DRAFT FINAL

ADMIN RECORD

PHASE I RFI/RI REPORT
WALNUT CREEK PRIORITY DRAINAGE
OPERABLE UNIT NO. 6

APPENDIX J
BASELINE HEALTH RISK ASSESSMENT

Volume I
Text

U.S. Department of Energy
Rocky Flats Environmental Technology Site
Golden, Colorado

August 1995

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AB	absorption factor
AOC	area of concern
Am-241	Americium 241
Bq	Becquerel
BW	body weight
CDH	Colorado Department of Health
CDPHE	Colorado Department of Public Health and Environment
CEDE	committed effective dose equivalent
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Ci	Curie
COCs	chemicals of concern
COIs	chemicals of interest
CRQL	Contract Required Quantitation Limit
CSM	conceptual site model
CT	central tendency
DOE	Department of Energy
ECAO	Environmental Criteria and Assessment Office
ED	exposure duration
EDE	effective dose equivalent
EF	exposure frequency
EPA	Environmental Protection Agency
ER	External Radiation exposure
f_i	fractional uptake
Gy	gray
HHRA	human health risk assessment
HI	hazard index
HSPF	Hydrological Simulation Program - FORTAN
HQ	hazard quotient
IAG	Interagency Agreement
ICRP	International Commission on Radiological Protection
IDL	instrument detection limit
IEUBK	Integrated Exposure Uptake Biokinetic
IHSS	Individual Hazardous Substance Site
IR	intake rate
LOAEL	lowest-observed-adverse-effect level
ME	matrix effect
mg	milligram
mg/kg-day	milligram per kilogram - day
mrem	millirem
NOAEL	no-observed-adverse-effect level

OU	operable unit
PA	Protected Area
PAH	polycyclic aromatic hydrocarbon
PC	permeability constant
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PM_{10}	Particulate Matter less than 10 microns
Pu-239/240	Plutonium-239/240
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
RfC	reference concentration
RfD	reference dose
RFETS	Rocky Flats Environmental Technology Site
RFI/RI	RCRA Facility Investigation/Remedial Investigation
RFP	Rocky Flats Plant
RI	Remedial Investigation
RME	reasonable maximum exposure
SF	slope factor
SI	Systeme Internationale
SQL	sample quantitation limit
Sv	sievert
SVE	soil vapor extraction
SVOC	semi-volatile organic compound
TCE	trichloroethene
TEDE	total effective dose equivalent
TM	technical memorandum
TSS	total suspended solids
U-233/234	Uranium-233/234
U-238	Uranium-238
UCL	upper confidence limit
UTL	upper tolerance limit
VOC	volatile organic compound
WQPL	Water Quality Parameter List

A Human Health Risk Assessment (HHRA) was performed for Operable Unit No. 6 (OU6) at the Rocky Flats Environmental Technology Site (RFETS) as part of the Phase I RCRA Facility Investigation/Remedial Investigation (RFI/RI) Report, as required by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). OU6 occupies approximately 1,061 acres east of the industrialized portion of RFETS and consists of the Walnut Creek Drainage system. OU6 contains 20 Individual Hazardous Substance Sites (IHSSs) where former waste disposal activities or releases may have occurred.

The HHRA is intended to estimate the level of potential human health risk from exposure to chemicals at or released from contaminant source areas within OU6. The human health risk estimates are used to support the determination of appropriate cleanup levels or other risk management measures, if warranted, in keeping with current and future land uses.

The HHRA was performed following U.S. Environmental Protection Agency (EPA) guidance for risk assessment and in keeping with procedures for selection of chemicals of concern (COCs), data aggregation, and exposure assessment that were agreed upon by the EPA, Colorado Department of Public Health and Environment (CDPHE), and the U.S. Department of Energy (DOE). These procedures are documented in various technical memoranda and correspondence cited in the HHRA.

Samples were collected from surface soil, subsurface soil, groundwater, pond sediment, pond surface water, and stream/dry sediment during the OU6 Phase I (1992-1993) field investigation and from RFETS-wide sampling programs. These sample results were used to characterize chemical constituents in OU6 and select COCs for risk assessment.

In 1994, additional samples of pond sediment were collected for separate evaluation. COCs were metals and radionuclides that were detected above background levels and detected organic chemicals present in the sampled media that could contribute significantly to overall health risk. COCs were evaluated in transport modeling and in risk assessment and will be the focus of any remedy selection deemed necessary. COCs in all of the sampled media were determined on an OU-wide basis following a multi-step process: (1) statistical background

comparison for inorganic chemicals: (2) frequency of detection screen (infrequently detected compounds were reserved for separate evaluation); (3) scientific and professional judgement; and (4) concentration/toxicity screens.

Chemicals of concern are summarized below:

OU-WIDE CHEMICALS OF CONCERN

Surface Soil	Subsurface Soil	Groundwater
Antimony	Benzo(a)pyrene	Chloroform
Silver	Benzo(b)fluoranthene	Methylene chloride
Vanadium	Barium	Tetrachloroethene
Zinc	Americium-241	Trichloroethene
Americium-241	Plutonium-239/240	Nitrate
Plutonium-239/240	Uranium-233/234	Americium-241
	Uranium-238	Plutonium-239/240
		Radium-226

Pond Sediment	Pond Surface Water	Stream/Dry Sediment
Aroclor-1254	1,2-Dichloroethene	Benzo(a)anthracene
Benzo(a)pyrene	Chloroform	Benzo(a)pyrene
Benzo(b)fluoranthene	Trichloroethene	Benzo(b)fluoranthene
Bis(2-ethylhexyl)phthalate	Di-n-butylphthalate	Indeno(1,2,3-cd)pyrene
Antimony		Cobalt
Silver		Strontium
Vanadium		Vanadium
Americium-241		Zinc
Plutonium-239/240		Americium-241
		Plutonium-239/240

Exposure scenarios for risk assessment were based on current land use and possible future land use at the site, in keeping with recommendations of local planning groups and the Rocky Flats Future Site Uses Working Group. Land use in OU6 is likely to remain restricted for the foreseeable future. If access becomes unrestricted, open space use or designation as an ecological reserve is possible. Industrial/commercial development in portions of the plant could also occur.

The receptor (exposed individual) evaluated in the risk assessment under the current use scenario was the onsite worker (security personnel in OU6). Receptors under future use scenarios were office worker, ecological researcher, open space recreational user, and construction worker. These receptors were evaluated for exposure to COCs via multiple exposure pathways appropriate to the exposure scenario. These included soil or sediment ingestion, inhalation, dermal contact and external irradiation; ingestion of surface water; dermal contact with surface water; and inhalation of VOCs released from subsurface soil and groundwater.

Health risks were evaluated for onsite receptors in four Areas of Concern (AOCs) in OU6. AOC No. 1 is the North Spray Field Area (IHSS 167.1). AOC No. 2 contains the Sludge Dispersal Area (IHSS 141), Triangle Area (IHSS 165), and Soil Dump Area (IHSS 156.2). AOC No. 3 includes Ponds A-1, A-2, and A-3 (IHSSs 142.1, 142.2 and 142.3) and the interconnecting stream segments. AOC No. 4 includes Ponds B-1, B-2, B-3, and B-4 (IHSSs 142.5, 142.6, 142.7, and 142.8) and the interconnecting stream segments. In addition, risks for the future office worker were evaluated in a 30-acre maximum exposure area in AOC No. 2. Other IHSSs except the Old Outfall (IHSS 143) were not included in the risk assessment because they were removed from further evaluation based on the results of CDPHE Risk-Based Conservative Screen (DOE 1994a). IHSS 143 (Old Outfall) was evaluated in the CDPHE Risk-Based Conservative Screen but not in the OU6 HHRA because, since it is located in the industrialized portion of RFETS, it is expected to be evaluated in OU8.

Exposure concentrations (usually the 95% upper confidence limit on the mean) were calculated for each COC in each sampled medium and for each exposure area. Air dispersion modeling and surface water modeling were also conducted to estimate exposure point concentrations in air at each AOC and in surface water and sediment in the ponds in North and South Walnut Creek.

Health risks were estimated by combining estimates of chemical intake, chemical concentration at the exposure point, and toxicity factors. The toxicity factors are EPA-established reference doses (RfDs) for noncarcinogens and cancer slope factors (SFs) for carcinogens. Noncarcinogenic hazard indexes (HIs) and cancer risk estimates were calculated using both central tendency (CT) and reasonable maximum exposure (RME) assumptions for each scenario. In addition, annual radiation doses were estimated for comparison to national radiation standards for protection of the general public and nonradiation workers (100 mrem/year).

Results of the risk assessment are summarized in Table ES-1 and described briefly below:

- AOC No. 1 and AOC No. 2: Cumulative HIs were below 1 for all exposure areas and all receptors and RME cancer risk estimates were below 1E-06 (1 in 1 million), which is the low end of EPA's acceptable risk range of 1E-06 to 1E-04. These results indicate that no adverse noncarcinogenic health hazards or cancer risks are expected.

- AOC No. 3 and AOC No. 4: Cumulative HIs were below 1 and RME cancer risk estimates were 6E-06 or below, which is within EPA's acceptable target cancer risk range of 1E-06 to 1E-04, indicating negligible risk for receptors in these AOCs.

- 1994 Pond Sediment Samples: Cumulative HIs were below 1 and RME cancer risk estimates were 9E-06 or below. These estimates support the risk results for AOC No. 3 and AOC No. 4, indicating no unacceptable risk for receptors exposed to pond sediment in OU6.

- Estimated annual radiation doses for onsite receptors were 0.1 mrem/year or below, which is well below the DOE standard of 100 mrem/year for protection of the public.

In general, cancer risk levels that do not exceed 1E-04, combined with HIs that do not exceed 1, may be used to support a decision that remediation is not warranted for the protection of public health (EPA 1991). These results suggest that remediation of surface and subsurface

soil, pond and stream/dry sediment, and pond surface water in OU6 may not be necessary for protection of public health.

REFERENCES

U.S. Department of Energy (DOE). 1994. Colorado Department of Public Health and Environment Source Area. Delineation and Risk-Based Conservative Screen and Environmental Protection Agency Areas of Concern Delineation Letter Report for Operable Unit No. 6. Rocky Flats Environmental Technology Site, Golden, Colorado. Final. October.

U.S. Environmental Protection Agency (EPA). 1991. Role of Baseline Risk in Superfund Remedy Selection Decisions. OSWER Directive 09355.0-30. April 22.

TABLE ES-1
SUMMARY OF ESTIMATED HEALTH RISKS

	Central Tendency		Reasonable Maximum	
	Hazard Index	Cancer Risk	Hazard Index	Cancer Risk
AOC No. 1				
Current Industrial Worker	1.78E-03	2.01E-09	1.13E-02	5.17E-08
Future Office Worker	8.91E-04	1.30E-09	1.13E-02	5.17E-08
Future Ecological Worker	1.74E-03	8.78E-10	6.21E-03	2.73E-09
Future Open Space Recreational Use	2.33E-03	4.12E-10	1.17E-02	7.22E-09
Future Construction Worker	9.28E-05	1.95E-09	5.21E-04	4.03E-09
AOC No. 2				
Current Worker	1.82E-03	1.23E-08	1.15E-02	4.26E-07
Future Ecological Worker	1.78E-03	6.90E-09	6.34E-03	2.30E-08
Future Open Space Recreational Use	2.83E-03	3.66E-09	1.19E-02	6.03E-08
Future Construction Worker	1.15E-04	2.69E-09	6.43E-04	1.16E-08
30-acre Maximum Exposure Area				
Future Office Worker	7.90E-04	1.31E-08	1.00E-02	5.18E-07
AOC No. 3 (Ponds A-1 to A-3 and Stream and Dry Sediment)				
Future Ecological Worker	5.37E-04	4.59E-09	5.28E-03	4.85E-08
Future Open Space Recreational Use	4.13E-03	5.88E-08	2.54E-02	1.26E-06
AOC No. 4 (Ponds B-1 to B-3 and Stream and Dry Sediment)				
Future Ecological Worker	3.67E-03	2.78E-08	3.50E-02	2.78E-07
Future Open Space Recreational Use	1.43E-02	2.34E-07	1.06E-01	6.10E-06

J1.0
OBJECTIVES AND METHODOLOGY

J1.1 PURPOSE AND AUTHORITY

The Human Health Risk Assessment (HHRA) is presented as part of the Phase I Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI) Report for the Walnut Creek Priority Drainage, Operable Unit No. 6 (OU6) at the U.S. Department of Energy (DOE) Rocky Flats Environmental Technology Site (RFETS) in Golden, Colorado. The HHRA is required by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA; also known as Superfund) (40 CFR 300.430) as part of the RI process. The HHRA is intended to estimate the level of health risk from potential exposures to chemicals at or released from source areas within OU6. The estimate of health risk is used to support the determination of appropriate cleanup levels or other risk management measures in keeping with current and future land uses. Health risks are estimated for both central tendency (CT) and reasonable maximum exposure (RME) conditions, in keeping with EPA guidance (EPA 1989a, 1992a).

The Phase I RFI/RI is being conducted pursuant to the DOE Environmental Restoration Program; a Compliance Agreement among DOE, the U.S. Environmental Protection Agency (EPA), and the Colorado Department of Public Health and Environment (CDPHE); and the Federal Facility Agreement and Consent Order (Interagency Agreement; IAG) signed in 1991.

J1.2 SITE DESCRIPTION

RFETS consists of an industrialized area of about 400 acres surrounded by an undeveloped buffer zone of about 6,150 acres. OU6 consists of 20 Individual Hazardous Substance Sites (IHSSs) within the Walnut Creek Priority Drainage as well as the land area between the IHSSs (Figure J1-1). The majority of OU6 is in the buffer zone north and east of the industrial portion of RFETS. A detailed description of the site location and general site conditions of the IHSSs are included in Sections 1.0 and 3.0 of the Phase I RFI/RI Report for OU6. The OU6 IHSS names and numbers are listed below:

- Sludge Dispersal Area (IHSS 141)
- A-Series Ponds (IHSSs 142.1, 142.2, 142.3, and 142.4)
- B-Series Ponds (IHSS 142.5, 142.6, 142.7, 142.8, and 142.9)
- Walnut and Indiana Pond (IHSS 142.12)
- Old Outfall Area (IHSS 143)
- Soil Dump Area (IHSS 156.2)
- Triangle Area (IHSS 165)
- Trenches A, B, and C (IHSSs 166.1, 166.2, and 166.3)
- North Spray Field and former South Spray Field Area (IHSS 167.1 and former IHSS 167.3)
- East Spray Field Area (IHSS 216.1)

In addition, North and South Walnut Creeks were included in the OU6 Phase I field program.

J1.3 SCOPE OF OU6 FIELD INVESTIGATIONS

Analytical data used in the HHRA are from environmental samples collected during the OU6 Phase I field sampling program and from site-wide sampling programs for groundwater and surface water. The OU6 Phase I field program began in August 1992 and was completed in May 1993. Samples were collected in surface soil, subsurface soil, pond sediment, and stream/dry sediment. Pond surface water samples were collected during the OU6 Phase I field program by the site-wide surface water sampling group. Surface and subsurface soil samples were collected in all IHSSs except the ponds. Pond and stream/dry sediment samples were collected from each pond and from the North and South Walnut Creek stream beds. Groundwater samples were collected from wells in OU6 by the site-wide groundwater sampling program during 12 consecutive quarters from first quarter 1991 to fourth quarter 1993. A detailed description of the samples collected in each IHSS appears in Section 2.0 of the RFI/RI Report.

Additional pond sediment samples were collected in a separate sampling program in 1994. These data are evaluated in Attachment J5.

J1.4 IHSSs EVALUATED IN THE HHRA

The HHRA does not evaluate potential risk at all of the IHSSs. Some IHSSs were removed from further evaluation based on findings presented in the CDPHE Source Area Delineation and Risk-Based Conservative Screen and EPA Areas of Concern Delineation Letter Report (DOE 1994a). The East Spray Field Area (IHSS 216.1), Walnut and Indiana Pond (IHSS 142.12), Pond A-4 (IHSS 142.4), and Pond B-5 (IHSS 142.9) were removed from further evaluation in the HHRA because concentrations of detected chemicals did not exceed criteria established in the CDPHE Risk-Based Conservative Screen. For the same reason, surface soil and subsurface soil in the South Spray Field Area (former IHSS 167.3) and at Trenches A, B, and C (IHSS 166) were removed from further evaluation in the HHRA; however, the groundwater samples collected in those areas are expected to be evaluated under OU7 (Landfill). The Old Outfall (IHSS 143.5), which is located inside the industrial area, is also not evaluated in this OU6 report because it is expected to be evaluated further in OU8, Industrialized Areas.

J1.5 GUIDANCE DOCUMENTS

The HHRA was performed using EPA guidance provided in Risk Assessment Guidance for Superfund (EPA 1989a and 1991a), Dermal Exposure Assessment: Principles and Applications (EPA 1992b), the Exposure Factors Handbook (EPA 1989b), and Guidance for Data Useability in Risk Assessment (Parts A and B) (EPA 1992c and 1992d). Other guidance documents and scientific literature were consulted as needed and cited where used. In addition, letters and memoranda from EPA Region VIII and CDPHE provided recommendations for identification of potential receptors, exposure areas, and chemicals of concern (COCs). Specific correspondence from EPA and CDPHE is cited in the relevant sections of the HHRA.

Four technical memoranda (TMs) were written in support of the HHRA. These memoranda are TM No. 2, Exposure Assessment (DOE 1995a); TM No. 3, Model Description (DOE 1994b); TM No. 4, Chemicals of Concern (DOE 1994c); and TM No. 5, Toxicity Assessment (DOE 1994d). These memoranda have been submitted to EPA and CDPHE and have provided the basis for performing the HHRA.

J1.6 REPORT ORGANIZATION

The HHRA consists of the following sections:

J2.0 Data Evaluation: This section describes the chemical analytical data used in the HHRA and how the data were aggregated for exposure assessment.

J3.0 Chemicals of Concern: This section describes the approach taken to identify COCs for quantitative evaluation in HHRA. COCs in each sampled medium (soil, groundwater, sediment, and surface water) were selected on an OU-wide basis. In addition, chemicals of interest (COIs) and special-case COCs are identified. The special-case COCs are infrequently detected compounds that have high toxicity. COIs are certain metals in groundwater and sediment that are probably not site contaminants but were selected for separate evaluation because of their potential toxicity at naturally occurring levels under long term exposure conditions. COIs and special-case COCs are evaluated in Section J10.

J4.0 Exposure Scenarios: This section summarizes current and future land use and describes the exposure areas, potential receptors (exposed individuals), and exposure pathways evaluated in the HHRA.

J5.0 Exposure Point Concentrations: This section presents the exposure point concentrations that were calculated for each COC in each exposure medium and exposure area. In addition, it summarizes the results of air modeling and surface water modeling.

J6.0 Estimating Chemical Intakes: This section describes the methodology and exposure parameters used to calculate chemical intake for each exposure pathway. This section also identifies the chemical-specific values used for soil matrix effects, dermal absorption from soil, and aqueous dermal permeability constants.

J7.0 Toxicity Assessment: This section describes the chemical-specific toxicity factors used in estimating noncarcinogenic and carcinogenic health risk from exposure to chemicals and radionuclides. It also presents the radiation dose coefficients used in calculating annual radiation doses. Detected chemicals without EPA toxicity factors are also identified.

J8.0 Risk Characterization: This section presents the results of the quantitative risk assessment for each exposure scenario.

J9.0 Radiation Dose Estimates: This section presents the results of the annual radiation dose calculations for each receptor and compares them to federal standards.

J10.0 Uncertainties and Limitations: This section identifies the chief sources of uncertainty in quantitative risk assessment and discusses potential risk from special-case COCs and COIs.

J11.0 Summary and Conclusions: This section summarizes and draws conclusions from the results of the risk assessment.

J12.0 References: This section lists the literature cited in the HHRA.

In addition, the following attachments provide detailed information on various aspects of the HHRA:

Attachment J1 Estimating the Concentration Term: discusses the statistical procedures used to determine exposure point concentrations of COCs and includes the tables of all sample results used in the calculations.

Attachment J2 Exposure Factor Tables: shows the numerical values for all exposure parameters for each receptor and exposure pathway evaluated in the HHRA.

Attachment J3	Health Risk Calculations: contains detailed spreadsheets showing health risk calculations for all chemicals, receptors, and pathways.
Attachment J4	Radiation Dose Calculations: contains detailed spreadsheets showing the calculation of annual radiation doses for each receptor.
Attachment J5	1994 Pond Sediment Sampling and Risk Evaluation: presents results of a separate pond sediment sampling program conducted in 1994 and a risk assessment for potential exposure to sediment.

J2.0
DATA EVALUATION AND AGGREGATION

This section provides a brief description of the development of the chemical analytical data set and data aggregation process used in the risk assessment.

J2.1 CHEMICAL ANALYTICAL DATABASE

Chemical analytical data from environmental samples collected during the OU6 Phase I field investigations and from RFETS-wide sampling programs were used to characterize chemical constituents in OU6 and select COCs for risk assessment. The sampling and analytical programs followed approved work plans, and chemical analytical results were validated by a subcontractor in accordance with EPA and RFETS data validation guidelines. Summaries of the work plans and the OU6 field investigations are presented in Section 1.0 and 2.0 of the RFI/RI Report. Appendix E, Quality Assurance, describes the chemical analytical database and additional data review and cleanup (such as averaging of field duplicate results) that were performed in establishing the final database used in the OU6 RFI/RI Report.

J2.1.1 Data Sets Used in the Risk Assessment

The data sets used for evaluation of surface soil, subsurface soil, groundwater, pond sediment, pond surface water, and stream/dry sediment are described below.

Surface Soil

Surface soil samples were collected using the RFP method, in which the top 2 inches of soil are collected in several locations within a plot and then composited. Samples were collected from the third quarter of 1992 through the first quarter of 1993. Surface soil samples were collected at the Sludge Dispersal Area, Soil Dump Area, Triangle Area, North Spray Field Area, and East Spray Field Area. The analytical parameters varied by location but generally included metals, radionuclides, nitrates, semivolatile organic compounds (SVOCs), pesticides, and polychlorinated biphenyls (PCBs). All of the IHSSs in which surface soil samples were collected were evaluated in the HHRA except for the East Spray Field Area,

which is a candidate for no action based on the CDPHE Risk-Based Conservative Screen (DOE 1994a).

Subsurface Soil

Subsurface soil samples were collected from the fourth quarter of 1992 through the first quarter of 1993. Boreholes drilled for OU6 investigations were within or downgradient of IHSS boundaries defined prior to the field investigation. Boundaries of several IHSSs were slightly redefined after publication of the Historical Release Report (DOE 1992a). Two IHSSs had significant changes in boundary definition. The South Spray Field Area (IHSS 167.3) was relocated further north, adjacent to the landfill pond (Figure J1-1); the location sampled in OU6 is referred to as former IHSS 167.3. The location of Trench C East (IHSS 166.3 east) was also newly defined after the OU6 sampling was conducted.

Subsurface soil samples were collected in 2- to 6-foot composites depending on sampling location. Subsurface soil was sampled at the Soil Dump Area, Triangle Area, Trenches (A, B, and C), North Spray Field Area, former South Spray Field Area, and East Spray Field Area. The Soil Dump Area, Triangle Area, and North Spray Field Area were evaluated in the HHRA. The East Spray Field, former South Spray Field Area (former IHSS 167.3), and soil at the Trenches were removed from further evaluation based on results of the CDPHE Risk-Based Conservative Screen (DOE 1994a).

Laboratory analyses of subsurface soil samples generally included the following analytical groups: volatile organic compounds (VOCs), SVOCs, metals, and radionuclides.

Groundwater

Groundwater samples were collected from onsite monitoring wells on a quarterly basis under a plant-wide groundwater sampling program. The plant-wide monitoring program included two monitoring wells installed during the OU6 Phase I investigation and wells installed during other investigations conducted from 1991 through 1993.

Samples used for evaluation of OU6 groundwater chemical concentrations were collected from the first quarter of 1991 through the fourth quarter of 1993. In general, the

groundwater samples were analyzed for VOCs, SVOCs, pesticides/PCBs, metals, and radionuclides.

Pond Sediment

Pond sediment samples were collected during the fourth quarter of 1992 as part of the plant-wide surface water sampling program. Each of the ponds was sampled at five locations. In each pond, one of the samples was collected within 5 feet of the inlet. The second sample was collected from the deepest part of the pond. The other three samples were collected at random locations within each pond. Composite samples were collected from 2-foot intervals. Samples were analyzed for VOCs, SVOCs, pesticides/PCBs, metals, radionuclides, and water quality parameters (WQPLs).

In 1994, additional pond sediment samples were collected near previous sampling locations at a depth of 0 to 6"; they were analyzed for PCBs and radionuclides. The 1994 data are evaluated separately in Attachment J5 of this HHRA.

Pond Surface Water

Pond surface water samples were collected from August to November of 1992 as part of the plant-wide surface water sampling program. Five surface water samples were collected from each of the ponds. One sample was collected from within 5 feet of the inlet to each pond. A second sample was collected from the deepest part of the pond. The third sample was collected within 5 feet of the spillway. The two remaining samples were collected randomly in each pond. Samples were analyzed for VOCs, SVOCs, pesticides/PCBs, metals, radionuclides, and WQPLs.

Stream/Dry Sediment

Sediment samples from the stream channels of North and South Walnut Creeks were collected in May 1993 during the OU6 Phase I investigation. Two-foot composite samples were collected using a 2-inch diameter core sampler with a hand driver. The samples were analyzed for VOCs, SVOCs, pesticides/PCBs, metals, radionuclides, and WQPLs.

Dry sediment samples were collected in North and South Walnut Creeks and the floodplains of the ponds in February 1993. The samples were collected using the RFP surface soil sampling method (top 2 inches). The samples were analyzed for SVOCs, pesticides/PCBs, metals, radionuclides, and WQPLs. Results from both stream and dry sediment samples were used in evaluating potential exposure to exposed (i.e., not submerged) sediment in North and South Walnut Creeks. Only results from samples collected upstream of Pond A-3 and Pond B-4 and east of the industrial area were used because (1) areas further downstream (i.e., Ponds A-4, B-5, and the W&I Pond) were eliminated from further evaluation in risk assessment based on results of the CDPHE Risk-Based Conservative Screen (DOE 1994a) and (2) areas upgradient of the industrial area are not within OU6.

J2.1.2 Chemical Data Qualifiers

Chemical data qualifiers are letter codes attached to analytical results by the laboratory or validator to indicate possible problems with chemical identification, quantification, or source. Use of qualified data in risk assessment depends upon the type of qualifier. Qualifiers found in the Rocky Flats data are summarized below.

- E qualifier for organics: Result exceeded calibration range. These results were replaced with the associated D-qualified result (diluted to within calibration range), if available.

- B qualifier for metals: Result is greater than the instrument detection limit (IDL) but less than the Contract Required Quantitation Limit (CRQL) for that analyte. These data were used as reported.

- B qualifier for organics: The chemical was detected in the associated laboratory blank. If validated and not U-qualified by the validator, the results were used as reported.

- J qualifier: The analyte was positively identified below the sample quantitation limit (SQL). The result is considered an estimate because of the uncertainty associated with quantifying low concentrations. Results were used as reported.

