidence of carcinogenicity in humans; human carcinogen
B1 = limited evidence of carcinogenicity in humans
B2 = sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans
D = not classifiable as to human carcinogenicity (lack of or no evidence)

Table 2.8. Toxicity information for noncarcinogenic potential contaminants of concern

Ingestion pathway						
Chemical	RfD (mg/kg•d)	Confidence level	Critical effect	RfD basis/ RfD source	UF	MF
Arsenic[a,b]	1.0×10^{-3}	High	Keratosis, hyperpigmentation	Occupational/IRIS	100	1
Barium[a,b]	7.0×10^{-2}	—[c]	—[c]	IRIS	3	1
Beryllium[b]	5.0×10^{-3}	Low	—[c]	Intratracheal Instillation/IRIS	100	1
Boron[a,b]	9.0×10^{-2}	—[c]	Testicular lesions	IRIS	100	1
Cadmium[a,b]	5.0×10^{-4} 1.0×10^{-3}	High High	Proteinuria	Water/IRIS Food/IRIS	10	1
Chromium[a,b](VI)	5.0×10^{-3}	Low	Hepatotoxicity nephrotoxicity dermatitis	Water/IRIS	500	1
Cobalt[a,b]	—[c]	—[c]	—[c]	—[c]		—[c]
Lead[a,b]	—[c]	—[c]	—[c]	—[c]		—[c]
Manganese[a,b]	1.0×10^{-1}	Medium	Neural tissue damage	Water/IRIS	1	1
Mercury[a,b]	3.0×10^{-4}	—[c]	Kidney effects	IRIS	1000	1
Molybdenum[a,b]	4.0×10^{-3}	—[c]	Changes in biochemical indices	IRIS	1	
Nickel[a,b]	2.0×10^{-2}	—[c]	—[c]	IRIS	100	3
Silver[b]	3.0×10^{-3}	Medium	Argyria	Oral/IRIS	2	1
Strontium[a,b]	—[c]	—[c]	—[c]	—[c]		—[c]
Vanadium[a,b]	7.0×10^{-3}	Low	—[c]	Water/IRIS	100	1
Zinc[a,b]	2.0×10^{-1}	Medium	Hyperactivity, decreased body weight, death at high doses	Gavage/IRIS	100	1

Table 2.8 (continued)

Chemical	RfD (mg/kg-d)	Confidence level	Critical effect	RfD basis/ RfD source	UF	MF
Ingestion pathway (continued)						
Chloroform[a,b]	1.0 × 10^{-2}	—[c]	Liver lesions	IRIS	1000	1
1,1-Dichloroethane[a]	1.0 × 10^{-1}	—[c]	None	Inhalation/IRIS	1000	
1,2-Dichloroethene(tot)[a]	2.0 × 10^{-1}	Low	Increased serum alkaline phosphate	Water/IRIS	100	1
Tetrachloroethene[a]	1.00 × 10^{-1}	Medium	Hepatotoxicity	Gavage/IRIS	1000	1
1,1,1-Trichloroethane[a]	9.0 × 10^{-2}	Medium	Hepatotoxicity	Inhalation/IRIS	1000	1
Trichloroethene[a]	Under review	—[c]	Ventricular fibrillation	—[c]		—[c]

Inhalation pathway

Chemical	RfD (mg/kg-d)	Confidence level	Critical effect	RfD basis/ RfD source	UF	MF
Arsenic[a,b]	—[c]	—[c]	—[c]	—[c]		—[c]
Barium[a,b]	1.4 × 10^{-4}	—[c]	Fetotoxicity	IRIS	1000	
Beryllium[b]	—[c]	—[c]	—[c]	—[c]		—[c]
Boron[a,b]	—[c]	—[c]	—[c]	—[c]		—[c]
Cadmium[a,b]	—[c]	—[c]	—[c]	—[c]		—[c]
Chromium[a,b]	5.7 × 10^{-7}	—[c]	Respiratory effects	IRIS	300	
Cobalt[a,b]	—[c]	—[c]	—[c]	—[c]		—[c]
Lead[a,b]	—[c]	—[c]	—[c]	—[c]		—[c]
Manganese[a,b]	1.14 × 10^{-4}	—[c]	Respiratory symptoms and psychomotor disturbances	Inhalation/IRIS	900	
Mercury[a,b]	8.57 × 10^{-5}	—[c]	Neurotoxicity	Inhalation/HEAST	30	
Molybdenum[a,b]	—[c]	—[c]	—[c]	—[c]		—[c]
Nickel[a,b]	—[c]	—[c]	—[c]	—[c]		—[c]
Silver[b]	—[c]	—[c]	—[c]	—[c]		—[c]

Table 2.8 (continued)

Inhalation pathway						
Chemical	RfD (mg/kg·d)	Confidence level	Critical effect	RfD basis/ RfD source	UF	MF
Strontium[a,b]	—[c]	—[c]	—[c]	—[c]		—[c]
Vanadium[a,b]						
Zinc[a,b]	—[c]	—[c]	—[c]	—[c]		—[c]
Chloroform[a,b]	—[c]	—[c]	—[c]	—[c]		—[c]
1,1-Dichloroethane[a]	1.0×10^{-1}	—[c]	Kidney damage	Inhalation/IRIS	1000	
1,2-Dichloroethene(tot)[a]	—[c]	—[c]	—[c]	—[c]		—[c]
Tetrachloroethene[a]	—[c]	—[c]	—[c]	—[c]		—[c]
1,1,1-Trichloroethane[a]	2.86×10^{-1}	—[c]	Hepatotoxicity	Inhalation/IRIS	1000	
Trichloroethene[a]	—[c]	—[c]	—[c]	—[c]		—[c]

[a]Contaminant found in K-1407-B Pond.
[b]Contaminant found in K-1407-C Pond.
[c]Toxicity information not available.

HEAST = Health Effects Assessment Summary Table
IRIS = Integrated Risk Information System
MF = Modifying factor
RfD = Reference dose
UF = Uncertainty factor

The excess cancer risk from exposure to contaminants at the K-1407-C Pond for the on-site worker are similar to the risks for the K-1407-B Pond on-site worker. Again, the excess cancer risk posed by exposure to wind-generated dust via the ingestion, dermal contact, and inhalation pathways are well below the range of concern. The total pathway risk from external exposure to ionizing radiation (4×10^{-6}), however, slightly exceeds the lower limit of concern (1×10^{-6}). This risk is predominately due to external exposure to ionizing radiation from ^{137}Cs.

Health risks to the general plant employee are well below the level of concern for both ponds.

The Blair Road receptor may be exposed to contaminants transported off-site by the wind. Potential exposure routes for this receptor are the same as those considered for the general plant employee. However, the Blair Road receptor would be exposed to windborne contamination for a much shorter period of time for two reasons: (1) the wind blows northeast toward Blair Road approximately 25% of the time, while the wind blows southwest toward the plant approximately 50% of the time; and (2) the only receptors would be people who occasionally drive or infrequently walk along the road. Of these potential receptors, the person who travels Blair Road every day to and from work is likely to be exposed for the greatest period, assumed to be only minutes a day for a maximum duration of 30 years (the upper-bound length of time spent at one residence). Therefore, the exposure frequency and duration expected for the Blair Road traveler is a small fraction of that considered in the evaluation of general plant employee exposure. Consequently, because the risks to the general plant employee were well below levels of concern, the risk to the Blair Road receptor is also expected to be well below levels of concern.

The hypothetical on-site resident at the K-1407-B Pond could be exposed to both soil and groundwater contamination. Residential exposure would result in the highest risk of all land uses considered, so greater detail is provided on chemical-specific and pathway-specific risks. Table 2.9 lists all chemical-specific carcinogenic risks, total pathway risk, and total exposure risk estimates. Every pathway evaluated indicated a risk greater than 1×10^{-6}; the highest risks are due to external exposure to ionizing radiation, ingestion of groundwater (as drinking water), and ingestion of homegrown produce. The excess cancer risks from exposure to ^{238}U, arsenic, and ^{234}U in surface soil dominate the ingestion, dermal contact, and inhalation pathways. Cesium-137 is a major contributor to external exposure to ionizing radiation, while ^{99}Tc dominates the ingestion pathway risk for homegrown produce. Exposure to TCE dominates the risks associated with ingestion of groundwater and dermal contact and inhalation during showering.

Exposure to noncarcinogenic COCs by the on-site resident at the K-1407-B Pond may result in adverse health effects from soil-related pathways and from ingestion of contaminated groundwater (Table 2.10). Exposure to chromium controls the inhalation pathway while mercury

Table 2.9. Cancer risk estimates for on-site residents at the K-1407-B Pond

Analyte	RME (mg/kg) (pCi/kg)	Intake (mg/kg·d) (pCi)	SF (mg/kg·d)-1 (pCi)-1	Weight of Evidence	Type of cancer	SF basis/SF source	Chemical-specific risk	Total pathway risk
Exposure Route: Ingestion of soil								
Chloroform	2.4×10^{-2}	3.77×10^{-8}	6.1×10^{-3}	B2	Liver	Gavage/IRIS	2×10^{-10}	
Tetrachloroethene	6.9×10^{-2}	1.08×10^{-7}	5.1×10^{-2}	B2	Liver	Gavage/IRIS	6×10^{-9}	
Trichloroethene	1.30×10^{-1}	2.04×10^{-7}	1.1×10^{-2}	B2	Liver	Gavage/IRIS	2×10^{-9}	
Arsenic	1.62×10^{1}	2.54×10^{-5}	1.70	A	Skin	—[a]	4×10^{-5}	
Beryllium	1.32	2.07×10^{-6}	4.30	B1	—[a]	Intratracheal Instillation/IRIS	9×10^{-6}	
Americium-241	1.34×10^{2}	1.69×10^{2}	3.1×10^{-10}	A	Many types	IRIS	5×10^{-8}	
Cesium-137	6.42×10^{3}	8.09×10^{3}	2.8×10^{-11}	A	Many types	IRIS	2×10^{-7}	
Neptunium-237	1.97×10^{3}	2.48×10^{3}	2.7×10^{-10}	A	Many types	IRIS	7×10^{-7}	
Plutonium-238	4.01×10^{2}	5.05×10^{2}	2.8×10^{-10}	A	Many types	IRIS	1×10^{-7}	
Plutonium-239	3.24×10^{3}	4.08×10^{3}	3.1×10^{-10}	A	Many types	IRIS	1×10^{-7}	
Potassium-40	1.86×10^{4}	2.35×10^{4}	1.1×10^{-11}	A	Many types	IRIS	3×10^{-7}	
Technetium-99	1.24×10^{6}	1.56×10^{6}	1.3×10^{-12}	A	Many types	IRIS	2×10^{-6}	
Thorium-228	5.08×10^{3}	6.4×10^{3}	1.5×10^{-11}	A	Many types	IRIS	1×10^{-7}	
Thorium-230	7.21×10^{4}	9.09×10^{4}	2.4×10^{-11}	A	Many types	IRIS	2×10^{-6}	
Thorium-232	3.53×10^{3}	4.45×10^{3}	2.2×10^{-11}	A	Many types	IRIS	1×10^{-7}	
Uranium-234	4.71×10^{5}	5.93×10^{5}	1.4×10^{-10}	A	Many types	IRIS	8×10^{-5}	
Uranium-235	2.05×10^{4}	2.59×10^{4}	1.3×10^{-10}	A	Many types	IRIS	3×10^{-6}	
Uranium-238	1.67×10^{6}	2.11×10^{6}	1.3×10^{-10}	A	Many types	IRIS	3×10^{-4}	
								4×10^{-4}
Exposure Route: Dermal contact with soil								
Chloroform	2.4×10^{-2}	8.71×10^{-8}	6.10×10^{-3}	B2	Liver	Gavage/IRIS	5×10^{-10}	
Tetrachloroethene	6.9×10^{-2}	2.50×10^{-7}	5.10×10^{-2}	B2	Liver	Gavage/IRIS	1×10^{-8}	
Trichloroethene	1.3×10^{-1}	4.72×10^{-7}	1.10×10^{-2}	B2	Liver	Gavage/IRIS	5×10^{-9}	
Arsenic	1.62×10^{1}	5.88×10^{-6}	1.70	A	Skin	—[a]	1×10^{-5}	
Beryllium	1.32	4.78×10^{-7}	4.30	B1	—[a]	Intratracheal Instillation/IRIS	2×10^{-6}	
								1×10^{-5}

Table 2.9 (continued)

Analyte	RME (mg/kg) (pCi/kg)	Intake (mg/kg·d) (pCi)	SF (mg/kg·d)-1 (pCi)-1	Weight of Evidence	Type of cancer	SF basis/SF source	Chemical-specific risk	Total pathway risk
Exposure Route: Inhalation of wind-generated dust								
Chloroform	7.68×10^{-9}	2.74×10^{-9}	8.10×10^{-2}	B2	—[a]	—[a]	2×10^{-10}	
Tetrachloroethene	2.21×10^{-7}	7.89×10^{-8}	1.82×10^{-3}	B2	Leukemia	Inhalation/IRIS	1×10^{-10}	
Trichloroethene	4.16×10^{-7}	1.49×10^{-7}	1.70×10^{-2}	B2	Lung	Inhalation/ HEAST	3×10^{-9}	
Arsenic	5.2×10^{-8}	1.86×10^{-8}	5.0×10^{1}	A	Respiratory tract	Various/IRIS	9×10^{-7}	
Beryllium	4.2×10^{-9}	1.5×10^{-9}	8.40	B2	Lung	Inhalation/IRIS	1×10^{-8}	
Cadmium	1.0×10^{-8}	3.57×10^{-9}	6.10	B1	—[a]	—[a]	2×10^{-8}	
Chromium	3.7×10^{-7}	1.32×10^{-7}	4.1×10^{1}	A	—[a]	—[a]	5×10^{-6}	
Nickel	1.0×10^{-6}	3.57×10^{-7}	8.4×10^{-1}	A	—[a]	—[a]	3×10^{-7}	
Americium-241	4.3×10^{-7}	1.16×10^{-1}	4.0×10^{-8}	A	Many types	IRIS	5×10^{-9}	
Cesium-137	2.1×10^{-5}	5.64	1.9×10^{-11}	A	Many types	IRIS	1×10^{-10}	
Neptunium-237	6.3×10^{-6}	1.69	3.6×10^{-8}	A	Many types	IRIS	6×10^{-8}	
Plutonium-238	1.3×10^{-6}	3.49×10^{-1}	4.2×10^{-8}	A	Many types	IRIS	1×10^{-8}	
Plutonium-239	1.0×10^{-5}	2.69	4.1×10^{-8}	A	Many types	IRIS	1×10^{-7}	
Potassium-40	6.0×10^{-5}	1.61×10^{1}	7.6×10^{-12}	A	Many types	IRIS	1×10^{-10}	
Technetium-99	4.0×10^{-3}	1.08×10^{3}	8.3×10^{-12}	A	Many types	IRIS	9×10^{-9}	
Thorium-228	1.6×10^{-5}	4.30	7.7×10^{-8}	A	Many types	IRIS	3×10^{-7}	
Thorium-230	2.3×10^{-4}	6.18×10^{1}	3.1×10^{-8}	A	Many types	IRIS	2×10^{-6}	
Thorium-232	1.1×10^{-5}	2.96	3.1×10^{-8}	A	Many types	IRIS	9×10^{-8}	
Uranium-234	1.5×10^{-3}	4.03×10^{2}	2.7×10^{-8}	A	Many types	IRIS	1×10^{-5}	
Uranium-235	6.6×10^{-5}	1.77×10^{1}	2.5×10^{-8}	A	Many types	IRIS	4×10^{-7}	
Uranium-238	5.4×10^{-3}	1.45×10^{3}	2.4×10^{-8}	A	Many types	IRIS	3×10^{-5}	
								6×10^{-5}
Exposure Route: External exposure to soil radiation								
Americium-241	1.34×10^{2}	6.17×10^{5}	1.6×10^{-12}	A	Many types	IRIS	1×10^{-6}	
Cesium-137	6.42×10^{3}	2.95×10^{7}	3.4×10^{-11}	A	Many types	IRIS	1×10^{-3}	
Neptunium-237	1.97×10^{3}	9.05×10^{6}	1.8×10^{-12}	A	Many types	IRIS	2×10^{-5}	
Plutonium-238	4.01×10^{2}	1.85×10^{6}	6.1×10^{-14}	A	Many types	IRIS	1×10^{-7}	
Plutonium-239	3.24×10^{3}	1.49×10^{7}	2.6×10^{-14}	A	Many types	IRIS	4×10^{-7}	

Table 2.9 (continued)

Analyte	RME (mg/kg) (pCi/kg)	Intake (mg/kg·d) (pCi)	SF (mg/kg·d)-1 (pCi)-1	Weight of Evidence	Type of cancer	SF basis/SF source	Chemical-specific risk	Total pathway risk
Potassium-40	1.86×10^{4}	8.58×10^{7}	7.8×10^{-4}	A	Many types	IRIS	7×10^{-4}	
Technetium-99	1.24×10^{6}	5.71×10^{9}	3.4×10^{-17}	A	Many types	IRIS	2×10^{-7}	
Thorium-228	5.08×10^{3}	2.34×10^{7}	1.6×10^{-13}	A	Many types	IRIS	4×10^{-6}	
Thorium-230	7.21×10^{4}	3.32×10^{8}	5.9×10^{-14}	A	Many types	IRIS	2×10^{-5}	
Thorium-232	3.53×10^{3}	1.62×10^{7}	4.6×10^{-14}	A	Many types	IRIS	7×10^{-7}	
Uranium-234	4.71×10^{5}	2.17×10^{9}	5.7×10^{-14}	A	Many types	IRIS	1×10^{-4}	
Uranium-235	2.05×10^{4}	9.45×10^{7}	9.6×10^{-12}	A	Many types	IRIS	9×10^{-4}	
Uranium-238	1.67×10^{6}	7.71×10^{9}	4.6×10^{-14}	A	Many types	IRIS	4×10^{-4}	
								4×10^{-3}
Exposure Route: Ingestion of groundwater								
Chloroform	6.0×10^{-3}	1.2×10^{-4}	6.1×10^{-3}	B2	Liver	Gavage/IRIS	7×10^{-7}	
Tetrachloroethene	9.3×10^{-1}	1.86×10^{-2}	5.1×10^{-2}	B2	Liver	Gavage/IRIS	9×10^{-4}	
Trichloroethene	1.0×10^{1}	2.0×10^{-1}	1.1×10^{-2}	B2	Liver	Gavage/IRIS	2×10^{-3}	
Technetium-99	1.14×10^{3}	2.28×10^{1}	1.3×10^{-1}	A	Many types	IRIS	3×10^{-5}	
								3×10^{-3}
Exposure Route: Dermal contact with groundwater while showering								
Chloroform	6.0×10^{-3}	2.34×10^{-7}	6.1×10^{-3}	B2	Liver	Gavage/IRIS	1×10^{-9}	
Tetrachloroethene	9.3×10^{-1}	3.63×10^{-5}	5.1×10^{-2}	B2	Liver	Gavage/IRIS	2×10^{-6}	
Trichloroethene	1.0×10^{1}	3.9×10^{-4}	1.1×10^{-2}	B2	Liver	Gavage/IRIS	4×10^{-6}	
								6×10^{-6}
Exposure Route: Inhalation of volatiles while showering								
Chloroform	0.003 mg/m^{3}	4.9×10^{-6}	8.1×10^{-2}	B2	—[a]	—[a]	3×10^{-7}	
Tetrachloroethene	0.47 mg/m^{3}	7.7×10^{-4}	1.82×10^{-3}	B2	Leukemia	Inhalation/IRIS	1×10^{-6}	
Trichloroethene	5.0 mg/m^{3}	8.2×10^{-3}	1.7×10^{-2}	B2	Lung	Inhalation/ HEAST	1×10^{-4}	
								1×10^{-4}
Exposure Route: Ingestion of homegrown produce								
Chloroform	6.7×10^{-2}	2.73×10^{-5}	6.1×10^{-3}	B2	Liver	Gavage/IRIS	2×10^{-7}	
Tetrachloroethene	8.4×10^{-2}	3.42×10^{-5}	5.1×10^{-2}	B2	Liver	Gavage/IRIS	6×10^{-7}	
Trichloroethene	2.1×10^{-1}	8.55×10^{-5}	1.1×10^{-2}	B2	Liver	Gavage/IRIS	2×10^{-7}	
Arsenic	9.7×10^{-2}	3.95×10^{-5}	1.70	A	Skin	—[a]	2×10^{-6}	