- U qualifier: The analyte was not detected above the SQL. U-qualified results were considered non-detect.

- R qualifier: The result was rejected during the validation process and was removed from the working data set. R-qualified data were not used in risk assessment in accordance with EPA guidance (EPA 1989a).

J2.2 DATA AGGREGATION FOR RISK ASSESSMENT

Data aggregation for risk assessment was performed in accordance with guidelines developed by CDPHE, EPA Region VIII, and DOE for application at RFETS (CDPHE/EPA/DOE 1994). First, source areas were identified on the basis of the spatial extent of potential contaminants. The IHSSs within OU6 are (1) physically separated and (2) defined by different types and sources of potential contamination. Therefore, with the exception of Trenches A, B, and C, which were evaluated together as a single source area, all other IHSSs were considered to be individual source areas.

Following the identification of source areas, Areas of Concern (AOCs) were delineated (DOE 1994a). AOCs were defined as one or several source areas that are in close proximity and can be evaluated as a unit in the HHRA. IHSSs excluded from further evaluation based on the CDPHE Risk-Based Conservative Screen were not included in AOCs (see Section J1.4). Four AOCs were identified in OU6 (Figure J2-1). These are listed below.

AOC No. 1 is the North Spray Field Area. This area is spatially separated from the other source areas evaluated in the HHRA.

AOC No. 2 includes the Triangle Area, Sludge Dispersal Area, and Soil Dump Area. These three source areas are in close proximity and represent the largest volume of potentially contaminated soil in OU6. Therefore, these source areas form a logical AOC for exposure and risk assessment and for evaluation of remedial alternatives, if required.

AOC No. 3 includes Ponds A-1, A-2 and A-3. These ponds all have similar chemical constituents in the pond sediment and all are in the North Walnut Creek drainage, so they

are hydrologically connected; therefore, they form a logical AOC for exposure and risk assessment and evaluation of potential remedial alternatives, if required.

AOC No. 4 includes Ponds B-1, B-2, B-3, and B-4. These ponds have similar chemical constituents in the sediment and all are hydrologically connected since they are in the South Walnut Creek drainage.

In addition, within AOC No. 2, a maximum exposure area of 30 acres was delineated for purposes of evaluating reasonable maximum risk to individuals in a future industrial or office park (30 acres).

Exposure concentrations used in the risk assessment were calculated for each media in each AOC using the results from all samples collected in that AOC. More detail on calculating exposure concentrations is provided in Section J5.0.

COCs are a subset of detected metals and radionuclides that had concentration distributions that differed significantly from background distributions and detected organic chemicals. COCs are selected to be the constituents most likely to contribute significantly to overall risk. COCs are evaluated in the quantitative risk assessment and are the focus of transport modeling, risk assessment, and remedy selection (if warranted). This section describes the process for determining COCs in surface soil, subsurface soil, groundwater, pond sediment, pond surface water, and stream/dry sediment. More detail is provided in the COC TM for OU6 (DOE 1994c).

J3.1 PROCESS FOR SELECTING OU-WIDE COCS

COCs in each medium were selected on an OU-wide basis; that is, all sample results from each medium were pooled for the evaluation. Risk-based and other screening methods were used to identify COCs; i.e., the chemicals that are likely to pose the greatest risk to human health. The COC selection process is illustrated in Figure J3-1 and summarized in the sections below.

J3.1.1 Background Comparison

Analytical results for metals and radionuclides detected in soil, sediment, surface water, and groundwater in OU6 were compared to background levels using four statistical tests: the Quantile test, Slippage test, Student's t-test, and the Gehan test (Gilbert 1993). In addition, analytical results were compared to the 99th percentile upper tolerance limit of the background data ($UTL_{99/99}$). Any analyte that failed one or more of the statistical tests or that had one or more results exceeding the $UTL_{99/99}$ was retained as a potential COC. A detailed description of the statistical methodology used to compare background data and tables showing results of the statistical tests are presented in Appendix A of the COC TM for OU6 (DOE 1994c).

J3.1.2 Essential Nutrients/Major Cations and Anions

Calcium, iron, magnesium, potassium, and sodium were eliminated from further consideration as COCs because they are essential nutrients, they occur naturally in the environment, and they are toxic only at very high doses. Cyanide, nitrate, and nitrite were retained for further evaluation, but other major cations and anions measured as water quality parameters, such as carbonates, were not evaluated.

J3.1.3 Frequency of Detection

Metals with concentration distributions in OU6 that were significantly different from background distributions and detected organic compounds were evaluated for frequency of detection. Chemicals that were detected at a frequency of 5 percent or greater were retained for further evaluation in concentration/toxicity screens to select OU-wide COCs. Organic chemicals and metals that were detected at less than 5 percent frequency were evaluated separately (see Section J3.1.6). Radionuclides were assumed to be detected at 100 percent frequency for statistical analysis (i.e., negative, zero, and positive results were retained in the data set); thus, the radionuclides were not screened based on frequency of detection.

J3.1.4 Professional Judgement

Some chemicals whose concentration distributions in OU6 were significantly different than background distributions based on results of the statistical tests were judged not to be potential OU6 contaminants based on spatial and temporal distribution, geochemical characteristics, the presence of high total suspended and dissolved solids in groundwater, or because their distribution was different from background but could not be considered to be above background. These chemicals were:

- Groundwater: all metals, bis(2-ethylhexyl)phthalate, cesium-137, and strontium-89,90
- Pond sediment: manganese
- Pond surface water: uranium isotopes
- Stream/dry sediment: arsenic, barium, and manganese

The evaluations and conclusions are described in detail in the COC TM for OU6 (DOE 1994c). However, to address concerns that some of these analytes, although probably not potential contaminants, could pose a health risk under long-term exposure to maximum detected concentrations, the following constituents were designated chemicals of interest (COIs) and were retained for consideration in a separate risk evaluation in Section J10.0, Uncertainties and Limitations (CDPHE 1994a; EPA Region VIII 1994; DOE 1994e):

- Groundwater: arsenic, antimony, beryllium, and manganese
- Stream/dry sediment: arsenic

J3.1.5 Concentration/Toxicity Screens

Concentration/toxicity screens were conducted separately for noncarcinogens, carcinogens, and radionuclides within each medium (surface soil, subsurface soil, groundwater, pond sediment, pond surface water, and stream/dry sediment). These screens were used to identify chemicals that, based on maximum concentration and toxicity criteria, are likely to contribute 1 percent or more of the total potential risk in each category (noncarcinogens, carcinogens, and radionuclides) in each medium. These chemicals were identified as COCs for evaluation in the quantitative risk assessment.

J3.1.6 Evaluation of Infrequently Detected Compounds

The maximum concentrations of organic compounds less than 5 percent frequency were compared to screening levels equivalent to 1,000 times risk-based concentrations (RBCs) to determine whether there was potential risk to human health on the basis of high concentration and toxicity even though the chemicals were rarely detected and exposure potential was low. RBCs were defined as chemical concentrations associated with an excess cancer risk of 1E-6 (1 in 1 million) or a hazard index of 1 for noncarcinogenic effects. RBCs for chemicals in surface soil were conservatively calculated assuming residential exposure via ingestion of soil and inhalation of airborne particulates. RBCs for chemicals in subsurface soil were calculated assuming construction worker exposure via soil ingestion and inhalation of particulates and VOCs. RBCs for chemicals in groundwater were calculated assuming residential exposure via ingestion of water and inhalation of VOCs during water use. The surface soil RBCs assuming residential exposure were used for comparison to chemical

concentrations in pond sediment, even through exposure to pond sediment would be much lower than exposure to soil. The groundwater RBCs, assuming residential exposure, were used for comparison to pond surface water as a conservative measure, even though the pond water is never expected to be used as a drinking water source. There were no infrequently detected compounds in stream/dry sediment, therefore no RBC comparison was performed in this medium. Only vinyl chloride in groundwater was identified as exceeding the 1,000 times RBC screen. The risk-based evaluation of infrequently detected chemicals is described in detail in Appendix B of the COC TM for OU6 (DOE 1994c).

J3.1.7 Special-Case COCs

Infrequently detected chemicals that were measured at concentrations greater than 1,000 times the RBC were retained as special-case COCs for separate evaluation in the risk assessment. Only vinyl chloride in groundwater was evaluated as a special-case COC.

J3.1.8 Chemicals of Interest (COIs)

COIs are compounds that are probably not environmental contaminants (i.e., they are naturally occurring) but were retained for separate consideration in the Section J10.0, Uncertainties and Limitations, because of their potential toxicity at environmental levels (Section J3.1.5).

J3.1.9 Chemicals Without EPA Toxicity Values

Chemicals that were detected in OU6 but do not have EPA-established toxicity values are listed in Table J3-1. These compounds cannot be evaluated in a toxicity or risk-based screen to select COCs. However, their potential contribution to overall risk was evaluated qualitatively in Section 10.0, Uncertainties and Limitations.

J3.2 SURFACE SOIL COCs

The sample set used to characterize extent of potential contamination and select COCs in surface soil is summarized in Section J2.0. COCs were identified using the process outlined in Section J3.1.

J3.2.1 Concentration/Toxicity Screens

Metals (except copper, lead, and those metals eliminated as essential nutrients in Section J3.1.2) and radionuclides with concentration distributions in OU6 significantly different from background distributions and detected at 5 percent or greater detection frequency were included in concentration/toxicity screens to select OU-wide chemicals of concern in surface soil. There were no organic chemicals detected at greater than 5 percent frequency, so no organic chemicals were evaluated in the concentration/toxicity screen. Detection frequencies are shown in Tables J3-2 and J3-3. Concentration/toxicity screens are shown in Tables J3-4 and J3-5.

In the concentration/toxicity screens, analytes that contributed at least 1 percent of the total risk factor were retained as OU-wide COCs. These are listed below.

OU-Wide Chemicals of Concern Surface Soil
Antimony
Silver
Vanadium
Zinc
Americium-241
Plutonium-239/240

Copper and lead cannot be evaluated quantitatively in toxicity-based screens, because they do not have EPA-approved toxicity factors. However, lead was evaluated qualitatively in the risk assessment by comparing the maximum concentration found in OU6 to EPA screening levels for residential soil (400 mg/kg; EPA 1994a). The maximum concentration of copper was low (62 mg/kg) and is not expected to have adverse effects because copper is not known to be particularly toxic.

J3.2.2 Special-Case COCs

Only Aroclor-1254 and molybdenum were detected at less than 5 percent frequency (Table J3-3). Neither of these chemicals exceeded 1,000 times the RBC (DOE 1994c, Appendix B). Thus, no special-case COCs in surface soil were identified.

J3.3 SUBSURFACE SOIL COCs

The sample set used to characterize extent of potential contamination and select COCs in subsurface soil is summarized in Section J2.0. COCs were identified using the process outlined in Section J3.1.

J3.3.1 Concentration/Toxicity Screens

All organic compounds that were detected at 5 percent or greater detection frequency and metals (except lead) and radionuclides with concentration distributions in OU6 significantly different from background distributions and also detected at 5 percent or greater detection frequency were included in the concentration/toxicity screens to select OU-wide COCs in subsurface soil. Detection frequencies are shown in Tables J3-6 and J3-7. Concentration/toxicity screens are shown in Tables J3-8 through J3-10.

In the concentration/toxicity screens, analytes that contributed at least 1 percent of the total risk factor were retained as OU-wide chemicals of concern. In addition, although Am-241 and Pu-239/240 represented less than 1 percent of the total risk factor, they were retained as COCs because (1) they are known to be waste related, (2) they were detected in numerous samples, and (3) the maximum activity for uranium-238 used in the concentration/toxicity screen was an extreme value (much higher than other sample results for this analyte) and could contribute to an underestimation of the potential contribution to overall risk from Am-241 and Pu-239/240.

Chemicals of concern in subsurface soil are listed as follows.

OU-Wide Chemicals of Concern Subsurface Soil
Benzo(a)pyrene
Benzo(b)fluoranthene
Barium
Americium-241
Plutonium-239/240
Uranium-233/234
Uranium-238

Lead cannot be evaluated quantitatively in the concentration/toxicity screen because it does not have EPA-approved toxicity factors. However, lead was evaluated qualitatively in the risk assessment by comparing to EPA screening levels for residential soil (400 mg/kg; EPA 1994a).

J3.3.2 Special-Case COCs

None of the chemicals detected at low frequency in subsurface soil exceeded 1,000 times the RBC (see DOE 1994c, Appendix B). Thus, there were no special-case COCs in subsurface soil.

J3.4 GROUNDWATER COCs

The sample set used to characterize extent of potential contamination and select COCs in groundwater is summarized in Section J2.0 of this risk assessment. Groundwater samples were analyzed for metals and radionuclides (in filtered and unfiltered samples) and for VOCs, SVOCs, pesticides/PCBs, and water quality parameters. Results from unfiltered samples were used in selecting COCs, using the process outlined in Section J3.1.

J3.4.1 Concentration/Toxicity Screens

All metals were eliminated as potential contaminants and therefore were excluded from the concentration/toxicity screens because their presence in unfiltered groundwater samples was determined to be associated with local geochemical conditions and with high levels of suspended solids in unfiltered samples (DOE 1994c). In fact, even common rock-forming elements such as calcium, iron, and sodium had concentration distributions in OU6 that were significantly different from background distributions; their concentrations in groundwater are also most likely related to local geochemical characteristics and to suspended solids in the samples.

Organic compounds that were detected at 5 percent or greater detection frequency, nitrate, and radionuclides with concentration distributions that were significantly different from background distributions were included in concentration/toxicity screens to select OU-wide COCs in groundwater. Detection frequencies are shown in Tables J3-11 and J3-12. Concentration/toxicity screens are shown in Tables J3-13 through J3-15.

In the concentration/toxicity screens, analytes that contributed at least 1 percent of the total risk factor were retained as OU-wide COCs. OU-wide COCs for groundwater are listed below.

OU-Wide Chemicals of Concern Groundwater
Chloroform
Methylene Chloride
Tetrachloroethene
Trichloroethene
Nitrate
Americium-241
Plutonium-239/240
Radium-226

The following paragraphs discuss several factors pertinent to the selection of COCs in groundwater.

Bis(2-ethylhexyl)phthalate was detected in three groundwater samples and in each case the result was an estimated value below the detection limit. The three detections were temporally isolated (detected in only one of multiple sampling rounds) and were from spatially distant wells. Since the data do not support an assumption of environmental contamination and since bis(2-ethylhexyl)phthalate is a common field and laboratory contaminant, it was eliminated from further consideration as a COC in groundwater.

Cesium-137 was not found to be significantly different than background levels in groundwater according to the four formal statistical tests. However, two of the results exceeded the background $UTL_{99/99}$, therefore identifying cesium-137 as a potential COC. The two results that exceeded the background $UTL_{99/99}$ were temporally isolated (unrelated in time) and all other results were within background range. Because only two of the results exceeded the background range and they were temporally isolated events, cesium-137 was not considered a potential contaminant in groundwater and was not evaluated further. Further detail is provided in the COC TM for OU6 (DOE 1994c).

Only three groundwater samples were analyzed for strontium-89,90 and all of the results were within or slightly above background levels (DOE 1994a). Because the size of the sample set was small and the results close to background, strontium-89,90 was not included in the determination of OU-wide COCs.

Based on the concentration/toxicity screen, radium-226 would be expected to contribute significantly to potential risk in OU6 if groundwater were used as a drinking water supply. However, the maximum value for radium-226 occurred in the Old Outfall (IHSS 143), which is not evaluated in this OU6 HHRA. Radium-226 was only analyzed for in two other samples outside IHSS 143, and the highest concentration in these samples was 1.2 pCi/L, close to background levels. Therefore, radium-226 should probably not be considered an OU-wide COC in groundwater.

J3.4.2 Groundwater COCs Evaluated in the HHRA

Direct contact with groundwater (e.g., ingestion) is not a complete exposure pathway for any exposure scenario evaluated in OU6 (see Section J4.4). Furthermore, groundwater in OU6 is not a significant source of transport to surface water (see Section J5.10.1 and Section 5.4 of the RFI/RI report). However, exposure to volatile chemicals in groundwater could potentially occur via inhalation of VOCs infiltrating through building foundations. Therefore, only volatile organic COCs were evaluated in the HHRA. Nitrates detected in some OU6 wells upgradient of the A-series ponds are related to sources in OU4 (Solar Ponds) and were not evaluated in the OU6 HHRA because (1) no exposure scenario under current and future use includes ingestion of UHSU groundwater and (2) the migration of nitrates could not be modeled because source terms cannot be defined based on OU6 data (see Section 5.0 of the RFI/RI report).

J3.4.3 Special-Case COCs

Vinyl chloride is not an OU-wide COC because it was detected infrequently (in only 3 percent of groundwater samples collected in OU6). However, vinyl chloride was identified as a special-case COC in groundwater because concentrations in one well exceeded 1,000 times the RBC (1,000 x RBC = 0.02 mg/L) (DOE 1994c, Appendix B).

J3.4.4 Chemicals of Interest (COIs)

To address concerns that some metals, although probably not contaminants, could pose a health risk under long-term exposure to maximum detected concentrations, parties to the IAG have agreed that antimony, arsenic, beryllium, and manganese in groundwater would be evaluated separately as COIs in the uncertainties section of the HHRA (CDPHE 1994a; EPA Region VIII 1994; DOE 1994b).

J3.5 POND SEDIMENT COCs

The two sample sets from the OU6 Phase I investigation used to characterize extent of potential contamination and select COCs in pond sediment are summarized in Section J2.0. COCs were identified using the process outlined in Section J3.1.

J3.5.1 Concentration/Toxicity Screens

All organic compounds that were detected at 5 percent or greater detection frequency and metals and radionuclides with concentration distributions in OU6 that were significantly different from background distributions and detected at 5 percent or greater detection frequency were included in the concentration/toxicity screens to select OU-wide COCs in pond sediment. Detection frequencies are shown in Tables J3-16 and J3-17. Concentration/toxicity screens are shown in Tables J3-18 through J3-20.

In the concentration/toxicity screens, analytes that contributed at least 1 percent of the total risk factor were retained as OU-wide COCs. These are listed as follows:

OU-Wide Chemicals of Concern
Pond Sediment

Aroclor-1254	Silver
Benzo(a)pyrene	Vanadium
Benzo(b)fluoranthene	Americium-241
Bis(2-ethylhexyl)phthalate	Plutonium-239/240
Antimony	

Manganese was not included in the selection of COCs for pond sediment, even though it failed the Gehan test when compared to background levels measured in seep/spring sediment samples. However, the mean (283.2 mg/kg) and maximum (558 mg/kg) concentrations of manganese in pond sediment were well below the mean (318 mg/kg) and maximum (1,740 mg/kg) concentrations in the background data set, and manganese in pond sediment was not detected above the background $UTL_{99/99}$. Other metals whose concentration distributions in pond sediment differed from distributions of background concentrations were also identified as COCs in surface soil. However, manganese was not a potential contaminant in surface soil, subsurface soil, or groundwater, and therefore would not be expected to be a potential contaminant in sediment. Therefore, manganese was eliminated from further evaluation as a COC in pond sediment.

J3.5.2 Special-Case COCs

None of the chemicals detected at low frequency in pond sediment exceeded 1,000 times the RBC (DOE 1994c, Appendix B). Thus, there were no special-case COCs in pond sediment.

J3.5.3 1994 Pond Sediment Samples

In 1994, in a separate sampling program, additional pond sediment samples were collected near the OU6 Phase I sampling locations and analyzed for PCBs and radionuclides. The sample depth (0 to 6 inches) was selected in order to evaluate concentrations of these analytes in the sediment layer where exposure of ecological and human receptors is most likely to occur. Compounds identified as OU-wide COCs in pond sediment (Aroclor-1254, Am-241, and Pu-234/240) were evaluated in a focused risk assessment presented in Attachment J5.

J3.6 POND SURFACE WATER COCs

The sample set used to characterize extent of potential contamination and select COCs in pond surface water is summarized in Section J2.0. Surface water samples were analyzed for metals and radionuclides (in filtered and unfiltered samples) and for VOCs, SVOCs, and WQPLS. Results from unfiltered samples were used in selecting COCs, using the process outlined in Section J3.1.

J3.6.1 Concentration/Toxicity Screens

Organic compounds that were detected at 5 percent or greater detection frequency were included in concentration/toxicity screens to select OU-wide COCs in pond surface water. No metals or radionuclides (except uranium, which is discussed below) had concentration distributions that were significantly different from background distributions. Detection frequencies are shown in Tables J3-21 and J3-22. The concentration/toxicity screens are shown in Tables J3-23 and J3-24.

In the concentration/toxicity screens, analytes that contributed at least 1 percent of the total risk factor were retained as OU-wide COCs. These are listed below.

OU-Wide Chemicals of Concern Pond Surface Water
Chloroform 1,2-Dichloroethene Trichloroethene Di-n-butylphthalate

Uranium isotopes (U-233/234, U-235, and U-238) were the only radionuclides in unfiltered pond water that had concentration distributions in OU6 that differed from background distributions measured in seep/spring water. The ratio of U-233/234 to U-238 activity is about 1 in naturally occurring uranium (DOE 1992b). In water from the various ponds, the ratio ranged from 0.7 to 1.3 (overall average = 1.0). Therefore, it was concluded that uranium in pond water derives from naturally occurring sources. In addition, levels of uranium isotopes in OU6 surface soil or in groundwater did not differ from background levels, which supports a conclusion that these isotopes are not potential contaminants but rather are naturally occurring. Therefore, uranium isotopes were eliminated from further evaluation as COCs in pond surface water.

J3.6.2 Special-Case COCs

None of the chemicals detected at low frequency in pond surface water exceeded 1,000 times the RBC (DOE 1994c, Appendix B). Thus, there were no special-case COCs in pond surface water.

J3.7 STREAM/DRY SEDIMENT COCs

The sample set used to characterize extent of potential contamination and select COCs in stream/dry sediment is summarized in Section J2.0. COCs were identified using the process outlined in Section J3.1. The statistical background comparison and COC selection were performed using only the stream sediment data and the same COCs were adopted for dry sediment. Dry sediment is exposed sediment near stream channels or in the floodplains of

the ponds; therefore exposure to dry sediment would likely occur under the same conditions as exposure to stream sediment. A comparison of chemicals detected in stream and dry sediment confirms that selecting COCs using stream sediment samples is a reasonable approach because the concentrations of chemicals and metals detected above background in dry sediment would have little or no effect on the selection of COCs (Table J3-29).

J3.7.1 Concentration/Toxicity Screens

Organic compounds and radionuclides and most metals with concentration distributions significantly different from background distributions were included in concentration/toxicity screens to select OU-wide COCs in stream/dry sediment. No analytes were detected at less than 5 percent frequency. Detection frequencies are shown in Table J3-25. Concentration/toxicity screens are shown in Tables J3-26 through J3-28.

In the concentration/toxicity screens, analytes that contributed at least 1 percent of the total risk factor were retained as OU-wide chemicals of concern. These are listed below.

OU-Wide Chemicals of Concern
Stream/Dry Sediment

Benzo(a)anthracene	Strontium
Benzo(a)pyrene	Vanadium
Benzo(b)fluoranthene	Zinc
Indeno(1,2,3-cd)pyrene	Americium-241
Cobalt	Plutonium-239/240

The following paragraphs discuss several factors pertinent to the selection of COCs in stream/dry sediment (DOE 1994c).

Arsenic in stream sediment failed the Gehan test used in the background comparison (DOE 1994c). However, further analysis of the distribution of arsenic around the plant site and

a review of historical release reports indicated that the presence of arsenic in stream sediment is likely to be naturally occurring. The maximum concentration of arsenic in stream sediment (5.8 mg/kg) was nearly three times lower than the background maximum (17.3 mg/kg) and was also well below the background $UTL_{99/99}$ (10.1 mg/kg). In addition, arsenic in OU6 surface soil did not differ significantly from background and surface soil is the only source of sediment loading to the stream beds. Therefore, because the maximum concentration of arsenic in stream sediment is significantly lower than the background maximum and arsenic is not a potential contaminant in surface soil, it was eliminated from further consideration as a COC in stream/dry sediment. However, arsenic was evaluated as a COI, as noted in Section J3.7.3 below.

Similarly, manganese and barium were also identified as being significantly different from background because they failed one of the four formal statistical tests. However, the maximum concentrations of barium and manganese in stream/dry sediment were below the respective background maximums. In addition, as with arsenic, barium and manganese levels in surface soil did not differ from their respective background levels, and surface soil is the only source of sediment loading to the stream beds. Therefore, barium and manganese were not considered potential contaminants in stream/dry sediment and were eliminated from further evaluation.

J3.7.2 Special-Case COCs

There were no chemicals detected at less than 5 percent frequency; therefore, comparison to RBCs to identify special-case COCs was not necessary.

J3.7.3 Chemicals of Interest (COIs)

To address concerns that arsenic, although probably not a contaminant, could pose a health risk under long-term exposure to maximum detected concentrations, even if naturally occurring, parties to the IAG have agreed to evaluate arsenic in stream/dry sediment separately in the HHRA as a COI (DOE 1995b).

J3.8 CHEMICALS OF CONCERN IN OU6

The chemicals of concern identified for each medium, including special-case COCs and COIs, are summarized in Table J3-30.

TABLE J3-1
DETECTED CHEMICALS AND METALS WITHOUT EPA TOXICITY FACTORS

Surface Soil
Copper
Lead[1]

Subsurface Soil
Lead[1]
Phenanthrene

Pond Sediment
2-Methylnaphthalene
Benzo(ghi)perylene
Phenanthrene
Dibenzofuran
Copper

Stream/Dry Sediment
Benzo(ghi)perylene
Dibenzofuran
Phenanthrene

[1] Lead was evaluated qualitatively in the risk assessment by comparing maximum concentrations to EPA screening levels for residential soil (Section J8.7)

TABLE J3-2
METALS DETECTED AT
5% OR GREATER FREQUENCY
SURFACE SOIL[1]

Chemical	Maximum Detected Concentration (mg/kg)	Detection Frequency[2] %	> Background [3]?
Aluminum	24,100	100	No
Antimony	43.6	47	Yes
Arsenic	11	100	No
Barium	272	100	No
Beryllium	1.5	90	No
Cadmium	6.4	41	No
Cesium	35.4	86	No
Chromium	35.1	99	Yes
Cobalt	20.3	100	Yes
Copper	61.6	100	Yes
Lead	68.7	100	Yes
Lithium	18.1	95	No
Manganese	823	100	No
Mercury	0.34	41	Yes
Nickel	22.5	95	Yes
Selenium	1.3	35	No
Silver	52.7	8	Yes
Strontium	255	100	Yes
Thallium	0.55	44	No
Tin	38.7	5	No
Vanadium	75.9	100	Yes
Zinc	650	100	Yes

[1] Excluding data from Old Outfall (IHSS 143), which was removed from evaluation in OU6.

[2] Detection frequency calculated without QA/QC duplicate samples.

[3] Background comparison is detailed in Appendix A of Technical Memorandum No. 4 (DOE 1994c).

TABLE J3-3
METALS AND PESTICIDES/PCBs DETECTED AT LESS THAN 5% FREQUENCY SURFACE SOIL[1]

Chemical	Maximum Detected Concentration (mg/kg)	Detection Frequency[2] %	> Background [3]?	> 1,000 x RBC?
Aroclor-1254	0.425	1		No
Molybdenum	9.9	1	Yes	No

[1] Excluding data from Old Outfall (IHSS 143), which was removed from evaluation in OU6.
[2] Detection frequency calculated without QA/QC duplicate samples.
[3] Background comparison is detailed in Appendix A of Technical Memorandum No. 4 (DOE 1994c).
RBC - Risk-based concentration

TABLE J3-4
CONCENTRATION/TOXICITY SCREEN
SURFACE SOIL[1]
NONCARCINOGENS

Chemical	Maximum Detected Conc. (mg/kg)	Inhalation RfD	Oral RfD	Risk Factor	Risk Index	% of Total Risk Factor
Antimony	43.6	n/a	4.0E-04	1.1E+05	8.0E-01	80.4
Vanadium	75.9	n/a	7.0E-03	1.1E+04	8.0E-02	8.0
Silver	52.7	n/a	5.0E-03	1.1E+04	7.8E-02	7.8
Zinc	650	n/a	3.0E-01	2.2E+03	1.6E-02	1.6
Mercury	0.34	n/a	3.0E-04	1.1E+03	8.4E-03	0.8
Nickel	22.5	n/a	2.0E-02	1.1E+03	8.3E-03	0.8
Strontium	255	n/a	6.0E-01	4.3E+02	3.1E-03	0.3
Cobalt	20.3	n/a	6.1E-02	3.3E+02	2.5E-03	0.2
Chromium	35.1	n/a	1.0E+00	3.5E+01	2.6E-04	0.0
Total Risk Factor				1.4E+05		

[1] Excluding data from Old Outfall (IHSS 143), which was removed from evaluation in OU6.
RfDs are in units of mg/kg-day.
n/a = not available.

TABLE J3-5
CONCENTRATION/TOXICITY SCREEN
SURFACE SOIL[1]
RADIONUCLIDES

Chemical	Maximum Detected Conc. (pCi/g)	Inhalation Slope Factor	Oral Slope Factor	Risk Factor	Risk Index	% of Total Risk Factor
Plutonium-239/240	15.22	2.8E-08	3.2E-10	4.3E-07	7.7E-01	77.1
Americium-241	3.243	3.9E-08	3.3E-10	1.3E-07	2.3E-01	22.9
Total Risk Factor				5.5E-07		

[1] Excluding data from Old Outfall (IHSS 143), which was removed from evaluation in OU6.
Slope factors are in units of risk/pCi.

TABLE J3-6
ORGANIC COMPOUNDS AND METALS DETECTED AT 5% OR GREATER FREQUENCY SUBSURFACE SOIL [1]

Chemical	Maximum Detected Concentration (mg/kg)	Detection Frequency[2] %	> Background [3]?
Organic Compounds:			
2-Butanone	3.7	22	
2-Chlorophenol	0.055	8	
Acetone	5.1	88	
Benzo(a)pyrene	0.13	8	
Benzo(b)fluoranthene	0.17	12	
Benzoic acid	0.26	19	
Bis(2-ethylhexyl)phthalate	0.11	27	
Fluoranthene	0.45	27	
Phenanthrene	0.17	12	
Pyrene	0.19	23	
Toluene	1.1	90	
Metals:			
Aluminum	24100	100	No
Antimony	21.65	7	No
Arsenic	10.9	99	No
Barium	2970	100	Yes
Beryllium	2.1	86	No
Cadmium	1.8	7	No
Cesium	33.7	71	No
Chromium	217	98	Yes
Cobalt	21.4	95	No
Copper	52.1	100	No
Lead	84.9	100	Yes
Lithium	29.8	89	No
Manganese	907	100	No
Mercury	0.93	28	No
Nickel	41.5	64	No
Selenium	1.3	8	No
Strontium	506	100	Yes
Thallium	0.69	34	No
Vanadium	118	100	Yes
Zinc	706	100	Yes

[1] Excluding data from Old Outfall (IHSS 143), which was removed from evaluation in OU6.
[2] Detection frequency calculated without QA/QC duplicate samples.
[3] Background comparison is detailed in Appendix A of Technical Memorandum No. 4 (DOE 1994c

TABLE J3-7
ORGANIC COMPOUNDS AND METALS DETECTED AT LESS THAN 5% FREQUENCY SUBSURFACE SOIL [1]

Chemical	Maximum Detected Concentration (mg/kg)	Detection Frequency[2] %	> Background [3]?	> 1,000 x RBC Screen?
Organic Compounds:				
1,4-Dichlorobenzene	0.064	4		No
4-Methyl-2-pentanone	0.004	1		No
Acenaphthene	0.056	4		No
Benzene	0.006	1		No
Benzo(a)anthracene	0.099	4		No
Benzo(k)fluoranthene	0.06	4		No
Chlorobenzene	0.074	0.3		No
Chloroform	0.002	0.3		No
Chrysene	0.12	4		No
Diethyl phthalate	0.3	4		No
Di-n-octyl phthalate	0.072	4		No
Indeno(1,2,3-cd)pyrene	0.099	4		No
Methylene chloride	0.007	3		No
Pentachlorophenol	0.66	4		No
Phenol	0.055	4		No
Styrene	0.001	0.3		No
Xylenes, total	0.002	0.3		No
Trichloroethene	0.021	2		No
Metals:				
Molybdenum	27.9	2	No	
Silver	2.7	0.4	No	
Tin	57.8	3	No	

[1] Excluding data from Old Outfall (IHSS 143), which was removed from evaluation in OU6.

[2] Detection frequency calculated without QA/QC duplicate samples.

[3] Background comparison is detailed in Appendix A of Technical Memorandum No. 4 (DOE 1994c).

RBC - Risk-based concentration.

TABLE J3-8
CONCENTRATION/TOXICITY SCREEN
SUBSURFACE SOIL[1]
NONCARCINOGENS

Chemical	Maximum Detected Conc. (mg/kg)	Inhalation RfD	Oral RfD	Risk Factor	Risk Index	% of Total Risk Factor
Barium	2,970	1.4E-04	7.0E-02	2.1E+07	1.0E+00	99.9
Vanadium	118	n/a	7.0E-03	1.7E+04	7.9E-04	0.1
Zinc	706	n/a	3.0E-01	2.4E+03	1.1E-04	0.0
Strontium	506	n/a	6.0E-01	8.4E+02	4.0E-05	0.0
Chromium	217	n/a	1.0E+00	2.2E+02	1.0E-05	0.0
Acetone	5.1	n/a	1.0E-01	5.1E+01	2.4E-06	0.0
2-Butanone	3.7	3.0E-01	6.0E-01	1.2E+01	5.8E-07	0.0
Fluoranthene	0.45	n/a	4.0E-02	1.1E+01	5.3E-07	0.0
2-Chlorophenol	0.055	n/a	5.0E-03	1.1E+01	5.2E-07	0.0
Toluene	1.1	1.1E-01	2.0E-01	1.0E+01	4.7E-07	0.0
Pyrene	0.19	n/a	3.0E-02	6.3E+00	3.0E-07	0.0
Bis(2-ethylhexyl)phthalate	0.11	n/a	2.0E-02	5.5E+00	2.6E-07	0.0
Benzoic acid	0.26	n/a	4.0E+00	6.5E-02	3.1E-09	0.0
Total Risk Factor				2.1E+07		

[1] Excluding data from Old Outfall (IHSS 143), which was removed from evaluation in OU6.
RFDs are in units of mg/kg-day.
n/a = not available

TABLE J3-9
CONCENTRATION/TOXICITY SCREEN
SUBSURFACE SOIL[1]
CARCINOGENS

Chemical	Maximum Detected Conc. (mg/kg)	Inhalation Slope Factor	Oral Slope Factor	Risk Factor	Risk Index	% of Total Risk Factor
Benzo(a)pyrene	0.13	n/a	7.3E+00	9.5E-01	8.8E-01	88.3
Benzo(b)fluoranthene	0.17	n/a	7.3E-01	1.2E-01	1.1E-01	11.5
Bis(2-ethylhexyl)phthalate	0.11	n/a	1.4E-02	5.5E-03	4.9E-03	0.1
Total Risk Factor				1.1E+00		

[1] Excluding data from Old Outfall (IHSS 143), which was removed from evaluation in OU6.
Slope factors are in units of risk/(mg/kg-day).
n/a = not available.

TABLE J3-10
CONCENTRATION/TOXICITY SCREEN
SUBSURFACE SOIL
RADIONUCLIDES

Chemical	Maximum Activity (pCi/g)	Inhalation Slope Factor	Oral Slope Factor	Risk Factor	Risk Index	% of Total Risk Factor
Uranium-238	141	1.2E-08	6.2E-11	1.7E-06	9.5E-01	95.1
Uranium-233/234	3.05	1.4E-08	4.4E-11	4.3E-08	2.4E-02	2.4
Plutonium-239/240	0.88	2.8E-08	3.2E-10	2.5E-08	1.4E-02	1.4
Americium-241	0.44	3.9E-08	3.3E-10	1.7E-08	9.6E-03	1.0
Uranium-235	0.16	1.3E-08	4.7E-11	2.1E-09	1.2E-03	0.1
Total Risk Factor				1.8E-06		

Slope factors are in units of risk/pCi.

TABLE J3-11
ORGANIC COMPOUNDS AND TOTAL METALS DETECTED AT 5% OR GREATER FREQUENCY GROUNDWATER

Chemical	Maximum Detected Concentration (mg/L)	Detection Frequency[1] %	> Background [2]?
Organic Compounds:			
1,1,1-Trichloroethane	0.012	9	
1,1-Dichloroethane	0.062	9	
1,2-Dichloroethene (total)	0.074	11	
1,2-Dichloroethene, cis	0.0007	6	
Acetone	0.027	5	
Bis(2-ethylhexyl)phthalate	0.008	21	
Chloroform	0.008	9	
Diethyl phthalate	0.002	7	
Methylene chloride	0.032	12	
Tetrachloroethene	0.013	15	
Toluene	0.016	6	
Trichloroethene	0.15	14	
Metals:			
Aluminum	456	95	Yes
Antimony	0.194	16	Yes
Arsenic	0.018	52	Yes
Barium	5.06	98	Yes
Beryllium	0.032	30	Yes
Cadmium	0.0329	26	Yes
Chromium	0.58	75	Yes
Cobalt	0.228	45	Yes
Copper	6.43	54	Yes
Lead	0.254	73	Yes
Lithium	0.456	93	Yes
Manganese	6.2	94	Yes
Mercury	0.0015	10	Yes
Molybdenum	0.0295	27	No
Nickel	1.07	66	Yes
Selenium	0.475	58	Yes
Silver	3.04	20	Yes
Strontium	6.96	100	Yes
Thallium	0.0027	5	No
Tin	0.267	19	No
Vanadium	0.754	74	Yes
Zinc	8	83	Yes

[1] Detection frequency calculated without QA/QC duplicate samples.
[2] Background comparison is detailed in Appendix A of Technical Memorandum No. 4 (DOE 1994c).

TABLE J3-12
ROCKY FLATS OU6
ORGANIC COMPOUNDS AND TOTAL METALS DETECTED AT LESS THAN 5% FREQUENCY
GROUNDWATER

Chemical	Maximum Detected Concentration (mg/L)	Detection Frequency[1] %	> Background [2]?	> 1000 x RBC Screen?
Organic Compounds:				
1,1-Dichloroethene	0.005	1		No
1,2-Dichloroethane	0.002	1		No
1,2-Dichloroethene, trans	0.009	2		No
1,2,4-Trimethylbenzene	0.0002	3		No
2-Butanone	0.001	1		No
2-Hexanone	0.005	0.4		No
4-Methyl-2-pentanone	0.002	1		No
Benzene	0.003	3		No
Carbon disulfide	0.004	1		No
Carbon tetrachloride	0.008	4		No
Chloromethane	0.00025	0.4		No
Ethylbenzene	0.001	2		No
Styrene	0.00011	0.4		No
Vinyl chloride	0.86	3		Yes
Xylenes (total)	0.014	4		No
Metals:				
Cesium	0.15	2	No	

[1] Detection frequency calculated without QA/QC duplicate samples.

[2] Background comparison is detailed in Appendix A of Technical Memorandum No. 4 (DOE 1994c).

RBC - Risk-based concentration.

TABLE J3-13
CONCENTRATION/TOXICITY SCREEN
GROUNDWATER
NONCARCINOGENS

Chemical	Maximum Detected Conc. (mg/L)	Inhalation RfD	Oral RfD	Risk Factor	Risk Index	% of Total Risk Factor
Nitrate	1,760	n/a	1.6E+00	1.1E+03	9.9E-01	98.9
1,2-Dichloroethene (total)	0.074	n/a	9.0E-03	8.2E+00	7.4E-03	0.7
Tetrachloroethene	0.013	n/a	1.0E-02	1.3E+00	1.2E-03	0.1
Chloroform	0.008	n/a	1.0E-02	8.0E-01	7.2E-04	0.1
1,1-Dichloroethane	0.062	1.4E-01	1.0E-01	6.2E-01	5.6E-04	0.1
Methylene chloride	0.032	9.0E-01	6.0E-02	5.3E-01	4.8E-04	0.0
Acetone	0.027	n/a	1.0E-01	2.7E-01	2.4E-04	0.0
Toluene	0.016	1.1E-01	2.0E-01	1.5E-01	1.3E-04	0.0
cis-1,2-Dichloroethene	0.0007	n/a	1.0E-02	7.0E-02	6.3E-05	0.0
Diethyl phthalate	0.002	n/a	8.0E-01	2.5E-03	2.2E-06	0.0
Total Risk Factor				1.1E+03		

RfDs are in units of mg/kg-day.
n/a = not available.

TABLE J3-14
CONCENTRATION/TOXICITY SCREEN
GROUNDWATER CARCINOGENS

Chemical	Maximum Detected Conc. (mg/L)	Inhalation Slope Factor	Oral Slope Factor	Risk Factor	Risk Index	% of Total Risk Factor
Trichloroethene	0.15	6.0E-03	1.1E-02	1.7E-03	5.1E-01	51.5
Tetrachloroethene	0.013	2.0E-03	5.2E-02	6.8E-04	2.1E-01	21.1
Chloroform	0.008	8.0E-02	6.1E-03	6.4E-04	2.0E-01	20.0
Methylene chloride	0.032	1.6E-03	7.5E-03	2.4E-04	7.5E-02	7.5
Total Risk Factor				3.2E-03		

Slope factors are in units of risk/(mg/kg-day).
n/a = not available.

TABLE J3-15
CONCENTRATION/TOXICITY SCREEN
GROUNDWATER RADIONUCLIDES

Chemical	Maximum Activity (pCi/L)	Inhalation Slope Factor		Oral Slope Factor	Risk Factor	Risk Index	% of Total Risk Factor
Radium-226[1]	8.8	2.8E-09	*	3.0E-10	2.6E-09	5.4E-01	54.3
Plutonium-239/240	3.65	2.8E-08	*	3.2E-10	1.2E-09	2.4E-01	24.0
Americium-241	3.2	3.9E-08	*	3.3E-10	1.1E-09	2.2E-01	21.7
Total Risk Factor					4.9E-09		

Slope factors are in units of risk/pCi.

* Inhalation of radionuclides from groundwater is an incomplete pathway. Therefore, oral toxicity factors were used in the screen.

[1] The maximum concentration of Radium-226 occurred at the Old Outfall (IHSS 143). Radium-226 was only analyzed for in two samples outside of the Old Outfall and the maximum concentration was 1.2 pCi/L.

TABLE J3-16
ORGANIC COMPOUNDS AND METALS DETECTED AT 5% OR GREATER FREQUENCY POND SEDIMENT

Chemical	Maximum Detected Concentration (mg/kg)	Detection Frequency[1] %	> Background[2]?
Organic Compounds:			
2-Butanone	0.13	53	
Acenaphthene	0.59	9	
Acetone	0.81	25	
Anthracene	0.8	20	
Aroclor-1254	10	44	
Benzene	0.01	6	
Benzo(a)anthracene	1.1	38	
Benzo(a)pyrene	0.87	41	
Benzo(b)fluoranthene	3.1	45	
Benzo(g,h,i)perylene	0.66	11	
Benzo(k)fluoranthene	1	32	
Benzoic acid	4.6	27	
Bis(2-ethylhexyl)phthalate	88	80	
Butyl benzylphthalate	0.12	5	
Chrysene	1.9	52	
Di-n-octyl phthalate	0.25	11	
Fluoranthene	3.5	66	
Indeno(1,2,3-cd)pyrene	0.66	14	
Phenanthrene	2.6	54	
Pyrene	3.8	66	
Toluene	1.1	90	
Metals:			
Aluminum	27,400	100	No
Antimony	68.5	39	Yes
Arsenic	10.2	100	No
Barium	254	100	No
Beryllium	15.2	98	No
Cadmium	9.9	39	No
Cesium	5.8	93	No
Chromium	96.1	100	Yes
Cobalt	15.5	100	Yes
Copper	125	100	Yes
Lead	155	100	No
Lithium	16.6	98	No
Manganese	558	100	Yes
Mercury	1.5	43	No
Nickel	58.1	70	No
Selenium	1.9	5	No
Silver	345	39	Yes
Strontium	307	100	No
Thallium	0.85	39	No
Vanadium	62.7	100	Yes
Zinc	1,270	100	Yes

[1] Detection frequency calculated without QA/QC duplicate samples.

[2] Background comparison is detailed in Appendix A of Technical Memorandum No. 4 (DOE 1994c).

TABLE J3-17
ORGANIC COMPOUNDS AND METALS DETECTED AT LESS THAN 5% FREQUENCY
POND SEDIMENT

Chemical	Maximum Detected Concentration (mg/kg)	Detection Frequency[1] %	> Background [2]?	>1,000 x RBC Screen?
Organic Compounds:				
1,2,4-Trichlorobenzene	0.13	2		No
2-Methylnaphthalene	0.17	2		-
4-Methyl-2-pentanone	0.006	2		No
Aldrin	0.054	2		No
Aroclor-1260	0.86	4		No
Dibenzo(a,h)anthracene	0.15	2		No
Dibenzofuran	0.18	2		-
Fluorene	0.46	4		No
gamma-BHC (Lindane)	0.025	2		No
Heptachlor	0.039	1		No
Methylene chloride	0.009	2		No
Naphthalene	0.39	2		No
Phenol	0.29	4		No
Metals:				
Tin	39.5	2	No	

[1] Detection frequency calculated without QA/QC duplicate samples.

[2] Background comparison is detailed in Appendix A of Technical Memorandum No. 4 (DOE 1994c).

RBC - Risk-based concentration.

- Toxicity factors are not available and an RBC cannot be calculated.

TABLE J3-18
CONCENTRATION/TOXICITY SCREEN
POND SEDIMENT
NONCARCINOGENS

Chemical	Maximum Detected Conc. (mg/kg)	Inhalation RfD		Oral RfD	Risk Factor	Risk Index	% of Total Risk Factor
Aroclor-1254	10	n/a		2.0E-05	5.0E+05	6.6E-01	65.9
Antimony	68.5	n/a		4.0E-04	1.7E+05	2.3E-01	22.6
Silver	345	n/a		5.0E-03	6.9E+04	9.1E-02	9.1
Vanadium	62.7	n/a		7.0E-03	9.0E+03	1.2E-02	1.2
Bis(2-ethylhexyl)phthalate	88	n/a		2.0E-02	4.4E+03	5.8E-03	0.6
Zinc	1,270	n/a		3.0E-01	4.2E+03	5.6E-03	0.6
Cobalt	15.5	n/a		6.0E-02	2.6E+02	3.4E-04	0.0
Methylene chloride	8.3	9.0E-01	*	6.0E-02	1.4E+02	1.8E-04	0.0
Pyrene	3.8	n/a		3.0E-02	1.3E+02	1.7E-04	0.0
Chromium	96.1	n/a		1.0E+00	9.6E+01	1.3E-04	0.0
Fluoranthene	3.5	n/a		4.0E-02	8.8E+01	1.2E-04	0.0
Di-n-octylphthalate	0.25	n/a		2.0E-02	1.3E+01	1.6E-05	0.0
Acenaphthene	0.59	n/a		6.0E-02	9.8E+00	1.3E-05	0.0
Acetone	0.81	n/a		1.0E-01	8.1E+00	1.1E-05	0.0
Toluene	1.1	1.1E-01	*	2.0E-01	5.5E+00	7.3E-06	0.0
Anthracene	0.8	n/a		3.0E-01	2.7E+00	3.5E-06	0.0
Benzoic acid	4.6	n/a		4.0E+00	1.2E+00	1.5E-06	0.0
Butyl benzylphthalate	0.12	n/a		2.0E-01	6.0E-01	7.9E-07	0.0
2-Butanone	0.13	3.0E-01	*	6.0E-01	2.2E-01	2.9E-07	0.0
Total Risk Factor					7.6E+05		

RfDs are in units of mg/kg-day.

n/a = not available.

* Inhalation is an incomplete pathway because pond sediments are assumed to remain saturated and contaminants are not released to air. Therefore, oral toxicity factors were used in this screen.

TABLE J3-19
CONCENTRATION/TOXICITY SCREEN
POND SEDIMENT
CARCINOGENS

Chemical	Maximum Detected Conc. (mg/kg)	Inhalation Slope Factor		Oral Slope Factor	Risk Factor	Risk Index	% of Total Risk Factor
Aroclor-1254	10	n/a		7.7E+00	7.7E+01	8.7E-01	87.2
Benzo(a)pyrene	0.87	n/a		7.3E+00	6.4E+00	7.2E-02	7.2
Benzo(b)fluoranthene	3.1	n/a		7.3E-01	2.3E+00	2.6E-02	2.6
Bis(2-ethylhexyl)phthalate	88	n/a		1.4E-02	1.2E+00	1.4E-02	1.4
Benzo(a)anthracene	1.1	n/a		7.3E-01	8.0E-01	9.1E-03	0.9
Indeno(1,2,3-cd)pyrene	0.66	n/a		7.3E-01	4.8E-01	5.5E-03	0.5
Chrysene	1.9	n/a		7.3E-02	1.4E-01	1.6E-03	0.2
Benzo(k)fluoranthene	1	n/a		7.3E-02	7.3E-02	8.3E-04	0.1
Benzene	0.01	2.9E-02	*	2.9E-02	2.9E-04	3.3E-06	0.0
Total Risk Factor					8.8E+01		

Slope factors are in units of risk/(mg/kg-day).

n/a = not available.

* Inhalation is an incomplete pathway because pond sediments are assumed to remain saturated and contaminants are not released to air. Therefore, oral toxicity factors were used in this screen.

TABLE J3-20
CONCENTRATION/TOXICITY SCREEN
POND SEDIMENT
RADIONUCLIDES

Chemical	Maximum Activity (pCi/g)	Inhalation Slope Factor		Oral Slope Factor	Risk Factor	Risk Index	% of Total Risk Factor
Plutonium-239/240	1174	2.8E-08	*	3.2E-10	3.8E-07	8.3E-01	82.5
Americium-241	230.53	3.9E-08	*	3.3E-10	7.6E-08	1.7E-01	16.7
Uranium-238	26.445	1.2E-08	*	6.2E-11	1.6E-09	3.6E-03	0.4
Uranium-233/234	15.935	1.4E-08	*	4.4E-11	7.0E-10	1.5E-03	0.2
Radium-228	2.3	9.9E-10	*	2.5E-10	5.8E-10	1.3E-03	0.1
Radium-226	1.25	2.8E-09	*	3.0E-10	3.8E-10	8.2E-04	0.1
Strontium-89,90	1.8	6.9E-11	*	5.6E-11	1.0E-10	2.2E-04	0.0
Uranium-235	0.854	1.3E-08	*	4.7E-11	4.0E-11	8.8E-05	0.0
Total Risk Factor					4.6E-07		

Slope factors are in units of risk/pCi.

* Inhalation is an incomplete pathway because pond sediments are assumed to remain saturated and contaminants are not released to air. Therefore, oral toxicity factors were used in the screen.

TABLE J3-21
ORGANIC COMPOUNDS AND TOTAL METALS DETECTED AT 5% OR GREATER FREQUENCY
POND SURFACE WATER

Chemical	Maximum Detected Concentration (mg/L)	Detection Frequency[1] %	> Background [2]?
Organic Compounds:			
1,2-Dichloroethene	0.003	8	
Chloroform	0.002	20	
Di-n-butylphthalate	0.002	12	
Trichloroethene	0.006	12	
Metals:			
Aluminum	1.02	98	No
Antimony	0.0205	6	No
Arsenic	0.0066	41	No
Barium	0.12	100	No
Cadmium	0.0022	22	No
Cesium	0.06	12	No
Chromium	0.0043	16	No
Cobalt	0.0036	35	No
Copper	0.0047	19	No
Lead	0.0158	78	No
Lithium	0.0545	100	No
Manganese	0.293	100	No
Mercury	0.00096	33	No
Molybdenum	0.0176	75	No
Nickel	0.0063	47	No
Selenium	0.0083	22	No
Silver	0.0027	6	No
Strontium	0.568	100	No
Tin	0.0119	20	No
Vanadium	0.0056	49	No
Zinc	0.0748	76	No

[1] Detection frequency calculated without QA/QC duplicate samples.
[2] Background comparison is detailed in Appendix A of Technical Memorandum No. 4 (DOE 1994c).

TABLE J3-22
ORGANIC COMPOUNDS AND TOTAL METALS DETECTED AT LESS THAN 5% FREQUENCY
POND SURFACE WATER

Chemical	Maximum Detected Concentration (mg/L)	Detection Frequency[1] %	> Background [2]?	>1,000 RBC Screen?
Organic Compounds:				
1,2-Dichloroethane	0.001	2		No
Tetrachloroethene	0.012	4		No
Acetone	0.018	4		No
Methylene chloride	0.034	4		No
Metals:				
Beryllium	0.00034	4	No	

[1] Detection frequency calculated without QA/QC duplicate samples.

[2] Background comparison is detailed in Appendix A of Technical Memorandum No. 4 (DOE 1994c).

RBC - Risk-based concentration.

TABLE J3-23
CONCENTRATION/TOXICITY SCREEN
POND SURFACE WATER
NONCARCINOGENS

Chemical	Maximum Detected Conc. (mg/L)	Inhalation RfD	Oral RfD	Risk Factor	Risk Index	% of Total Risk Factor
1,2-Dichloroethene	0.003	n/a	9.0E-03	3.3E-01	6.0E-01	60.2
Chloroform	0.002	n/a	1.0E-02	2.0E-01	3.6E-01	36.1
Di-n-butylphthalate	0.002	n/a	1.0E-01	2.0E-02	3.6E-02	3.6
Total Risk Factor				5.5E-01		

RfDs are in units of mg/kg-day.
n/a = not available.

TABLE J3-24
CONCENTRATION/TOXICITY SCREEN
POND SURFACE WATER
CARCINOGENS

Chemical	Maximum Detected Conc. (mg/L)	Inhalation Slope Factor		Oral Slope Factor	Risk Factor	Risk Index	% of Total Risk Factor
Trichloroethene	0.006	6.0E-03	*	1.1E-02	6.6E-05	8.4E-01	84.4
Chloroform	0.002	8.0E-02	*	6.1E-03	1.2E-05	1.6E-01	15.6
Total Risk Factor					7.8E-05		

Slope factors are in units of risk/(mg/kg-day).

n/a = not available.