Table 2.9 (continued)

Analyte	RME (mg/kg) (pCi/kg)	Intake (mg/kg·d) (pCi)	SF (mg/kg·d)-1 (pCi)-1	Weight of Evidence	Type of cancer	SF basis/SF source	Chemical-specific risk	Total pathway risk
Beryllium	2.0×10^{-3}	8.14×10^{-7}	4.30	B1	—[a]	Intratracheal Instillation/IRIS	9×10^{-7}	
Americium-241	3.4×10^{-2}	1.43×10^{1}	3.1×10^{-10}	A	Many types	IRIS	4×10^{-9}	
Cesium-137	1.93×10^{2}	8.11×10^{4}	2.8×10^{-11}	A	Many types	IRIS	2×10^{-6}	
Neptunium-237	2.0×10^{1}	8.4×10^{3}	2.7×10^{-10}	A	Many types	IRIS	2×10^{-6}	
Plutonium-238	1.8×10^{-2}	7.56	2.8×10^{-10}	A	Many types	IRIS	2×10^{-9}	
Plutonium-239	1.4×10^{-1}	5.88×10^{1}	3.1×10^{-10}	A	Many types	IRIS	2×10^{-9}	
Potassium-40	1.03×10^{4}	4.31×10^{6}	1.1×10^{-11}	A	Many types	IRIS	5×10^{-5}	
Technetium-99	1.86×10^{6}	7.81×10^{8}	1.3×10^{-12}	A	Many types	IRIS	1×10^{-3}	
Thorium-228	4.3×10^{-1}	1.81×10^{2}	1.5×10^{-11}	A	Many types	IRIS	3×10^{-9}	
Thorium-230	6.00	2.52×10^{3}	2.4×10^{-11}	A	Many types	IRIS	6×10^{-8}	
Thorium-232	3.0×10^{-1}	1.26×10^{2}	2.2×10^{-11}	A	Many types	IRIS	3×10^{-9}	
Uranium-234	1.88×10^{3}	7.9×10^{5}	1.4×10^{-10}	A	Many types	IRIS	1×10^{-4}	
Uranium-235	8.2×10^{1}	3.44×10^{4}	1.3×10^{-10}	A	Many types	IRIS	4×10^{-6}	
Uranium-238	6.7×10^{3}	2.81×10^{6}	1.3×10^{-10}	A	Many types	IRIS	4×10^{-4}	
								2×10^{-3}
Total exposure risk								1×10^{-2}

[a]These data are either not available or not applicable.

HEAST = Health Effect Assessment Summary Tables
IRIS = Integrated Risk Information System
RME = Reasonable maximum exposure
SF = Slope factor
A = sufficient evidence of carcinogenicity in humans; human carcinogen
B1 = limited evidence of carcinogenicity in humans
B2 = sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans
D = not classifiable as to human carcinogenicity (lack of or no evidence)

Table 2.10. Hazard index estimates for on-site residents at the K-1407-B Pond

Analyte	RME (mg/kg)	Intake (mg/kg·d)	RfD (mg/kg·d)	CL	Critical effect	RfD basis/source	UF	MF	Hazard quotient	Pathway hazard index
Exposure Route: Ingestion of soil										
1,1-Dichloroethane	3.0×10^{-3}	4.26×10^{-8}	1.0×10^{-1}	—[a]	None	Inhalation/IRIS	1000	1	4.26×10^{-7}	
1,2-Dichloroethene	3.3×10^{-2}	4.69×10^{-7}	2.0×10^{-1}	Low	Incr. serum alk. phos.	Water/IRIS	1000	1	2.34×10^{-6}	
1,1,1-Trichloroethane	1.0×10^{-3}	1.42×10^{-8}	9.0×10^{-2}	Med	Hepatotoxicity	Inhalation/IRIS	1000	1	1.58×10^{-7}	
Chloroform	2.4×10^{-2}	3.41×10^{-7}	1.0×10^{-2}	—[a]	—[a]	IRIS	1000	1	3.41×10^{-5}	
Tetrachloroethene	6.9×10^{-2}	9.80×10^{-7}	1.0×10^{-1}	Med	Hepatotoxicity	Gavage/IRIS	1000	1	9.80×10^{-6}	
Arsenic	1.62×10^{1}	2.3×10^{-4}	1.0×10^{-3}	High	Keratosis/ hyperpigment.	Occupational/ IRIS	100	1	2.3×10^{-1}	
Barium	1.33×10^{2}	1.89×10^{-3}	7.0×10^{-2}	—[a]	—[a]	IRIS	3	1	2.7×10^{-2}	
Beryllium	1.32	1.87×10^{-5}	5.0×10^{-3}	Low	—[a]	IRIS	100	1	3.74×10^{-3}	
Boron	9.94	1.41×10^{-4}	9.0×10^{-2}	—[a]	—[a]	Intratrac. instill./IRIS	100	1	1.57×10^{-3}	
Cadmium	3.19	4.52×10^{-5}	1.0×10^{-3}	High	Proteinuria	Food/IRIS	10	1	4.52×10^{-2}	
Chromium	1.15×10^{2}	1.63×10^{-3}	5.0×10^{-3}	Low	Hepatotox/ nephrotox	Water/IRIS	500	1	3.26×10^{-1}	
Manganese	8.67×10^{2}	1.23×10^{-2}	1.0×10^{-1}	Med	Neural tissue damage	Water/IRIS	1	1	1.23×10^{-1}	
Mercury	6.58	9.34×10^{-5}	3.0×10^{-4}	—[a]	Neurotoxicity	—[a]	10	1	3.11×10^{-1}	
Molybdenum	2.30	3.27×10^{-5}	4.0×10^{-3}	—[a]	—[a]	—[a]	—[a]	1	8.17×10^{-3}	
Nickel	3.24×10^{2}	4.6×10^{-3}	2.0×10^{-2}	—[a]	—[a]	IRIS	100	3	2.3×10^{-1}	
Vanadium	3.54×10^{1}	5.03×10^{-4}	7.0×10^{-3}	Low	—[a]	Water/IRIS	100	1	7.19×10^{-2}	
Zinc	7.25×10^{1}	1.03×10^{-3}	2.0×10^{-1}	Med	Hyperactivity	Gavage/IRIS	100	1	5.15×10^{-3}	
										1.38
Exposure Route: Dermal contact with soil										
1,1-Dichloroethane	3.0×10^{-3}	6.09×10^{-7}	1.0×10^{-1}	—[a]	None	Inhalation/IRIS	1000	1	6.09×10^{-6}	
1,2-Dichloroethene	3.3×10^{-2}	6.70×10^{-6}	2.0×10^{-1}	Low	Incr. serum alk. phos.	Water/IRIS	1000	1	3.35×10^{-5}	
1,1,1-Trichloroethane	1.0×10^{-3}	2.03×10^{-7}	9.0×10^{-2}	Med	Hepatotoxicity	Inhalation/IRIS	1000	1	2.26×10^{-6}	
Chloroform	2.4×10^{-2}	4.87×10^{-6}	1.0×10^{-2}	—[a]	—[a]	IRIS	1000	1	4.87×10^{-4}	

Table 2.10 (continued)

Analyte	RME (mg/kg)	Intake (mg/kg·d)	RfD (mg/kg·d)	CL	Critical effect	RfD basis/source	UF	MF	Hazard quotient	Pathway hazard index
Tetrachloroethene	6.9×10^{-2}	1.40×10^{-5}	1.0×10^{-1}	Med	Hepatotoxicity	Gavage/IRIS	1000	1	1.40×10^{-4}	
Arsenic	1.62×10^{1}	3.29×10^{-4}	1.0×10^{-3}	High	Keratosis/ hyperpigment	Occupational/ IRIS	100	1	3.29×10^{-1}	
Barium	1.33×10^{2}	2.7×10^{-3}	7.0×10^{-2}	—[a]	—[a]	IRIS	3	1	3.86×10^{-2}	
Beryllium	1.32	2.67×10^{-5}	5.0×10^{-3}	Low	—[a]	IRIS	100	1	5.35×10^{-3}	
Boron	9.94	2.02×10^{-4}	9.0×10^{-2}	—[a]	—[a]	Intratrac. instill./IRIS	100	1	2.24×10^{-3}	
Cadmium	3.19	6.47×10^{-5}	1.0×10^{-3}	High	Proteinuria	Food/IRIS	10	1	6.47×10^{-2}	
Chromium	1.15×10^{2}	2.33×10^{-3}	5.0×10^{-3}	Low	Hepatotox/ nephrotox	Water/IRIS	500	1	4.65×10^{-1}	
Manganese	8.67×10^{2}	1.76×10^{-2}	1.0×10^{-1}	Med	Neural tissue damage	Water/IRIS	1	1	1.76×10^{-1}	
Mercury	6.58	1.34×10^{-4}	3.0×10^{-4}	—[a]	Neurotoxicity	—[a]	10	1	4.45×10^{-1}	
Molybdenum	2.30	4.67×10^{-5}	4.0×10^{-3}	—[a]	—[a]	—[a]	—[a]	1	1.17×10^{-2}	
Nickel	3.24×10^{2}	6.58×10^{-3}	2.0×10^{-2}	—[a]	—[a]	IRIS	100	3	3.29×10^{-1}	
Vanadium	3.54×10^{1}	7.19×10^{-4}	7.0×10^{-3}	Low	—[a]	Water/IRIS	100	1	1.03×10^{-1}	
Zinc	7.25×10^{1}	1.47×10^{-3}	2.0×10^{-1}	Med	Hyperactivity	Gavage/IRIS	100	1	7.36×10^{-3}	
										1.98
Exposure Route: Inhalation of wind-generated dust										
1,1-Dichloroethane	9.6×10^{-12}	3.21×10^{-11}	1.0×10^{-1}	—[a]	Kidney damage	Inhalation/IRIS	1000	—[a]	3.2×10^{-10}	
1,1,1-Trichloroethane	3.2×10^{-12}	1.07×10^{-11}	2.86×10^{-1}	—[a]	Hepatotoxicity	Inhalation/IRIS	1000	—[a]	3.7×10^{-11}	
Barium	4.3×10^{-7}	1.44×10^{-6}	1.43×10^{-4}	—[a]	Fetotoxicity	IRIS	1000	—[a]	1.0×10^{-2}	
Chromium	3.7×10^{-7}	1.24×10^{-6}	5.7×10^{-7}	—[a]	Respiratory effects	IRIS	—[a]	—[a]	2.2	
Manganese	2.8×10^{-6}	9.35×10^{-6}	1.14×10^{-4}	—[a]	Respiratory/ psychomotor	Inhalation/IRIS	900	—[a]	8.2×10^{-2}	
Mercury	2.1×10^{-8}	7.01×10^{-8}	8.57×10^{-5}	—[a]	Neurotoxicity	Inhalation/ HEAST	30	—[a]	8.2×10^{-4}	
										2.3

Table 2.10 (continued)

Analyte	RME (mg/kg)	Intake (mg/kg·d)	RfD (mg/kg·d)	CL	Critical effect	RfD basis/source	UF	MF	Hazard quotient	Pathway hazard index
Exposure Route: Ingestion of groundwater										
1,1-Dichloroethane	1.00	1.55×10^{-1}	1.0×10^{-1}	—[a]	None	Inhalation/IRIS	1000	1	1.55	
1,2-Dichloroethene	1.90	2.95×10^{-1}	2.0×10^{-1}	Low	Incr. serum alk. phos.	Water/IRIS	1000	1	1.47	
1,1,1-Trichloroethane	2.9×10^{-1}	4.5×10^{-2}	9.0×10^{-2}	Med	Hepatotoxicity	Inhalation/IRIS	1000	1	4.99×10^{-1}	
Chloroform	6.0×10^{-3}	9.3×10^{-4}	1.0×10^{-2}	—[a]	—[a]	IRIS	1000	1	9.3×10^{-2}	
Tetrachloroethene	9.3×10^{-1}	1.44×10^{-1}	1.0×10^{-1}	Med	Hepatotoxicity	Gavage/IRIS	1000	1	1.44	
Boron	2.1×10^{-1}	3.26×10^{-2}	9.0×10^{-2}	—[a]	—[a]	Intratrac. instill./IRIS	100	1	3.62×10^{-1}	
										5.42
Exposure Route: Dermal contact with groundwater										
1,1-Dichloroethane	1.00	2.2×10^{-4}	1.0×10^{-1}	—[a]	None	Inhalation/IRIS	1000	1	2.2×10^{-3}	
1,2-Dichloroethene	1.90	4.18×10^{-4}	2.0×10^{-1}	Low	Incr. serum alk. phos.	Water/IRIS	1000	1	2.09×10^{-3}	
1,1,1-Trichloroethane	2.9×10^{-1}	6.38×10^{-5}	9.0×10^{-2}	Med	Hepatotoxicity	Inhalation/IRIS	1000	1	7.09×10^{-4}	
Chloroform	6.0×10^{-3}	1.32×10^{-6}	1.0×10^{-2}	—[a]	—[a]	IRIS	1000	1	1.32×10^{-4}	
Tetrachloroethene	9.3×10^{-1}	2.05×10^{-4}	1.0×10^{-1}	Med	Hepatotoxicity	Gavage/IRIS	1000	1	2.05×10^{-3}	
Boron	2.1×10^{-1}	4.62×10^{-5}	9.0×10^{-2}	—[a]	—[a]	Intratrac. instill./IRIS	100	1	5.13×10^{-4}	
										7.69×10^{-3}
Exposure Route: Inhalation of volatiles while showering										
1,1-Dichloroethane	$0.5\ mg/m^3$	8.2×10^{-4}	1.0×10^{-1}	—[a]	Kidney damage	Inhalation/IRIS	1000	—[a]	8.0×10^{-3}	
1,1,1-Trichloroethane	$0.15\ mg/m^3$	2.47×10^{-4}	2.86×10^{-1}	—[a]	Hepatotoxicity	Inhalation/IRIS	1000	—[a]	8.6×10^{-4}	
										8.86×10^{-3}
Exposure Route: Ingestion of homegrown produce										
1,1-Dichloroethane	1.10×10^{-2}	3.42×10^{-5}	1.0×10^{-1}	—[a]	None	Inhalation/IRIS	1000	1	3.42×10^{-4}	
1,2-Dichloroethene	1.79×10^{-1}	5.57×10^{-4}	2.0×10^{-1}	Low	Incr. serum alk. phos.	Water/IRIS	1000	1	2.78×10^{-3}	
1,1,1-Trichloroethane	1.39×10^{-3}	4.32×10^{-6}	9.0×10^{-2}	Med	Hepatotoxicity	Inhalation/IRIS	1000	1	4.80×10^{-5}	
Chloroform	6.74×10^{-2}	2.10×10^{-4}	1.0×10^{-2}	—[a]	—[a]	IRIS	1000	1	2.10×10^{-2}	

Table 2.10 (continued)

Analyte	RME (mg/kg)	Intake (mg/kg·d)	RfD (mg/kg·d)	CL	Critical effect	RfD basis/source	UF	MF	Hazard quotient	Pathway hazard index
Tetrachloroethene	8.42×10^{-2}	2.62×10^{-4}	1.0×10^{-1}	Med	Hepatotoxicity	Gavage/IRIS	1000	1	2.62×10^{-3}	
Arsenic	9.7×10^{-2}	3.02×10^{-4}	1.0×10^{-3}	High	Keratosis/ hyperpigment	Occupational/ IRIS	100	1	3.02×10^{-1}	
Barium	2.00	6.21×10^{-3}	7.0×10^{-2}	—[a]	—[a]	IRIS	3	1	8.87×10^{-2}	
Beryllium	2.0×10^{-3}	6.22×10^{-6}	5.0×10^{-3}	Low	—[a]	IRIS	100	1	1.24×10^{-3}	
Boron	1.99×10^{1}	6.18×10^{-2}	9.0×10^{-2}	—[a]	—[a]	Intratrac. instill./IRIS	100	1	6.87×10^{-1}	
Cadmium	4.78×10^{-1}	1.49×10^{-3}	1.0×10^{-3}	High	Proteinuria	Food/IRIS	10	1	1.49	
Chromium	5.16×10^{-1}	1.6×10^{-3}	5.0×10^{-3}	Low	Hepatotox/ nephrotox	Water/IRIS	500	1	3.21×10^{-1}	
Manganese	4.34×10^{1}	1.35×10^{-1}	1.0×10^{-1}	Med	Neural tissue damage	Water/IRIS	1	1	1.35	
Mercury	1.32	4.09×10^{-3}	3.0×10^{-4}	—[a]	Neurotoxicity	—[a]	10	1	1.36×10^{1}	
Molybdenum	8.6×10^{-2}	2.67×10^{-4}	4.0×10^{-3}	—[a]	—[a]	—[a]	—[a]	1	6.69×10^{-2}	
Nickel	1.95×10^{1}	6.05×10^{-2}	2.0×10^{-2}	—[a]	—[a]	IRIS	100	3	3.03	
Vanadium	1.06×10^{-1}	3.3×10^{-4}	7.0×10^{-3}	Low	—[a]	Water/IRIS	100	1	4.71×10^{-2}	
Zinc	6.53×10^{1}	2.03×10^{-1}	2.0×10^{-1}	Med	Hyperactivity	Gavage/IRIS	100	1	1.02	
										2.21×10^{1}
Total pathway hazard index										3.35×10^{1}

[a]These data are either not available or not applicable.

CL = Confidence level
HEAST = Health Effects Assessment Summary Tables
IRIS = Integrated Risk Information System
MF = Modifying factor
RfD = Reference dose
RME = Reasonable maximum exposure
UF = Uncertainty factor

drives the pathway hazard index associated with ingestion of homegrown produce. Additional noncarcinogenic effects could be incurred from exposure to those contaminants present on-site for which toxicity data are not available.