* Inhalation of volatile organic compounds released to air in the outdoors is a negligible pathway. Therefore, oral toxicity factors were used in the screen.

TABLE J3-25
ORGANIC COMPOUNDS AND METALS DETECTED AT 5% OR GREATER FREQUENCY[1]
STREAM SEDIMENT

Chemical	Maximum Detected Concentration (mg/kg)	Detection Frequency[2] %	> Background [3]?
Organic Compounds:			
Acenaphthene	0.13	7	
Acetone	0.063	7	
Anthracene	0.15	20	
Benzo(a)anthracene	0.43	27	
Benzo(a)pyrene	0.48	33	
Benzo(b)fluoranthene	0.65	27	
Benzo(g,h,i)perylene	0.16	13	
Benzo(k)fluoranthene	0.23	20	
Benzoic acid	0.51	33	
Benzyl alcohol	0.041	7	
Bis(2-ethylhexyl)phthalate	0.19	27	
Butyl benzylphthalate	0.12	7	
Chrysene	0.51	33	
Di-n-butyl phthalate	0.075	33	
Dibenzofuran	0.037	7	
Fluoranthene	1	47	
Fluorene	0.089	7	
Indeno(1,2,3-cd)pyrene	0.18	20	
Methylene chloride	0.007	7	
Naphthalene	0.046	7	
Phenanthrene	0.75	33	
Pyrene	0.96	33	
Metals:			
Aluminum	11,600	100	No
Antimony	26.3	13	No
Arsenic	5.8	93	Yes
Barium	177	100	Yes
Beryllium	1	53	No
Cadmium	0.8	7	No
Cesium	18.1	47	No
Chromium	12.3	100	No
Cobalt	12.4	100	Yes
Copper	17.7	60	No
Lead	94.8	100	No
Lithium	15.2	93	No
Manganese	1,000	100	Yes
Mercury	0.13	27	No
Nickel	19.2	47	No
Selenium	0.45	13	No
Silver	1.4	7	No
Strontium	95.8	100	Yes
Thallium	0.46	33	No
Vanadium	33.9	100	Yes
Zinc	178	100	Yes

(1) All detected analytes were detected at a frequency greater than 5 percent.
(2) Detection frequency calculated without QA/QC duplicate samples.
(3) Background comparison is detailed in Appendix A of Technical Memorandum No. 4 (DOE 1994c).

TABLE J3-26
CONCENTRATION/TOXICITY SCREEN
STREAM SEDIMENT
NONCARCINOGENS

Chemical	Maximum Detected Conc. (mg/kg)	Inhalation RfD	Oral RfD	Risk Factor	Risk Index	% of Total Risk Factor
Vanadium	33.9	n/a	7.0E-03	4.8E+03	8.2E-01	82.4
Zinc	178	n/a	3.0E-01	5.9E+02	1.0E-01	10.1
Cobalt	12.4	n/a	6.0E-02	2.1E+02	3.5E-02	3.5
Strontium	95.8	n/a	6.0E-01	1.6E+02	2.7E-02	2.7
Pyrene	0.96	n/a	3.0E-02	3.2E+01	5.4E-03	0.5
Fluoranthene	1	n/a	4.0E-02	2.5E+01	4.3E-03	0.4
Bis(2-ethylhexyl)phthalate	0.19	n/a	2.0E-02	9.5E+00	1.6E-03	0.2
Fluorene	0.089	n/a	4.0E-02	2.2E+00	3.8E-04	0.0
Acenaphthene	0.13	n/a	6.0E-02	2.2E+00	3.7E-04	0.0
Naphthalene	0.046	n/a	4.0E-02	1.2E+00	2.0E-04	0.0
Di-n-butylphthalate	0.075	n/a	1.0E-01	7.5E-01	1.3E-04	0.0
Acetone	0.063	n/a	1.0E-01	6.3E-01	1.1E-04	0.0
Butyl benzylphthalate	0.12	n/a	2.0E-01	6.0E-01	1.0E-04	0.0
Anthracene	0.15	n/a	3.0E-01	5.0E-01	8.5E-05	0.0
Benzyl alcohol	0.041	n/a	3.0E-01	1.4E-01	2.3E-05	0.0
Benzoic acid	0.51	n/a	4.0E+00	1.3E-01	2.2E-05	0.0
Methylene chloride	0.007	9.0E-01	6.0E-02	1.2E-01	2.0E-05	0.0
Total Risk Factor				5.9E+03		

RfDs are in units of mg/kg-day.
n/a = not available.

TABLE J3-27
CONCENTRATION/TOXICITY SCREEN
STREAM SEDIMENT
CARCINOGENS

Chemical	Maximum Detected Conc. (mg/kg)	Inhalation Slope Factor	Oral Slope Factor	Risk Factor	Risk Index	% of Total Risk Factor
Benzo(a)pyrene	0.48	n/a	7.3E+00	3.5E+00	7.8E-01	78.2
Benzo(b)fluoranthene	0.65	n/a	7.3E-01	4.7E-01	1.1E-01	10.6
Benzo(a)anthracene	0.43	n/a	7.3E-01	3.1E-01	7.0E-02	7.0
Indeno(1,2,3-cd)pyrene	0.18	n/a	7.3E-01	1.3E-01	2.9E-02	2.9
Chrysene	0.51	n/a	7.3E-02	3.7E-02	8.3E-03	0.8
Benzo(k)fluoranthene	0.23	n/a	7.3E-02	1.7E-02	3.7E-03	0.4
Bis(2-ethylhexyl)phthalate	0.19	n/a	1.4E-02	2.7E-03	5.9E-04	0.1
Methylene chloride	0.007	1.6E-03	7.5E-03	5.3E-05	1.2E-05	0.0
Total Risk Factor				4.5E+00		

Slope factors are in units of risk/(mg/kg-day).
n/a = not available.

TABLE J3-28
CONCENTRATION/TOXICITY SCREEN
STREAM SEDIMENT
RADIONUCLIDES

Chemical	Maximum Activity (pCi/g)	Inhalation Slope Factor	Oral Slope Factor	Risk Factor	Risk Index	% of Total Risk Factor
Plutonium-239/240	1.95	2.8E-08	3.2E-10	5.5E-08	6.5E-01	65.1
Americium-241	0.75	3.9E-08	3.3E-10	2.9E-08	3.5E-01	34.9
Total Risk Factor				8.4E-08		

Slope factors are in units of risk/pCi.

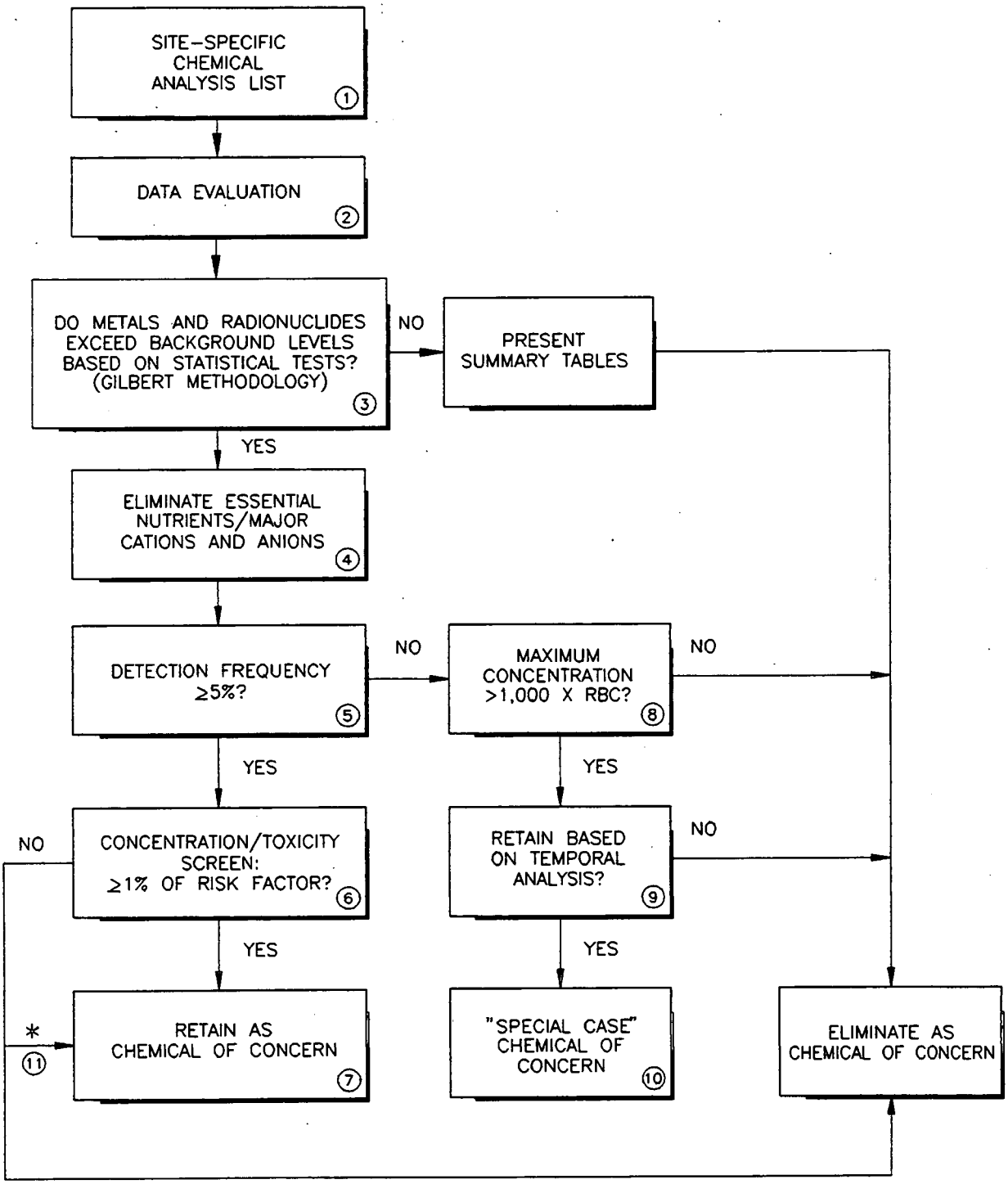
TABLE J3-29
ROCKY FLATS OU6
EVALUATION OF DRY SEDIMENT CONCENTRATIONS AND SELECTION OF COCS FOR STREAM/DRY SEDIMENTS (1)

	Maximum Concentration			
Organic Compounds	**Stream Sediment**	**Dry Sediment**	**Dry > Stream?**	**Effect of Using Stream Sediment Concentration in COC Selection for Stream/Dry Sediments**
Acenaphthene	0.13	0.12	No	
Anthracene	0.15	0.17	Yes	No effect: Dry sediment concentration would not alter results of COC selection (Table J3-26).
Benzo(a)anthracene	0.43	0.28	No	
Benzo(a)pyrene	0.48	0.38	No	
Benzo(b)fluoranthene	0.65	0.5	No	
Benzo(g,h,i)perylene	0.16	0.15	No	
Benzo(k)fluoranthene	0.23	0.18	No	
Benzoic acid	0.51	-	No	
Bis(2-ethylhexyl)phthalate	0.19	0.35	Yes	No effect: Same as above.
Chrysene	0.51	0.35	No	
Dibenzofuran	0.037	-	No	
Di-n-butyl phthalate	0.068	-	No	
Fluoranthene	1.0	0.9	No	
Fluorene	0.09	0.08	No	
Indeno(1,2,3-cd)pyrene	0.18	0.19	No	
Naphthalene	0.046	0.12	Yes	No effect: Dry sediment concentration would yield a risk factor of 3E+0, roughly
Phenanthrene	0.75	0.72	No	comparable to that of fluorene in Table J3-26, and would not alter COC selection.
Pyrene	0.96	0.61	No	
Metals (2)				
Copper	17.7 (3)	22.8	Yes	No effect: Copper is not evaluated quantitatively in the health risk assessment.
Mercury	0.13 (3)	0.18	Yes	No effect: Dry sediment concentration and RfD of 3E-4 would yield a risk factor of 6E+2, roughly comparable to fluorene in Table J3-26, and would not alter COC selection.
Nickel	19.2 (3)	26.4	Yes	Minimal effect: The maximum concentration yields a hazard quotient of 5E-03 (DOE 1994a, Table 5-34) conservatively assuming residential exposure, and would not contribute to overall risk.
Strontium	95.8	92.4	No	
Zinc	178	293	Yes	Selected as a COC in Stream/Dry Sediment; exposure term was calculated using stream and dry sediment sample results.

(1) COCs were selected using stream sediment samples. This table shows that including dry sediments would not have altered the COCs or risk results.
(2) Only metals in dry sediment with concentrations greater than background mean plus 2 standard deviations are listed.
(3) Not a PCOC in Stream Sediment

TABLE J3-30
SUMMARY OF CHEMICALS OF CONCERN

	Surface Soil	Subsurface Soil	Groundwater	Pond Sediment	Pond Surface Water	Stream/Dry Sediment
Aroclor-1254				X		
Benzo(a)anthracene						X
Benzo(a)pyrene		X		X		X
Benzo(b)fluoranthene		X		X		X
Bis(2-ethylhexyl)phthalate				X		
Chloroform			X		X	
1,2-Dichloroethene					X	
Di-b-butylphthalate					X	
Methylene chloride			X			
Indeno(1,2,3-cd)pyrene						X
Tetrachloroethene			X			
Trichloroethene			X		X	
Nitrate			X			
Antimony	X			X		
Barium		X				
Cobalt						X
Silver	X			X		
Strontium						X
Vanadium	X			X		X
Zinc	X					X
Americium-241	X	X	X	X		X
Plutonium-239/240	X	X	X	X		X
Radium-226			X			
Uranium-233/234		X				
Uranium-238		X				
Special-Case Chemicals						
Vinyl chloride			X			
Chemicals of Interest						
Antimony			X			
Arsenic			X			X
Beryllium			X			
Manganese			X			



* PROFESSIONAL JUDGEMENT
RBC RISK-BASED CONCENTRATION

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

OPERABLE UNIT NO. 6
PHASE I RFI/RI REPORT

PROCESS FOR IDENTIFYING CHEMICALS OF CONCERN

FIGURE J3-1 MARCH 1995

OU6RI297 1=1

J4.0
EXPOSURE SCENARIOS

This section describes the exposure scenarios (receptors, exposure areas, and exposure pathways) that were evaluated quantitatively in the risk assessment. Exposure scenarios for OU6 were discussed in detail in OU6 TM No. 2 (DOE 1995a)

Exposure scenarios were identified for both current and possible future site uses. Current and future exposure scenarios in OU6 were developed based on:

- Identification of current onsite and offsite land uses and characterization of future land use scenarios

- Identification of potential receptors based on current and future land use scenarios

- Development of a conceptual site model (CSM) that summarizes information regarding chemical sources, chemical release mechanisms, environmental transport media, and human intake routes. The CSM is used to identify the complete exposure pathways for quantitative risk assessment and to identify pathways that are incomplete or do not warrant quantitative assessment because they would not contribute measurably to the estimate of overall risk.

J4.1 CURRENT AND FUTURE LAND USE

Table J4-1 summarizes the current patterns of land use on and near RFETS and categorizes future land use scenarios as (1) improbable (unlikely to occur) or (2) credible (could reasonably occur or is expected to occur).

Current Onsite Land Use: As described in Section J1.2, RFETS consists of an approximately 400-acre industrial area surrounded by an undeveloped buffer zone of approximately 6,150 acres. OU6 includes IHSSs in the Walnut Creek Priority Drainage.

Most of OU6 is in the buffer zone east and northeast of the industrial area. On the west side of the RFETS property is an active gravel mine and processing plant.

Current activities in OU6 consist of environmental investigations, monitoring, cleanup, and routine security surveillance. No industrial or commercial operations occur in OU6. RFETS is fenced and guarded, and trespassing does not occur. Activities in the industrialized portion of the plant include maintenance, waste management, and environmental restoration activities.

Future Onsite Land Use: Probable future onsite land use at RFETS includes environmental restoration, decontamination and decommissioning, economic development, and waste management. The Rocky Flats Local Impact Initiative (RFLII 1992) is working with DOE and local economic development agencies to encourage business development at RFETS, using new or existing facilities. The Rocky Flats Future Site Uses Working Group is also developing recommendations regarding future use of the RFETS property. Residential development at RFETS has not been recommended by this group or by other planning groups. Commercial and industrial uses of developed portions of the site are considered beneficial. Commercial development in undeveloped portions of the property has not been ruled out, although preservation as open space is consistent with DOE policy and with the Jefferson County Planning Department's recommendations (Jefferson County 1990). The Jefferson County Board of Commissioners has also adopted a resolution stating its support of maintaining, in perpetuity, the undeveloped buffer zone of open space around Rocky Flats for environmental and safety reasons (Jefferson County Board of Commissioners 1994).

Ecological surveys performed in compliance with the Threatened and Endangered Species Act indicate the presence of habitat that is potentially suitable to four plant species and several wildlife species of concern. The plant species are the forktip threeawn, Colorado butterfly plant, toothcup, and Diluvium lady's tresses (EG&G 1991). The wildlife species include the bald eagle, peregrine falcon, whooping crane, Prebles meadow jumping mouse, and the black-footed ferret (DOE 1991; FWS 1990; DOE 1994f). The Prebles meadow jumping mouse inhabits creek drainages and is a candidate for listing as an endangered species (DOE 1994f). Because of the undisturbed nature of the buffer zone and the presence of a rare species such as the Prebles meadow jumping mouse, onsite commercial or other development in the buffer zone may be precluded.

Future onsite residential development is inconsistent with recommendations being considered for future onsite land use. The Future Site Use Working Group indicated that a residential scenario in OU6 could be considered outside the range of what is reasonable for future land use at Rocky Flats (EPA 1995a). In addition, the Board of County Commissioners of Jefferson County unanimously passed a resolution requiring that the undeveloped buffer zone of "open space" around RFETS be maintained in perpetuity (DOE 1995b). Therefore, residential development in OU6 is considered to be an improbable future land use scenario and was not evaluated in the HHRA. Onsite agricultural development is considered to be improbable because of the decline of agriculture in the Northeast Jefferson County area.

In summary, future onsite land use in OU6 is most likely open space, although portions adjacent to the industrialized part of the plant could be developed for commercial use.

Current Offsite Land Use: Land adjacent to RFETS is lightly populated, with current use being primarily open space and grazing. A few residences and horse-boarding businesses are located east of RFETS. The nearest resident is located across Indiana Street at the southeast corner of the property line. Another nearby residence in the predominant wind direction (southeast) is located about 0.8 miles east of Indiana street, also near the southeast border of RFETS. Small cattle herds graze seasonally in fields near the site. Commercial/ industrial facilities, such as the TOSCO laboratory and Great Western Inorganics Plant, are located to the south.

Future Offsite Land Use: The "North Plains Community Plan" (Jefferson County 1990) was developed by representatives of Jefferson County, five cities (Arvada, Broomfield, Golden, Superior, and Westminster), and a variety of interest groups. Under the plan, the predominant future land uses to the south and southeast of Rocky Flats will consist of commercial, industrial, and office space. Directly to the east, zoning and land use plans include open space, grazing, and vacant land. Residential development is indicated for areas further removed from the RFETS property. Mixed land uses are planned for areas north of Rocky Flats that have been annexed by the cities of Broomfield and Superior (Jefferson County 1990; City of Broomfield 1990; Boulder County 1991).

Current and future offsite receptors were not evaluated in the HHRA for OU6 because estimating effects from individual OUs would not address potential cumulative impacts to

offsite receptors from other sources at RFETS. However, exposure of offsite receptors will be evaluated in a future site-wide risk assessment.

J4.2 ONSITE EXPOSURE AREAS

Current and future onsite exposures were evaluated in four separate AOCs identified in OU6 and in two maximum exposure areas, which were described in Section J2.2 and shown in Figures J4-1 through J4-5. Each IHSS evaluated in the OU6 HHRA was considered to be an individual source area (DOE 1994a). As noted in Section J1.4, some IHSSs were removed from further evaluation in the HHRA on the basis of the CDPHE Risk-Based Conservative Screen.

Area of Concern No. 1: AOC No. 1 is the North Spray Field Area (IHSS 167.1). This source area forms a logical AOC because it is isolated from the other source areas within OU6. The entire AOC is less than 10 acres (Figure J4-2).

Area of Concern No. 2: AOC No. 2 includes the Triangle Area (IHSS 165), Soil Dump Area (IHSS 156.1), and the Sludge Dispersal Area (IHSS 141). These source areas form a logical AOC because they are in close proximity and have chemical constituents in the same media. The three IHSSs comprise less than 50 acres (Figure J4-3).

Maximum Exposure Area in AOC No. 2: Within AOC No. 2, a maximum exposure area of 30 acres was delineated. This size is comparable to a hypothetical future industrial or office park and contains the highest levels of chemical constituents within AOC No. 2, namely the Triangle Area and adjacent portions of AOC No. 2.

Area of Concern No. 3: AOC No. 3 includes Ponds A-1, A-2, and A-3 and the associated stream segments. Data from samples collected in these ponds and the interconnecting streams were used to estimate chemical exposure. AOC No. 3 is shown on Figure J4-4; it comprises approximately 50 acres.

Area of Concern No. 4: AOC No. 4 includes Ponds B-1, B-2, B-3 and B-4 and the associated stream segments. Data from samples collected in these ponds and the interconnecting streams were used to estimate chemical exposure. AOC No. 4 is shown on Figure J4-5; it comprises approximately 50 acres.

J4.3 RECEPTORS SELECTED FOR QUANTITATIVE RISK ASSESSMENT

Receptors selected for quantitative evaluation in the HHRA are listed below:

J4.3.1 Current Use

Current Onsite Workers: Current onsite workers are RFETS plant security personnel who are assumed to spend a portion of their time in OU6 while conducting routine patrols in the buffer zone. Current onsite workers were evaluated for exposures in AOC No. 1 and in AOC No. 2.

J4.3.2 Future Use

Future Onsite Office Worker: The future office worker is assumed to work indoors in a building complex. Future workers are evaluated for exposure in AOC No. 1 (less than 10 acres) and in the 30-acre maximum exposure area in AOC No. 2. Risks associated with worker exposure in the entire AOC No. 2 would be lower than those estimated for the maximum 30-acre exposure area.

Future Onsite Ecological Researcher: The future onsite ecological researcher is assumed to perform specific field research projects of relatively limited duration involving contact with surface soil, pond surface water, and sediment. These research projects would involve a combination of periodic field work coupled with time in the library, office, or laboratory. Exposure areas are AOC No. 1 (10 acres), and AOC No. 2, AOC No. 3, and AOC No. 4, each of which are approximatley 50 acres in size. Fifty acres was defined by parties to the IAG as an appropriate-sized area for evaluating potential exposure of ecological researchers (DOE 1994a).

Future Open Space Recreation User: The open space exposure scenario was developed to estimate potential risks from recreational use of open space at RFETS. Future open space use by children and adults is assumed to include recreational activities such as hiking and wading in creeks and ponds and to involve contact with surface soil, pond surface water, and pond and stream/dry sediment. An open space use scenario was evaluated in AOC No. 1 (10 acres), and in AOC No. 2, AOC No. 3, and AOC No. 4, each of which are approximately 50 acres in size.

Future Onsite Construction Worker: The future onsite construction worker is assumed to contact subsurface soil during excavation activities associated with construction of commercial buildings in AOC No. 1 and in AOC No. 2.

These receptors were selected to represent the potentially exposed populations based on current and probable future use. Onsite industrial or office workers, open space users, and the onsite ecological researcher provide realistic, yet still conservative, estimates of potential risk under various future use scenarios.

J4.4 EXPOSURE PATHWAYS

This section identifies exposure pathways by which receptors could be exposed to chemicals in or released from sources in OU6. A complete exposure pathway requires a chemical source, chemical release mechanism, environmental transport medium, exposure point, and human intake route. If one of these elements is lacking, the pathway is incomplete and no human exposures can occur. Incomplete pathways were not evaluated in the HHRA.

Potentially complete pathways include all pathways for which human exposure is possible, no matter how trivial. A potentially complete pathway was not assessed when, based on professional judgement and logic, the contribution of the pathway to overall exposure is likely to be orders of magnitude lower than exposure from other pathways and the pathway is not expected to contribute significantly to overall risk to the receptor. These potentially complete but not assessed pathways are unlikely to have any bearing on mathematical estimations of total risk to receptors and therefore do not warrant quantitative evaluation in the HHRA.

Figure J4-6 shows the CSM of potential human exposure pathways for OU6. The CSM is a schematic representation of the chemical sources, chemical release mechanisms, environmental transport media, human intake routes, and human receptors for OU6. Site-wide incomplete or negligible pathways are described in Subsection J4.4.1. Additional subsections describe the exposure pathways evaluated for each receptor and identify receptor-specific pathways that were not quantitatively evaluated. A summary of potentially complete exposure pathways evaluated in the risk assessment is provided in Table J4-2.

J4.4.1 Site-wide Exposure Pathways That Are Incomplete or Potentially Complete But Not Assessed

The CSM indicates that the following exposure pathways are incomplete or potentially complete but not assessed for all receptors. These pathways were not quantitatively addressed in the risk assessment and are indicated with an "N" (not evaluated) in the CSM.

- Ingestion of fish in Walnut Creek is an incomplete exposure pathway for all OU6 receptors because sport fishing is unlikely (due to intermittent flow in the creeks), and because fishing will not occur under open space or occupational use.

- Ingestion of livestock is an incomplete pathway for all OU6 receptors, because beef ingestion will not occur under occupational and open space uses.

- Groundwater direct exposure pathways are incomplete for all receptors because drinking water is currently provided by a municipal supply that does not tap aquifers at RFETS. This supply, which has provided all of the drinking and industrial supply for thousands of on-site workers, is expected to be maintained in the future. Ecological researchers and open space recreational users are expected to bring their own water during outdoor activities.

- Inhalation of VOCs released to outdoor air through volatilization from soil or groundwater is a potentially complete but not assessed pathway for all receptors, because volatile chemicals in surface soils, if once present, will

have already volatilized, and volatile chemicals released from subsurface soil or groundwater will be significantly retarded through the subsurface soil and diluted in the ambient air.

- Dermal uptake of metals and radionuclides from soil and sediment is considered a potentially complete but not assessed pathway for all receptors, because their permeability constants are low (EPA 1989a) and binding to soil matrix further reduces absorption potential.

- Ingestion of homegrown produce is an incomplete pathway for all receptors because gardening will not occur under occupational or open space use.

J4.4.2 Current Onsite Worker

For the current onsite worker (security personnel), exposure pathways associated with wind suspension of particulates and direct contact with and external irradiation from surface soil are potentially complete.

Pathways evaluated:

- Inhalation of airborne particulates

- Surface soil ingestion and dermal contact

- External irradiation from decay of radionuclides in surface soil

Receptor-Specific Incomplete Pathways (not evaluated):

- Contact with pond surface water and sediments and with subsurface soil are incomplete exposure pathways for current onsite workers in OU6 (security personnel).

- Inhalation of VOCs migrating from subsurface soil or groundwater into buildings is an incomplete exposure pathway for current workers because they

work outdoors and there are no permanent buildings located on OU6 (other than trailers, which do not contact the ground surface, and tents that contain granular activated carbon units for treating pond surface water).

J4.4.3 Future Office Workers

The future onsite office worker is assumed to work primarily indoors. However, for purposes of risk assessment, the worker is assumed to be exposed to outdoor air particulate matter and surface soil for the entire time at work.

Pathways evaluated:

- Inhalation of airborne particulates released from surface soil
- Surface soil ingestion and dermal contact
- External irradiation from decay of radionuclides in surface soil
- Inhalation of VOCs migrating from subsurface soil or groundwater through building foundations into indoor air

Receptor-specific incomplete pathways (not evaluated) are the same as described for the current onsite worker, with the exception that the future office worker is assumed to be exposed to indoor VOCs released from soils and groundwater.

J4.4.4 Future Construction Workers

A future construction worker scenario was used to evaluate potential risk from exposure to subsurface soil.

Pathways evaluated:

- Inhalation of airborne particulates released from surface and subsurface soil
- Ingestion of and dermal contact with subsurface soil
- External irradiation from decay of radionuclides in subsurface soil

Receptor-Specific Incomplete Pathways (not evaluated):

- Exposure to surface water and sediments is considered an incomplete exposure pathway for construction workers because construction cannot occur in the drainage channels or flood plains.
- Inhalation of indoor air VOCs is an incomplete pathway because construction workers work outdoors.

J4.4.5 Future Ecological Researcher

The ecological researcher is assumed to be exposed to surface soil, airborne particulate matter, stream/dry sediment, and pond surface water and sediment in Walnut Creek and the A- and B-series ponds during the course of field work in OU6.

Pathways evaluated:

- Inhalation of airborne particulates released from surface soil and stream/dry sediment
- Surface soil ingestion and dermal contact
- Surface water ingestion and dermal contact
- Pond sediment ingestion and dermal contact

- Stream/dry sediment ingestion and dermal contact

- External irradiation from surface soil and sediment

Receptor-Specific Incomplete Pathways (not evaluated):

- Inhalation of indoor air VOCs is an incomplete pathway because onsite ecological research is conducted outdoors or in trailers that do not have foundations.

J4.4.6 Future Open Space Recreational User

Pathways evaluated for the open space use scenario are the same as described for the future ecological researcher. Soil and sediment ingestion pathways were evaluated for both children and adults.

TABLE J4-1
SUMMARY OF CURRENT AND FUTURE LAND USES

	Current		Future	
Land Use Category	**Offsite**	**Onsite**	**Offsite**	**Onsite**
Residential	Yes	No	Credible[a]	Improbable[b]
Commericial/Industrial	Yes	Yes	Credible	Credible[c]
Recreational/Open Space	Yes	No	Credible	Credible[d]
Ecological Reserve	No	No	Improbable	Credible[d]
Agricultural	Yes	No	Credible	Improbable

[a] Credible is used to indicate scenarios that could reasonably occur.
[b] Improbable is used to indicate scenarios that are unlikely to occur.
[c] Expected in the currently developed area of the plant site.
[d] Expected in the buffer zone.

TABLE J4-2
POTENTIALLY COMPLETE EXPOSURE PATHWAYS TO BE QUANTITATIVELY EVALUATED

Potentially Exposed Receptor	Scenario	Potentially Complete Exposure Pathways
Onsite worker	Current	Inhalation of airborne particulates from OU6 surface soil
		Ingestion of surface soil
		Dermal contact with surface soil
		External irradiation from surface soil
Onsite office worker	Future	Inhalation of airborne particulates from OU6 surface soil
		Ingestion of surface soil
		Dermal contact with surface soil
		External irradiation from surface soil
		Inhalation of indoor VOCs (from migration through foundation)
Onsite open space recreational user	Future	Inhalation of airborne particulates from OU6 surface soil
		Ingestion of surface soil
		Dermal contact with surface soil
		External irradiation from surface soil
		Inhalation of airborne particulates from sediment
		Ingestion of sediment
		Dermal contact with sediment
		External irradiation from sediment
		Ingestion of surface water
		Dermal contact with surface water
Onsite ecological worker	Future	Ingestion of surface water
		Dermal contact with surface water
		Ingestion of sediment
		Dermal contact with sediment
		Inhalation of airborne particulates from sediment
		External irradiation from sediment
		Inhalation of airborne particulates from surface soil
		Ingestion of surface soil
		Dermal contact with surface soil
		External irradiation from surface soil
Onsite construction worker	Future	Inhalation of airborne particulates from subsurface soil
		Ingestion of subsurface soil
		Dermal contact with subsurface soil
		External irradiation from subsurface soil

J5.0
EXPOSURE POINT CONCENTRATIONS

Exposure point concentrations of COCs were calculated for each exposure area and exposure medium (surface soil, subsurface soil, groundwater, air, pond surface water, pond sediment, and stream/dry sediment). The exposure point concentration of a chemical in a sampled medium is usually the 95 percent upper confidence limit (95% UCL) on the arithmetic mean, based on a normal or lognormal distribution. The 95% UCL on the mean is a conservative estimate of the average concentration to which people would be exposed over time in the exposure area. Sometimes the maximum detected concentration was used as the exposure concentration if the data set did not permit a good estimate of the mean. This can occur with small data sets or in data sets with a high frequency of nondetects. If the calculated 95% UCL concentration exceeded the maximum detected concentration, the maximum was used as the exposure concentration (EPA 1989a). For convenience in this report, the 95% UCL or maximum concentration is referred to as the reasonable maximum exposure (RME) concentration. RME concentrations were used in estimating risk for both the central tendency (CT) and RME exposure conditions.

J5.1 CALCULATING THE RME CONCENTRATION

Tables J5-1 through J5-6 summarize the exposure concentrations of COCs in surface soil, subsurface soil, groundwater, pond sediment, pond surface water, and stream/dry sediment for each exposure area evaluated in the HHRA. Attachment J1 shows analytical results used in the calculations. In calculating exposure concentrations from chemical analytical results, one-half the SQL was used to represent the chemical concentration in samples that were validated as "nondetect" for a chemical, provided that chemical was detected in at least one other sample in the data set (EPA 1989a). An exception to this rule is when the SQL is unusually high due to sample dilution. The SQL for diluted samples can far exceed the measured concentrations of the chemical in other samples. In keeping with EPA guidance (1989a), these samples were excluded from the data set if they caused the arithmetic mean concentration to exceed the maximum detected concentration.

This same principle applies when a compound is detected in very few samples and only at estimated quantities below the CRQL. If using one-half the CRQL for nondetects caused the arithmetic mean concentration to exceed the maximum reported concentration, those nondetect samples were excluded from the calculation.

Attachment J1 contains tables showing all analytical results in the data sets and the calculation of 95% UCL concentrations for the sampled media. The 95% UCL concentrations were based on either a normal or lognormal distribution, as appropriate. In some cases, the calculation of the 95% UCL based on a lognormal distribution gave an unreasonable result (e.g., a value much higher than the maximum observation), even though the data appear to fit a lognormal distribution. These cases were most common for small data sets and for larger data sets that had a range of several orders of magnitude between the minimum and maximum observations. When unreasonable results were obtained, other values (either the maximum or the 95% UCL based on a normal distribution) were used as the exposure concentration for risk assessment. These cases are noted in Tables J5-1 through J5-6.

Attachment J1 also contains a detailed discussion of the statistical treatment of data sets that contained greater than 15 percent nondetects and data sets that contained negative or zero values, which were common for radionuclides.

J5.2 SURFACE SOIL

Table J5-1 summarizes the RME concentrations of COCs in surface soil in each exposure area. COCs are antimony, silver, vanadium, zinc, Am-241, and Pu-239/240. Exposure point concentrations were calculated for AOC No. 1, AOC No. 2, and the 30-acre maximum exposure area in AOC No. 2.

The exposure concentrations in surface soil were used to estimate health risks associated with soil ingestion and dermal contact by current onsite workers, future office workers, ecological researchers, and open space recreational users. In addition, the concentrations were used in air modeling to predict airborne particulate concentrations. Silver was not detected in AOC No. 1, so it is not a COC in that area.

J5.3 SUBSURFACE SOIL

Exposure concentrations of COCs in subsurface soil are summarized in Table J5-2. COCs are barium, Am-241, Pu-239/240, U-233/234, and U-238. The subsurface soil concentrations were used to estimate health risks associated with construction worker exposure. Exposure concentrations were calculated for AOC No. 1 and AOC No. 2, where construction activities are assumed to potentially occur.

J5.4 GROUNDWATER

Groundwater in OU6 is not ingested and is not expected to be used as a drinking water source in the future. Furthermore, groundwater in OU6 is not a significant source of transport to surface water (see Section J5.10.1 and additional discussion in the RFI/RI Report Section 5.4 and Appendix G). Therefore, direct exposure to groundwater is not evaluated in the HHRA. However, exposure to groundwater COCs via inhalation of VOCs migrating into a future office building was evaluated in the HHRA. Maximum concentrations of volatile COCs in groundwater are summarized in Table J5-3. These concentrations were used as conservative source concentrations for soil gas modeling and estimating basement air concentrations in a building (future office worker exposure). This scenario was evaluated in the 30-acre maximum exposure area in AOC No. 2. There is no measurable groundwater in AOC No. 1.

J5.5 POND SEDIMENT

Exposure concentrations of COCs in pond sediment are summarized in Table J5-4. COCs in pond sediment are Aroclor-1254, benzo(a)pyrene, benzo(b)fluoranthene, bis(2-ethylhexyl)phthalate, antimony, silver, vanadium, zinc, Am-241, and Pu-239/240. The pond sediment concentrations were used to estimate health effects associated with incidental ingestion and dermal contact by future ecological workers and open space recreational users. Future exposure concentrations of antimony, Am-241, and Pu-239/240, which are COCs in surface soil and in pond sediment, were modeled (as discussed in Section J5.10) assuming contribution from surface soil transported in storm runoff. Exposure concentrations for the remaining COCs in AOCs No. 3 and No. 4 were calculated from sediment sample results.

In 1994, additional pond sediment samples were collected and analyzed for PCBs and radionuclides. COCs for this data set were Aroclor-1254, Am-241, and Pu-239/240. The sampling results are evaluated in Attachment J5.

J5.6 POND SURFACE WATER

RME concentrations of COCs in pond surface water are summarized in Table J5-5. COCs in pond surface water are 1,2-dichloroethene (1,2-DCE), chloroform ($CHCl_3$), di-n-butylphthalate, and trichloroethene (TCE). The pond surface water concentrations were used to estimate health effects associated with incidental ingestion and dermal contact with surface water by ecological workers and open space recreational users. RME concentrations were calculated for AOCs No. 3 and No. 4. In addition, although they are not COCs in surface water, concentrations of the surface soil COCs antimony, Am-241, and Pu-239/240 transported in storm runoff were also estimated (Section J5.10 and Table J5-13) and used in the risk assessment.

J5.7 STREAM/DRY SEDIMENT

Exposure concentrations of COCs in stream/dry sediment are summarized in Table J5-6. COCs in stream/dry sediment are benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, indeno(1,2,3-cd)pyrene, cobalt, strontium, vanadium, zinc, Am-241, and Pu-239/240. The RME concentrations were used to estimate health risks associated with incidental ingestion, dermal contact, and inhalation of airborne particulates by ecological workers and open space recreational users. RME concentrations were calculated for AOCs No. 3 and No. 4.

J5.8 OUTDOOR AIR (PARTICULATE-ASSOCIATED COCs)

Air emissions and dispersion models were used to estimate concentrations of SVOCs, metals, and radionuclides in air that are released from surface soil and from stream/dry sediment by wind erosion and from subsurface soil during construction activities. Airborne emissions of SVOCs, metals, and radionuclides associated with wind erosion of particulate matter (dust) less than 10 microns in diameter (PM_{10}) were evaluated.

J5.8.1 Onsite Air Concentrations from Wind Erosion of Surface Soil

Tables J5-7 through J5-9 summarize the modeling results for onsite air concentrations of COCs associated with PM_{10}. Onsite air concentrations from wind erosion of surface soil were estimated using the Ventilated Valley Dispersion Model, a box model that is often used to estimate ambient air concentrations in the immediate vicinity of an emission source. The box model incorporates a site-specific wind erosion emission rate for PM_{10} and other site-specific variables such as surface area and length and width of the emission source area, threshold wind speed, mean annual wind speed, and mixing height. Details are provided in Appendix I.

The modeling was performed using 5 years of meteorological data (1989 - 1993) to yield five different estimates of annual average PM_{10} concentrations. Meteorological data collected at the Rocky Flats meteorological tower was provided by EG&G Rocky Flats. Air concentrations of COCs were calculated by multiplying the PM_{10} concentrations by the chemical concentrations in surface soil. The maximum of the five estimated annual average air concentrations was used as a conservative estimate of the exposure point concentration in the risk assessment.

COCs in surface soil were antimony, silver, vanadium, zinc, Am-241, and Pu-239/240. Air concentrations were calculated for AOC No. 1, AOC No. 2, and for the 30-acre maximum exposure area in AOC No. 2. Silver was not detected in soil in AOC No. 1, so it is not a COC in that area. Air concentrations of COCs were used to estimate health risks associated with dust inhalation by current onsite workers, future office workers, future ecological researchers, and future open space recreational users.

J5.8.2 Onsite Air Concentrations from Construction Activities

Tables J5-10 and J5-11 summarize the estimated air concentrations of COCs adhered to airborne PM_{10} at potential future construction sites in AOCs No. 1 and No. 2. COCs for inhalation of PM_{10} are metals and radionuclides in surface soil and SVOCs, metals, and radionuclides in subsurface soil.

In the construction scenario, three air emission sources were evaluated: (1) wind erosion of surface soil in the AOC, (2) wind erosion of subsurface soil in a 10-acre excavation site, and (3) emissions during heavy construction (earth moving). Emissions from earth moving activities were estimated using a standard equation for heavy construction from AP-42 (EPA 1993a), and wind erosion was evaluated using a box model as described in Section J5.8.1. The exposure point concentrations are the sum of air concentrations resulting from wind erosion of surface soil, wind erosion of subsurface soil, and heavy construction activities.

J5.8.3 Onsite Air Concentrations from Wind Erosion of Stream/Dry Sediment

Concentrations of COCs from wind erosion of stream/dry sediment were calculated for AOC No. 3 and AOC No. 4. The air concentrations were modeled using the RME concentrations in stream/dry sediment and a particulate emission factor of 4.65E+09 m^3/kg (EPA 1991a). The air concentration calculations are included in the risk calculations for inhalation of particulates and are shown in Attachment J3. The modeled air concentrations of windborne COCs in stream/dry sediment are used to estimate risks to the future ecological worker and future open space recreational user.

J5.9 INDOOR AIR (VOCs)

Table J5-12 summarizes the exposure point concentrations of COCs in basement air from migration of VOCs from groundwater through building foundations. This scenario was evaluated for the future office worker in the 30-acre maximum exposure area in AOC No. 2. The modeling approach and results are presented in detail in Appendix I of the RFI/RI Report. COCs are chloroform, methylene chloride, PCE, and TCE. For simplicity, and because this is not expected to be a significant exposure route, maximum detected groundwater concentrations were used in modeling, although this could overestimate basement air VOC concentrations because only a few wells were potentially contaminated and the maximum concentrations are not characteristic of the entire exposure area. There is no measurable groundwater in AOC No. 1, so soil gas transport modeling was not done for that area.

J5.10 SURFACE WATER AND SEDIMENT MODELING RESULTS

Surface water and sediment transport modeling was performed to evaluate the potential for downstream migration of chemical constituents in pond sediment and to estimate future concentrations of selected chemical constituents in pond sediment and surface water from source loads in OU6. The modeling approach and results are discussed in detail in Section 5.5 and in Appendix H of the RFI/RI Report. A brief summary is provided here.

J5.10.1 Modeling Approach

A comprehensive mathematical model, the Hydrological Simulation Program - FORTRAN (HSPF) (Bicknell et al. 1993) was applied to simulate the movement of water, surface soil, sediment, and associated chemicals to and in the Walnut Creek watershed. To support the OU6 risk assessment, only sources within OU6 were used to estimate chemical loads to the Walnut Creek drainage system.

OU6 chemical constituent sources to the drainage system are surface soils and stream and pond sediment within the OU6 IHSSs. Groundwater loads were not considered a significant source and were not included in the model (see discussion in Section 5.0 and Appendix G). The fate and transport of VOCs detected in pond water samples were also not modeled because their concentrations are low (maximum concentrations ranging from 2 to 6 μg/L; Table J5-5) and fate and transport processes, such as volatilization, would render their concentrations negligible over an exposure duration of several years. Instead, measured concentrations of VOCs in pond water were used as exposure point concentrations in risk assessment.

The potential for resuspension and migration of existing pond sediment was estimated to be very low, even under extreme flow conditions, according to a conservative screening-level evaluation discussed in Attachment A of Appendix H. Therefore, migration of sediment out of the A- and B-series ponds is not expected. Pond sediment concentrations will not increase in the future because source loads in OU6 are insignificant compared to existing pond sediment concentrations.

In conclusion, the only significant OU6 source load to the drainage system is surface soil. Of the six COCs identified in surface soil, the three most potentially hazardous, namely, antimony, Am-241, and Pu-239/240, were modeled as chemical loads to the drainage system. For purposes of the HHRA, the model was used to generate 30 simulations of 30-year average concentrations of each modeled COC in newly deposited sediment and in surface water in each of the A- and B-series ponds and in selected stream segments. The 30-year averaging period corresponds to the longest reasonable maximum exposure duration evaluated in the HHRA (open space use). The 95% UCLs of the means of the thirty 30-year average concentrations were used to represent the RME concentrations in newly deposited sediment and in pond surface water.

The sediment concentration terms used in risk assessment were depth-weighted averages of RME concentrations in existing and newly deposited sediment, assuming 15 years of deposition (one-half the total deposition time evaluated). This concentration represents the reasonable maximum estimate of the average concentration during a 30-year exposure duration. Total depth of sediment assumed for exposure was 2 feet, corresponding to the pond sediment sampling interval used in the OU6 Phase I field investigations.

J5.10.2 Exposure Point Concentrations in A-series and B-series Ponds

Table J5-13 summarizes the depth-weighted exposure concentrations of antimony, Am-241, and Pu-239/240 in sediment and surface water in the A- and B-series ponds. For simplicity, the maximum concentrations derived from the model were used in risk assessment. The surface water and pond sediment concentrations were used to estimate health risks associated with surface water and sediment ingestion and dermal exposure by future ecological researchers and future open space recreational users. Concentration terms for other COCs in pond sediment and surface water were calculated from sampling results (i.e., they were not modeled) and are described in Sections J5.5 and J5.6.

As mentioned previously in Section J5.5, results of additional pond sediment sampling conducted in 1994 are evaluated in Attachment J5.

TABLE J5-1
MAXIMUM AND RME CONCENTRATIONS FOR CHEMICALS OF CONCERN SURFACE SOIL

Analyte	Maximum Concentration (mg/kg or pCi/g)	RME Concentration (mg/kg or pCi/g)	
AOC No. 1			
Antimony	24.15	16.50	n
Vanadium	40.1	33.39	n
Zinc	60.2	48.38	n
Americium-241	1.147	0.151	n
Plutonium-239/240	1.849	0.284	n
AOC No. 2, 30-acre maximum exposure area			
Antimony	38.9	14.09	ln
Silver	52.7	2.64	ln
Vanadium	75.9	34.31	ln
Zinc	650	85.66	ln
Americium-241	3.243	1.27	ln
Plutonium-239/240	15.22	3.10	ln
AOC No. 2			
Antimony	43.6	16.49	ln
Silver	52.7	2.31	ln
Vanadium	75.9	36.13	ln
Zinc	650	80.46	ln
Americium-241	3.243	1.24	n
Plutonium-239/240	15.22	2.78	ln

Note: Analytical results used in the calculation of the RME concentrations are shown in Attachment J1.

RME - Reasonable maximum exposure

n - 95% UCL based on normal distribution.

ln - 95% UCL based on lognormal distribution.

TABLE J5-2
MAXIMUM AND RME CONCENTRATIONS FOR CHEMICALS OF CONCERN SUBSURFACE SOIL

Analyte	Maximum Concentration (mg/kg or pCi/g)	RME Concentration (mg/kg or pCi/g)	
AOC No. 1			
Barium	866	129.33	ln
Americium-241	0.025	0.013	ln
Plutonium-239/240	0.072	0.021	ln
Uranium-233/234	3.05	0.8	ln
Uranium-238	141	1.54	ln
AOC No. 2			
Benzo(a)pyrene	0.13	0.13	m
Benzo(b)fluoranthene	0.17	0.17	m
Barium	1050	159.7	ln
Americium-241	0.44	0.025	ln
Plutonium-239/240	0.88	0.138	ln
Uranium-233/234	1.3	0.785	n
Uranium-238	1.6	0.793	ln

Note : Analytical results used in the calculation of RME concentrations are shown in Attachment J1.

RME - Reasonable maximum exposure

n - 95% UCL based on normal distribution

ln - 95% based on lognormal distribution

m - Maximum detected concentration

TABLE J5-3
MAXIMUM CONCENTRATIONS FOR CHEMICALS OF CONCERN GROUNDWATER

Analyte	Maximum Concentration[1] (µg/L)
AOC No. 2, 30-acre maximum exposure area	
Chloroform	1
Methylene chloride	14
Tetrachoroethene	3
Trichloroethene	6

[1] For simplicity and as a conservative approach, maximum concentrations of COCs in groundwater were used to model soil gas to indoor air.

TABLE J5-4
MAXIMUM AND RME CONCENTRATIONS
FOR CHEMICALS OF CONCERN
POND SEDIMENT
0 - 2 ft.

Analyte	Maximum Concentration (mg/kg)	RME Concentration (mg/kg)	
AOC No. 3			
Aroclor-1254	0.59	0.332	n
Benzo(a)pyrene	0.31	0.274	n
Benzo(b)fluoranthene	0.42	0.319	n
Bis(2-ethylhexyl)phthalate	7.8	2.637	ln
Antimony [1]	30.4	22.9	n
Silver	3.9	1.65	n
Vanadium	62.7	42.2	ln
Americium-241[1]	13.23	5.98	n,d
Plutonium-239/240 [1]	36.2	15.95	n,d
AOC No. 4			
Aroclor-1254	6.6	2.424	n
Benzo(a)pyrene	0.45	0.383	n
Benzo(b)fluoranthene	2	0.861	n
Bis(2-ethylhexyl)phthalate	46	30.26	ln
Antimony [1]	68.5	68.5	m
Silver	240	95.86	n,d
Vanadium	46.2	30.59	n
Americium-241[1]	194.5	54.5	n,d
Plutonium-239/240 [1]	180.2	60.91	n

Note: Analytical results used in the calculation of the RME concentrations are shown in Attachment J1.

[1] Antimony, Am-241, and Pu-239/240 are COCs in surface soil. The RME sediment concentrations shown here are based on sediment sample results and were used in estimating future sediment concentrations following loading from surface soil
The modeled concentrations (shown on Table J5-13) were used in the risk assessment.

RME- Reasonable maximum exposure
n - 95% UCL based on normal distribution
ln - 95% UCL based on lognormal distribution
m - maximum detected concentration
d - See discussion in Attachment J1.

TABLE J5-5
MAXIMUM AND RME CONCENTRATIONS FOR CHEMICALS OF CONCERN POND SURFACE WATER

Analyte	Maximum Concentration (µg/l)	RME Concentration (µg/l)	
AOC No. 3			
Di-n-butyl phthalate	2.0	2.00	m
AOC No. 4			
1,2-Dichloroethene	3	2.53	n,d
Chloroform	2	2	m
Trichloroethene	6	2.96	n,d
Di-n-butyl phthatlate	1.0	1.0	m

Note: Analytical results used in the calculation of RME concentrations are shown in Attachment J1.

RME - Reasonable maximum exposure

n - 95% UCL based on normal distribution

m - Maximum detected concentration

d - See discussion in Attachment J1.

TABLE 5-6
MAXIMUM AND RME CONCENTRATIONS FOR CHEMICALS OF CONCERN STREAM/DRY SEDIMENTS

Analyte	Maximum Concentration (mg/kg or pCi/g)	RME Concentration (mg/kg or pCi/g)	
AOC No. 3			
Benzo(a)anthracene	0.19	0.19	m
Benzo(a)pyrene	0.26	0.26	m
Benzo(b)fluoranthene	0.40	0.297	n
Indeno(1,2,3-cd)pyrene	0.11	0.11	m
Cobalt	12.6	10.98	n
Strontium	95.40	69.7	n
Vanadium	34.4	31.24	n
Zinc	293	180.58	n
Americium-241	0.327	0.311	n
Plutonium-239/240	4.444	2.519	n,d
AOC No. 4			
Benzo(a)anthracene	0.43	0.302	n
Benzo(a)pyrene	0.48	0.48	m
Benzo(b)fluoranthene	0.65	0.41	n
Indeno(1,2,3-cd)pyrene	0.19	0.19	m
Cobalt	11.5	8.77	n
Strontium	95.8	74.49	n
Vanadium	31.3	26.66	n
Zinc	286	152.6	ln
Americium-241	1.293	0.660	n
Plutonium-239/240	3.095	1.392	n

Note: Analytical results used in the calculation of RME concentrations are shown in Attachment J1.

RME - Reasonable maximum exposure

n - 95% UCL based on normal distribution

ln - 95% based on lognormal distribution

m - Maximum detected concentration

d - See discussion in Attachment J1

TABLE J5-7
FIVE YEAR AIR CONCENTRATIONS
FROM WIND EROSION OF SURFACE SOIL
AOC NO. 1

Chemical	Annual Average Air Concentration ($\mu g/m^3$) for Year[1] 1989	1990	1991	1992	1993	Five-year Maximum ($\mu g/m^3$)	Specific Activity Conversion ($pCi/\mu g$)	Five-year Maximum (pCi/m^3)
Antimony	1.57E-06	1.78E-04	8.38E-06	3.71E-06	1.00E-05	1.78E-04	-	-
Vanadium	3.18E-06	3.61E-04	1.70E-05	7.50E-06	2.03E-05	3.61E-04	-	-
Zinc	4.61E-06	5.22E-04	2.46E-05	1.09E-05	2.94E-05	5.22E-04	-	-
Americium-241	4.19E-15	4.74E-13	2.23E-14	9.86E-15	2.67E-14	4.74E-13	3.44E+06	1.63E-06
Plutonium-239/240	3.71E-13	4.20E-11	1.98E-12	8.74E-13	2.37E-12	4.20E-11	7.32E+04	3.07E-06

[1] From Tables in Appendix I.

- No specific activity conversion is necessary for nonradionuclides.