The hypothetical on-site resident at the K-1407-C Pond could be exposed to soil and groundwater contamination. All chemical-specific carcinogenic risks, total pathway risk, and the total exposure risk estimates are listed in Table 2.11. Although each evaluated pathway yielded a risk greater than 1×10^{-6}, with the exception of dermal contact with groundwater while showering, the highest risk is due to external exposure to ionizing radiation. The aggregate risk from exposure to multiple substances across multiple pathways is controlled by the risk incurred from external exposure to ionizing radiation. It is likely that this risk would be lowered if radiological decay were taken into account. The excess cancer risk is dominated by exposure to ^{137}Cs and ^{154}Eu. The excess cancer risks from exposure to arsenic and ^{234}U in surface soil dominate the ingestion pathway risk. The dermal contact pathway risk is driven by arsenic exposure, while the inhalation pathway risk is dominated by exposure to chromium, ^{234}U, and ^{238}U. Europium-154 and ^{137}Cs control the total pathway risk from external exposure to ionizing radiation, while ^{99}Tc dominates the ingestion pathway risk for homegrown produce. The excess cancer risk for ingestion of groundwater is due exclusively to arsenic.

Because SFs are not available for all carcinogens of potential concern, the excess cancer risk for exposure to some contaminants cannot be fully quantified. Although lead is a B2 carcinogen, it is not likely that the additional effects of lead in the soil or groundwater at the K-1407-B/C Ponds will increase the risk significantly over the relatively high cumulative risk posed by external exposure to radionuclides. The maximum soil concentrations for lead detected during the CERCLA soil sampling event was 58 mg/kg and 72 mg/kg for the K-1407-B and K-1407-C Ponds, respectively; these concentrations are well below the interim soil cleanup level for lead of 500 to 1000 ppm set forth in the Office of Solid Waste and Emergency Response Directive 9355.4-02.

Because detection limits for some historic groundwater analyses for lead are above the 15 μg/L action level established in 56 *Federal Register* (FR) 26460, comparison of lead concentrations detected in groundwater at the site cannot be fully evaluated against this criteria. Only one confirmed analysis for lead at each downgradient monitoring well at the K-1407-B Pond exceeds the 15 μg/L action level in unfiltered samples (32 μg/L in UNW-2; 74 μg/L in UNW-3). Downgradient monitoring wells UNW-8 and UNW-9 at the K-1407-C Pond have periodically exceeded the 15 μg/L action level for unfiltered samples with a maximum concentration of 280 μg/L in UNW-8. However, lead concentrations in upgradient monitoring wells UNW-6 and UNW-11 have exceeded the action limit with greater frequency and at greater concentrations than

Table 2.11. Cancer risk estimates for on-site residents at the K-1407-C Pond

Analyte	RME (mg/kg) (pCi/kg)	Intake (mg/kg·d) (pCi)	SF (mg/kg·d)-1 (pCi)-1	Weight of evidence	Type of cancer	SF basis/SF source	Chemical-specific risk	Total pathway risk
Exposure Route: Ingestion of soil								
Arsenic	2.07×10^{1}	3.25×10^{-5}	1.70	A	Skin	—[a]	6×10^{-5}	
Beryllium	1.05	1.64×10^{-6}	4.30	B1	—[a]	Intratracheal Instillation/IRIS	7×10^{-6}	
Americium-241	4.04×10^{3}	5.09×10^{3}	3.1×10^{-10}	A	Many types	IRIS	2×10^{-6}	
Cesium-137	2.23×10^{4}	2.81×10^{4}	2.8×10^{-11}	A	Many types	IRIS	8×10^{-7}	
Cobalt-60	4.3×10^{1}	5.42×10^{1}	1.5×10^{-11}	A	Many types	IRIS	8×10^{-10}	
Curium-244	-8.00	0.0	2.0×10^{-10}	A	Many types	IRIS		
Europium-154	2.13×10^{3}	2.69×10^{3}	3.0×10^{-12}	A	Many types	IRIS	8×10^{-9}	
Neptunium-237	1.31×10^{4}	1.65×10^{4}	2.7×10^{-10}	A	Many types	IRIS	4×10^{-6}	
Plutonium-238	1.56×10^{3}	1.96×10^{3}	2.8×10^{-10}	A	Many types	IRIS	6×10^{-7}	
Plutonium-239	2.05×10^{4}	2.58×10^{4}	3.1×10^{-11}	A	Many types	IRIS	8×10^{-7}	
Potassium-40	1.18×10^{4}	1.48×10^{4}	1.1×10^{-11}	A	Many types	IRIS	2×10^{-7}	
Technetium-99	5.87×10^{5}	7.39×10^{5}	1.3×10^{-12}	A	Many types	IRIS	1×10^{-6}	
Uranium-234	3.48×10^{5}	4.38×10^{5}	1.4×10^{-10}	A	Many types	IRIS	6×10^{-5}	
Uranium-235	1.24×10^{4}	1.56×10^{4}	1.3×10^{-10}	A	Many types	IRIS	2×10^{-6}	
Uranium-238	1.87×10^{5}	2.35×10^{5}	1.3×10^{-10}	A	Many types	IRIS	3×10^{-5}	
								2×10^{-4}
Exposure Route: Dermal contact with soil								
Arsenic	2.07×10^{1}	7.52×10^{-6}	1.70	A	Skin	—[a]	1×10^{-5}	
Beryllium	1.05	3.8×10^{-7}	4.30	B1	—[a]	Intratracheal Instillation/IRIS	2×10^{-6}	
								1×10^{-5}
Exposure Route: Inhalation of wind-generated dust								
Arsenic	6.6×10^{-8}	2.36×10^{-8}	5.0×10^{1}	A	Respiratory tract	Various/IRIS	1×10^{-6}	
Beryllium	3.4×10^{-9}	1.21×10^{-9}	8.40	B2	Lung	Inhalation/IRIS	1×10^{-8}	
Cadmium	7.4×10^{-9}	2.64×10^{-9}	6.10	B1	—[a]	—[a]	2×10^{-8}	
Chromium	2.8×10^{-7}	1.0×10^{-7}	4.1×10^{1}	A	—[a]	—[a]	4×10^{-6}	
Nickel	1.6×10^{-6}	5.71×10^{-7}	8.4×10^{-1}	A	—[a]	—[a]	5×10^{-7}	
Americium-241	1.3×10^{-5}	3.49	4.0×10^{-8}	A	Many types	IRIS	1×10^{-7}	
Cesium-137	7.1×10^{-5}	1.91×10^{1}	1.9×10^{-11}	A	Many types	IRIS	4×10^{-10}	
Cobalt-60	1.4×10^{-7}	3.76×10^{-2}	1.6×10^{-10}	A	Many types	IRIS	6×10^{-12}	
Curium-244	-2.6×10^{-8}	0.0	2.7×10^{-8}	A	Many types	IRIS		

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Table 2.11 (continued)

Analyte	RME (mg/kg) (pCi/kg)	Intake (mg/kg-d) (pCi)	SF (mg/kg-d)-1 (pCi)-1	Weight of evidence	Type of cancer	SF basis/SF source	Chemical-specific risk	Total pathway risk
Europium-154	6.8×10^{-6}	1.83	1.4×10^{-10}	A	Many types	IRIS	3×10^{-10}	
Neptunium-237	4.2×10^{-5}	1.13×10^{1}	3.6×10^{-8}	A	Many types	IRIS	4×10^{-7}	
Plutonium-238	5.0×10^{-6}	1.34	4.2×10^{-8}	A	Many types	IRIS	6×10^{-8}	
Plutonium-239	6.6×10^{-5}	1.77×10^{1}	4.1×10^{-8}	A	Many types	IRIS	7×10^{-7}	
Potassium-40	3.8×10^{-5}	1.02×10^{1}	7.6×10^{-12}	A	Many types	IRIS	8×10^{-11}	
Technetium-99	1.9×10^{-3}	5.11×10^{2}	8.3×10^{-12}	A	Many types	IRIS	4×10^{-9}	
Uranium-234	1.1×10^{-3}	2.96×10^{2}	2.7×10^{-8}	A	Many types	IRIS	8×10^{-6}	
Uranium-235	4.0×10^{-5}	1.08×10^{1}	2.5×10^{-8}	A	Many types	IRIS	3×10^{-7}	
Uranium-238	6.0×10^{-4}	1.61×10^{2}	2.4×10^{-8}	A	Many types	IRIS	4×10^{-6}	
								2×10^{-5}
Exposure Route: External exposure to soil radiation								
Americium-241	4.04×10^{3}	1.86×10^{7}	1.6×10^{-12}	A	Many types	IRIS	3×10^{-5}	
Cesium-137	2.23×10^{4}	1.03×10^{8}	3.4×10^{-11}	A	Many types	IRIS	3×10^{-3}	
Cobalt-60	4.3×10^{1}	1.98×10^{5}	1.3×10^{-10}	A	Many types	IRIS	3×10^{-5}	
Curium-244	-8.00	0.0	5.8×10^{-14}	A	Many types	IRIS		
Europium-154	2.13×10^{3}	9.82×10^{6}	6.8×10^{-11}	A	Many types	IRIS	7×10^{-4}	
Neptunium-237	1.31×10^{4}	6.04×10^{7}	1.8×10^{-12}	A	Many types	IRIS	1×10^{-4}	
Plutonium-238	1.56×10^{3}	7.18×10^{6}	6.1×10^{-14}	A	Many types	IRIS	4×10^{-7}	
Plutonium-239	2.05×10^{4}	9.43×10^{7}	2.6×10^{-14}	A	Many types	IRIS	2×10^{-6}	
Potassium-40	1.18×10^{4}	5.42×10^{7}	7.8×10^{-12}	A	Many types	IRIS	4×10^{-4}	
Technetium-99	5.87×10^{5}	2.7×10^{9}	3.4×10^{-17}	A	Many types	IRIS	9×10^{-8}	
Uranium-234	3.48×10^{5}	1.6×10^{9}	5.7×10^{-14}	A	Many types	IRIS	9×10^{-5}	
Uranium-235	1.24×10^{4}	5.7×10^{7}	9.6×10^{-12}	A	Many types	IRIS	5×10^{-4}	
Uranium-238	1.87×10^{5}	8.59×10^{8}	4.6×10^{-14}	A	Many types	IRIS	4×10^{-5}	
								5×10^{-3}
Exposure Route: Ingestion of groundwater								
Arsenic	9.0×10^{-3}	1.8×10^{-4}	1.70	A	Skin	Water/IRIS	3×10^{-4}	
								3×10^{-4}
Exposure Route: Dermal contact with groundwater while showering								
Arsenic	9.0×10^{-3}	3.51×10^{-7}	1.70	A	Skin	Water/IRIS	6×10^{-7}	
								6×10^{-7}

Table 2.11 (continued)

Analyte	RME (mg/kg) (pCi/kg)	Intake (mg/kg·d) (pCi)	SF (mg/kg·d)-1 (pCi)-1	Weight of evidence	Type of cancer	SF basis/SF source	Chemical-specific risk	Total pathway risk
Exposure Route: Ingestion of homegrown produce								
Arsenic	1.24×10^{-1}	5.05×10^{-5}	1.70	A	Skin	—[a]	9×10^{-5}	
Beryllium	2.0×10^{-3}	8.14×10^{-7}	4.30	B1	—[a]	Intratracheal Instillation/IRIS	4×10^{-6}	
Americium-241	1.00	4.2×10^{2}	3.1×10^{-10}	A	Many types	IRIS	1×10^{-7}	
Cesium-137	6.69×10^{2}	2.81×10^{5}	2.8×10^{-11}	A	Many types	IRIS	8×10^{-6}	
Cobalt-60	3.0×10^{-1}	1.26×10^{2}	1.5×10^{-11}	A	Many types	IRIS	2×10^{-9}	
Curium-244	-1.2×10^{-4}	0.0	2.0×10^{-10}	A	Many types	IRIS		
Europium-154	9.00	3.78×10^{3}	3.0×10^{-12}	A	Many types	IRIS	1×10^{-8}	
Neptunium-237	1.31×10^{2}	5.5×10^{4}	2.7×10^{-10}	A	Many types	IRIS	1×10^{-5}	
Plutonium-238	7.0×10^{-2}	2.94×10^{1}	2.8×10^{-10}	A	Many types	IRIS	8×10^{-9}	
Plutonium-239	1.00	4.2×10^{2}	3.1×10^{-11}	A	Many types	IRIS	1×10^{-8}	
Potassium-40	6.47×10^{3}	2.72×10^{6}	1.1×10^{-11}	A	Many types	IRIS	3×10^{-5}	
Technetium-99	8.8×10^{5}	3.7×10^{8}	1.3×10^{-12}	A	Many types	IRIS	5×10^{-4}	
Uranium-234	1.39×10^{3}	5.85×10^{5}	1.4×10^{-10}	A	Many types	IRIS	8×10^{-5}	
Uranium-235	5.0×10^{1}	2.1×10^{4}	1.3×10^{-10}	A	Many types	IRIS	3×10^{-6}	
Uranium-238	7.46×10^{2}	3.13×10^{5}	1.3×10^{-10}	A	Many types	IRIS	4×10^{-5}	
								7×10^{-4}
Total exposure risk								7×10^{-3}

[a]These data are either not available or not applicable.

HEAST = Health Effect Assessment Summary Tables
IRIS = Integrated Risk Information System
RME = Reasonable maximum exposure
SF = Slope factor

A = sufficient evidence of carcinogenicity in humans; human carcinogen
B1 = limited evidence of carcinogenicity in humans
B2 = sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans
D = not classifiable as to human carcinogenicity (lack of or no evidence)

downgradient wells (maximum concentration of 334 $\mu g/L$ in UNW-6). This indicates that lead in downgradient wells is not attributable to migration from the pond soils.

Results of the evaluation of exposure to noncarcinogenic contaminants for the on-site resident at the K-1407-C Pond are given in Table 2.12. Noncarcinogenic effects could occur from exposure to the soil and the groundwater by ingestion, dermal contact, inhalation, and consumption of homegrown produce. Exposure to chromium drives the pathway hazard index associated with the inhalation of wind-generated dust while exposure to mercury contributes substantially to the elevated pathway hazard index values for the ingestion of homegrown produce. Additional non-carcinogenic effects could be incurred from exposure to those contaminants at the site that do not have RfDs; however, these effects cannot be quantified.

Tables 2.13 and 2.14 show general and site-specific uncertainty factors that may influence the human health risk assessment results for the K-1407-B/C Ponds.

Environmental Risks

There are no critical habitats or threatened or endangered species affected by site contaminants. The K-1407-B/C Ponds do not provide a habitat to support significant aquatic communities, do not currently discharge to surface waters, and are not expected to discharge to surface waters via direct surface flow in the future. Therefore, aquatic ecological effects were not assessed. Because the ponds encompass a small area within an industrial complex and do not incorporate highly valued habitat features, effects on natural terrestrial communities were not assessed. However, because it may be desirable to revegetate these ponds, an assessment was performed on the ability of the pond soils to support a plant community sufficiently vigorous to cover and stabilize the soil. The results indicate that the pond soils could be toxic to plants due to high concentrations of Hg, Ni, Zn, and other metals. However, these results are highly uncertain due to differences in soil composition, metal form, and plant sensitivity. Additional evaluation of environmental and ecological risks may be provided as part of a subsequent sitewide ecological risk assessment at K-25.

Summary

According to EPA, an excess cancer risk greater than 1×10^{-6} (1 in a million) is cause for concern and requires close scrutiny, and an excess cancer risk greater than 1×10^{-4} (1 in 10,000) is considered unacceptable by the EPA (EPA 1989a). The excess risk to the general plant worker are well below the EPA lower threshold of concern. On-site workers are exposed through inhalation of airborne dust, dermal contact and ingestion of contaminated soil, and external exposure to ionizing radiation. The on-site worker is estimated to be exposed to an excess cancer risk of 4×10^{-6}, or four chances in a million more likely to contract cancer in a

Table 2.12. Hazard index estimates for on-site residents at the K-1407-C Pond

Analyte	RME (mg/kg)	Intake (mg/kg·d)	RfD (mg/kg·d)	CL	Critical effect	RfD basis/source	UF	MF	Hazard quotient	Pathway hazard index
Exposure Route: Ingestion of soil										
Arsenic	2.07×10^{1}	2.94×10^{-4}	1.0×10^{-3}	High	Keratosis/ hyperpigment	Occupational/ IRIS	100	1	2.94×10^{-1}	
Barium	1.17×10^{2}	1.65×10^{-3}	7.0×10^{-2}	—[a]	—[a]	IRIS	3	1	2.36×10^{-2}	
Beryllium	1.05	1.49×10^{-5}	5.0×10^{-3}	Low	—[a]	IRIS	100	1	2.97×10^{-3}	
Boron	1.37×10^{1}	1.95×10^{-4}	9.0×10^{-2}	—[a]	—[a]	Intratrac. instill./IRIS	100	1	2.17×10^{-3}	
Cadmium	2.31	3.28×10^{-5}	1.0×10^{-3}	High	Proteinuria	Food/IRIS	10	1	3.28×10^{-2}	
Chromium	8.6×10^{1}	1.22×10^{-3}	5.0×10^{-3}	Low	Hepatotox/ nephrotox	Water/IRIS	500	1	2.44×10^{-1}	
Manganese	1.56×10^{3}	2.22×10^{-2}	1.0×10^{-1}	Med	Neural tissue damage	Water/IRIS	1	1	2.22×10^{-1}	
Mercury	1.04×10^{1}	1.47×10^{-4}	3.0×10^{-4}	—[a]	Neurotoxicity	—[a]	10	1	4.9×10^{-1}	
Molybdenum	3.74	5.31×10^{-5}	4.0×10^{-3}	—[a]	—[a]	—[a]	—[a]	1	1.33×10^{-2}	
Nickel	5.07×10^{2}	7.21×10^{-3}	2.0×10^{-2}	—[a]	—[a]	IRIS	100	3	3.6×10^{-1}	
Silver	9.0×10^{-1}	1.28×10^{-5}	3.0×10^{-3}	Med	Argyria	Oral/IRIS	2	1	4.26×10^{-3}	
Vanadium	5.02×10^{1}	7.13×10^{-4}	7.0×10^{-3}	Low	—[a]	Water/IRIS	100	1	1.02×10^{-1}	
Zinc	8.79×10^{1}	1.25×10^{-3}	2.0×10^{-1}	Med	Hyperactivity	Gavage/IRIS	100	1	6.24×10^{-3}	
										1.80
Exposure Route: Dermal contact with soil										
Arsenic	2.07×10^{1}	4.21×10^{-4}	1.0×10^{-3}	High	Keratosis/ hyperpigment	Occupational/ IRIS	100	1	4.21×10^{-1}	
Barium	1.17×10^{2}	2.37×10^{-3}	7.0×10^{-2}	—[a]	—[a]	IRIS	3	1	3.38×10^{-2}	
Beryllium	1.05	2.13×10^{-5}	5.0×10^{-3}	Low	—[a]	IRIS	100	1	4.25×10^{-3}	
Boron	1.37×10^{1}	2.79×10^{-4}	9.0×10^{-2}	—[a]	—[a]	Intratrac. instill./IRIS	100	1	3.1×10^{-3}	
Cadmium	2.31	4.68×10^{-5}	1.0×10^{-3}	High	Proteinuria	Food/IRIS	10	1	4.68×10^{-2}	

Table 2.12 (continued)

Analyte	RME (mg/kg)	Intake (mg/kg·d)	RfD (mg/kg·d)	CL	Critical effect	RfD basis/source	UF	MF	Hazard quotient	Pathway hazard index
Chromium	8.6×10^{1}	1.75×10^{-3}	5.0×10^{-3}	Low	Hepatotox/ nephrotox	Water/IRIS	500	1	3.49×10^{-1}	
Manganese	1.56×10^{3}	3.17×10^{-2}	1.0×10^{-1}	Med	Neural tissue damage	Water/IRIS	1	1	3.17×10^{-1}	
Mercury	1.04×10^{1}	2.1×10^{-4}	3.0×10^{-4}	—[a]	Neurotoxicity	—[a]	10	1	7.01×10^{-1}	
Molybdenum	3.74	7.59×10^{-5}	4.0×10^{-3}	—[a]	—[a]	—[a]	—[a]	1	1.9×10^{-2}	
Nickel	5.07×10^{2}	1.03×10^{-2}	2.0×10^{-2}	—[a]	—[a]	IRIS	100	3	5.15×10^{-1}	
Silver	9.0×10^{-1}	1.83×10^{-5}	3.0×10^{-3}	Med	Argyria	Oral/IRIS	2	1	6.09×10^{-3}	
Vanadium	5.02×10^{1}	1.02×10^{-3}	7.0×10^{-3}	Low	—[a]	Water/IRIS	100	1	1.46×10^{-1}	
Zinc	8.79×10^{1}	1.79×10^{-3}	2.0×10^{-1}	Med	Hyperactivity	Gavage/IRIS	100	1	8.93×10^{-3}	
										2.57
Exposure Route: Inhalation of wind-generated dust										
Barium	3.7×10^{-7}	1.24×10^{-6}	1.43×10^{-4}	—[a]	Fetotoxicity	IRIS	1000	—[a]	8.6×10^{-3}	
Chromium	2.8×10^{-7}	9.35×10^{-7}	5.7×10^{-7}	—[a]	Respiratory effects	IRIS	—[a]	—[a]	1.6	
Manganese	5.0×10^{-6}	1.67×10^{-5}	1.14×10^{-4}	—[a]	Respiratory/ psychomotor	Inhalation/ IRIS	900	—[a]	1.5×10^{-1}	
Mercury	3.3×10^{-8}	1.1×10^{-7}	8.57×10^{-5}	—[a]	Neurotoxicity	Inhalation/ HEAST	30	—[a]	1.3×10^{-3}	
										1.8
Exposure Route: Ingestion of groundwater										
Arsenic	9.0×10^{-3}	1.4×10^{-3}	1.0×10^{-3}	High	Keratosis/ hyperpigment	Occupational/ IRIS	100	1	1.40	
Cadmium	1.7×10^{-2}	2.64×10^{-3}	5.0×10^{-4}	High	Proteinuria	Food/IRIS	10	1	5.27	
Manganese	3.3×10^{1}	5.12	1.0×10^{-1}	Med	Neural tissue damage	Water/IRIS	1	1	5.12×10^{1}	
Mercury	5.1×10^{-3}	7.91×10^{-4}	3.0×10^{-4}	—[a]	Neurotoxicity	IRIS	10	1	2.64	

Table 2.12 (continued)

Analyte	RME (mg/kg)	Intake (mg/kg·d)	RfD (mg/kg·d)	CL	Critical effect	RfD basis/source	UF	MF	Hazard quotient	Pathway hazard index
Molybdenum	1.3×10^{-2}	2.02×10^{-3}	4.0×10^{-3}	—[a]	—[a]	IRIS	—[a]	1	5.04×10^{-1}	
										6.1×10^{1}
Exposure Route: Dermal contact with groundwater										
Arsenic	9.0×10^{-3}	1.98×10^{-6}	1.0×10^{-3}	High	Keratosis/ hyperpigment	Occupational/ IRIS	100	1	1.98×10^{-3}	
Cadmium	1.7×10^{-2}	3.74×10^{-6}	5.0×10^{-4}	High	Proteinuria	Food/IRIS	10	1	7.48×10^{-3}	
Manganese	3.3×10^{1}	7.26×10^{-3}	1.0×10^{-1}	Med	Neural tissue damage	Water/IRIS	1	1	7.26×10^{-2}	
Mercury	5.1×10^{-3}	1.12×10^{-6}	3.0×10^{-4}	—[a]	Neurotoxicity	IRIS	10	1	3.74×10^{-3}	
Molybdenum	1.3×10^{-2}	2.86×10^{-6}	4.0×10^{-3}	—[a]	—[a]	IRIS	—[a]	1	7.15×10^{-4}	
										8.65×10^{-2}
Exposure Route: Ingestion of homegrown produce										
Arsenic	1.24×10^{-1}	3.86×10^{-4}	1.0×10^{-3}	High	Keratosis/ hyperpigment	Occupational/ IRIS	100	1	3.86×10^{-1}	
Barium	1.75	5.44×10^{-3}	7.0×10^{-2}	—[a]	—[a]	IRIS	3	1	7.77×10^{-2}	
Beryllium	2.0×10^{-3}	6.22×10^{-6}	5.0×10^{-3}	Low	—[a]	IRIS	100	1	1.24×10^{-3}	
Boron	2.75×10^{1}	8.55×10^{-2}	9.0×10^{-2}	—[a]	—[a]	Intratrac. instill./IRIS	100	1	9.5×10^{-1}	
Cadmium	3.46×10^{-1}	1.08×10^{-3}	1.0×10^{-3}	High	Proteinuria	Food/IRIS	10	1	1.08	
Chromium	3.87×10^{-1}	1.2×10^{-3}	5.0×10^{-3}	Low	Hepatotox/ nephrotox	Water/IRIS	500	1	2.41×10^{-1}	
Manganese	7.82×10^{1}	2.43×10^{-1}	1.0×10^{-1}	Med	Neural tissue damage	Water/IRIS	1	1	2.43	
Mercury	2.07	6.44×10^{-3}	3.0×10^{-4}	—[a]	Neurotoxicity	—[a]	10	1	2.15×10^{1}	
Molybdenum	2.24×10^{-1}	6.97×10^{-4}	4.0×10^{-3}	—[a]	—[a]	—[a]	—[a]	1	1.74×10^{-1}	
Nickel	3.04×10^{1}	9.47×10^{-2}	2.0×10^{-2}	—[a]	—[a]	IRIS	100	3	4.73	
Silver	9.0×10^{-2}	2.8×10^{-4}	3.0×10^{-3}	Med	Argyria	Oral/IRIS	2	1	9.33×10^{-2}	
Vanadium	1.51×10^{-1}	4.7×10^{-4}	7.0×10^{-3}	Low	—[a]	Water/IRIS	100	1	6.71×10^{-2}	

Table 2.12 (continued)

Analyte	RME (mg/kg)	Intake (mg/kg·d)	RfD (mg/kg·d)	CL	Critical effect	RfD basis/source	UF	MF	Hazard quotient	Pathway hazard index
Zinc	7.92×10^{1}	2.46×10^{-1}	2.0×10^{-1}	Med	Hyperactivity	Gavage/IRIS	100	1	1.23	3.29×10^{1}
Total pathway hazard index										1.0×10^{2}

[a]These data are either not available or not applicable.

CL = Confidence level
HEAST = Health Effects Assessment Summary Tables
IRIS = Integrated Risk Information System
MF = Modifying factor
RfD = Reference dose
RME = Reasonable maximum exposure
UF = Uncertainty factor

Table 2.13. General uncertainty factors

Uncertainty factor	Effect of uncertainty	Comment
Use of cancer slope factors	May overestimate risks	Slopes are upper 95th percent confidence limits derived from the linearized model. Considered unlikely to underestimate true risk
Risks/doses within an exposure route assumed to be additive	May over- or underestimate risks	Does not account for synergism or antagonism
Toxicity values derived primarily from animal studies	May over- or underestimate risks	Extrapolation from animals to humans may induce error due to differences in pharmacokinetics, target organs, and population variability
Toxicity values derived primarily from high doses; most exposures are at low doses	May over- or underestimate risks	Assumes linearity at low doses. Tends to have conservative exposure assumptions
Toxicity values	May over- or underestimate risks	Not all values represent the same degree of certainty. All are subject to change as new evidence becomes available
Effect of absorption	May over- or underestimate risks	The assumption that absorption is equivalent across species is implicit in the derivation of the critical toxicity values. Absorption may actually vary with species and age
Effect of applying critical toxicity values to soil exposures	May overestimate risks	Assumes bioavailability of contaminants sorbed onto soils is the same as detected in laboratory studies. Contaminants detected in studies may be more bioavailable
Exposures assumed constant over time	May over- or underestimate risks	Does not account for environmental fate, transport, or transfer that may alter concentration

Table 2.14. Site-specific uncertainty factors

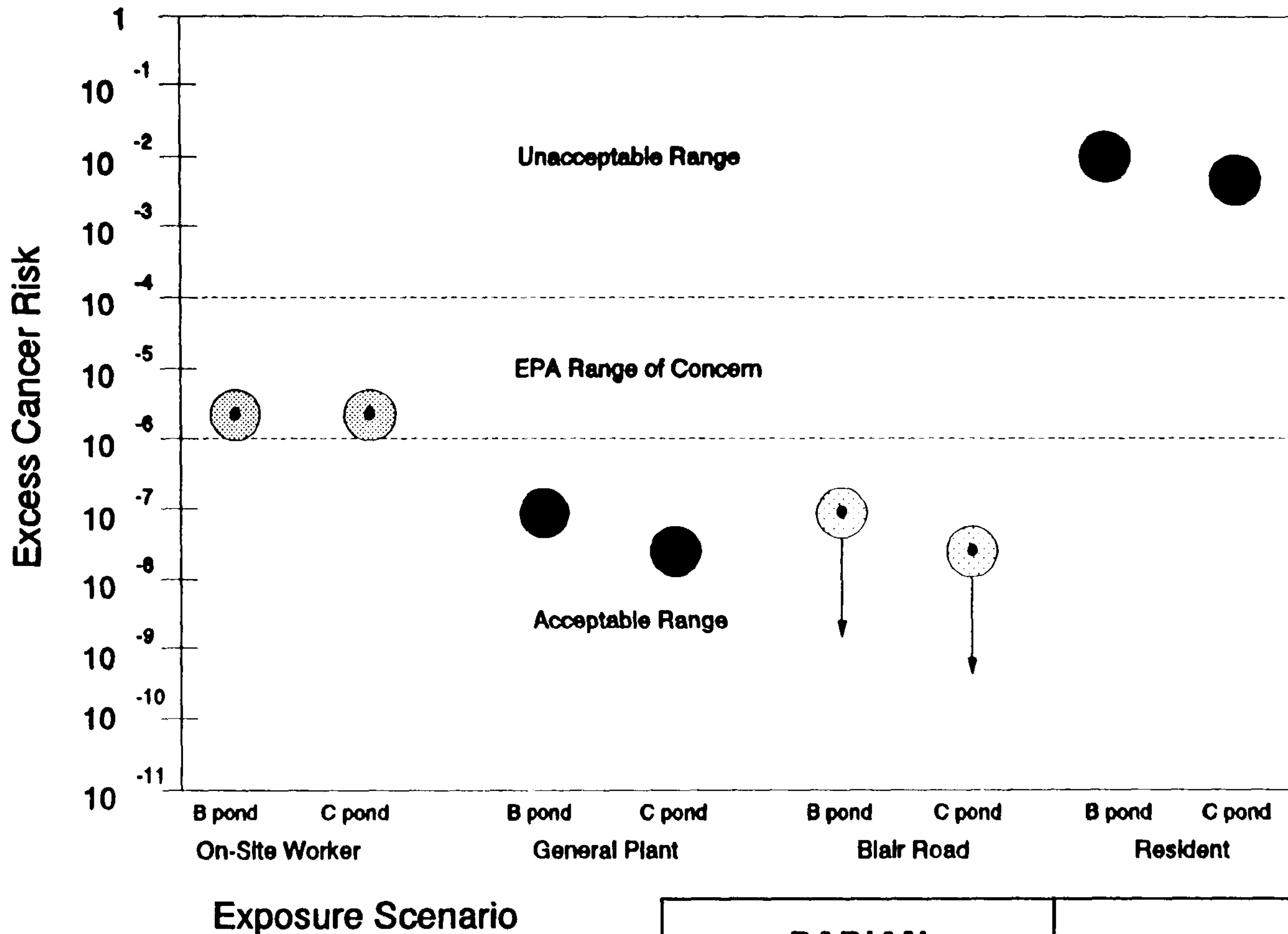
Uncertainty Factor	Effect of Uncertainty	Comment
Metals analysis for total metals only	May overestimate risks	Did not distinguish between valences or speciation. Assumed the metal was present in its most toxic form
Not all chemicals at the site have toxicity values	May underestimate risks	These chemicals are not addressed quantitatively
Exposure assumptions	May over- or underestimate risks	Assumptions regarding media intake, population characteristics, and exposure patterns may not characterize exposures
It is difficult to determine the sources and their relative contributions to groundwater contamination downgradient of the ponds	May over- or underestimate risks	Statistical t-test used in selecting potential contaminants of concern for groundwater
Radioisotopes are not included as analytes in groundwater	May underestimate risks	Soil in both ponds contain radionuclides; comprehensive assessment of groundwater is not possible
The source of organics in K-1407-B soil is indeterminable	May overestimate risks	It is likely that organics are not related to K-1407-B, but to groundwater
Soil background samples are not available	May overestimate risks	It is impossible to eliminate metals which are not site-related based on a screening evaluation
No air monitoring data are available	May over- or underestimate risks	Models were used to develop air concentrations
Transport equations used to estimate the air concentration lacked constraints on the availability of soil particles for transport	May overestimate risks	Soil moisture and the cohesive nature of the clay soil in the ponds act to reduce the erosion rate and the subsequent concentrations in air
Exposures assumed constant over time	May over- or underestimate risks	Does not account for environmental fate, transport, or transfer that may alter concentration

lifetime than if no contamination existed at the K-1407-B/C Ponds. The hypothetical future on-site resident would be exposed through ingestion and contact with contaminated soil, external exposure to ionizing radiation, inhalation of airborne dust, ingestion of contaminated groundwater, dermal contact with water, inhalation of organic volatiles during bathing, and consumption of contaminated homegrown vegetables. The aggregate excess risk from exposure to multiple contaminants across all pathways for the hypothetical resident is estimated at 1×10^{-2}, or 1 extra chance in 100 to contract cancer solely because of site contamination.

The remedial action will provide protection to the on-site worker, the general plant employee, and wildlife by eliminating pathways of exposure by backfilling at the site. This remedial action will also provide protection to the potential intruder or future on-site resident by eliminating pathways of exposure and through the use of institutional controls. Institutional controls eliminate the potential risk to the hypothetical homesteader for as long as the controls remain in place by preventing access to the ponds area. The risk level following implementation of this action will be reduced below the threshold of concern (10^{-6}, or 1 in a million) established by EPA. Systematic toxicity will also be reduced.

The results of the risk assessment for the K-1407-B Pond and K-1407-C Pond are summarized in Fig. 2.5. The risk assessments for the K-1407-B Pond and the K-1407-C Pond indicate that present and future on-site exposure is likely to be a concern. Estimated risks incurred by an individual living near or on K-1407-B Pond or K-1407-C Pond at baseline conditions would be unacceptable.

Actual or threatened releases of hazardous substances from this site, if not addressed by implementing the response action selected in this ROD, may present an imminent and substantial endangerment to public health, welfare, or the environment.



RADIAN Source: Energy Systems Date: 1991	A comparison by scenario of total excess cancer risk from exposure to contaminants at the K-1407-B/C Ponds.
Environmental Restoration Program	Fig. 2.5

DESCRIPTION OF ALTERNATIVES

As part of the FS conducted for the K-1407-B/C Ponds, remedial alternatives were developed to address residual metals, radiological, and VOC contamination in the pond soils. Remedial alternatives developed under CERCLA must protect human health and the environment from the hazards at K-1407-B/C Ponds and comply with the associated administrative requirements. Each alternative was evaluated with respect to CERCLA screening criteria. Groundwater contamination at the site will be addressed as part of the K-25 Groundwater OU RI/FS and is not addressed by these remedial alternatives. Under the focused FS process, six alternatives were evaluated for remediation of soil contamination at the K-1407-B/C Ponds site:

- **Alternative 1: No action**—Under Alternative 1, no further action would be taken at the site.
- **Alternative 2: Engineered Rock Fill**—This alternative consists of filling the K-1407-B Pond with rock fill, placing a cover layer of a few feet of compacted soil above the rock, and filling the K-1407-C Pond with soil.
- **Alternative 3: Engineered Soil Fill**—This alternative entails backfilling both the ponds with borrow soil in accordance with precise technical specifications.
- **Alternative 4: Backfill and Clay Cap**—Backfilling and placement of a clay cap according to engineering specifications provides a hydraulic barrier and helps minimize infiltration and percolation of surface waters.
- **Alternative 5: Five-Component RCRA Cap**—The composite five-component RCRA cap is a sophisticated cap consisting of multiple layers, including a synthetic membrane that eliminates virtually all infiltration.
- **Alternative 6: Excavation and Treatment**—Excavation entails the removal of contaminated soils and subsequent treatment by fixation for storage of waste.

Alternative 1 is included as a comparison baseline in accordance with the NCP. Alternatives 2, 3, 4, 5, and 6 each intend to fulfill the requirements of Sect. 121(d)(1) of SARA.

As part of the RI/FS, soil cleanup levels for the protection of human health were generated as preliminary remediation goals (PRGs) based on EPA-recommended equations. The EPA-recommended equation for calculating PRGs for radionuclides in soil combines the two pathways of external irradiation and soil ingestion because a residential receptor could be exposed by both pathways simultaneously. The produce ingestion pathway was not considered in calculating PRGs for radionuclides because the risks associated with this pathway are negligible in comparison with those for external irradiation and soil ingestion. Remediation resulting in soil concentrations that adequately reduce risks associated with soil ingestion and external irradiation would likewise eliminate unacceptable risks (i.e., $> 1 \times 10^{-6}$) associated with produce ingestion.

The equation for calculating PRGs was derived by EPA from the equation used to calculate risk. The EPA-recommended default value for the shielding factor was used to allow consideration of the shielding effect of buildings, such as the walls of the on-site resident's house. The age-adjusted soil ingestion factor combines the different ingestion rates and body weights of the child and adult receptors. In accordance with EPA guidance, each SF used in calculating a PRG for a radionuclide incorporated the SFs for all decay products since secular equilibrium is assumed. The values used for the other variables in the equation were the same ones used in the risk calculations.

Since EPA has not provided equations for calculating PRGs for the produce ingestion and dust inhalation exposure pathways, PRGs were back-calculated using the same equations used to calculate risk. Likewise, the values used in the risk calculations for ingestion rate, inhalation rate, exposure frequency, exposure duration, body weight, and averaging time were used in deriving PRGs. However, because the majority (approximately 80%) of the risk from ingestion of metals in produce is due to the 6 years of childhood exposure, a body weight of 15 kg and exposure duration of 6 years were used to calculate these PRGs. The calculated risk-based PRGs are shown in Table 2.15. The PRG shown for chromium is a target air concentration rather than a target soil concentration.