TABLE J5-8
FIVE YEAR AIR CONCENTRATIONS
FROM WIND EROSION OF SURFACE SOIL
AOC NO. 2, 30-ACRE AREA

Chemical	Annual Average Air Concentration ($\mu g/m^3$) for Year[1] 1989	1990	1991	1992	1993	Five-year Maximum ($\mu g/m^3$)	Specific Activity Conversion ($pCi/\mu g$)	Five-year Maximum (pCi/m^3)
Antimony	1.49E-06	1.69E-04	7.93E-06	3.51E-06	9.50E-06	1.69E-04	-	-
Silver	2.79E-07	3.16E-05	1.49E-06	6.57E-07	1.78E-06	3.16E-05	-	-
Vanadium	3.63E-06	4.10E-04	1.93E-05	8.54E-06	2.31E-05	4.10E-04	-	-
Zinc	9.05E-06	1.02E-03	4.82E-05	2.13E-05	5.77E-05	1.02E-03	-	-
Americium-241	3.91E-14	4.43E-12	2.08E-13	9.21E-14	2.49E-13	4.43E-12	3.44E+06	1.52E-05
Plutonium-239/240	4.49E-12	5.08E-10	2.39E-11	1.06E-11	2.86E-11	5.08E-10	7.32E+04	3.72E-05

[1] From Tables in Appendix I.

- No specific activity conversion is necessary for nonradionuclides.

TABLE J5-9
FIVE YEAR AIR CONCENTRATIONS
FROM WIND EROSION OF SURFACE SOIL
AOC NO. 2

Chemical	Annual Average Air Concentration ($\mu g/m^3$) for Year[1] 1989	1990	1991	1992	1993	Five-year Maximum ($\mu g/m^3$)	Specific Activity Conversion ($pCi/\mu g$)	Five-year Maximum (pCi/m^3)
Antimony	1.80E-08	2.04E-06	9.59E-08	4.24E-08	1.15E-07	2.04E-06	-	-
Silver	2.52E-09	2.86E-07	1.34E-08	5.94E-09	1.61E-08	2.86E-07	-	-
Vanadium	3.95E-08	4.47E-06	2.10E-07	9.29E-08	2.52E-07	4.47E-06	-	-
Zinc	8.79E-08	9.95E-06	4.68E-07	2.07E-07	5.61E-07	9.95E-06	-	-
Americium-241	3.94E-16	4.46E-14	2.10E-15	9.29E-16	2.52E-15	4.46E-14	3.44E+06	1.53E-07
Plutonium-239/240	4.16E-14	4.71E-12	2.22E-13	9.80E-14	2.65E-13	4.71E-12	7.32E+04	3.45E-07

[1] From Tables in Appendix I.
- No specific activity conversion is necessary for nonradionuclides.

TABLE J5-10
SUMMARY OF ANNUAL AVERAGE AIR CONCENTRATIONS FROM WIND EROSION AND CONSTRUCTION ACTIVITIES
AOC NO. 1

Analyte	Surface Soil Wind Erosion 5-Year Maximum Annual Average Air Concentrations ($\mu g/m^3$)	Subsurface Soil Wind Erosion[1] Annual Average Air Concentrations ($\mu g/m^3$)	Heavy Construction Activities[1] Annual Average Air Concentrations ($\mu g/m^3$)	Total Annual Average Air Concentrations ($\mu g/m^3$)	Conversion Factor ($pCi/\mu g$)	Total Annual Average Air Concentrations (pCi/m^3)
Metals						
Antimony	1.78E-04	[3]	[3]	1.78E-04	[4]	[4]
Barium	[2]	1.55E-07	1.31E-06	1.46E-06	[4]	[4]
Vanadium	3.61E-04	[3]	[3]	3.61E-04	[4]	[4]
Zinc	5.22E-04	[3]	[3]	5.22E-04	[4]	[4]
Radionuclides						
Americium-241	4.74E-13	4.48E-18	3.78E-17	4.74E-13	3.44E+06	1.63E-06
Plutonium-239/240	4.20E-11	3.40E-16	2.87E-15	4.20E-11	7.32E+04	3.07E-06
Uranium-233/234	[2]	1.55E-13	1.31E-12	1.47E-12	6.19E+03	9.10E-09
Uranium-238	[2]	5.53E-09	4.67E-08	5.22E-08	3.33E-01	1.74E-08

[1]At a 10-acre construction site.
[2]Substance is not a COC in surface soil.
[3]Substance is not a COC in subsurface soil.
[4]No specific activity conversion is necessary for nonradionuclides.

TABLE J5-11
SUMMARY OF ANNUAL AVERAGE AIR CONCENTRATIONS FROM WIND EROSION AND CONSTRUCTION ACTIVITIES AOC NO. 2, 50-ACRE AREA

Analyte	Surface Soil Wind Erosion 5-Year Maximum Annual Average Air Concentrations ($\mu g/m^3$)	Subsurface Soil Wind Erosion[1] Annual Average Air Concentrations ($\mu g/m^3$)	Heavy Construction Activities[1] Annual Average Air Concentrations ($\mu g/m^3$)	Total Annual Average Air Concentrations ($\mu g/m^3$)	Conversion Factor ($pCi/\mu g$)	Total Annual Average Air Concentrations (pCi/m^3)
Semi-volatiles						
Benzo(a)pyrene	[2]	1.56E-10	1.31E-09	1.47E-09	[4]	[4]
Benzo(b)fluoranthene	[2]	2.04E-10	1.72E-09	1.92E-09	[4]	[4]
Metals						
Antimony	2.04E-06	[3]	[3]	2.04E-06	[4]	[4]
Barium	[2]	1.91E-07	1.61E-06	1.81E-06	[4]	[4]
Silver	2.86E-07	[3]	[3]	2.86E-07	[4]	[4]
Vanadium	4.47E-06	[3]	[3]	4.47E-06	[4]	[4]
Zinc	9.95E-06	[3]	[3]	9.95E-06	[4]	[4]
Radionuclides						
Americium-241	4.46E-14	8.68E-18	7.33E-17	4.47E-14	3.44E+06	1.54E-07
Plutonium-239/240	4.71E-12	2.26E-15	1.91E-14	4.73E-12	7.32E+04	3.46E-07
Uranium-233/234	[2]	1.52E-13	1.29E-12	1.44E-12	6.19E+03	8.91E-09
Uranium-238	[2]	2.85E-09	2.40E-08	2.69E-08	3.33E-01	8.96E-09

[1]At a 10-acre construction site.
[2]Substance is not a COC in surface soil.
[3]Substance is not a COC in subsurface soil.
[4]No specific activity conversion is necessary for nonradionuclides.

TABLE J5-12
INDOOR AIR CONCENTRATIONS OF VOCs FROM SOIL GAS TRANSPORT

Analyte	Indoor Air Concentration[1] ($\mu g/m^3$)
Chloroform	6.22E-09
Methylene chloride	5.42E-08
Tetrachloroethene	8.22E-08
Trichloroethene	1.07E-07

[1]Maximum modeled concentration (from Tables in Appendix I)

TABLE J5-13
SUMMARY OF MODELED
SEDIMENT AND SURFACE WATER CONCENTRATIONS
AOC NO. 3 AND AOC NO. 4

	RME Concentration in Sediment at 15 years			RME Concentration in Surface Water		
Pond	Americium-241 (pCi/g)	Plutonium-239/240 (pCi/g)	Antimony (mg/kg)	Americium-241 (pCi/L)	Plutonium-239/240 (pCi/L)	Antimony (mg/L)
AOC No. 3						
A-1	9.28E+00	2.89E+01	2.05E+01	1.40E-02	4.30E-02	4.42E-08
A-2	1.01E+00	3.17E+00	1.19E+01	1.30E-02	4.20E-02	1.21E-08
A-3	2.30E-02	4.70E-02	3.17E-01	2.04E-05	4.65E-05	1.92E-07
Maximum	9.28E+00	2.89E+01	2.05E+01	1.40E-02	4.30E-02	1.92E-07
AOC No. 4						
B-1	9.93E+01	5.56E+01	1.19E+01	1.67E-01	3.80E-02	6.08E-11
B-2	1.14E+01	2.67E+01	1.20E+01	2.90E-02	6.90E-02	3.37E-08
B-3	2.35E+01	7.83E+01	4.70E+01	3.26E-05	1.10E-04	3.02E-09
B-4	4.00E-03	8.00E-03	1.62E-01	1.03E-04	3.41E-04	9.69E-08
Maximum	9.93E+01	7.83E+01	4.70E+01	1.67E-01	6.90E-02	9.69E-08

Note: Sediment concentrations at 15 years represent the mean concentration over 30 years of runoff and deposition. Sediment concentrations are depth-weighted averages of COC concentrations in current and future deposits. Surface water concentrations represent suspended sediment in the water column (95% UCLs on the means of multiple 30-year average modeled concentrations).

J6.0
ESTIMATING CHEMICAL INTAKES

This section describes the methodology and equations for estimating intake of chemicals and radionuclides. Numerical values for exposure factors for CT and RME for each of the receptors and exposure pathways are presented in Attachment J2.

J6.1 GENERAL METHOD FOR CALCULATING INTAKE

Chemical intake is expressed in terms of milligram (mg) chemical ingested, inhaled, or dermally absorbed per kilogram of body weight per day (mg/kg-day). Intake of radionuclides is expressed simply in terms of pCi total intake. Intakes are estimated following guidance in "Risk Assessment Guidance for Superfund" (EPA 1989a), the "Exposure Factors Handbook" (EPA 1989b), other EPA guidance documents, relevant scientific literature, and professional judgement regarding probable site-specific exposure conditions. Intakes are based on reasonable estimates of body weight, inhalation volume, ingestion rates, soil matrix effects, frequency and duration of exposure, and chemical concentration.

Intakes were estimated for CT and RME conditions, as recommended by EPA (EPA 1992a). The RME is estimated by values for exposure variables so that the combination of all variables results in the maximum exposure that can reasonably be expected to occur at the site. The CT is estimated by selecting average values for exposure variables.

The following discussion focusses on the methodology for calculating chemical intakes. Special features of estimating intake of radionuclides are discussed in Section J6.3.

The general equation for calculating chemical intake in terms of mg/kg-day is:

$$\text{Intake} = \frac{\text{chemical concentration x contact rate x exposure frequency x exposure duration}}{\text{body weight x averaging time}}$$

with corresponding units of:

$$\text{mg/kg-day} = \frac{\text{mg/volume or mass x volume or mass/day x day/year x year}}{\text{kg x day}}$$

The variable "averaging time" is expressed in days to calculate daily intake. For noncarcinogenic chemicals, intakes are calculated by averaging over the exposure duration to yield an average daily intake for the period of exposure. For carcinogens, intakes are calculated by averaging the total intake over a 70-year lifetime, yielding "lifetime average daily intake." Different averaging times are used for carcinogens and noncarcinogens because it is thought that their effects occur by different mechanisms. The approach for carcinogens is based on the scientific opinion and EPA policy that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime, and that even very low doses of carcinogens have the potential to cause cancer. Therefore, the average daily intake of a carcinogen is estimated over a 70-year lifetime (EPA 1989a). Intake of noncarcinogens is averaged only over the period of exposure in order to compare an estimate of daily dose to a reference dose considered to be without appreciable risk of adverse effects during long-term exposure.

Omitting chemical concentration from the intake equation yields an "intake factor" for each exposure pathway/receptor combination. The intake factor can then be multiplied by the concentration of each chemical to obtain the pathway/receptor-specific intake of that chemical. Intake factors were calculated for each potentially exposed receptor and exposure pathway identified in Section J4.0. Except for soil ingestion, intake rates are approximately proportional to body weight, and therefore adult exposure parameters are considered adequately protective for calculating chemical doses used in estimating risk for all exposed populations, including children. While it is acknowledged that body surface area is not exactly proportional to body weight and that age-specific ratios of inhalation rate to body weight may differ (by about a factor of two or less), these differences are assumed to be negligible in estimating potential risk. Therefore, child intakes are not estimated for any exposure pathway except ingestion of soil (and sediment), because children age 0 to 6 are thought to ingest considerably more soil and dust per kilogram body weight than adults. Childhood intake of soil and sediment is estimated for the open space recreational user only.

J6.2 PATHWAY-SPECIFIC INTAKE EQUATIONS

This section presents the intake equations for each pathway evaluated in the risk assessment. Numerical values for exposure factors shown in Attachment J2 were used in the equations to yield numerical intake factors for each receptor/pathway combination.

J6.2.1 Soil and Sediment Ingestion

Soil ingestion is estimated using the following equation:

$$\text{Intake} = \frac{\text{Conc x IR x FC x ME x EF x ED x CF}}{\text{BW x AT}}$$

where:

Intake	=	Chemical intake, mg/kg-day
Conc.	=	Chemical concentration in soil, mg/kg
IR	=	Soil ingestion rate, mg/day
FC	=	Fraction contaminated, unitless
ME	=	Soil matrix effect, unitless
EF	=	Exposure frequency, days/year
ED	=	Exposure duration, years
CF	=	Conversion factor, 10^{-6} kg/mg
BW	=	Body weight, kg
AT	=	Averaging time, days

The intake equation for sediment ingestion is the same as for soil ingestion; however, some parameter values are different. Parameter values shown in Attachment J2 were used to calculate intake for each receptor.

Age-Adjusted IRs: Both child and adult soil ingestion rates were evaluated in the open space use exposure scenario. For noncarcinogens, child and adult soil ingestion were evaluated separately, using the equation shown above and parameter values listed in Attachment J2.

This approach yields separate hazard indexes (HIs) for children and adults for the soil ingestion exposure route. The separate HI for children is a more protective estimate of potential noncarcinogenic hazard for this age group because it accounts for the greater amount of soil ingested by children relative to body weight.

For carcinogens, a combined child and adult weighted ingestion rate was calculated, combining the soil IR, BW, EF, and ED for both age groups. It is not necessary to calculate separate cancer risk estimates for children and adults because, according to theories of carcinogenesis currently advocated by EPA, a higher dose of a potential carcinogen over a short period of time is thought to have the same carcinogenic potential as a lower dose over a longer period of time. The calculation of age-adjusted soil ingestion rates for carcinogenic chemicals and radionuclides is explained in Table J6-1.

Matrix Effect: The soil matrix effect (ME) describes the reduced bioavailability of a chemical bound to a soil matrix compared to the same chemical in solution. For COCs in soil whose toxicity factors were derived from studies in which the agent was administered in solution, a soil ME of 0.5 was used in calculating intake for risk assessment. Chemical-specific soil matrix effects for COCs in soil are listed in Table J6-2. The ME of 0.5 is a conservative value derived from a review of literature, summarized in Table J6-3. The ME is used to account for decreased bioavailability of ingested compounds bound to a solid matrix relative to their bioavailability from drinking water or other solutions such as corn oil. Adjustments of this type may be necessary if "the medium of exposure in the site exposure assessment differs from the medium of exposure assumed by the toxicity value" (EPA 1989a). The EPA guidance further states that "a substance might be more completely absorbed following exposure to contaminated drinking water than following exposure to contaminated food or soil (e.g., if the substance does not desorb from soil in the gastrointestinal tract)." The ME is applied to COCs in soil and in sediment. The literature values for soil matrix effects shown in Table J6-3 are discussed in more detail below.

There are several EPA precedents for assuming decreased bioavailability of inorganics from soil compared to that in water. For example, cadmium and manganese each have two oral reference doses (RfDs), one for ingestion in food or other solid media, and one for ingestion in water. In deriving media-specific RfDs for cadmium, EPA assumed that 5 percent of cadmium ingested in water is bioavailable, compared to 2.5 percent for cadmium ingested

in food (EPA 1995b). The corresponding matrix effect for cadmium ingested in food is 0.5. The RfD for manganese ingested in water is 28 times smaller than the RfD for manganese ingested in food (EPA 1995b). Although relative bioavailability of manganese in food and water is not discussed in IRIS, one explanation for a 28-fold decrease in toxicity of manganese ingested in food is a matrix effect resulting in greatly decreased bioavailability. Another example of media-specific differences in toxicity is suggested by EPA's RfD for cyanide. In deriving the RfD for cyanide, based on a dietary study in rats, EPA included a safety factor of 5 to protect for an expected increase in toxicity of cyanide ingested in water (EPA 1995b). The use of this safety factor implies that cyanide ingested in food is 0.2 times as toxic as cyanide ingested in water, corresponding to a matrix effect of 0.2.

Other evidence in the literature indicated that absolute absorption of inorganics ingested in food is less than that from water. Sixty percent of radiolabeled lead chloride administered to adult humans in water was bioavailable, compared to 3 percent for lead chloride ingested in food (Heard and Chamberlain 1982). Similarly, nickel chloride administered to adult humans in food was much less bioavailable (0.7 percent) than nickel chloride administered in water (28 percent) (Sunderland et al. 1989). Increased blood levels of manganese were observed in humans ingesting high doses in water, but not when similar doses of manganese were ingested in food (Bales et al. 1987).

The absolute absorption of inorganics ingested in soil is also less than that from water. This is expected because inorganics only partially desorb from soil. EPA's Integrated Exposure Uptake Biokinetic (IEUBK) lead model assumes that the bioavailability for lead ingested in soil is 30 percent, compared to 50 percent bioavailability of lead ingested in water. The corresponding soil matrix value is 0.6. In rats, the bioavailability of lead ingested in soil was 8 percent of that for lead acetate ingested in water (Freeman et al. 1992). Arsenic administered to rabbits in soil was much less bioavailable (28 percent) than arsenic administered to rabbits in water (59 percent), corresponding to a soil matrix effect of 0.47 (Freeman et al. 1993).

Several studies show that organic chemicals, including pesticides, also bind tightly to soil, reducing their bioavailability through both oral and dermal exposure. Clays and organic colloids have a large surface area and cation exchange capacity, which permits significant adsorption of virtually all classes of pesticides. Furthermore, the adsorbed fraction desorbs

slowly and is effectively a bound fraction that increases over time as the soil-pesticide bond "ages" (Calderbank 1989). The bound fraction is estimated to be about 20 to 70 percent of the total amount applied. McConnell et al. (1984) showed, using soil containing TCDD (a dioxin), that 3 μg/kg-bw TCDD in corn oil resulted in 6/6 deaths among treated guinea pigs and 13.3 ppb TCDD in the liver, but 3.3 μg/kg-bw TCDD from soil caused only 2/6 deaths and 1.4 ppb in the liver, indicating about 10 percent relative bioavailability of TCDD from the soil. Shu et al. (1988) conducted further studies on TCDD and found an average 43 percent (range, 25 to 50 percent) bioavailability of TCDD to rats from soils from Times Beach, Missouri. Goon et al. (1991) showed that benzo(a)pyrene (BaP) that had aged 6 months in soil was only 34 and 51 percent orally bioavailable for clayey and sandy soil respectively, relative to BaP administered alone to rats. PCBs, DDT, chlordane, and heptachlor may be expected to adsorb strongly to soil similarly to BaP (Ney 1990), resulting in reduced bioavailability due to this matrix effect. These studies support a conservative estimate of 50 percent relative bioavailability of SVOCs in soil compared to those in solution.

In summary, a matrix factor of 0.5 was used in the health risk assessment to account for the decreased toxicity of COCs in soil and in sediment relative to that in water or other solutions. This value is based in part on EPA-derived relative bioavailability factors for cadmium in food (0.5) and lead in soil (0.6), a literature-derived relative bioavailability factor of 0.47 for arsenic in soil (Freeman et al. 1993; EPA 1995b), and the evidence supporting a 50 percent relative bioavailability of SVOCs in soil. Note that several studies indicate that the decrease in bioavailability from matrix effects can be substantially greater than 50 percent (as much as 95 percent), indicating that a matrix effect of 0.5 is conservative (Freeman et al. 1992; Heard and Chamberlain 1982; Sunderland et al. 1989; EPA 1995b).

As shown on Table J6-2, the following COCs in surface soil, subsurface soil, and sediment have toxicity values that were derived from studies using drinking water or other solution and were therefore evaluated using a matrix effect: antimony, Aroclor-1254, barium, silver, vanadium, and zinc. Where the critical toxicity study was dietary but no vehicle was indicated in IRIS, a default matrix effect of 1 was used.

For radionuclides, ingestion slope factors were calculated using gastrointestinal absorption factors (f_1) for soluble forms of each radionuclide; consequently, it would be appropriate to

consider matrix effects as well as mineralized form to estimate carcinogenic effects from ingestion of radionuclides in a soil matrix (Nelson 1995). However, the reduction in potential toxic effects cannot be quantified simply using a matrix effect because the adjustment must account for differential effects on target organs. Therefore, a matrix effect of 1 has been adopted for radionuclides in the present risk assessment, even though this factor probably overestimates the effects of radionuclides ingested in soil.

J6.2.2 Inhalation of Airborne Particulate Matter and of Indoor VOCs

Chemical intake through inhalation exposure routes is estimated using the following equation:

$$\text{Intake} = \frac{\text{Conc.} \times \text{IR} \times \text{DF} \times \text{ET} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}}$$

where:

Intake	=	Chemical intake, mg/kg-day
Conc.	=	Chemical concentration in air, mg/m^3
IR	=	Ingestion rate, m^3/hr
DF	=	Particulate deposition factor in lungs, unitless
ET	=	Exposure time, hr/day
EF	=	Exposure frequency, days/year
ED	=	Exposure duration, years
BW	=	Body weight, kg
AT	=	Averaging time, days

Parameter values shown in Attachment J2 were used to calculate intake via inhalation for each receptor.

J6.2.3 Soil and Sediment Dermal Contact

Chemical intake through absorption of organic chemicals in soil and sediment through skin is estimated using the following equation:

$$\text{Intake} = \frac{\text{Conc.} \times \text{SA} \times \text{AB} \times \text{AD} \times \text{FC} \times \text{EF} \times \text{ED} \times \text{CF}}{\text{BW} \times \text{AT}}$$

where:

Intake	=	Chemical intake, mg/kg-day
Conc.	=	Chemical concentration in soil, mg/kg
SA	=	Surface area, cm^2/day
AB	=	Absorption factor, unitless
AD	=	Soil adherence factor, mg/cm^2
FC	=	Fraction contacted that is contaminated, unitless
EF	=	Exposure frequency, days/year
ED	=	Exposure duration, years
CF	=	Conversion factor, kg soil/mg soil
BW	=	Body weight, kg
AT	=	Averaging time, days

Parameter values shown in Attachment J2 were used to calculate intake via dermal contact with soil or sediment for each receptor evaluated.

Absorption Factors: The parameter AB is a chemical-specific value describing the fraction of organic chemical in soil and sediment that is absorbed by the skin. Table J6-4 lists the values for AB used in this risk assessment. Dermal absorption of metals from contact with soil is not considered a significant uptake route, because metals bind strongly to soil which greatly reduces their bioavailability. Most metals form strong bonds with other soil constituents and, due to polarity and solubility, metals are not absorbed well across the skin (EPA 1991b). Therefore, dermal uptake of metals was considered negligible and was not evaluated in this risk assessment. Likewise for radionuclides, EPA guidance states that "dermal uptake is generally not an important route of uptake for radionuclides, which have small dermal permeability constants" (EPA 1989a). Dermal permeability constants describe the rate at which dissolved (aqueous phase) chemicals permeate the skin. Absorption of radionuclides adhered to soil is also expected to be negligible.

J6.2.4 Surface Water Ingestion

Chemical intake via ingestion of surface water during intermittent contact with the streams and ponds is estimated using the following equation:

$$\text{Intake} = \frac{\text{Conc.} \times \text{IR} \times \text{ET} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}}$$

where:

Intake	=	Chemical intake, mg/kg-day
Conc.	=	Chemical concentration in water, mg/L
IR	=	Ingestion rate, L/hr
ET	=	Exposure time, hr/day
EF	=	Exposure frequency, days/year
ED	=	Exposure duration, years
BW	=	Body weight, kg
AT	=	Averaging time, days

Parameter values shown in Attachment J2 were used to calculate intake for each receptor evaluated.

J6.2.5 Surface Water Dermal Contact

Chemical intake through absorption of VOCs in water through skin is estimated using the following equation:

$$\text{Intake} = \frac{\text{Conc.} \times \text{SA} \times \text{PC} \times \text{ET} \times \text{EF} \times \text{ED} \times \text{CF}}{\text{BW} \times \text{AT}}$$

where:

Intake	=	Chemical intake, mg/kg-day
Conc.	=	Chemical concentration in water, mg/L
SA	=	Surface area, cm^2/day
PC	=	Permeability constant, cm/hr (chemical-specific)
ET	=	Exposure time, hr/day
EF	=	Exposure frequency, days/year
ED	=	Exposure duration, years
CF	=	Conversion factor, L/cm^3
BW	=	Body weight, kg
AT	=	Averaging time, days

Parameter values shown in Attachment J2 were used to calculate intake for each receptor evaluated.

Permeability constants (PCs): PCs are chemical-specific factors that describe the rate at which dissolved (aqueous-phase) chemicals permeate the skin. Absorption of metals and radionuclides adhered to suspended sediment is assumed to be negligible and was not evaluated. PCs for organic chemicals in surface water are listed in Table J6-4.

J6.3 CALCULATING INTAKE OF RADIONUCLIDES

Exposure to radionuclides was evaluated in two ways. First, the total intake or external irradiation exposure for each radionuclide was calculated and multiplied by the respective carcinogenic slope factor to provide an estimate of lifetime excess cancer risk. The equations for estimating intake of radionuclides and external irradiation exposure are described in this section.

Second, the annual radiation dose (more precisely, the annual committed effective dose equivalent) was calculated and compared to annual radiation protection standards. Radiation dose calculations are discussed in Section J9.0.

J6.3.1 Intake of Radionuclides from Ingestion and Inhalation

Intake of radionuclides was calculated using equations similar to those for calculating intake of chemicals. Intake of radionuclides by either ingestion or inhalation is a function of radionuclide activity concentration, intake rate (or the amount of potentially contaminated medium contacted per unit time or event), and exposure frequency and duration. The only difference between calculating intake for radionuclides and nonradioactive substances is that averaging time and body weight are excluded from the intake equations for radionuclides.

Intake of radionuclides by ingestion or inhalation is calculated using the following equation:

$$\text{Intake} = C \times IR \times EF \times ED$$

where:

Intake	=	Lifetime internal radionuclide intake via inhalation or ingestion, pCi
C	=	Activity concentration of a radionuclide at the exposure point, pCi/m^3, pCi/L, or pCi/g
IR	=	Intake rate, m^3/day, L/day, or kg/day
EF	=	Exposure frequency, days/year
ED	=	Exposure duration, year

Excess lifetime cancer risk is then estimated by multiplying the total intake in pCi by the cancer slope factor expressed in units of risk/pCi.

J6.3.2 External Irradiation

For estimating lifetime excess cancer risk, external irradiation exposure is estimated using the following equation:

$$ER = C \times (1 - Se) \times Te \times EF \times ED$$

where:

ER	=	External irradiation exposure, pCi/g soil per year, or pCi-yr/g
C	=	Mass activity concentration of a radionuclide at the exposure point, pCi/g soil
Se	=	Gamma shielding factor, unitless
Te	=	Gamma exposure time factor, fraction of day, unitless
EF	=	Exposure frequency, fraction of year, unitless
ED	=	Exposure duration, years

Excess lifetime cancer risk is then estimated by multiplying ER in pCi-yr/g by the slope factor for external irradiation expressed in risk per pCi-yr/g.