Remediation that achieves these PRGs for protection of human health is likely to also eliminate the potential for adverse effects on plant life. The PRGs listed in Table 2.15 are lower than the minimum phytotoxic concentrations (i.e., those toxic to plants) for the same metals, with the exception of zinc. The phytotoxicity value for zinc is based on one study of one plant species, suggesting considerable uncertainty in that value being applied to all plants in all soil types.

A great deal of conservatism has been incorporated into the PRGs. In addition to the very conservative exposure assumptions adapted from EPA risk assessment guidance documents, SFs and RfDs established by EPA directly influence the outcome of PRG calculations. It is important to keep in mind that the PRGs are the target concentrations to which the hypothetical on-site resident would be exposed for baseline, or current, site conditions. Therefore, excavation of soil containing contaminant levels above the PRGs is not necessarily required if uncontaminated soil or other shielding material is placed over the contaminated soil such that residential exposure to the soil exceeding PRGs is eliminated.

Treatment options for the disposal of residual radiological contamination in soil were evaluated in the FS for the K-1407-B/C Ponds. Treatment/disposal of radioactive waste is based

Table 2.15. **Preliminary remediation goals for the K-1407-B/C Pond soils**

Contaminant	Exposure route	Target soil concentration/activity
Europium-154	External radiation/soil ingestion	4×10^{-3} pCi/g
Cesium-137	External radiation/soil ingestion	4×10^{-3} pCi/g
Thorium-230	External radiation/soil ingestion	3×10^{-3} pCi/g
Americium-241	External radiation/soil ingestion	2×10^{-3} pCi/g
Cobalt-60	External radiation/soil ingestion	2×10^{-3} pCi/g
Neptunium-237	External radiation/soil ingestion	2×10^{-3} pCi/g
Potassium-40	External radiation/soil ingestion	3.3×10^{-2} pCi/g
Uranium-234	External radiation/soil ingestion	3×10^{-3} pCi/g
Uranium-235	External radiation/soil ingestion	7×10^{-3} pCi/g
Uranium-238	External radiation/soil ingestion	1×10^{-3} pCi/g
Technetium-99	Produce ingestion	1.8 pCi/g
Mercury	Produce ingestion	0.1 mg/kg
Manganese	Produce ingestion	156 mg/kg
Nickel	Produce ingestion	130 mg/kg
Zinc	Produce ingestion	52 mg/kg
Cadmium	Produce ingestion	1 mg/kg
Chromium	Inhalation of dust	2×10^{-6} mg/m^3 (air concentration)

on three technical principles that are not always simultaneously applicable or administratively feasible.

- A sufficient delay will allow the complete decay of short-lived isotopes, first, and of all radioactivity in the long term ("delay and decay").
- Dilution of concentrated waste will reduce the specific bulk radioactivity of the material to acceptable levels.
- Containment and confinement of the waste will limit the risk posed by the radioactive material.

Since a cement batch plant was operated on-site during a previous fixation project, treatment by stabilization and solidification with cement appears to be a viable treatment choice. The nature and threat of radiologically contaminated soils at the bottom of the ponds is comparable, even if less intense, to waste previously treated by portland cement fixation. Hypothetically, after excavation the contaminated soils may be stockpiled, mixed with cement, and formed in solid blocks for storage. However, this and all other currently available methods to accomplish remediation of a site contaminated with radionuclides when the "delay and decay" method is impractical will result in the production of further waste materials, the nature of which is possibly different than the original waste.

Although the treatment option would reduce residual risks at the K-1407-B/C Ponds site, it would increase the risk associated with treating, handling, and storage of the waste. Furthermore, this option would create the need for long-term management of containerized waste. While such treatment would be consistent with CERCLA preference for treatment as a principal element to remediate threats at the site, it would be inconsistent with CERCLA preference for permanent solutions (the waste would still exist, would be stored above ground, and would still require management) and preference for in situ treatment of waste and minimization of waste by-products resulting from remedial action. In a practical sense, the real overall advantage that solidification could offer with regard to risk reduction is questionable.

Because current technology does not offer a means to effectively treat residual radiological contamination such as that found at the K-1407-B/C Ponds site, the treatment of principal threats is deemed to be impracticable. Therefore, management of in situ residues is a more appropriate remedy at this site.

Engineering controls proposed under the fill/cap Alternatives 2, 3, 4, and 5, would effectively deactivate all direct exposure and soil pathways of exposure identified in the baseline risk assessment, to all receptors. All existing exposure pathways and accordingly all risk associated with each pathway would be eliminated. The effectiveness of the fill/cap remedies is evidenced by RESRAD computer modeling conducted as part of the RI/FS for the K-1407-B/C Ponds. The RESRAD computer code was developed as a compliance tool to develop residual contamination guidelines at DOE facilities. RESRAD modeling conducted for the K-1407-B/C Ponds and included in the RI/FS report show that the effectiveness of the engineered fill option would be sufficient to maintain exposure levels within DOE guidelines for at least 10,000 years (the maximum span for which the model was run), even without maintenance (DOE 1992a). For the foreseeable future, the integrity of the fill/cap options would be enhanced by regular surveillance and maintenance as part of ongoing operations at the K-25 Site.

Although engineering controls proposed under Alternatives 2, 3, 4, and 5 would effectively deactivate all direct exposure and soil pathways of exposure identified in the baseline risk assessment, the continued presence of residual soil contamination on-site represents a potential threat for the hypothetical future on-site resident. Therefore, institutional controls are considered a component of all of these alternatives.

The purpose of institutional controls at the K-1407-B/C Ponds is to prevent the inadvertent exhumation of the residual soil contamination buried under the soil cover. Further discussion of the protection provided by Alternatives 2 through 5 to the hypothetical future on-site resident in the absence of institutional controls is given in the *Summary of Comparative Analysis of Alternatives* section of this ROD. It is worth mentioning that, while excavation and treatment of residual soil contamination at the K-1407-B/C Ponds would eliminate the need for institutional controls on a site-specific basis, the stored waste would create a hazard for which the implementation and maintenance of institutional controls would still be necessary.

The implementation of institutional controls requires the use of physical barriers or legal restrictions or both. The K-1407-B/C Ponds are inside the perimeter fence of the K-25 Site, a DOE facility with controlled access. As long as K-25 is under the jurisdiction of the U.S. government, residential use of the property can easily be avoided through controlled access. If the property is released in the future and the preclusion of residential use is deemed necessary, this preclusion may depend more on legal restrictions than on physical means of access control. For instance, if the ORR were to become a wildlife refuge, the problem of avoiding residential use may solve itself. Otherwise, covenants and deed restrictions can be implemented as customary with the transfer of any commercial property. It is reasonable to express a realistic and effective commitment to the premise that physical institutional controls will be maintained as long as the property is owned by the U.S. government and that legal provisions for the prevention of residential land use will be part of any property release agreement, in accordance with Sect. 120(h) of CERCLA, as amended.

Institutional controls, reopeners, and contingencies to ensure that the remedy remains effective, to be agreed upon with the state, will be implemented. For example, under DOE Order 5400.5 the selected remedy is considered restricted closure. Therefore, if at any point in the future unconditional release of the site becomes a possibility, DOE (or its successor) shall conduct a review of the remedy and current site conditions prior to transfer of the K-25 Site from DOE (or its successor) to another person or entity. Any property transfer will follow the procedure outlined in the *Federal Facility Agreement for the Oak Ridge Reservation* (hereafter referred to as the FFA) (DOE 1992d), Sect. XLIII, Property Transfer. Additionally, because this remedy will result in hazardous substances remaining on-site above health-based levels, a review will be conducted every 5 years, beginning within 5 years after commencement of the remedial action, to ensure that the remedy continues to provide adequate protection of human health and the environment, in accordance with CERCLA 121(c).

Each alternative in this section is evaluated for compliance with applicable or relevant and appropriate requirements (ARARs) and to be considered (TBC) guidance for the remediation of the K-1407-B/C surface impoundments. Those ARARs considered applicable for the remediation of the ponds are those pertaining to floodplain protection [10 CFR 1022 and 40 CFR 6 (Appendix A)], RCRA clean closure (40 CFR 265), on-site construction/excavation [Tennessee Code Annotated (TCA) Sect. 1200-3-8], fugitive dust control (TCA Sect. 1200-3-8.01), and surface water control (40 CFR 122, TCA Sect. 1200-4-3). DOE orders regulating exposure and long-term management and disposal of residual waste, while not regarded as ARARs, are treated as TBC guidance and/or criteria. The wetlands survey conducted for the site indicated that there are no wetlands areas present in the K-1407-B or -C Ponds. Pending concurrence with this finding from the U.S. Army Corps of Engineers (USACE), regulations pertaining to wetlands [10 CFR 1022 and 40 CFR 6 (Appendix A)] are not ARARs for this site. A detailed evaluation of ARAR compliance is presented for each alternative description in this section, and a comparison of alternative ARAR compliance is presented in the *Summary of Comparative Analysis of Alternatives* section of this ROD.

Alternatives 2 through 5 each would meet the exposure limits of DOE Order 5400.5. This order generically sets guideline exposure limits for all radionuclides except ^{226}Ra, ^{228}Ra, ^{230}Th, and ^{232}Th, for which activity guidelines are set. The exposure limits are satisfied by the elimination of exposure pathways. Although the specific activity limits for ^{230}Th are exceeded in some areas of the K-1407-B Pond, there will be no risk from this contaminant after taking necessary control measures at the site. However, the K-1407-B/C Ponds will be revisited by DOE or its successor with regard to residual radiological contamination if unconditional release of the property becomes a possibility in the future, and any property transfer will follow the procedure outlined in the FFA (DOE 1992d), Sect. XLIII, Property Transfer.

Common Assumptions for Alternatives 2 through 5

Components of the conceptual design common to Alternatives 2 through 5 are summarized below. This list includes assumptions and activities for these remedial alternatives.

- The K-1407-B Pond would be dewatered before and during backfill operations, except for Alternative 2.
- Silt fences and other erosion control devices will be employed as necessary.
- Surface water diversion is included as a percentage of the total cost; design of necessary control works will take place at a later stage.
- No roads other than temporary access roads will be built.
- Minimal dust suppression measures will be implemented as required for the haul roads.
- If removed, it is likely water from the K-1407-B Pond will be processed through the CNF.
- Health and Safety personnel will monitor the site and workers.
- All alternatives include surface contouring and revegetation as applicable.

- Construction equipment used during operations will be decontaminated on-site if required.
- Work will be done in Level D protective equipment.
- All borrow soils and clays will be taken either from the West Borrow Area, approximately 11 km from the site (21 km round trip), or from a site with similar soil properties. Rock borrow is also available in the vicinity of the K-1407-B/C Ponds site.
- The in-place density of the soils in the borrow area is assumed to be 125 lb/ft^3.

Specific design criteria for the K-1407-B/C Ponds will be developed during the remedial design phase. The following description of alternatives uses the design assumptions established in the RI/FS (DOE 1992a). All estimates for soil and rock fill and soil excavation are based on generalized assumptions; actual volumes could vary significantly during the design/construction phase of remediation.

For the purpose of cost comparisons, present worth was calculated for a 30-year period for each alternative. However, the use of this 30-year period does not infer that the site will necessarily be suitable for release from institutional controls at the end of that period. It is recognized that institutional controls, consisting of the use of physical barriers, legal restrictions, or both, will remain as long as unacceptable risks exist at the site. Institutional controls may be required at the site for a period substantially longer than 30 years.

Alternative 1—No Action

CERCLA requires that the no-action alternative be evaluated to serve as a baseline for comparison. This alternative would not mitigate current or future potential risk of the site through soil or surface water pathways and does not comply with DOE Order 5400.5 regarding exposure limits or DOE Orders 5400.5, Chapters II and IV, and 5820.2A regarding long-term management of residual radioactive contamination left in place.

Alternative 2—Engineered Rock Fill

This alternative consists of filling the K-1407-B Pond with coarse, granular material (crushed rock) and filling the K-1407-C Pond with engineered compacted soil. It is estimated that 63,000 yd^3 of soils and 14,000 yd^3 of crushed rock would be placed in the ponds for the implementation of Alternative 2.

For the K-1407-B Pond, rock fill is a suitable backfill material that can be placed in its waterlogged environment without difficulty. It is expected that displaced water will flow away naturally as groundwater, establishing a dry surface above the water table. Soil will then be applied over the rock fill; it will be graded; and vegetation will be planted.

The K-1407-C Pond, unlike the K-1407-B Pond, is not waterlogged. Because compacted soil is more cost-effective than crushed rock fill, the K-1407-C Pond would be filled with compacted borrow soil; its surface would also be graded and planted with vegetation. The borrow soil will be spread in thin lifts and compacted to specification with rollers or vibratory compactors. Placement of fill is monitored against prescribed technical specifications. Engineered-compacted fill must meet precisely defined in situ quality tests before its approval for use. Because of compaction and quality control, this fill is not subject to significant settlement; therefore, it requires little or no maintenance. Alternative 2 would not generate man-made by-product wastes that require management.

Flooding in the area would not compromise the remedial action taken at the ponds; therefore, 10 CFR 1022 and 40 CFR 6 (Appendix A) would be met. Final remediation under Alternative 2 would meet RCRA clean closure requirements (40 CFR 265). During construction, stormwater runoff controls (40 CFR 122, TCA Sect. 1200-4-3) and fugitive dust controls (TCA Sect. 1200-03-8.01) would be implemented. Alternative 2 would meet the exposure limits of DOE Order 5400.5 and comply with the requirements of 5400.5, Chapters II and IV, and 5820.2A regarding the long-term management of residual radioactive contamination left in place. No wetlands areas were identified in the ponds by the wetlands survey conducted for the site, and concurrence with this finding is expected from the USACE. If wetlands were determined to be present at the site, they would be destroyed by this alternative; however, mitigative measures would be taken to enhance other wetlands areas so no net loss of wetlands would occur, thus meeting 10 CFR 1022 and 40 CFR 6 (Appendix A).

Capital cost: $4.5 million
Annual Operations and Maintenance (O&M) cost: $33,000
Present worth cost over 30 years: $5.0 million
Months to implement: 15

Alternative 3—Engineered Fill

The K-1407-B Pond would be dewatered, and the ponded water would be pumped to and processed at the CNF. This alternative would entail placing an estimated 75,000 yd^3 of compacted fill, grading materials, and soils over existing empty impoundments for filling, contouring, drainage control, and revegetation. This alternative would require water treatment at CNF but would not generate other by-product wastes that require management. Compliance with ARARs and TBCs would be the same for Alternatives 3 as for Alternative 2.

Capital cost: \$5.5 million
Annual O&M cost: \$33,000
Present worth cost over 30 years: \$6.0 million
Months to implement: 15

Alternative 4—Backfill and Clay Cap

The K-1407-B Pond would be dewatered, and soil fill would be emplaced to the appropriate engineering specifications in both ponds before placement of a clay cap. A clay cap would act as a hydraulic barrier, adding a measure of protection from infiltration of rain and surface waters to the backfilled pond. This cap is an engineered-compacted fill layer that must meet both structural and hydraulic performance criteria for acceptance. While compacted backfill must meet specifications aimed primarily at structural performance, a clay cap also must achieve a very low in situ permeability—the lower the permeability to water, the more impervious the cap. Usually, this cap is a 2-ft or thicker clay layer placed on top of the backfill. Construction of an impervious clay cap is a labor-intensive process with stringent engineering requirements. Construction of a sufficiently impervious cap demands well-specified methods and material selection practices, and results must be verified by in situ testing.

The placement of a 2-ft-thick native soil and topsoil layer above the cap will protect it from excessive changes in temperature and freeze-thaw cycles, which can compromise its integrity. This alternative would entail placing an estimated 90,000 yd^3 of compacted fill, clay, grading materials, and soils over the existing empty impoundments for filling, contouring, lining, drainage control, and revegetation. This alternative would require that the water from the K-1407-B Pond be treated at the CNF but would not generate by-product wastes that require management.

Alternative 4 meets DOE Orders 5400.5 and 5820.2A with regard to exposure limits and the long-term management of residual radioactive contamination left in place, RCRA clean closure requirements (40 CFR 265), and floodplain/wetlands regulations [10 CFR 1022 and 40 CFR 6 (Appendix A)], as described in Alternatives 2 and 3. Alternative 4 utilizes the NCP hybrid closure guidance [52 FR 8712 and 53 FR 51446]. The NCP hybrid closure guidance makes use of RCRA [40 CFR 265.228 (a)(2)] requirements for closure with waste in place, i.e., closure and post closure care requirements. These are considered TBC guidance for implementation of a modified RCRA cap in the instance where no hazardous waste remains.

Capital cost: \$6.3 million
Annual O&M cost: \$33,000
Present worth cost over 30 years: \$6.8 million
Months to implement: 15

Alternative 5—Five-Component Cap

EPA provides detailed technical guidance for the design of this type of cap, as explained in the RI/FS document. A composite five-component cap is very impervious and would be a conservative means of isolating the remaining contaminants. The cap is designed in five parts, each having a specific function to enhance the cap's reliability. The cap includes a composite clay and synthetic liner impervious layer, which enhances the effectiveness of clay. This membrane, also called a flexible membrane liner, is a continuous sheet of a synthetic polymer impervious to gas and liquids. A five-component cap requires specialized personnel for installation and must comply with demanding performance standards. This type of cap is used mostly on landfills or where a closure with waste in place is planned from the inception. It is intended as the "lid" for zero discharge waste disposal sites, where waste is completely isolated from the environment. Its effectiveness for this site is very similar to that of Alternative 4.

This alternative would entail placing an estimated 90,000 yd^3 of compacted fill, clay and grading materials, and soils over the existing empty impoundments for filling, contouring, lining and drainage control, and revegetation. An estimated 180,000 ft^2 of composite cap would be installed. Material for drainage and filter layers would be needed—possibly 6,000 yd^3 of natural materials or 360,000 ft^2 of geosynthetic materials. This alternative does not generate by-product wastes.

Alternative 5 meets DOE Orders 5400.5 and 5820.2A requirements regarding exposure limits and the long-term management of residual radioactive contamination left in place, RCRA clean closure regulations (40 CFR 265), and floodplain/wetlands requirements [10 CFR 1022 and 40 CFR 6 (Appendix A)], as described in Alternatives 2 and 3. Alternative 5 also utilizes the NCP hybrid closure guidance (52 FR 8712 and 53 FR 51446) and RCRA requirements for an impervious cap [40 CFR 265.228 (a)(2)]; these are considered TBC guidance.

Capital cost: $8.4 million
Annual O&M cost: $52,000
Present worth cost over 30 years: $9.1 million
Months to implement: 15

Alternative 6—Excavation and Treatment

Excavating the contaminated soils would involve removing a few feet of soil from the side slopes and the bottoms of the K-1407-B/C Ponds. The soil matrix would then be immobilized through fixation in a free-standing solid to allow storage, minimize contaminant mobility, and reduce the health risk associated with the fixed waste. The technology of fixation by means of portland cement and a sorbent was assumed for the cost estimate, but any applicable technology may be used. A different system would not necessarily entail the same costs estimated here.

This alternative is a contingent plan for the remediation of the ponds; if other actions prove infeasible, it would be reconsidered. If this alternative is selected, treatability and the extent of contamination will need further investigation. After removal, the excavation would be backfilled to reclaim the use of the surface. Engineered compacted fill would be acceptable and suitable for backfilling.

The exact volume of contaminated soils to be excavated is uncertain. The excavation and solidification of an estimated 21,000 yd^3 of contaminated soils was assumed. This volume of soil would generate an estimated 30,000 yd^3 of solidified, low-level waste by-product for long-term storage. Management of this waste is a long-term liability that is difficult to evaluate. Backfilling involves placing at least 70,000 yd^3 of clean fill, depending on surface runoff control and the volume of fill required to restore the site.

Alternative 6 meets RCRA clean closure regulations (40 CFR 265), and floodplain/wetlands requirements [10 CFR 1022 and 40 CFR 6 (Appendix A)], as described in Alternatives 2 and 3. Alternative 6 would remove the source of contamination, meeting compliance with DOE Order 5400.5 requirements for exposure limits and the requirements for management and disposal of waste containing residual radioactive contaminants in 5400.5, Chapters II and IV, and 5820.2A. A storage area for the excavated soil is available on-site (DOE Orders 5400.5 and 5280.2A). Stormwater runoff controls (40 CFR 122, TCA Sect. 1200-4-3) and fugitive dust controls (TCA Sect. 1200-3-8.01) would be implemented.

Capital cost: $13 million
Annual O&M cost: $30,000
Present worth cost over 30 years: $13.4 million
Months to implement: 15

SUMMARY OF COMPARATIVE ANALYSIS OF ALTERNATIVES

EPA has established nine evaluation criteria as described in *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988b) for the evaluation of remedial alternatives at CERCLA sites. These nine criteria are organized into three groups:

- **Threshold Criteria**—These criteria relate to statutory findings and address (1) overall protection of human health and environment and (2) compliance with ARARs.
- **Primary Criteria**—These criteria address the performance of the remedial alternative. They also verify that the alternative is realistic. The primary criteria are (3) long-term effectiveness and permanence; (4) reduction in toxicity, mobility, or volume through treatment; (5) short-term effectiveness; (6) implementability; and (7) cost.
- **Modifying Criteria**—The viability of the solution is evaluated based on (8) state agency acceptance and (9) community acceptance.

Threshold Criteria

Overall Protection of Human Health and the Environment—The assessment against this criterion describes how the alternative as a whole achieves and maintains protection of human health and the environment.

Compliance with ARARs—The assessment against this criterion describes how the alternative complies with ARARs or, if a waiver is required, how it is justified. The assessment also addresses other information from advisories, criteria, and guidance that the lead and support agency have agreed is TBC.

Primary Criteria

Long-Term Effectiveness and Permanence—The assessment of alternatives against this criterion evaluates the long-term effectiveness of alternatives in maintaining protection of human health and the environment after response objectives have been met.

Reduction of Toxicity, Mobility, or Volume Through Treatment—The assessment against this criterion evaluates the anticipated performance of the specific treatment technologies an alternative may employ.

Short-Term Effectiveness—The assessment against this criterion examines the effectiveness of alternatives in protecting human health and the environment during the construction and implementation of a remedy until response objectives have been met.

Implementability—This assessment evaluates the technical and administrative feasibility of alternatives and the availability of goods and services.

Cost—This assessment evaluates the estimated capital, O&M costs, and present worth cost for a life of 30 years of each alternative in 1991 dollars. The estimates are order of magnitude estimates that necessarily incorporate many assumptions. Although they are also useful for comparing alternatives, the uncertainty associated with them is significant.

Modifying Criteria

State Acceptance—This assessment reflects the state's apparent preferences or concerns about alternatives.

Community Acceptance—This assessment reflects the community's apparent preferences or concerns about alternatives.

The six remedial alternatives considered for the K-1407-B/C Ponds are evaluated against the nine CERCLA evaluation criteria in the following discussion. A summary comparison of the seven threshold and primary criteria against the six alternatives is presented in Table 2.16.

Overall Protection of Human Health and the Environment

Alternative 1, No Action, is not protective of and offers no reduction in risks to human health or the environment. Alternatives 2 through 5 provide protection from exposure to the contaminants remaining on-site through shielding and the management of contaminant migration. These alternatives do not remove the residual contamination but limit its effects through isolation. Alternative 6 protects human health and the environment at the K-1407-B/C Ponds site through source control by removal of the contaminants, but generates additional risks to human health and the environment associated with the removal, handling, and long-term storage of waste. Alternative 6, while reducing risk at the site-specific level, results in a transfer of risk and, therefore, may not represent an overall risk reduction.

For both the general plant employee and the on-site worker risk scenarios, the completed exposure pathways considered in the baseline risk assessment for the K-1407-B/C Ponds were ingestion of, dermal contact with, and inhalation of wind-generated dust. The general plant employee scenarios additionally included external exposure to radiation in dust; the on-site worker scenario additionally included exposure to ionizing radiation. Implementation of any of Alternatives 2 through 6 will effectively eliminate all these exposure pathways and the associated risk to receptors. Therefore, for the general plant employee and the on-site worker risk scenarios, Alternatives 2 through 6 are equally protective. The potential difference between the alternatives for overall protection of human health and the environment arises only for protection

Table 2.16. Evaluation of alternatives for remediation of the K-1407-B/C Ponds

No.	Alternative	Protection	ARARs	Effective-ness	Reduction by treatment	Short-term	Implement-ability	Cost
1	No Action	○	○	N/A	N/A	N/A	N/A	N/A
2	Engineered Rock Fill	✓	✓	✓	N/A	✓	✓	✓
3	Engineered Fill	✓	✓	●	N/A	✓	✓	●
4	Backfill and Clay Cap	✓	✓	●	N/A	✓	✓	●
5	Five-Component Cap	✓	✓	●	N/A	✓	✓	●
6	Excavation and Treatment	✓	✓	✓	○	●	✓	●

○ = *Unsatisfactory* ● = *Intermediate* ✓ = *Good* N/A = *Not Applicable* offered to the hypothetical future on-site resident in the comparison of Alternatives 2 through 5 with Alternative 6.

Completed exposure pathways considered in the baseline risk assessment for the on-site resident risk scenario at the K-1407-B/C Ponds were ingestion of soil, dermal contact with soil, inhalation of wind-generated dust, external exposure to soil radiation, ingestion of groundwater, dermal contact with groundwater while showering, inhalation of volatiles while showering, and ingestion of homegrown produce. Total excess cancer risks estimated in the baseline risk assessment for the on-site resident are 1×10^{-2} and 7×10^{-3} for the K-1407-B and K-1407-C Ponds, respectively.

Alternatives 2 through 5, although different in terms of engineering design, are equal in the protection of human health and the environment. Because Alternative 6 represents source control by removal of the contaminants, there are different ramifications for overall protection for the on-site resident than for Alternatives 2 through 5. In evaluating the true effectiveness of Alternative 6, it is necessary to evaluate (1) the reduction of risk that would occur as a result of its implementation, (2) the chance that baseline risk conditions for the on-site resident could be realized at the site in the future, and (3) the additional risks generated by implementation of the alternative.

Alternative 6 would eliminate the potential for cross-contamination and migration of contaminants from the pond soils in groundwater at the K-1407-B/C Ponds site. However, the analysis of contaminant migration, based on the comparison of data for K-1407-B/C Pond soils and monitoring wells and the computer-simulated modeling indicate that there is very little risk associated with migration of contaminants in the groundwater from the pond soils. Groundwater migration of contaminants from the K-1407-B/C Pond soils into groundwater does not appear to represent a significant risk even for the most conservative assumptions. Accordingly, the excavation of residual soil contamination under Alternative 6 would not result in a meaningful reduction of risk for groundwater pathways for the on-site resident scenario.

The protection afforded by Alternative 6 would be primarily from the elimination of direct exposure to ionizing radiation and the elimination of contact to contaminants in the soil for all exposure pathways by removing contamination. However, the true protection provided by excavation and removal under this alternative must take into account the realistic probability of future exposure to baseline risks at the site. The conservative approach to evaluating the maximum risk to human health for future scenarios is to assume that a future on-site resident could reestablish baseline conditions and thereby be exposed to baseline risks at the site. However, if the ponds were filled, this would be highly unlikely to occur even with residual soil contamination left in place; a combination of highly improbable events would be necessary to reestablish baseline conditions.

To reestablish baseline conditions at the site, the future on-site resident would have to excavate the pond(s) to its original depth to build a residential structure and plant a garden. For the K-1407-B Pond, this would involve excavating to a level below the water table and through many feet of rock fill that would be present from the implementation of the proposed remedy for the site. For both the K-1407-B and K-1407-C Ponds, placing a house below the 100-year flood plain would be required.

Even assuming such construction activities were to occur, the level of excavation would have to coincide almost perfectly with the current level of the pond bottoms for the on-site resident to be exposed to baseline risk conditions. To be exposed to the total risks from ingestion of homegrown produce, the root systems of crops would have to be situated within a narrow 1-ft zone of maximum contaminant concentration. Even if the considerable obstacles were overcome to build a residential structure and plant a garden in the original pond bottoms, crops probably could not grow because of the poor agricultural nature of the soils.

The construction of a single-level residential structure in either the K-1407-B or -C Pond would in all likelihood involve the excavation of no more than a few feet of soil. Based on the proposed thickness of pond fill, an excavation of such a depth would not reach the site's soil contamination and, therefore, would not result in the completion of the soil exposure pathways considered in the baseline risk assessment for the on-site resident. The construction and occupancy of a basement home could create a greater potential for exposure to soil contaminants at the site than a single-story dwelling. However, occupancy of such a structure would not approximate baseline risk conditions because shielding offered by the walls and floor of the basement area would eliminate or drastically reduce soil pathways.

Aside from the practical and physical obstacles to reestablishing baseline conditions at the site in the future, the role of institutional controls must be considered. Realization of the hypothetical future on-site scenario must assume that there would be unlimited use of the site if institutional controls were lifted. However, it is reasonable to assume that institutional controls will be in force at the site as long as it is held by DOE. Furthermore, DOE's future release of any property, particularly property with residual contamination, would carry restrictions regarding the use of the land, and any property transfer will follow the procedure outlined in the FFA (DOE 1992d), Sect. XLIII, Property Transfer. Because of their widespread acceptance and enforceability, future restrictions to land use warrant consideration of their ability to limit future exposure to residual site contamination. The institution of such legally binding obligations would serve to further reduce the likelihood of future human exposure to residual contamination at the site.

In assessing the overall protectiveness of Alternative 6, it is important to recognize that the removal of residual soil contamination from the K-1407-B/C Ponds would not resolve the issue of institutional control for waste generated from the site. Because no effective technology for the detoxification of radioactive material exists, the exhumation of the residual radiological contamination from the bottom of the K-1407-B/C Ponds and its transformation into a different form of waste would suffer from the same complications associated with institutional controls at the ponds site. To protect public health and the environment, it would be much safer for residual radiological contamination to remain at the bottom of the ponds, below 10 ft of soil cover, than to be stored in any manner above surface should institutional controls fail at some future time. Accordingly, there are greater potential problems associated with institutional controls for the storage of the exhumed waste above surface than for residual contamination left in place.

Alternative 6 does not offer advantages for the overall protection of human health and the environment when compared to Alternatives 2 through 5 because (1) it is extremely improbable that baseline conditions could ever be established at the K-1407-B/C Ponds at any time in the future even in the absence of institutional controls, (2) there is the high likelihood that institutional controls will prevail at the site even in the case of property transfer, and (3) the excavation, handling, and long-term storage of waste will generate a potential risk to human health and the environment. Conversely, the implementation of Alternative 6 could actually result in an increase of risk, especially in the absence of institutional controls for the long-term storage of waste at the surface.

In summary, Alternatives 2 through 5 provide protection at least equal to Alternative 6 for all human risk scenarios.

Compliance with ARARs

There are no chemical-specific ARARs for the cleanup of contaminated soils at the K-1407-B/C Ponds associated with any of the alternatives. There are several location-specific and action-specific ARARs pertinent to the remediation of the ponds that are associated with all the alternatives as shown in Table 2.17.

The ponds are located within the 100-year and 500-year floodplain areas. Therefore, location-specific federal and state ARARs for the protection of floodplains are applicable to all alternatives and must be met for any remedial activities taken in the K-1407-B/C Ponds area. The wetlands survey conducted for the site indicated that no wetlands areas are present in the K-1407-B/C Ponds; concurrence with this finding is expected from USACE. However, if any

Table 2.17. Comparison of compliance for each alternative for the K-1407-B/C Ponds with ARARs and TBCs

Regulations and guidance	ARAR	TBC	Alternative 1 No action	Alternative 2 Engineered rock fill	Alternative 3 Engineered fill	Alternative 4 Backfill and clay cap	Alternative 5 Five-component RCRA cap	Alternative 6 Excavation and treatment
Radiation Protection of the Public and Environment: DOE Order 5400.5		✓[a]	-	+	+	+	+	N/P
Long-term management of residual radioactive contaminants left in place: DOE Order 5400.5 Chapter II and IV, DOE Order 5820.2A		✓[a]	-	+	+	+	+	N/P
Floodplain protection: 10 CFR 1022, and 40 CFR 6 (Appendix A)	✓		+	+	+	+	+	+
Wetlands protection: 10 CFR 1022, and 40 CFR 6 (Appendix A)	*		*	*	*	*	*	*
Removal or decontamination of all waste residues and contaminated subsoils at interim status surface impoundments: 40 CFR 265.228(a)(1); TCA §1200-1-11-.05(11)(g-1)	✓		+	+	+	+	+	+
RCRA closure and postclosure care requirement: 40 CFR 265.228(a)(2)		✓	N/P	N/P	N/P	+	+	N/P
NCP hybrid closure guidance[b]		✓	N/P	+	+	+	+	N/P
On-site construction/excavation: Control of fugitive dust emissions: TCA §1200-3-8.01	✓		N/P	+	+	+	+	+
Surface water control: 40 CFR 122, TCA §1200-4-3	✓		+	+	+	+	+	+

Table 2.17 (continued)

Regulations and guidance	ARAR	TBC	Alternative 1 No action	Alternative 2 Engineered rock fill	Alternative 3 Engineered fill	Alternative 4 Backfill and clay cap	Alternative 5 Five-component RCRA cap	Alternative 6 Excavation and treatment
Stormwater discharges associated with construction activity at industrial sites (disturbed site is 5 acres or more): TCA §1200-4-10-.05	✓		N/P	+	+	+	+	+
Stormwater discharges associated with industrial activities: 40 CFR 122, TCA §1200-4-10-.04	✓		+	+	+	+	+	+

+ =meets ARAR or TBC guidance -=does not meet ARAR or TBC guidance N/P=not pertinent

*=The wetlands survey conducted for the site indicated that there are no wetlands areas present at the K-1407-B/C Ponds and the USACE is expected to concur with this finding. However, if wetlands were determined to be present at the site, then ARARs pertaining to wetlands would be met.

ARAR = applicable or relevant and appropriate requirement
CFR = Code of Federal Regulations
FR = Federal Register
TBC = to be considered
TCA = Tennessee Code Annotated
TDEC = Tennessee Department of Environment and Conservation
USACE = U.S. Army Corps of Engineers

[a]DOE, while not ARARs, are treated as TBC guidance and/or criteria.

[b]This hybrid closure TBC guidance comes from the proposed rule found in 52 FR 8712 and discussed as an option in 53 FR 51446. RCRA also implies that the same type of hybrid closure is acceptable [40 CFR 265.228 (a) and (b)].

wetlands were present at the site, they would be destroyed by the implementation of Alternatives 2 through 6. In this case, mitigative measures would be taken to enhance other wetlands areas so no net loss of wetlands would occur, thus meeting 10 CFR 1022 and 40 CFR 6 (Appendix A).

The action-specific ARARs for closure of the ponds includes 40 CFR 265.228(a)(1), which details the requirements for RCRA clean closure and applies to all alternatives. There are several action-specific ARARs that apply to the construction and implementation of Alternatives 2, 3, 4, 5, and 6. These include Tennessee state regulations and Clean Water Act regulations requiring that surface water runoff and stormwater discharge during construction activities at industrial sites be controlled and monitored; the surface water runoff must meet the substantive requirements of the state stormwater discharge permit. Tennessee regulations also require that fugitive dust emissions be controlled during site construction and excavation. DOE orders, while not regarded as ARARs, are treated as TBC guidance and/or criteria.

Nuclear Regulatory Commission (NRC) regulations are not considered applicable for CERCLA remediation of DOE facilities but are considered potentially relevant and appropriate. However, none of the NRC regulations are relevant and appropriate for the proposed remedial action at the K-1407-B/C Ponds. For the purposes of this closure, DOE Order 5400.5, Radiation Protection of the Public and the Environment, must be met. Under this DOE order, the remedial action may be considered a restricted closure if residual radioactive contamination remains in place. If unconditional release of the property becomes a possibility in the future, any property transfer will follow the procedure outlined in the FFA (DOE 1992d), Sect. XLIII, Property Transfer.

While the no-action alternative meets the location- and action-specific ARARs, it clearly does not meet DOE orders for radiation protection. Alternatives 2, 3, 4, 5, and 6 comply with all the location-specific and action-specific ARARs (see Table 2.17 and the *Description of Alternatives* section of this report). Compliance with ARARs and TBCs for Alternative 2, the selected remedy for the K-1407-B/C Ponds, is further discussed in the *Selected Remedy, Compliance with ARARs and TBCs* section of this report.

Long-Term Effectiveness and Permanence

Alternative 1 provides no long-term effectiveness, but present conditions at the K-1407-B/C Ponds are not likely to worsen in the long-term if no action is taken. Risk due to airborne contamination may actually be reduced by further growth of vegetation. The risks posed by ^{137}Cs and ^{99}Tc will naturally abate through radioactive decay and dilution within the soil horizon. This natural abatement would result in the reduction of risk at the site by a full order of magnitude (to 3×10^{-3}) over a 100-year span. However, the baseline risk assessment conducted for the K-1407-B/C Ponds shows that the hypothetical on-site resident who lives on-site for 30 years (the national upper-bound residency term for baseline risk assessment estimates) is estimated to have 1 chance in 50 of developing cancer from exposure to contaminants present on-site (risk of 2×10^{-2}). Alternative 1 does not provide any reduction of this risk to human health or the environment and, therefore, is unacceptable.

Engineering controls proposed under Alternatives 2, 3, 4, and 5 would effectively deactivate all the direct exposure and soil pathways of exposure identified in the baseline risk assessment to all receptors. All existing exposure pathways and all risk associated with each pathway would be eliminated. The effectiveness of the fill/cap remedies is evidenced by RESRAD computer modeling conducted as part of the RI/FS for the K-1407-B/C Ponds. The RESRAD computer code was developed as a compliance tool to develop residual contamination guidelines at DOE facilities. RESRAD modeling conducted for the K-1407-B/C Ponds indicated that the protection offered by the engineered fill option would be sufficient to maintain exposure levels within DOE guidelines for at least 10,000 years (the maximum span for which the model was run), even without maintenance. For the foreseeable future, the integrity of the fill/cap options would be enhanced by regular surveillance and maintenance as part of ongoing operations at the K-25 Site.

Rock fill incorporated as a stable subgrade as part of Alternative 2 would not be compromised by time or by long-term exposure to groundwater. The soil cover above the rock fill would be graded for effective drainage and vegetated, and would enhance the effectiveness of the rock fill as a means to deactivate pathways of exposure. Hence, the soil cover would add to the reliability of this alternative and to its effectiveness.