TABLE J6-1
AGE-WEIGHTED SOIL AND SEDIMENT INGESTION RATES FOR CARCINOGENS AND RADIONUCLIDES

For carcinogens: age-weighted soil and sediment ingestion rates for child and adult openspace use were calculated using the following formula:

$$IRadj = \frac{IRc \times EDc \times FCc}{BWc} + \frac{IRa \times EDa \times FCa}{BWa}$$

where:

IRadj	=	Age and time-weighted soil or sediment ingestion rate, mg-years/day-kg
IRc	=	Childhood soil ingestion rate
EDc	=	Childhood exposure duration
FCc	=	Fraction ingested from contaminated source (child)
BWc	=	Child body weight
IRa	=	Adult soil ingestion rate
EDa	=	Adult exposure duration
FCa	=	Fraction ingested from contaminated source (adult)
BWa	=	Adult body weight

Applying exposure factors from Attachment J2 for open space use, soil ingestion, and sediment ingestion yields the following weighted IRs for chemical intake (1):

			Open Space Use
CT	IRadj	=	9.2 mg-years/day-kg
RME	IRadj	=	57 mg-years/day-kg

For radionuclides: For radionuclides, BW is not included in the equation. IRadj for radionuclides:

			Open Space Use
CT	IRadj	=	179 mg-years/day
RME	IRadj	=	1800 mg-years/day

CT = Central tendency
RME = Reasonable maximum exposure

TABLE J6-2
SOIL MATRIX EFFECTS

Chemical of Concern	Type of Critical Study (1)		Soil Matrix Effect (2)
	Oral Reference Dose	Oral Slope Factor	
Antimony	Drinking water (rats)		0.5
Aroclor-1254	Glycerol & corn oil vehicle (monkeys)	Corn oil vehicle, stirred in food (rats) (3)	0.5
Barium	Drinking water (humans)		0.5
Benzo(a)pyrene (4)		Dietary: vehicle not specified (rats, mice, dogs)	1
Bis(2-ethylhexyl)phthalate	Dietary vehicle not specified (guinea pigs)	Dietary:vehicle not specified (rats, mice)	1
Cobalt	Inhalation (humans) (5)		1
Silver	Intravenous (humans)		0.5
Strontium	Dietary: vehicle not specified (rats)		1
Vanadium	Drinking water (rats)		0.5
Zinc	Dietary supplements (human) (6)		0.5
Americium-241		Soluble form in food or water (7)	1
Plutonium-239/240		Soluble form in food or water (7)	1
Uranium-233/234		Soluble form in food or water (7)	1
Uranium-238		Soluble form in food or water (7)	1

(1) Source: IRIS, unless otherwise noted.
(2) A soil matrix effect of 0.5 in supported by literature review: see text and Table J6-3.
(3) Study actually done for Aroclor-1260; used by analogy.
(4) Adopted for all carcinogenic PAHs that are chemicals of concern in sediment.
(5) In the absence of information on the critical study supporting the provisional oral RfD for cobalt, a default matrix effect of 1 is adopted. This may overestimate absorption of cobalt from soil.
(6) Dietary supplements are designed to be readily absorbed in the gastrointestinal tract; therefore, a soil matrix effect is appropriate.
(7) Personal communication (Nelson, 1995). Slope factors were derived using gastrointestinal absorption factors for soluble forms of each radionuclide. Retardation of radionuclide intake from soil matrix is appropriate to consider, but cannot be quantified using a simple soil matrix effect because the adjustment must account for differential effects on target organs. Therefore, a matrix effect of 1 is adopted, even though it probably overestimates bioavailability of mineralized forms of radionuclides in soils at Rocky Flats.

TABLE J6-3
DERIVATION OF 0.5 SOIL MATRIX EFFECT

Compound (Species)	Fraction Absorbed from Food or Soil (Fm)	Fraction Absorbed from Water (Fw)	Matrix Effect	Source
Cadmium (in adults)	0.025	0.05	0.50 (1)	EPA 1995; Kjellstrom and Nordberg, 1978
Manganese (adults)	--	--	0.04 (2)	EPA 1995
Cyanide (rats)	--	--	0.20 (3)	EPA 1995
Lead (children)	0.3	0.5	0.60 (1)	EPA 1994
Lead (adults)	0.03	0.6	0.05 (1)	Heard and Chamberlain (1982)
Lead (rats)	--	--	0.08 - 0.20 (4)	Freeman et al. 1993
Nickel (adults)	0.007	0.28	0.03 (1)	Sunderland et al. 1989
Arsenic (rabbits)	0.28	0.59	0.47 (1)	Freeman et al. 1994
TCDD (guinea pigs)	--	--	0.10 (5)	McConnell et al. 1984
Benzo(a) pyrene (rats)	--	--	0.34-0.51 (6)	Goon et al. 1991
Matrix Effect Selected For Use In HHRA			0.5	

(1) Based on Fm/Fw.
(2) Based on relative toxicity of manganese in water vs food (RfD water = 5E-03 mg/kg-d; RfD food = 1.4E-01 mg/kg-d; ratio = 0.04).
(3) Based on relative toxicity of cyanide in food and water; see text.
(4) Based on relative retention of lead in blood, bone, and liver.
(5) Based on relative retention of TCDD in liver.
(6) Based on relative bioavailability from soil compared to water.

TABLE J6-4
DERMAL ABSORPTION FRACTIONS AND DERMAL PERMEABILITY CONSTANTS FOR COCs IN SOIL AND SURFACE WATER

Chemical	Soil Absorbed Fraction	Dermal Permeability Constant (cm/hr)	Source
1,2-Dichloroethene	-	0.01	1
Aroclor-1254	0.06	-	2
Bis(2-ethylhexyl)phthalate	0.01	-	3
Chloroform	-	0.13	4
Di-n-butyl phthatlate		0.07	5
Trichloroethene	-	0.23	4
Vinyl Chloride	-	0.0073	6

Source:

1. EPA 1992b. Table 5-8, Estimated Kp value for trans-1,2-dichloroethene.
2. EPA 1992b. Experimentally measured. Table 6-3.
3. EPA 1992c. New Interim Region IV Guidance recommending 1 percent absorption for all organics.
4. EPA 1992b. Table 5-8, Measured K_p.
5. EPA 1992b. Calculated using Equation 5.8.
6. EPA 1992b. Table 5-8, Estimated K_p.

- Chemical not evaluated in this medium.

J7.1 INTRODUCTION

This section describes the toxicity factors that are compared to estimated levels of intake of COCs to estimate potential risk associated with exposure. The toxicity factors used in the HHRA are EPA-verified or provisional carcinogenic slope factors (SFs) and noncarcinogenic reference doses (RfDs) or reference air concentrations (RfCs) for the COCs in OU6. The toxicity factors presented in Tables J7-1 and J7-2 are the most current factors available at this writing.

The principal indices of toxicity for chemicals with noncarcinogenic effects are the oral RfD and inhalation RfC. RfDs and RfCs can be considered threshold doses or exposure levels. At chemical doses or exposures below threshold values, adverse effects are not expected to occur. RfDs and RfCs incorporate a number of safety factors to ensure that they are protective of the health of all human populations, including sensitive subgroups (e.g., children and the elderly).

Oral and inhalation SFs are used to characterize the potency of carcinogens. A SF is a dose-response factor used to relate carcinogenic response to chemical dose. SFs are used to estimate the upperbound probability of an individual developing cancer as a result of exposure to a potential carcinogen. EPA policy assumes that carcinogenic responses have no threshold, and that exposure to a carcinogen may result in some finite cancer risk at any dose, no matter how small (EPA 1989a).

SFs for radionuclides are derived considering the energy level of the radionuclide and residence time of the radionuclide in various body tissues. Duration of exposure is determined by the residence time of the radionuclide. SFs for external exposure to radionuclides are determined by the energy level of the radionuclide and duration of the exposure (i.e., time spent at the exposure point).

EPA assumes that any dose of a radionuclide has the potential to produce carcinogenic effects (no threshold). However, EPA does not recommend the evaluation of noncarcinogenic effects of radionuclides because the impacts have been shown to be insignificant compared to carcinogenic effects at most Superfund sites with potential radionuclide contamination (EPA 1989a). EPA has developed both internal (i.e., inhalation and ingestion) and external SFs for the carcinogenic response to radionuclide exposure (EPA 1994b).

Note on assessing effects of dermal exposure to chemicals: EPA recommends using oral toxicity factors, adjusted if possible by a gastrointestinal absorption fraction, to evaluate toxic effects from dermal contact with potentially contaminated media (EPA 1989a; 1992f). The oral toxicity factor relates the toxic response to an administered dose of chemical, only some of which may be absorbed by the body, whereas chemical intake from dermal contact is estimated as an absorbed dose, whose toxic effects could be underestimated by using unadjusted oral toxicity factors. Therefore, EPA (1989a) suggests adjusting the oral toxicity factors by chemical-specific gastrointestinal absorption rates, if available, to yield toxicity factors for dermally absorbed chemicals. When chemical-specific gastrointestinal absorption rates are not available, gastrointestinal absorption is assumed to be 100% and the unadjusted oral toxicity factor is used to assess response to dermal absorption.

Regarding using oral toxicity factors to evaluate response to dermal exposure, EPA (1992f) states:

> Until more appropriate dose-response factors are available, it is recommended that assessors use the oral factors.... Alternatively, if estimates of the gastrointestinal absorption fraction are available for the compound of interest in the appropriate vehicle, then the oral dose-response factor, unadjusted for absorption, can be converted to an absorbed dose basis.... Lacking this information, the oral factor should be used as is accompanied by a strong statement of the uncertainty involved. (p. 10-9, 10-10)

Since chemical-specific gastrointestinal absorption rates are not available for most chemicals, unadjusted oral toxicity factors were used to assess effects of dermal absorption. If dermal absorption of particular chemicals is demonstrated to be a potential significant contributor

to overall risk in the risk assessment, a more detailed analysis of the toxicity by dermal absorption may be warranted.

EPA guidance (EPA 1989a) states that it is inappropriate to use oral SFs to evaluate the risks associated with dermal exposure to polycyclic aromatic hydrocarbons (PAHs), which can cause skin cancer through direct action at the point of application. In accordance with EPA guidance, generally only a qualitative assessment of risks from dermal exposure to PAHs is possible. In addition, PAHs do not have RfCs or SFs for the inhalation pathway. Therefore, only oral exposures to PAHs were evaluated quantitatively in the risk assessment.

The RfDs, RfCs, and SFs that were used in the OU6 risk assessment were obtained from the following sources:

- EPA's Integrated Risk Information System on-line database (EPA 1995b)
- EPA's Health Effects Assessment Summary Tables and Supplements (EPA 1994b)
- EPA's Environmental Criteria and Assessment Office (ECAO) for interim and provisional values.

J7.2 REFERENCE DOSES AND REFERENCE CONCENTRATIONS

The noncarcinogenic effects for all chemicals are generally thought to have a threshold dose below which there are no observable adverse health effects. In developing a toxicity value for noncarcinogenic effects, the approach used by EPA is to identify a no-observed-adverse-effect level (NOAEL) through studies with laboratory animals or from epidemiological (human) studies. A NOAEL is defined as an experimentally (or epidemiologically) determined highest dose at which there was no observed statistically or biologically significant effect of concern. For certain substances, only a lowest-observed-adverse-effect level (LOAEL) has been determined. This is the lowest dose of a substance that produces either a statistically or biologically significant indication of the critical toxic effect. The RfD is usually based on the most sensitive animal species tested (i.e., the species that experiences adverse effects at the lowest dose). RfDs are typically calculated by dividing the NOAEL (or LOAEL) by uncertainty factors, which may range from 10 to 10,000. Uncertainty factors (usually a factor of 10 each) are used to account for protection of sensitive

individuals, extrapolation from animals to humans, extrapolation from subchronic studies to chronic exposure, and extrapolation from LOAELs to NOAELs. In addition, modifying factors ranging from >0 to 10 may be included to reflect a qualitative assessment of additional uncertainties in the derivation of the RfD or RfC.

The majority of our toxicological knowledge of chemicals comes from experiments on laboratory animals. Experimental animal data historically have been relied upon by regulatory agencies and other expert groups to assess the hazards of human chemical exposures, although uncertainty is inherent in this approach because there are known interspecies differences in chemical absorption, metabolism, excretion, and toxic responses. There are also uncertainties concerning the relevance of animal studies using exposure routes (i.e., intravenous injection) that differ from the human exposure routes under consideration. Additionally, the extrapolation of results from short-term or subchronic animal studies to long-term exposures in humans has inherent uncertainty (EPA 1989a).

Despite the limitations of experimental animal data, such information is essential for chemical toxicity assessment, especially in the absence of human epidemiological evidence. The uncertainty factors used in the derivation of RfDs and RfCs are intended to compensate for data limitations. The use of uncertainty factors is conservative by design and results in toxicity values that are likely to be protective, and may well be overly protective (EPA 1989a).

The RfD is expressed in units of intake of milligrams of chemical per kilogram of body weight per day (mg/kg-day) for oral exposure. The methodology for deriving RfDs is described in detail in the EPA's human health risk assessment guidance (EPA 1989a).

Potential hazards from inhalation exposures may be estimated by comparing an air concentration of a chemical to the RfC. RfCs are expressed in concentration units of milligrams of chemical per cubic meter of air (mg/m^3). For the purposes of the OU6 risk assessment, in order to assess cumulative effects of oral, dermal, and inhalation exposures, the RfCs were converted to inhalation RfDs so that chemical intake, rather than inhalation exposure, could be evaluated. A body weight of 70 kg and a respiration rate of 20 m^3/day were used to convert the RfC to the RfD (mg/kg-day) using the following equation:

$$\text{RfD (mg/kg-day)} = \frac{\text{RfC mg/m}^3 \times 20 \text{ m}^3\text{/day}}{70 \text{ kg}}$$

Oral and inhalation RfDs for COCs and the inhalation RfCs used in the derivation of the inhalation RfDs are presented in Table J7-1.

J7.3 SLOPE FACTORS FOR CHEMICAL CARCINOGENS

In estimating the risk posed by potential chemical carcinogens, it is EPA practice to assume that any exposure level is associated with a finite probability, however minute, of producing a carcinogenic response. In other words, it is assumed that a small number of molecular events can evoke changes in a single cell that can lead to uncontrolled cellular proliferation. This mechanism for carcinogenicity is referred to as "non-threshold" since there is theoretically no level of exposure that does not pose a small probability of producing a carcinogenic response. This is a conservative (protective) assumption that may overestimate the response to low doses of some suspected carcinogens, especially those for which there is scientific evidence of a threshold dose.

SFs for most chemicals are based upon the results of animal studies which, as previously discussed, involve uncertainty. It is not certain that all animal carcinogens are carcinogenic in humans. While many chemical substances are carcinogenic in one or more animal species, only a small number of chemical substances are known to be human carcinogens. The EPA assumes that humans are as sensitive to all animal carcinogens as the most sensitive animal species. This policy decision is designed to prevent underestimating risk and introduces the potential to overestimate carcinogenic risk (EPA 1989a).

The EPA also uses an evaluation process in which the chemical is assigned a cancer weight-of-evidence classification. The weight-of-evidence classification describes the degree of confidence or likelihood, based on scientific evidence, that the substance is a human carcinogen. EPA cancer weight-of-evidence classifications are shown on the bottom of Table J7-1.

SFs are calculated from experimental or epidemiological data that quantitatively define the relationship between average lifetime dose and carcinogenic risk (EPA 1989a). A number

of mathematical models and procedures have been developed to extrapolate from carcinogenic responses observed at high doses in laboratory animals to potential responses expected at low doses in humans. EPA uses a conservative mathematical model, the linearized multistage model, for low-dose extrapolation. EPA identifies the SF as the upper 95th percentile confidence limit of the slope on the resulting dose-response curve. The SF is expressed in units of risk per mg/kg-day or $(mg/kg\text{-}day)^{-1}$ and is used to estimate excess incremental lifetime cancer risk from the lifetime average daily intake of a chemical. This represents an estimation of an upperbound probability that an individual will develop cancer as a result of exposure to the potential carcinogen. This model provides a conservative (protective) estimate of cancer risk at low doses and is likely to overestimate the actual cancer risk. The EPA acknowledges that actual SFs are likely to be between zero and the estimate provided by the linearized multistage model (EPA 1989a). SFs for COCs in OU6 are presented in Table J7-1.

J7.4 SLOPE FACTORS FOR RADIONUCLIDES

EPA's Health Effects Assessment Summary Tables (EPA 1994a Supplement 2) list cancer SFs for selected radionuclides of potential concern at Superfund sites. These values were calculated by the Office of Radiation Programs and are intended for use in human health risk assessments. EPA classifies all radionuclides as Group A (human) carcinogens based on the extensive weight-of-evidence provided by epidemiological studies of radiation-induced cancers in humans.

Radionuclides that enter the body may become incorporated into body tissues and emit alpha, beta, or gamma radiation for the duration of the radionuclide's lifetime. The potential adverse effects of radiation are proportional to energy deposition. The energy deposited in tissues is proportional to the decay rate and the type of radiation (alpha, beta, gamma) rather than the mass of the radionuclide (EPA 1989a). Radionuclide intake is typically expressed in terms of activity, either Curies (Ci), picocuries (pCi or 10^{-12} Ci), or Becquerels (Bqs) rather than mass (mg). Activity refers to the number of nuclear disintegrations per unit time. The historic unit of activity is the Ci, which is equal to 3.7×10^{10} disintegrations per second. The SI (Systeme Internationale) unit of activity is the Bq, equal to one disintegration per second (1 Bq = 2.7×10^{-11} Ci). EPA SFs are provided in both units, risk per picocurie

$(pCi)^{-1}$ and risk per Bq $(Bq)^{-1}$. Table J7-2 shows the SFs for radionuclides of concern expressed in risk per pCi.

EPA SFs for radionuclides are characterized as best estimates (median or 50th percentile) of the age-averaged, lifetime excess total cancer incidence (fatal and nonfatal) risk per unit exposure to a radionuclide. The SFs are based on the unique chemical, metabolic, and radiological properties of individual radionuclides. They were calculated using a non-threshold, linear dose-response model. The model accounts for the amount of radionuclide absorbed into the body, distribution, and retention, as well as the age, sex, and weight of an average individual. Therefore, EPA SFs for radionuclides are not expressed as a function of body weight or time, and do not require corrections for absorption or lung transfer efficiencies. These slope factors include daughter products when appropriate (EPA 1994b).

Ingestion and inhalation SFs, expressed as risk/pCi, estimate risk per unit of activity inhaled or ingested and are expressed as risk/pCi. External exposure SFs are best estimates of risk for each year of exposure to external irradiation from photon-emitting radionuclides distributed uniformly in a thick layer of soil. They are expressed as risk/yr per pCi/gram soil. It should be noted that the dose delivered to tissues from external irradiation occurs only while the radiation field is present. However, the dose delivered to body tissues due to intake of radionuclides consumed in soil or water continues long after intake of the contaminated medium has ceased.

Because the SFs for external irradiation from Pu-239 and Pu-240 are different (Table J7-2), a site-specific external irradiation SF for RFETS Pu-239/240 was estimated by the specific activity-weighted average of the slope factors for Pu-239 and Pu-240, as shown in the following equation:

$$SF_W = (SF_{239} \times F_{239}) + (SF_{240} \times F_{240})$$

where:

SF_w = Weighted external irradiation slope factor (SF) for RFETS Pu-239/240 (1.37 E-11 per pCi-yr/g)

SF_{239} = External irradiation SF for Pu-239 (1.26E-11 per pCi-yr/g)

SF_{240} = External irradiation SF for Pu-240 (1.87E-11 per pCi-yr/g)

F_{239} = Fraction of RFETS Pu-239/240 specific activity that is attributable to Pu-239 (0.8153; EG&G 1993)

F_{240} = Fraction of RFETS Pu-239/240 specific activity that is attributable to Pu-240 (0.1847; EG&G 1993)

This weighted SF (1.37E-11) is a site-specific estimate of the carcinogenic potential for RFETS Pu-239/240.

Radionuclide concentrations in air, water, or soil are multiplied by intake rates for internal exposure, or by exposure times for external exposure, and then multiplied by SFs to estimate potential health risk.

Radionuclide intake can also be multiplied by a dose coefficient to estimate equivalent dose, which can then be compared to a radiation protection standard. Differences in the biological effects of different types of ionizing radiation (i.e., alpha, beta, gamma) are accounted for in the dose coefficients. Table J7-3 lists the dose coefficients for Am-241, Pu-239, Pu-240, U-234, and U-238. Coefficients for Pu-239 and U-234 were used to evaluated Pu-239/240 and U233/234, respectively.

TABLE J7-1
TOXICITY FACTORS FOR
CHEMICALS OF CONCERN
ORGANIC COMPOUNDS AND METALS

Analyte	Slope Factors		EPA Cancer Weight of Evidence	Reference Doses		RfC
	Oral	Inhalation		Oral	Inhalation (*)	
Antimony	-	-	-	4.0E-04 (1)	-	-
Aroclor-1254	7.7E+00 (1)	-	B2	2.0E-05 (1)	-	-
Arsenic	1.7E+00 **	1.5E+01 **	A	3.0E-04 (1)	-	-
Barium	-	-	-	7.0E-02 (1)	1.4E-04	5.0E-04 (2)
Benzo(a)anthracene	7.3E-01 (3)	-	B2	-	-	-
Benzo(a)pyrene	7.3E+00 (3)	-	B2	-	-	-
Benzo(b)fluoranthene	7.3E-01 (3)	-	B2	-	-	-
Beryllium	4.3E+00 (1)	8.4E+00 (1)	B2	5.0E-03 (1)	-	-
Bis(2-ethylhexyl)phthalate	1.4E-02 (1)	-	B2	2.0E-02 (1)	-	-
Chloroform	6.1E-03 (1)	8.0E-02 (1)	B2	1.0E-02 (1)	-	-
Cobalt	-	-	-	6.0E-02(4)	-	-
1,2-Dichloroethene	-	-	-	9.0E-03 (5)	-	-
Di-n-butylphthalate	-	-	D	1.0E-01 (1)	-	-
Indeno(1,2,3-cd)pyrene	7.3E-01 (3)	-	B2	-	-	-
Manganese (food)	-	-	D	1.4E-01 (1)	1.4E-05	5.0E-05 (1)
Manganese (water)	-	-	D	5.0E-03 (1)	-	-
Methylene chloride	7.5E-03 (1)	1.6E-03 (1)	B2	6.0E-02 (1)	9.0E-01	3.0E+00 (5)
Nitrate	-	-	-	1.6E+00 (1)	-	-
Silver	-	-	-	5.0E-03 (1)	-	-
Strontium	-	-	-	6.0E-01 (1)	-	-
Tetrachloroethene	5.2E-02 (6)	2.0E-03 (6)	B2	1.0E-02 (1)	-	-
Trichloroethene	1.1E-02 (6)	6.0E-03 (6)	B2	-	-	-
Vanadium	-	-	-	7.0E-03 (5)	-	-
Vinyl chloride	1.9E+00 (5)	3.0E-01 (5)	A	-	-	-
Zinc	-	-	D	3.0E-01 (1)	-	-

Sources:
1 = IRIS (EPA 1995b).
2 = HEAST (EPA 1994b) Table 2
3 = EPA 1993b.
4 = Provisional value for cobalt. USEPA. ECAO.
5 = HEAST (EPA 1994b)
6 = Joan S. Dollarhide, Superfund Health Risk Technical Support Center. "Carcinogenicity Characterization of Perchloroethylene (PERC) and Trichloroethylene (TCE) (Luke Air Force Base. Arizona)." ECAO.

Notes:
* Calculated from RfC. RfD = RfC x $20m^3$/day/70kg.
** Converted from IRIS unit risks (U.R.). Oral proposed U.R. = 5.00E-05/µg/L. Inhalation U.R. = 4.30E-03/$\mu g/m^3$.
Oral SF = 5.00E-05 x 1000µg/mg x 70kg/2L. Inhalation SF = 4.30E-03/$\mu g/m^3$x1000µg/mgx70kg/$20m^3$.

EPA Cancer Weight of Evidence :
A = Human carcinogen
B1 = Probable human carcinogen (limited human data)
B2 = Probable human carcinogen (animal data only)
C = Possible human carcinogen
D = Noncarcinogenic (inadequate evidence)
- = Not classifiable or not carcinogenic

TABLE J7-2
SLOPE FACTORS
FOR RADIONUCLIDES

Analyte	GI Absorption Factor (F_i)[1]	Oral (Risk/pCi)	ICRP Lung Class [2]	Inhalation (Risk/pCi)	External (Risk per pCi-year/g)	EPA Cancer Weight of Evidence
Americium-241	1E-03	3.28E-10	W	3.85E-08	4.59E-09	A
Plutonium-239[3]	1E-03	3.16E-10	Y	2.78E-08	1.26E-11[4]	A
Plutonium-240[3]	1E-03	3.15E-10	Y	2.78E-08	1.87E-11[4]	A
Uranium-233/234[5]	5E-02	4.44E-11	Y	1.40E-08	2.14E-11	A
Uranium-238 +D	5E-02	6.20E-11	Y	1.24E-08	5.25E-08	A

Source: HEAST Supplement No. 2 (EPA 1994b).

[1]Gastrointestinal (GI) absorption factors are the fractional amounts of each radionuclide absorbed across the GI tract into the bloodstream.

[2]Lung clearance classification recommended by the International Commission on Radiological Protection (ICRP): Y=year, W=week,

[3]The external irradiaition slope factor for plutonium-239/240 at RFETS was calculated using the slope factors for each isotope, weighted for site-specific activities at RFETS (see Section J7.4).

[4]A site-specific external irradiation SF for RFETS Pu-239/240 (1.37E-11 per pCi-year/g), based on the specific activity-weighted average of the slope factors for Pu-239 and Pu-240, was used as a site-specific estimate of the potential for RFETS Pu-239/240 to produce cancer risk.

[5]Slope factors shown are for U-234.

A = Class A (human) carcinogen.

+D = Risks from radioactive decay products are included.

TABLE J7-3
EFFECTIVE DOSE COEFFICIENTS FOR RADIONUCLIDES

Radionuclide	f_i [1]	Ingestion (Sv/Bq)	Class [2]	Inhalation (Sv/Bq)	External [3]
Americium-241	1.00E-03	9.84E-07	W	1.20E-04	2.99E+00
Plutonium-239	1.00E-03	9.56E-07	W	1.16E-04	3.78E-02
	1.00E-04	9.96E-08	Y	8.33E-05	
	1.00E-05	1.40E-08			
Uranium-234[4]	5.00E-02	7.66E-08	D	7.37E-07	8.07E-02
	2.00E-03	7.06E-09	W	2.13E-06	
			Y	3.58E-05	
Uranium-238	5.00E-02	6.88E-08	D	6.62E-07	6.46E-02
	2.00E-03	6.42E-09	W	1.90E-06	
			Y	3.20E-05	

[1] Fractional uptake from small intestine to blood.

[2] Lung clearance class: D = days; W = weeks; Y = years

[3] In units of millirem/yr per microcurie/square meters.

[4] Used to evaluate U-233/234.

Risk characterization is the final step of the risk assessment process. In this step, the toxicity factors (RfDs and SFs) for the COCs are applied in conjunction with estimated chemical intakes to predict noncarcinogenic and carcinogenic health risks to exposed individuals.