Risks to the hypothetical future on-site resident subsequent to the implementation of Alternative 2 are estimated to be negligible because all exposure pathways, with the exception of groundwater-related pathways, would be eliminated because (1) contaminated dust will no longer be generated, (2) roots of homegrown garden produce are not expected to extend into the contaminated layer, and (3) the alternative will effectively shield individuals from external exposure to ionizing radiation. Excess cancer risk subsequent to the implementation of Alternative 2 would be below the EPA threshold of concern ($< 1 \times 10^{-6}$). Systemic toxicity after remediation would be absent and background conditions would be reestablished.

PRGs for reducing risk to acceptable levels would be met by reducing the exposure of potential human receptors to contamination, as opposed to reducing the level of contamination; the contaminants would remain in place, but the exposure pathways would be eliminated. After placement of clean fill material, the level of exposure to contamination for the potential human receptor, including the on-site resident, would be no greater than background.

External exposure to ionizing radiation would be reduced to background levels by physical shielding of the radionuclides in the pond soils with the fill material. Intake of contaminants by way of produce ingestion would be eliminated because the roots of plants grown for food will not extend through fill material to reach the contaminated pond soils. Incidental ingestion of contaminated soils and inhalation of contaminated soils as dust would not be possible because the soils will be inaccessible.

The only potential negative ecological impact subsequent to the implementation of Alternative 2 is the possibility of phytotoxicity from plant uptake of contaminants present in the substrate. The application of clean backfill is expected to provide a sufficient barrier to root uptake of contaminants by grasses and shrubs. However, this barrier may not be sufficient to prevent root uptake of some contamination by trees.

Similar to the rock fill under Alternative 2, engineered fill of Alternative 3 is not subject to significant long-term subsidence, and any settling of the foundations would probably be manageable. Surface vegetation would help to minimize erosion of the cover, thereby preserving the contour of the graded surface and drainage conditions. However, engineered fill is not an impervious medium, and infiltration and percolation do occur. Post-remediation conditions and residual risk for Alternative 3 is comparable to that of Alternative 2.

The long-term preservation of effectiveness for Alternative 4 appears possible with minimum regular maintenance. Original drainage conditions would be maintained and the presence of a hydraulic barrier provided by the clay cap would reduce surface water infiltration and percolation rates. The addition of this hydraulic barrier would be expected to eliminate the percolation of meteoric water through the vadose zone. However, because of the low potential for contaminant migration indicated by the RI/FS, the elimination of surface water infiltration is not viewed as an advantage in reducing the migration of contaminants through groundwater exposure pathways at the site. Furthermore, there would be little conceivable advantage in reducing surface water infiltration at the K-1407-B Pond where the residual contamination is found mainly below the water table. It is assumed that no improvement to the risk to human health and the environment at the site is derived from the construction of an impervious barrier, as compared to the reduction already achieved by Alternatives 2 and 3. Therefore, post-remediation risk for Alternative 4 is comparable to that of Alternatives 2 and 3.

Alternative 5 offers a potential increase in long-term reliability with the implementation of a five-component RCRA cap. Initial excellent drainage conditions provided by the system would be maintained; the presence of a composite impervious liner completely eliminates infiltration and percolation. However, reservations about the usefulness of a hydraulic barrier at the site are the same as for Alternative 4. The residual risk exposure associated with Alternative 5 is equivalent to that of Alternatives 2, 3, and 4.

Under Alternative 6, the excavation of radiologically contaminated soil would eliminate the source of toxicity at the ponds site. It can be assumed that residual risk at the site would be reduced to acceptable levels. However, there is no currently available technology for the effective treatment of residual radioactive waste such as found at the K-1407-B/C Ponds. Any treatment would subsequently require storage of waste by-products. This generates an onerous long-term commitment and the potential necessity of further treatment.

This alternative would generate risks associated with the excavation, handling, and long-term storage of waste. Alternative 6, therefore, has the net effect of transferring, rather than reducing, risk associated with residual contamination from the K-1407-B/C Pond soils. The long-term effectiveness and permanence for the K-1407-B/C Pond site under Alternative 6 would be good. However, the long-term effectiveness and permanence for the by-product waste is considered to be poor; the need would be created for storage, handling, and possibly additional treatment in the future. In terms of ecological risk, Alternative 6 would be somewhat better than Alternatives 2 through 5; however, the existing risk to ecological receptors at the site is considered to be negligible.

Although engineering controls would effectively deactivate all direct exposure pathways and soil pathways of exposure at the K-1407-B/C Ponds, some CERCLA hazardous substances would remain on-site for Alternatives 2, 3, 4, and 5. Therefore, these alternatives would be subject to the 5-year review period mandated in Sect. 121(c) of SARA and Sect. 105 of CERCLA 40 CFR 300.430, Final Remedy Selection. This review would be augmented by data provided from post-remediation groundwater monitoring to be conducted at the K-1407-B/C Ponds subsequent to implementation of the remedial action.

Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 1, no action, does not employ treatment or confinement of contaminants and achieves no direct or immediate reduction of toxicity, mobility, or volume of contamination. With time, the toxicity of the residual contamination in the K-1407-B/C Pond soils would be reduced by radioactive decay and dilution of contaminant concentrations in soils, and the migration of airborne contamination might be reduced by the spontaneous growth of vegetation.

Alternatives 2 through 5 involve the placement of fill into the existing impoundments; Alternatives 4 and 5 additionally include the emplacement of caps over the fill. No reduction of toxicity, mobility, or volume of residual soil contamination is achieved through treatment for these alternatives. However, mobility is reduced by physical means of confinement of the contaminated soils. There are varying implications for Alternatives 2 through 5 for the infiltration of surface waters and the associated potential for leaching of contaminants for the K-1407-B/C Ponds.

Alternative 3 offers a reduction in surface water percolation rates for the K-1407-B Pond compared to Alternative 2 because the soil fill subgrade for Alternative 3 would be less conducive to infiltration than the rock fill subgrade of Alternative 2. Alternative 4 and 5 would reduce surface water infiltration at both ponds compared to Alternatives 2 and 3; surface water infiltration would be curtailed by means of an impervious cap or liner. Therefore, Alternative 3 would offer a reduction in the infiltration of surface waters and the associated potential for leaching of residual soil contaminants when compared to Alternative 2 for the K-1407-B Pond, and Alternatives 4 and 5 would eliminate this potential altogether for both ponds.

However, the analysis of contaminant migration conducted as part of the K-1407-B/C Ponds RI/FS indicates a limited potential for leaching and migration of residual soil contamination at the site. Accordingly, surface water leaching of soil contaminants and the resultant contribution to groundwater contaminant migration is not viewed as posing any significant potential for the contaminant migration. The reduction of surface water infiltration by the emplacement of an impervious cap or liner would not result in a meaningful reduction in contaminant migration. Furthermore, the reduction of surface water infiltration at the K-1407-B Pond would be meaningless since most of the contaminated soil is below the water table.

Alternative 6 would achieve a reduction in the volume of contaminated soils at the K-1407-B/C Ponds by excavation and removal and would reduce or eliminate the issues of mobility and toxicity for the ponds site. However, the excavated by-product waste would be toxic, and there is no currently available method to effectively reduce the toxicity of residual radiological contamination such as that found at the K-1407-B/C Ponds. Treatment of excavated waste would pursue reduction of mobility through fixation. Such fixation would result in the generation of a considerably greater volume of low-level residual waste than that initially excavated. The waste properties would be irreversibly altered and thereby nullify the presently existing threat posed by the contaminants. However, a different type of waste with toxic properties would be created in quantities greater than those of the original waste. The excavation and fixation of the estimated 21,000 yd^3 of contaminated soils would likely result in no less than 30,000 yd^3 of solidified low-level radioactive waste.

Because of the lack of available technology, the alternatives proposed for remediation of the K-1407-B/C Ponds do not use treatment as a means to reduce the principal threat at the site. Therefore, management of in situ residues is a more appropriate remedy for this site.

Short-Term Effectiveness

Alternative 1, no action, would present no short-term risks in excess of baseline risk conditions estimated for the site. The implementation of Alternatives 2 through 6 would result in increased risk to human health and the environment related to construction, hauling, and treatment activities.

It is estimated that the implementation of Alternative 2 would require about three months of consecutive work days of suitable weather conditions, or the equivalent, for the completion of construction activities, with some variation for Alternatives 3 through 5 based on the complexity of the alternative. The short-term effectiveness of these alternatives is similar. In the short term, there is a possibility of negative cross-media impacts. During and after construction, the foundation of the ponds could undergo limited consolidation and settlement. The overburden imposed by the weight of the fill would compress pond subsoils, possibly causing pore water to spread.

Part of the contaminated pore water trapped in these soils, especially in the K-1407-B Pond, could be released to the environment, causing a temporary increase in contamination of surface water in the impoundments. The release of contaminated pore water could also cause a temporary increase in contaminant migration in the groundwater. However, any increase in contamination of surface or groundwater is expected to be temporary, limited to the immediate pond areas, and not to pose a significant threat to human health or the environment.

The implementation of Alternatives 2 through 5 would also require the transport of significant quantities of borrow materials. Road-related risk for the truck drivers hauling the fill material to the ponds site is evaluated at 1 chance in 1000 for death and 6 chances in 100 for injury. Because of the secluded setting of the ponds, there is no direct risk to the community during implementation of these remedial alternatives except for the increase in truck traffic between the ponds site and the designated borrow area. Risk to the community would be limited by normal traffic and hauling safety precautions.

Excess lifetime cancer risk to remediation workers has been quantified at 2×10^{-5} (20 chances in 1 million) under the following assumptions: (1) the remedial worker is exposed for 8 months to representative concentrations of contaminants in soils for 8 h/day, 5 days/week; (2) personal protective equipment (PPE) is used; (3) external exposure to ionizing radiation is a complete exposure pathway, but dermal contact, inhalation and ingestion of dust, and ingestion of groundwater are not; and (4) the shielding effect of progressive backfilling is not considered (which is an extremely conservative assumption). The estimated risk of 2×10^{-5} is within the range of acceptable exposure according to EPA, and the actual risk is expected to be substantially lower.

The possibility of short-term cross-media impacts exists for the implementation of Alternative 6. Significant volumes of contaminated soils would be excavated and would need temporary storage before treatment. Also, mounds of contaminated soils allowed to air dry might temporarily affect air quality in the vicinity of the workplace. Backfilling would occur with the associated risk estimated for Alternatives 2 through 5.

From a risk standpoint, significant amounts of dust could be generated and exposure from inhaling or ingesting contaminated airborne dust would increase potential risk to the on-site worker. These potential risks would be mitigated by the employment of appropriate techniques for dust control and the donning of proper PPE. The wearing of appropriate PPE by on-site remediation workers would effectively eliminate dermal absorption and inhalation of contaminants present on-site. Groundwater is not currently used by the on-site worker, and ingestion of contaminated groundwater is not considered a complete exposure pathway to the remediation worker.

Alternative 6 would require a greater duration and level of on-site activity than Alternatives 2 through 5. However, risks to the on-site remedial worker for the implementation of Alternative 6 would not be expected to be appreciably greater than the risks for the implementation of Alternatives 2 through 5, and the hauling of the additional volume of fill on area roads would not pose a substantial increase in risk to truck drivers or the community.

For Alternative 6, the ponds would be dewatered and the soils excavated; therefore, the potential cross-media impacts to surface and groundwater would be less than for Alternatives 2 through 5. It is not expected that the implementation of Alternative 6 would result in an increased risk to the environment above baseline conditions.

Implementability

All remedial alternatives are based on mature technologies, and their implementation does not present new technical challenges. The goals projected for each alternative are technically realistic in the scope of the alternative. The administrative feasibility of these alternatives depends on the achievement of a consensus among DOE and regulatory agencies involved in the evaluation and approval process. This will center on compliance with ARARs and the CERCLA/RCRA approach adopted for this remedial initiative.

The implementation of any of these alternatives would be consistent with future planned RIs and activities at the site, such as the K-25 Groundwater RI/FS, and would allow continued monitoring at the site necessary to verify the effectiveness of the remedial alternative.

Cost

Alternative 1 involves no cost. The estimated costs increase from $4.5 million for Alternative 2 to $13.0 million for Alternative 6. Cost is one of the five primary criteria for the analysis of alternatives under CERCLA and is relevant when choosing among solutions offering a comparable degree of protection. The estimated increased costs of Alternatives 3 through 6 over the estimated cost of Alternative 2 do not correlate to the protection, permanence, and advantages provided by these alternatives. The safeguards provided by Alternative 2 comply with available guidelines to protect human health and the environment in a cost-effective manner. Table 2.18 shows the cost and present worth cost for Alternatives 2 through 6.

Table 2.18. Cost and present worth for Alternatives 2 through 6

	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Cost	$4.5 million	$5.5 million	$6.3 million	$8.4 million	$13.0 million
Present worth[a]	$5.0 million	$6.0 million	$6.8 million	$9.1 million	$13.4 million

[a]Present worth costs over 30 years

For the purpose of cost comparisons, present worth was calculated for a 30-year period for each alternative. However, the use of this 30-year period does not infer that the site will necessarily be suitable for release from institutional controls at the end of that period. It is recognized that institutional controls, consisting of the use of physical barriers, legal restrictions, or both, will remain as long as unacceptable risks exist at the site. Institutional controls may be required at the site for a period substantially longer than 30 years.

Regulatory Agency Acceptance

TDEC and EPA have reviewed the alternatives proposed for remedial action at the K-1407-B/C Ponds and concur with the selection of Alternative 2, Engineered Rock Fill, as the alternative best suited for remediation of the K-1407-B/C Ponds.

Community Acceptance

No public comments or questions were submitted during the public comment period for the Proposed Plan for the K-1407-B/C Ponds. By the absence of comments, it is assumed that the public is in favor of the selection of Alternative 2 as the most appropriate remedial action for the K-1407-B/C Ponds.

SELECTED REMEDY

Based on the detailed analysis of alternatives against CERCLA requirements, the most appropriate remedy for the K-1407-B/C Ponds is Alternative 2, Engineered Rock Fill. Alternative 3 does not achieve objectives as effectively as Alternative 2. Alternatives 4 and 5 represent an increase in cost with no increase in risk reduction to human health or the environment at the site. Alternative 6 offers no further advantages that justify the added cost or the long-term health and financial liabilities associated with the handling, treatment, and storage of waste by-products generated by its implementation. Alternative 2 represents the best balance of trade-offs of all the alternatives evaluated.

Alternative 2 consists of filling the K-1407-B Pond with an estimated 14,000 yd^3 of crushed rock fill and filling the K-1407-C Pond with an estimated 63,000 yd^3 of engineered compacted soil. These estimates are based on generalized assumptions; actual volumes may vary significantly during the design and construction phase of remediation. At the K-1407-B Pond, crushed and graded rock fill will be emplaced and compacted with appropriate equipment. Rock fill is suited for the waterlogged environment of the K-1407-B Pond because it can be placed there without difficulty; subgrade stabilization will not be required. Rock fill is also appropriate for use at the K-1407-B Pond because the low surface activity of the coarse granular material will limit the potential for chemical fixing of groundwater contaminants onto the fill.

It is expected that water displaced by the emplacement of rock fill into the K-1407-B Pond will flow away naturally as groundwater, establishing a dry, stable surface above the water table that will facilitate the placement of the overlying soil cover. Surface grading and contouring will be accomplished by placing an engineered soil cover above the rock fill. This soil cover will be separated from the underlying coarser material by a filter, possibly a synthetic geotextile, to prevent piping. The cover will then be graded to direct drainage away from the pond area.

The K-1407-C Pond will not require a rock fill subgrade because it is not waterlogged. The K-1407-C Pond will be filled with more cost-effective compacted borrow soil. The borrow soil will be spread in thin lifts and compacted. Because of compaction and quality control, the fill will not be subject to significant settlement and, therefore, should require little maintenance.

For both impoundments, revegetation in native soil, and possibly topsoil, will control erosion and stabilize the soil cover for long-term reliability. No engineering structures other than those required for surface water runoff and erosion control will be necessary during construction. Alternative 2 will not generate man-made by-product waste that requires management. Modifications may be made to this remedy as a result of the remedial design and construction process; such changes, in general, would reflect modifications resulting from the engineering design process.

The baseline exposure pathways considered complete at the K-1407-B/C Ponds for the general plant employee and the on-site worker risk scenarios are dermal contact with, and ingestion and inhalation of wind-generated dust. The external exposure to radiation in dust pathway is additionally considered complete for the general plant employee and the direct exposure to ionizing radiation pathway for the on-site worker. The implementation of Alternative 2 will effectively eliminate all these baseline exposure pathways and their associated risks to receptors. After the placement of clean fill material, the level of on-site contamination to which any potential human receptor would be exposed will be no greater than background. The contaminants will remain in place, but the exposure pathways will be eliminated. Thus, risk-based PRGs will be met.

Based on current site conditions, the exposure pathways considered complete for the hypothetical future on-site resident are ingestion of soil, dermal contact with soil, inhalation of wind-generated dust, external exposure to soil radiation, ingestion of groundwater, dermal contact with groundwater while showering, inhalation of volatiles while showering, and ingestion of homegrown produce. The remediation of groundwater contamination is not addressed as part of this remedial action but will be addressed under the K-25 Groundwater OU RI/FS. All other exposure pathways for the hypothetical future on-site resident will be eliminated by the implementation of Alternative 2.

Although the contaminants will remain in place, it will be virtually impossible for anyone in the future to reestablish baseline conditions at the ponds in the attempt of establishing residency at the site. However, because the continued presence of contamination on-site represents a potential threat, institutional controls (as already in place at the site) are considered as a component of this alternative to provide added protectiveness.

Institutional controls, reopeners, and contingencies to ensure that the remedy remains effective, to be agreed upon with the state, will be implemented. For example, under DOE Order 5400.5, the selected remedy is considered a restricted closure. Therefore, if at any point in the future unconditional release of the site becomes a possibility, DOE (or its successor) shall conduct a review of the remedy and current site conditions prior to transfer of the K-25 Site from DOE (or its successor) to another person or entity. Any property transfer will follow the procedure outlined in the FFA (DOE 1992d), Sect. XLIII, Property Transfer. Additionally, because this remedy will result in hazardous substances remaining on-site above health-based levels, a review will be conducted every 5 years, beginning within 5 years after commencement of the remedial action, to ensure that the remedy continues to provide adequate protection of human health and the environment in accordance with CERCLA 121(c). This review will be augmented by data available from post remediation groundwater monitoring at the site. Post remediation groundwater monitoring will be conducted in accordance with the groundwater monitoring plan for the K-1407-B/C Ponds, which will be finalized upon EPA and TDEC approval.

Flooding would not compromise the remedial action taken at the ponds, meeting 10 CFR 1022 and 40 CFR 6 (Appendix A). Final remediation under Alternative 2 would meet RCRA clean closure requirements (40 CFR 265). Certification of RCRA clean closure will be completed before remedial activities are implemented at the site. During construction, stormwater runoff controls (40 CFR 122, TCA Sect. 1200-4-3) and fugitive dust controls (TCA Sect. 1200-03-8.01) would be implemented. This alternative will meet the exposure limits of DOE Order 5400.5 and comply with DOE Order 5400.5, Chapters II and IV, and DOE Order 5820.2A requirements for the long-term management of residual radioactive contamination left in place. No wetlands areas were identified in the ponds by the wetlands survey conducted for the site, and concurrence with this finding is expected from the USACE. If wetlands were determined to be present at the site, they would be destroyed by this alternative; however, mitigative measures would be taken to enhance other wetlands areas so no net loss of wetlands would occur, thus meeting 10 CFR 1022 and 40 CFR 6 (Appendix A).

Furthermore, following remedial construction activities at the K-1407-B/C Ponds, the K-25 Site Environmental Sites and Exterior Properties organization will (1) conduct periodic site inspections, radiological and industrial hygiene surveillance, and other assessment activities as necessary to keep inactive sites in compliance with environmental, safety, and health requirements, as well as maintain records of all related activities; (2) ensure that site access and activity controls are established and maintained in compliance with security and environmental, safety, and health requirements; and (3) implement maintenance activities required as a result of site inspections, including maintenance of containment systems, monitoring instrumentation, and facility support equipment, general area upkeep, and grounds maintenance. Surveillance and maintenance activities for the K-1407-B/C Ponds will follow the *Surveillance and Maintenance Plan for Inactive ER Remedial Action Sites at the Oak Ridge K-25 Site, Oak Ridge, Tennessee*, K/ER-54 (Energy Systems 1993), which describes site inspection activities and the frequency of the site inspection.

An estimate of the capital cost for a 30-year period for each major component of Alternative 2 is presented in Table 2.19. The present worth for Alternative 2 was calculated using an estimated O&M cost of $50,000/year for 5 years and $30,000/year for the next 25 years with an interest rate of 7% over the entire 30-year period, resulting in a present worth of $455,000 for the annualized O&M in 1991 dollars.

For the purpose of cost estimation, present worth was calculated for a 30-year period for Alternative 2. However, the use of this 30-year period does not infer that the site will necessarily be suitable for release from institutional controls at the end of that period. It is recognized that institutional controls, consisting of the use of physical barriers, legal restrictions, or both, will remain as long as unacceptable risks exist at the site. Institutional controls may be required at the site for a period substantially longer than 30 years.

Table 2.19. Capital costs for Alternative 2

Component	Cost
Site preparation	$81,000
Mobilization and demobilization	$28,000
Rock and soil fill	$3,295,000
Site restoration	$27,000
Engineering costs	$100,000
Construction oversight	$50,000
15% Contingency at start-up	$895,000
Total	$4,476,000

STATUTORY DETERMINATIONS

Under its legal authority, DOE's primary responsibility at CERCLA sites is to undertake remedial actions that achieve adequate protection of human health and the environment. CERCLA Sect. 121 establishes this criterion and other statutory requirements and preferences for the selection of remedial alternatives. Aside from the mandate to protect human health and the environment, selected remedial actions must (1) comply with applicable or relevant and appropriate environmental standards established under federal and state environmental laws unless a statutory waiver is justified, (2) be cost-effective, (3) utilize permanent solutions and alternative treatment or resource recovery technologies to the maximum extent practical, and (4) satisfy the preference for remedies that employ treatments that permanently and significantly reduce the volume, toxicity, or mobility of hazardous wastes as their principal elements.

Protection of Human Health and the Environment

The selected remedy will reduce risk to the general plant employee and the on-site worker at the K-1407-B/C Ponds by effectively eliminating all exposure pathways to these receptors. The ingestion of wind-generated dust, dermal contact with wind-generated dust, inhalation of wind-generated dust, external exposure to radiation in dust, and direct exposure to ionizing radiation pathways will be eliminated, thereby eliminating all risks associated with these pathways. The elimination of these pathways is achieved by physically confining residual contamination and shielding potential receptors from ionizing radiation in pond soils. Once Alternative 2 is implemented, the level of exposure to a human receptor would be no greater than background conditions.

The implementation of Alternative 2 will further eliminate the pathways of ingestion of soil, dermal contact with soil, and ingestion of homegrown produce, which are considered completed for the hypothetical future on-site resident. Therefore, once Alternative 2 is implemented, the level of exposure to the hypothetical on-site resident at surface conditions would be the same as for the on-site worker and general plant employee, i.e., equal to background conditions. Although the residual contaminants will remain in place, it will be virtually impossible for any person in the future to reestablish baseline conditions at the ponds in the attempt of establishing a residence at the site. However, because the continued presence of contamination on-site represents a potential threat, institutional controls at the site will be maintained as a component of this alternative to provide added protection.

Because this remedial alternative does not address groundwater contamination, risks associated with the potential exposure pathways for the hypothetical future on-site resident of ingestion of groundwater, dermal contact with groundwater while showering, and inhalation of volatiles while showering will not be reduced. The analysis of historical groundwater data conducted as part of the RI indicates that there is not a significant potential for migration of contaminants from the pond soils into groundwater at the site, with the exception of ^{99}Tc. This conclusion is supported by groundwater modeling conducted to augment the analysis of historical data. Technetium-99, the beta-emitting radionuclide with the greatest level of activity in the K-1407-B/C Pond soils, is highly mobile in the soil column and has been detected in groundwater monitoring wells downgradient from the K-1407-B Pond. However, risk associated with groundwater pathways for ^{99}Tc for even the conservative on-site resident scenario are below the EPA unacceptable range (1×10^{-4}) at 3×10^{-5}. Furthermore, ^{99}Tc in groundwater, along with many other groundwater contaminants, has shown a trend of steadily decreasing concentrations subsequent to the removal of sludge from the ponds. Therefore, the potential for migration of contaminants from pond soils to groundwater is limited, and risks associated with groundwater exposure pathways at the site do not currently pose a threat to human health or the environment. The remediation of groundwater contamination and the reduction of risks from associated exposure pathways will be addressed under the K-25 Groundwater OU RI/FS.

Alternative 2 will also be protective of the environment. Backfilling the ponds will eliminate contact with the contaminated pond soils by plants and animals. Plants will receive direct benefit from this remedy in that pond soils that are potentially phytotoxic due to the metals content will be below the root zones of most plants. Animals will be protected from contaminant uptake in their diet because plant foods will not be contaminated. Furthermore, animals will be less likely to burrow into contaminated pond soils when those soils are covered by a considerable barrier of clean fill material. Therefore, nondietary exposure pathways for animals will be eliminated. The potential for burrowing to the level of contaminated pond soils is further reduced at the K-1407-B Pond where a rock fill subgrade will be emplaced.

Subsequent to the implementation of Alternative 2, exposure to site risks will fall below the EPA range of concern of 1×10^{-6} for carcinogenic risks and below a hazard index of 1 for noncarcinogenic toxicity. The implementation of this alternative does not pose significant short-term risks to remediation workers; there is no direct risk to the community; and there is little potential for negative cross-media impacts. During and after construction, the foundation of the ponds could undergo limited consolidation and settlement. The overburden imposed by the weight of the fill would compress subsoils of the ponds, possibly causing pore water to spread. This could cause a temporary increase in contamination of surface water in the impoundments. The release of contaminated pore water could also cause a temporary increase in contaminant migration in the groundwater. However, any increase in contamination of surface or groundwater is expected to be temporary and limited to the immediate pond areas and should pose no significant threat to human health or the environment. Therefore, the implementation of Alternative 2 generates no unacceptable short-term risks or cross-media impacts.

Compliance with ARARs

Alternative 2 will comply with all the ARARs and TBCs. Table 2.20 provides a summary of the ARARs and TBCs pertinent to the remedial action at the K-1407-B/C Ponds.

The selected remedial action meets the exposure limits of DOE Order 5400.5, "Radiation Protection of the Public and the Environment," which is TBC for this remedial action, and it also meets DOE Order 5400.5, Chapters II and IV, and DOE Order 5820.2A, which address long-term management of residual radiological contamination left in place. However, the K-1407-B/C Ponds will be revisited by DOE or its successor with regard to residual radiological contamination if unconditional release of the property becomes a possibility in the future, and any property transfer will follow the procedure outlined in the FFA (DOE 1992d), Sect. XLIII, Property Transfer.

No adverse impact to the floodplain will occur. RCRA clean closure will be achieved by implementing the selected remedial action. Certification of clean closure will be completed before remedial activities are implemented at the site. During construction, measures will be taken to control stormwater runoff, fugitive dust emissions, and exposure to on-site workers as required by federal and state law. No wetlands areas were identified in the ponds by the wetlands survey conducted for the site, and concurrence with this finding is expected from the USACE. If wetlands were determined to be present at the site, they would be destroyed by this alternative; however, mitigative measures would be taken to enhance other wetlands areas so no net loss of wetlands would occur, thus meeting 10 CFR 1022 and 40 CFR 6 (Appendix A).

Cost Effectiveness

The remedy covering the K-1407-B/C Ponds will remain in place for long-term control of radioactive and chemical contaminants. The use of rock in the K-1407-B Pond and soil in the K-1407-C Pond as fill material will provide control of exposure and contaminant migration by using a technology that is cost-effective in comparison to other technologies and techniques proposed in the remaining alternatives.

The $4.5 million cost estimate for Alternative 2 represents the most cost-effective action alternative evaluated. Alternative 3 is not as well suited for the K-1407-B Pond, where the rock fill is needed to facilitate construction activities and reduce the potential for cross-media impact. Alternatives 3, 4, and 5 offer reduction in infiltration of surface water compared to Alternative 2; however, there is little significant migration of contaminants in the groundwater at the site from the pond soils. A decrease in surface water infiltration would be of little advantage at the K-1407-B Pond where most of the contaminants are below the water table. Because the potential for leaching of contaminants from the pond soils is limited, there is no appreciable advantage to

Table 2.20. ARARs and TBCs for the K-1407-B/C Ponds Alternative 2

Actions	Requirements	Prerequisites	Federal citation	Tennessee Code Annotated
Chemical-specific	None	None	None	None
Location-specific[a]				
Within floodplain areas	Actions must be taken to reduce the risk of flood loss, minimize the impact of floods on human safety, health, and welfare, and restore and preserve the natural and beneficial values of floodplains Agencies must evaluate potential effects of actions in floodplains and ensure consideration of flood hazards and floodplain management. If action is taken in floodplains, the Agency shall consider alternatives to avoid adverse effects and incompatible development and minimize potential harm	Agency action that involves: - providing federally undertaken, financed, or assisted construction and improvements - conducting federal activities and programs affecting land use - **applicable**	40 CFR 6.302(b); 40 CFR 6 (Appendix A); 10 CFR 1022	
Action-specific				
On-site construction/ excavation	Must take reasonable precautions to prevent particulate matter from becoming airborne	Handling or transporting any materials - **applicable**		1200-3-8-.01
	Fugitive dust may not be emitted as visible emissions beyond property boundary lines for more than 5 min/h or 20 min/day	Handling or transporting any materials - **applicable**		1200-3-8-.01
Surface water control	Monitor surface waters to ensure compliance with state water quality standards	Wastes discharged into adjacent streams or other surface waters - **applicable**	40 CFR 122	1200-4-3
	Consultation with TDEC is required to ensure compliance with the substantive requirements of the permitting process Implementation of good site planning and best management practices to control storm water discharges	Stormwater discharges associated with construction activity at industrial sites involving disturbance of 5 acres total land - **relevant and appropriate**		1200-4-10-.05

Table 2.20 (continued)

Actions	Requirements	Prerequisites	Federal citation	Tennessee Code Annotated
Clean closure	No post-closure monitoring or post-closure care required	Removal or decontamination of all waste residues and contaminated subsoils at interim status surface impoundments - **applicable**	40 CFR 265.228(a)(1)	1200-1-11-.05(11)(g-1)
	Consultation with TDEC is required to ensure compliance with the substantive requirements of the permitting process	Storm water discharges associated with industrial activity - **applicable**	40 CFR 122	1200-4-10-.04
Residual radioactivity	Public exposures from all sources must not exceed an effective dose equivalent of 100 mrem/year	Management of residual radioactive material left in place - **TBC**	DOE Order[b] 5400.5(IV.3a)	
	All releases of radioactive material shall be ALARA		DOE Order 5400.5(IV.2a) DOE Order 5820.2A(III.3j)	
	Authorized limits are levels of residual radioactive material that shall not be exceeded if the remedial action is to be considered completed and the property is to be released without restrictions on use		DOE Order 5400.5(IV.2d) DOE Order 5820.2A(III.3j)	

ALARA = as low as reasonably achievable
ARAR = applicable or relevant and appropriate requirement
TDEC = Tennessee Department of Environment and Conservation
TBC = to be considered
USACE = U.S. Army Corps of Engineers

[a]The wetlands survey conducted for the site indicated that there are no wetlands areas present at the K-1407-B/C Ponds, and concurrence with this finding is expected from the USACE. However, if wetlands were determined to be present at the site, then ARARs pertaining to wetlands would be met.
[b]DOE orders, while not ARARs, are treated as TBC guidance and/or criteria.

be gained by the added cost of these alternatives. Alternative 6 would remove all residual contaminants from the site, but its implementation would create health and financial liabilities associated with the removal, handling, and long-term maintenance of the waste and would represent a significant increase in cost.

The increased costs of Alternatives 3 through 6 compared to Alternative 2 do not correlate to a commensurate increase in protection, permanence, effectiveness, or other advantages to justify the increase in cost. The safeguards provided by Alternative 2 comply with available guidelines to protect human health and the environment in a cost-effective manner.

Use of Permanent Solutions and Treatment Technologies

Alternative 2 provides a solution to existing and potential threats posed by contaminants in the K-1407-B/C Pond soils. All exposure pathways to contaminants in the pond soils and the associated risks will be effectively eliminated by the implementation of the remedy. Although residual contamination will remain in place at the site, it will not pose a risk to human health and the environment because of the isolation of contaminants and the shielding of exposure to direct ionizing radiation. The implementation of Alternative 2 will make it virtually impossible to reestablish baseline conditions at the site in the future in an attempt of establishing residency. Therefore, the remedy has a high degree of effectiveness even for the most conservative risk scenario, the hypothetical on-site resident.

Alternative 2 does not address groundwater contamination at the site; groundwater contamination will be addressed under the K-25 OU Groundwater RI/FS. However, the potential for contaminant mobility by leaching and migration of contaminants from pond soils into groundwater at the site is very limited, and there is currently no risk posed to human health or the environment by groundwater exposure pathways. Remediation will reduce the mobility of soil contaminants by eliminating transport by air or surface water. The toxicity of residual soil contamination will not be reduced, but risk will be reduced by eliminating all existing exposure pathways. Alternative 6 would remove all contaminants from the site but would result in risks associated with removal, handling, and long-term storage of waste by-products.

Because there is no effective treatment for residual radiological contamination such as found in the pond soils, Alternative 6 would not reduce the toxicity; instead, the volume of waste would be significantly increased. Although mobility might potentially be decreased, the waste by-product from excavation and treatment would be above ground, and any failure in long-term management could result in an eventual increase of contamination migration. Because of the considerable technical and logistical problems associated with removal and treatment and because of the considerable cost, this alternative is not viable.

Alternative 2 utilizes permanent solutions and treatment technologies to the maximum extent practicable. Because treatment of the principal threats at the site is not practicable, management of in situ residues is a more appropriate remedy at this site. Furthermore, this remedy is easily implemented, cost-effective, and presents no short-term unacceptable risks to human health or the environment. Based on its advantages and cost effectiveness, Alternative 2 represents the best balance of trade-offs for remediation of the K-1407-B/C Ponds.

Preference for Treatment as a Principal Element

The principal threats to human health and the environment to current and potential receptors at the K-1407-B/C Ponds site are posed by residual metals and radiological contamination in the pond soils and by contaminants in groundwater. All visible traces of sludge (the original contaminant source at the site) and associated soil were removed under RCRA closure activities conducted between 1987 and 1989. The contamination remaining in the pond soils represents residual contamination that migrated from the sludges into underlying soil prior to sludge removal.

Because treatment of the principal threats at the site is not practicable, this remedy does not satisfy the statutory preference for treatment as a principal element. Current technology does not offer means to effectively treat residual radiological contamination such as that found at the K-1407-B/C Ponds site. Therefore, management of in situ residues is a more appropriate remedy at this site.

The implementation of the selected remedy will effectively eliminate all current and potential exposure pathways and associated risks at the site except for groundwater pathways; groundwater will be remediated under the K-25 Groundwater OU. However, because residual contamination will remain on-site, institutional controls, reopeners, and contingencies to ensure the remedy remains effective, to be agreed upon with the state, will be implemented. For example, under DOE Order 5400.5 the selected remedy is considered a restricted closure. Therefore, if in the future unconditional release of the site becomes a possibility, DOE (or its successor) shall conduct a review of the remedy and current site conditions prior to transfer of the K-25 Site from DOE (or its successor) to another person or entity, and any property transfer will follow the procedure outlined in the FFA (DOE 1992d), Sect. XLIII, Property Transfer.

Additionally, because this remedy will result in hazardous substances remaining on-site above health-based levels, a review will be conducted every 5 years, beginning within 5 years after commencement of the remedial action, to ensure that the remedy continues to provide adequate protection of human health and the environment in accordance with CERCLA 121(c). This review will be augmented by data available from post-remediation groundwater monitoring at the site.

EXPLANATION OF SIGNIFICANT CHANGES

The Proposed Plan for the K-1407-B/C Ponds (DOE 1992c) was released for public comment in February 1993. It identified Alternative 2, Engineered Rock Fill, as the K-1407-B/C Ponds preferred alternative. No written or verbal comments were submitted during the public comment period. Accordingly, it was determined that no significant changes to the remedy, as it was originally identified in the Proposed Plan, were necessary.

PART 3. RESPONSIVENESS SUMMARY

COMMUNITY PREFERENCES

The Proposed Plan for the K-1407-B/C Ponds (DOE 1992c) remedial action was released to the public on February 3, 1993. The remedial action described in the Proposed Plan is intended to reduce the potential threats to human health and the environment posed by the radiological and chemical hazards associated with the contaminated soils remaining in the K-1407-B Holding Pond and the K-1407-C Retention Basin, and to prevent the spread of contamination. The major component of the remedial action is isolation and shielding provide by filling the ponds.

No comments were received during the public comment period. Based on the absence of public comment, it is assumed that the public is in favor of the proposed solution. Accordingly, the preferred alternative has been selected for remedial action at the K-1407-B/C Ponds as presented in the Proposed Plan.

INTEGRATION OF COMMENTS

The Proposed Plan for the K-1407-B/C Ponds (DOE 1992c) remedial action was released to the public in February 1993 by inclusion in the Administrative Record maintained at the IRC in Oak Ridge, Tennessee. The Notice of Availability of the Proposed Plan was published in the *Oak Ridger* on February 2, 1993; in the *Knoxville News Sentinel* on January 31, 1993; and in the *Roane County News* on February 2, 1993. A public comment period was held from February 3 through March 4, 1993. The opportunity for a public meeting was offered in the Notice of Availability published in the newspapers. No comments were received from the public.

The public at large has been involved in the general environmental restoration of DOE's facilities on the ORR through various activities on many occasions. The contamination of the K-1407-B/C Ponds has raised little interest in the community at large because of the isolated location and restricted access to this area.

Summary of Comments Received and Agency Responses

No public comments were received during the public comment period.

Remaining Concerns

At the end of the public comment period, no other concerns had been raised by the community.

PART 4. REFERENCES

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