J8.1 HAZARD INDEX FOR NONCARCINOGENIC EFFECTS

The potential for noncarcinogenic effects is characterized by comparing estimated chemical intakes with chemical-specific RfDs. The resulting ratio is called a hazard quotient (HQ). It is derived in the following manner:

$$\text{Noncancer Hazard Quotient} = \frac{\text{Chemical Intake (mg/kg-day)}}{\text{RfD (mg/kg-day)}}$$

Use of the RfD assumes that there is a level of intake (the RfD) below which it is unlikely that even sensitive individuals will experience adverse health effects over a lifetime of exposure. If the average daily intake exceeds the RfD (that is, if the HQ exceeds 1), there may be cause for concern for potential noncancer effects (EPA 1989a). It should be noted, however, that the level of concern does not increase linearly as the RfD is approached or exceeded. This is because all RfDs are not assessed equally and are not based on the same severity of toxic effects. Since the HQ does not define a dose-response relationship, its numerical value cannot be construed as a direct estimate of risk (EPA 1986).

To assess exposure to multiple chemicals, the HQs for each chemical are summed to yield a hazard index (HI) for each pathway for each receptor. The assumption of additive effects reflected in the HI is most properly applied to substances that induce the same effect by the same mechanism (EPA 1986). Consequently, summing HQs for substances that are not expected to induce the same type of effect could overestimate the potential for adverse effects. The HI provides a measure of the potential for adverse effects, but it is conservative and dependent on the quality of experimentally derived evidence.

Where an individual may be exposed by multiple pathways, the HIs from all relevant pathways are summed to obtain the total HI for that receptor. If the total HI is less than or equal to 1, multiple-pathway exposures to COCs at the site are judged unlikely to result in an adverse effect. If the sum is greater than 1, further evaluation of exposure assumptions and toxicity, including consideration of specific target organs affected and mechanisms of toxic actions of COCs, is warranted to ascertain if the cumulative exposure would in fact be likely to harm exposed individuals.

J8.2 CARCINOGENIC RISK

Potential carcinogenic effects are characterized in terms of the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen. Excess lifetime cancer risk is estimated from the projected lifetime daily average intake and the cancer SF, which represents an upperbound estimate of the dose-response relationship. Excess lifetime cancer risk is calculated by multiplying the average daily chemical intake by the cancer SF as follows:

$$\text{Cancer Risk} = \text{Chemical Intake (mg/kg-day)} \times \text{SF (mg/kg-day)}^{-1}$$

EPA states that carcinogenic risks estimated using SFs are upperbound estimates. This means that the actual risk is likely to be less than the predicted risk (EPA 1989a). RME cancer risks could be significantly overestimated because they are calculated by multiplying together 95th percentile estimates of cancer potency, 95% UCLs of concentrations, and high-end estimates of several exposure parameters.

The risks resulting from exposure to multiple carcinogens are assumed to be additive. The total cancer risk is estimated by summing the risks estimated for each COC and for each pathway. This is a highly conservative approach that results in an artificially elevated estimate of cancer risk, especially if several carcinogens are present, because 95th percentile estimates are not strictly additive (EPA 1989a).

EPA policy must be considered in order to interpret the significance of the cancer risk estimates. In the National Oil and Hazardous Substances Pollution Contingency Plan (EPA 1990a), EPA states that: "For known or suspected carcinogens, acceptable exposure levels

are generally concentration levels that represent an excess upperbound lifetime cancer risk of between 10^{-4} and 10^{-6}." Additionally, where cumulative carcinogenic risk to an individual based on RME exposure does not exceed 10^{-4} and the total HI does not exceed 1, action is generally not warranted for protection of public health (EPA 1991c).

J8.3 AOC NO. 1

As discussed in Section J4.4, health hazards/risks for onsite receptors were evaluated in four AOCs identified in the operable unit. Onsite receptors evaluated in AOC No. 1 include current workers, future office workers, future ecological workers, future open space recreational users, and future construction workers.

AOC No. 1 is the North Spray Field Area (IHSS 167.1), which comprises less than 10 acres. Hazard/risk results for current and future receptors evaluated in AOC No. 1 are summarized in Table J8-1 and detailed in Attachment J3.

J8.3.1 Noncarcinogenic Hazard Index

The cumulative HIs for noncarcinogenic health effects for current and future onsite nonresidential receptors in AOC No. 1 are 0.01 or less for the CT and RME conditions (Table J8-1). Because the HIs are less than 1, no adverse noncancer health effects are expected even for sensitive individuals exposed under RME conditions. Results for each receptor are discussed below:

Current Worker: Exposure pathways evaluated for the current worker were:

- Inhalation of airborne particulates
- Surface soil ingestion and dermal contact
- External irradiation from decay of radionuclides in surface soil

The cumulative HIs for noncarcinogenic health effects for current onsite workers are 0.002 and 0.01 for the CT and RME conditions, respectively (Table J8-1) indicating that no adverse noncancer effects are expected for the current worker in AOC No. 1.

Future Office Worker: Exposure pathways evaluated for the future office worker were the same as for the current worker with the addition of inhalation of VOCs migrating from groundwater to indoor air. However, there is no groundwater in AOC No. 1 therefore, exposure to VOCs was not evaluated in AOC No. 1.

The cumulative HIs for noncarcinogenic health effects for the future office worker are 0.0009 and 0.01 for the CT and RME conditions, respectively (Table J8-1). These values are below 1, indicating that no adverse noncancer effects are expected for the future office worker in AOC No. 1.

Future Ecological Worker: Exposure pathways evaluated for the ecological worker are the same as for the current industrial worker because there is no surface water/sediment in AOC 1. The cumulative HIs for noncarcinogenic health effects for the future ecological worker are 0.002 and 0.006 for the CT and RME conditions, respectively (Table J8-1) and indicate that no adverse noncancer effects are expected for the future ecological worker in AOC No. 1.

Future Open Space Recreational Use: Exposure pathways evaluated for the open space recreational user were the same as listed for the current worker, with the addition of soil ingestion by young children. The cumulative HIs for noncarcinogenic health effects for the future open space recreational user are 0.002 and 0.01 for the CT and RME conditions, respectively (Table J8-1), indicating that no adverse noncancer effects are expected from future open space recreational use in AOC No. 1.

Future Construction Worker: The future construction worker was evaluated for the following exposure pathways:

- Inhalation of airborne particulates from subsurface and surface soil
- Subsurface soil ingestion and dermal contact
- External irradiation from decay of radionuclides in subsurface soil

The cumulative HIs for noncarcinogenic health effects for the future construction worker are 0.00009 and 0.0005 for the CT and RME conditions, respectively (Table J8-1), indicating that no adverse noncancer effects are expected for this receptor in AOC No. 1.

J8.3.2 Carcinogenic Risk

Excess lifetime cancer risk estimates for onsite receptors in AOC No. 1 are summarized in Table J8-1 and detailed in Attachment J3. Cancer estimates for all receptors did not exceed 5E-08 (5 in 100 million), which is below EPA's target risk range 1E-06 to 1E-04 for evaluating risk associated with exposure to chemicals released from hazardous waste sites (EPA 1989a). Results for each receptor are discussed below.

Current Worker: Exposure pathways evaluated for the current worker were described in Section J8.3.1. The estimated excess lifetime cancer risk for the current worker in AOC No. 1 is 2E-09 under the CT exposure condition and 5E-08 under the RME condition (Table J8-1).

Future Office Worker: Exposure pathways evaluated for the future office worker were the same as for the current worker (Section J8.3.1). The estimated excess lifetime cancer risk for the future office worker in AOC No. 1 is 1E-09 under the CT exposure condition and 5E-08 under the RME condition (Table J8-1).

Future Ecological Worker: Exposure pathways evaluated for the ecological worker were described in Section J8.3. The estimated excess lifetime cancer risk for the future ecological worker in AOC No. 1 is 9E-10 under the CT exposure condition and 3E-09 under the RME condition (Table J8-1).

Future Open Space Recreational User: Exposure pathways for the future open space recreational user were described in Section J8.3.1. The estimated excess lifetime cancer risk for future open space use in AOC No. 1 is 4E-10 under the CT exposure condition and 7E-09 under the RME condition (Table J8-1).

Future Construction Worker: Exposure pathways for the future construction worker were described in Section J8.3.1. The cumulative excess lifetime cancer risk is 2E-09 under the CT condition and 4E-09 under the RME condition (Table J8-1).

J8.4 AOC NO. 2

AOC No. 2 includes the Sludge Dispersal Area, Triangle Area, and Soil Dump Area and is approximately 50 acres in areal extent. Onsite receptors evaluated in this AOC were current workers, future ecological workers, future open space recreational users, and future construction workers. Exposure pathways evaluated for these receptors were the same as for AOC No. 1, except that future office workers in AOC No. 2 were also evaluated for inhalation of VOCs migrating from groundwater to indoor air. Hazards/risk for future office workers were evaluated in a 30-acre maximum exposure area in AOC No. 2, which includes all of the Sludge Dispersal Area, the Triangle Area, and approximately half of the Soil Dump Area. Exposure pathways evaluated and hazard/risk results for all receptors in AOC No. 2 are summarized in Table J8-2 and detailed in Attachment J3.

J8.4.1 Noncarcinogenic Hazard Index

For all current and future onsite receptors, the cumulative HIs for noncarcinogenic effects in AOC No. 2 are 0.01 or less for the CT and RME conditions. Because the HIs are well below 1, no adverse health effects are expected even for sensitive individuals exposed under RME conditions. Results for each receptor are listed below.

Current Worker: The cumulative HIs for noncarcinogenic health effects are 0.002 and 0.01 for the CT and RME conditions, respectively.

Future Office Worker: The cumulative HIs for noncarcinogenic health effects are 0.0008 and 0.01 for the CT and RME conditions, respectively.

Future Ecological Worker: The cumulative HIs for noncarcinogenic health effects are 0.002 and 0.006 for the CT and RME conditions, respectively.

Future Open Space Recreational User: The cumulative HIs for noncarcinogenic health effects for a future open space recreational user are 0.002 and 0.01 for the CT and RME conditions, respectively.

Future Construction Worker: The cumulative HIs for noncarcinogenic health effects for a future construction worker are 0.0001 and 0.0006 for the CT and RME conditions, respectively.

J8.4.2 Carcinogenic Risk

For current and future onsite receptors, the estimated excess lifetime cancer risks in AOC No. 2 and in the 30-acre maximum exposure area are less than 1E-06 (1 in 1 million) (Table J8-2). These levels are below EPA's target acceptable risk range of 1E-06 to 1E-04 for risk from exposure to chemicals released from hazardous waste sites (EPA 1989a) and indicate that cancer risks are negligible for each of these receptors. Cancer risk results for each receptor are listed below.

Current Worker: The excess lifetime cancer risk is 1E-08 under the CT exposure condition and 4E-07 under the RME condition.

Future Office Worker: The excess lifetime cancer risk is 1E-08 under the CT exposure condition and 5E-07 under the RME condition.

Future Ecological Worker: The excess lifetime cancer risk is 7E-09 under the CT exposure condition and 2E-08 under the RME condition.

Future Open Space Recreational User: The excess lifetime cancer risk is 4E-09 under the CT exposure condition and 6E-08 under the RME condition.

Future Construction Worker: The excess lifetime cancer risk is 3E-09 under the CT exposure condition and 1E-08 under the RME condition.

J8.5 AOC NO. 3

AOC No. 3 includes Ponds A-1, A-2 and A-3 and the interconnecting stream segments; AOC No. 3 is approximately 50 acres in areal extent. Onsite receptors evaluated in AOC No. 3 include future ecological workers and future open space recreational users. Exposure

pathways evaluated and hazard/risk results for these receptors are summarized in Table J8-3 and detailed in Attachment J3.

J8.5.1 Noncarcinogenic Hazard Index

The cumulative HIs for noncarcinogenic health effects for future onsite receptors in AOC No. 3 are 0.03 or less for the CT and RME conditions (Table J8-3). Because the HIs are less than 1, no adverse noncancer health effects are expected even for sensitive individuals exposed under RME conditions. Results for each receptor are discussed below:

Future Ecological Worker: Exposure pathways evaluated for the future ecological worker were:

- Inhalation of airborne particulates from stream/dry sediment
- Ingestion of and dermal contact with pond sediment and stream/dry sediment
- Surface water ingestion and dermal contact
- External irradiation from decay of radionuclides in stream/dry sediment

The cumulative HIs for noncarcinogenic health effects for future ecological workers are 0.0005 and 0.005 for the CT and RME conditions, respectively (Table J8-3).

Future Open Space Recreational Use: Exposure pathways evaluated for open space use were the same as for the future ecological receptor with the addition of soil ingestion by young children. The cumulative HIs for noncarcinogenic effects for the future open space recreational user are 0.004 and 0.03 for the CT and RME conditions, respectively (Table J8-3).

J8.5.2 Carcinogenic Risk

Excess lifetime cancer risk estimates for receptors in AOC No. 3 are summarized in Table J8-3 and detailed in Attachment J3. Estimated cancer risks did not exceed 1E-06 (1 in 1 million) for either receptor, which is the low end of EPA's target acceptable risk range of 1E-06 to 1E-04 for exposure to chemicals released from hazardous waste sites (EPA 1989a). The estimated cancer risks are therefore negligible. Results for each receptor are discussed below.

Future Ecological Worker: Exposure pathways evaluated for the ecological worker were described in Section J8.5.1. The estimated excess lifetime cancer risk in AOC No. 3 is 5E-09 under the CT exposure condition and 5E-08 under the RME condition (Table J8-3).

Future Open Space Recreational Use: Exposure pathways for the future open space recreational user were described in Section J8.5.1. The estimated excess lifetime cancer risk in AOC No. 3 is 6E-08 under the CT exposure condition and 1E-06 under the RME condition.

J8.6 AOC No. 4

AOC No. 4 includes Ponds B-1, B-2, B-3, and B-4 and the interconnecting stream segments; AOC No. 4 is approximately 50 acres in areal extent. Onsite receptors evaluated in AOC No. 4 future ecological workers and future open recreational space recreational users. Exposure pathways evaluated and hazard/risk results for these receptors are summarized in Table J8-4 and detailed in Attachment J3.

J8.6.1 Noncarcinogenic Hazard Index

The cumulative HIs for noncarcinogenic health effects for future onsite receptors in AOC No. 4 are 0.1 or less for the CT and RME conditions (Table J8-4). Because the HIs are less than 1, no adverse noncancer health effects are expected even for sensitive individuals exposed under RME conditions. Results for each receptor are discussed below.

Future Ecological Worker: Exposure pathways evaluated for the future ecological worker were the same as those described in Section J8.5.1. The cumulative HIs for noncarcinogenic health effects in AOC No. 4 are 0.004 and 0.04 for the CT and RME conditions, respectively (Table J8-4).

Future Open Space Recreational Use: Exposure pathways evaluated for the open space recreational use were the same as those described in Section J8.5.1 The cumulative HIs for noncarcinogenic effects are 0.01 and 0.1 for the CT and RME conditions, respectively (Table J8-4).

J8.6.2 Carcinogenic Risk

Excess lifetime cancer risk estimates for receptors in AOC No. 4 are summarized in Table J8-4 and detailed in Attachment J3. Cancer risk estimates were 6E-06 (6 in 1 million) or less. These levels are well within EPA's target acceptable risk range of 1E-06 to 1E-04 for risk associated with exposure to chemicals released from hazardous waste sites (EPA 1989a) and indicate negligible risk for these receptors. Results for each receptor are discussed below.

Future Ecological Worker: Exposure pathways evaluated for the ecological worker were described in Section J8.5.1. The estimated excess lifetime cancer risk in AOC No. 4 is 3E-08 under the CT exposure condition and 3E-07 under the RME condition (Table J8-4).

Future Open Space Recreational User: Exposure pathways for future the open space recreational user were described in Section J8.5.1. The estimated excess lifetime cancer risk in AOC No. 4 is 2E-07 under the CT exposure condition and 6E-06 (6 in 1 million) under the RME condition.

J8.7 1994 POND SEDIMENT SAMPLES

Additional pond sediment sampling was performed in 1994. Samples were collected from the 0- to 6-inch depth interval in ponds A-1, A-2, B-1, and B-2 and were analyzed for PCBs and radionuclides. Sediments in these ponds contain the highest concentrations of these analytes in all the ponds and the 0- to 6-inch depth represents the depth to which ecological and human receptors are likely to be exposed. Results from these samples were used in an assessment of risk from exposure of the open space recreational user and ecological researcher, presented in Attachment J5. Cumulative HIs were below 1 and RME cancer risk estimates were 9E-06 or below. These results are similar to those reported for the OU6 Phase I pond sediment data (Tables J8-3 and J8-4), indicating no unacceptable risk for receptors exposed to pond sediment.

J8.8 EVALUATION OF POTENTIAL HEALTH HAZARDS FROM EXPOSURE TO LEAD

Lead was detected in greater than 5 percent of surface soil, subsurface soil, and groundwater samples in OU6. EPA-established toxicity factors for lead were not available at this writing, and therefore hazard indexes or cancer risk cannot be estimated for lead. In this section, the potential for health hazards from exposure to lead in soil and groundwater are discussed.

J8.8.1 Surface Soil

Concentrations of lead in surface soil were not different than background according to statistical background comparisons (DOE 1994c, Appendix A). However, four sample results from surface soil exceeded the background $UTL_{99/99}$ of 61.4 mg/kg. EPA's Revised Interim Soil Lead Guidance recommends a screening level of 400 mg/kg for residential scenarios (EPA 1994a). The maximum detected concentration of lead in surface soil in OU6 (68.7 mg/kg) was far less than EPA's screening level for residential soil, indicating that lead in surface soil would not be expected to pose a health risk even under long-term residential exposure conditions.

J8.8.2 Subsurface Soil

Concentrations of lead in subsurface soil were not different than background according to the statistical background comparison (DOE 1994c, Appendix A). However, two sample results from subsurface soil exceeded the background $UTL_{99/99}$ of 31 mg/kg. The maximum detected concentration of lead in subsurface soil in OU6 (84.9 mg/kg) was less than EPA's screening level of 400 mg/kg for residential soil (EPA 1994a), indicating that lead in subsurface soil would not be expected to pose a health threat.

J8.8.3 Groundwater

Lead was found to be above background levels in unfiltered groundwater samples but not in filtered groundwater samples (DOE 1994c, Appendix A). The maximum concentration of lead in filtered groundwater (3.4 µg/l) did not exceed the federal standard for tap water (15 µg/l). A summary of lead concentrations in OU6 and background samples is shown below:

Concentrations of Lead in Groundwater, µg/l

Sample Type	Background Mean	Site Mean	Background Maximum	Site Maximum	$UTL_{99/99}$	No. > $UTL_{99/99}$
Unfiltered	3.8	18.5	52.5	254	19.3	21
Filtered	2.4	1.4	64	3.4	15.8	0

Total suspended solids (TSS) in OU6 groundwater samples were higher than in background samples. As a result, unfiltered groundwater samples collected in OU6 had elevated levels of numerous metals, including lead, that are associated with TSS. Based on comparing concentrations of lead in unfiltered and filtered samples, lead in groundwater in OU6 is not considered to be a site contaminant, but rather the result of high TSS in the samples. In addition, exposure to lead in groundwater is an incomplete pathway for all receptors in OU6 because groundwater from OU6 is not currently used as a water supply, nor is it expected to be used in the foreseeable future.

J8.9 SUMMARY OF CUMULATIVE HAZARD/RISK RESULTS

Noncarcinogenic HIs and cancer risks were estimated for five onsite receptors in four AOCs in RFETS OU6. Results are summarized in Tables J8-1 through J8-4 and detailed in Attachment J3.

The exposure pathways evaluated for all receptors included soil ingestion and dermal contact, inhalation of particulates from soil, and external irradiation from soil. Additional pathways evaluated for the future ecological worker and future open space recreational user included sediment ingestion and dermal contact, inhalation of particulates from stream/dry sediment, surface water ingestion and dermal contact, and external irradiation from sediment. Exposure of current and future onsite receptors to OU6 groundwater is an incomplete pathway because it is expected that drinking water will continue to be provided from a public water supply and groundwater is not available in sufficient quantities to support commercial use (See Section 3.0 of the RFI/RI Report). Therefore, ingestion of groundwater is not expected for current or future onsite receptors in OU6.

Cumulative HIs were less than 1 and cancer risk estimates were 6E-06 or lower for all receptors in all AOCs, and 9E-06 or lower for exposure to sediment in ponds using 1994 sediment sample results. These risk results indicate that there is no unacceptable risk under the exposure scenarios evaluated in OU6.

TABLE J8-1
SUMMARY OF RISK
AOC NO. 1

Pathway	Central Tendency		Reasonable Maximum	
	Hazard Index	Cancer Risk	Hazard Index	Cancer Risk
Current Worker				
Ingestion of surface soil	1.78E-03	1.10E-09	1.13E-02	4.35E-08
Inhalation of particulates from surface soil	-	6.59E-10	-	5.22E-09
Dermal contact with surface soil*	-	-	-	-
External irradiation	-	2.51E-10	-	2.84E-09
Total	1.78E-03	2.01E-09	1.13E-02	5.16E-08
Future Office Worker				
Ingestion of surface soil	8.91E-04	5.49E-10	1.13E-02	4.35E-08
Inhalation of particulates from surface soil	-	5.00E-10	-	5.22E-09
Dermal contact with surface soil *	-	-	-	-
External irradiation	-	2.51E-10	-	2.93E-09
Total	8.91E-04	1.30E-09	1.13E-02	5.17E-08
Future Ecological Worker				
Ingestion of surface soil	1.74E-03	6.72E-10	6.21E-03	2.40E-09
Inhalation of particulates from surface soil	-	1.22E-10	-	2.29E-10
Dermal contact with surface soil *	-	-	-	-
External irradiation	-	8.36E-11	-	1.05E-10
Total	1.74E-03	8.78E-10	6.21E-03	2.73E-09
Future Open Space Recreational Use				
Ingestion of surface soil by a child	2.11E-03	-	1.05E-02	-
Ingestion of surface soil by an adult	2.26E-04	-	1.13E-03	-
Carcinogenic effects of ingestion of surface soil	-	3.83E-10	-	6.27E-09
Inhalation of particulates from surface soil	-	1.41E-11	-	6.61E-10
Dermal contact with surface soil*	-	-	-	-
External irradiation	-	1.51E-11	-	2.93E-10
Total	2.34E-03	4.12E-10	1.17E-02	7.22E-09
Future Construction Worker				
Ingestion of subsurface soil	9.27E-05	3.64E-10	5.21E-04	2.04E-09
Inhalation of particulates from surface and subsurface soil	9.37E-08	3.41E-11	1.17E-07	4.24E-11
Dermal contact with subsurface soil*	-	-	-	-
External irradiation	-	1.55E-09	-	1.94E-09
Total	9.28E-05	1.95E-09	5.21E-04	4.03E-09

*Dermal absorption of metals and radionuclides is considered insignificant.

- Exposure pathway is not relevant for COCs (e.g., COCs have carcinogenic, but no non-carcinogenic, affects)

TABLE J8-2
SUMMARY OF RISK
AOC NO. 2

Pathway	Central Tendency Hazard Index	Central Tendency Cancer Risk	Reasonable Maximum Hazard Index	Reasonable Maximum Cancer Risk
Future Office Worker, 30-acre area				
Ingestion of surface soil	7.90E-04	5.50E-09	1.00E-02	4.36E-07
Inhalation of particulates from surface soil	-	5.47E-09	-	5.71E-08
Dermal contact with surface soil *	-	-	-	-
External irradiation	-	2.11E-09	-	2.47E-08
Inhalation of VOCs from infiltration	2.34E-12	3.09E-15	2.45E-11	3.23E-14
Total	7.90E-04	1.31E-08	1.00E-02	5.18E-07
Current Worker				
Ingestion of surface soil	1.82E-03	1.01E-08	1.15E-02	4.02E-07
Inhalation of particulates from surface soil	-	6.89E-11	-	5.46E-10
Dermal contact with surface soil*	-	-	-	-
External irradiation	-	2.06E-09	-	2.41E-08
Total	1.82E-03	1.23E-08	1.15E-02	4.26E-07
Future Ecological Worker				
Ingestion of surface soil	1.78E-03	6.20E-09	6.34E-03	2.21E-08
Inhalation of particulates from surface soil	-	1.28E-11	-	2.82E-11
Dermal contact with surface soil *	-	-	-	-
External Iirradiation	-	6.88E-10	-	8.59E-10
Total	1.78E-03	6.90E-09	6.34E-03	2.30E-08
Future Open Space Recreational Use				
Ingestion of surface soil by a child	2.15E-03	-	1.08E-02	-
Ingestion of surface soil by an adult	2.31E-04	-	1.15E-03	-
Carcinogenic effects of ingestion of surface soil	-	3.53E-09	-	5.78E-08
Inhalation of particulates from surface soil	-	1.47E-12	-	6.91E-11
Dermal contact with surface soil*	-	-	-	-
External irradiation	-	1.24E-10	-	2.41E-09
Total	2.38E-03	3.66E-09	1.19E-02	6.03E-08
Future Construction Worker				
Ingestion of subsurface soil	1.15E-04	1.89E-09	6.43E-04	1.06E-08
Inhalation of particulates from surface and subsurface soil	1.16E-07	3.62E-12	1.45E-07	4.51E-12
Dermal contact with subsurface soil*	-	-	-	-
External irradiation	-	8.02E-10	-	1.00E-09
Total	1.15E-04	2.69E-09	6.43E-04	1.16E-08

* Dermal contact with metals and radionuclides is considered insignificant.

- Exposure pathway is not relevant for COCs (e.g., COCs have carcinogenic, but no non-carcinogenic, affects)

TABLE J8-3
SUMMARY OF RISK
AOC NO. 3

Pathway	Central Tendency Hazard Index	Central Tendency Cancer Risk	Reasonable Maximum Hazard Index	Reasonable Maximum Cancer Risk
Future Ecological Worker				
Ingestion of pond sediment	7.32E-05	1.79E-09	8.71E-04	2.13E-08
Ingestion of stream/dry sediment	5.57E-06	2.78E-10	6.63E-05	3.30E-09
Inhalation of particulates from stream/dry sediment	-	5.27E-13	-	9.03E-13
Dermal contact with pond sediment	4.55E-04	2.51E-09	4.33E-03	2.39E-08
Dermal contact with stream/dry sediment*	-	-	-	-
Ingestion of surface water	5.60E-08	3.18E-12	4.80E-07	2.73E-11
Dermal contact with surface water	3.55E-06	-	6.08E-06	-
External irradiation from stream/dry sediment	-	1.67E-11	-	3.62E-11
Total	5.37E-04	4.59E-09	5.28E-03	4.85E-08
Future Open Space Recreational Use				
Ingestion of pond sediment by a child	3.40E-03	-	1.70E-02	-
Ingestion of pond sediment by an adult	3.66E-04	-	1.82E-03	-
Carcinogenic effects of ingestion of pond sediment	-	4.62E-08	-	7.47E-07
Ingestion of stream/dry sediment by a child	2.59E-04	-	1.29E-03	-
Ingestion of stream/dry sediment by an adult	2.77E-05	-	1.39E-04	-
Carcinogenic effects of ingestion of stream/dry sediment	-	1.08E-08	-	1.71E-07
Inhalation of particulates from stream/dry sediment	-	1.69E-12	-	7.90E-11
Dermal contact with pond sediment	7.81E-05	1.55E-09	5.17E-03	3.42E-07
Dermal contact with stream/dry sediment*	-	-	-	-
Ingestion of surface water	5.01E-08	1.02E-11	6.01E-07	4.09E-10
Dermal contact with surface water	6.23E-07	-	7.62E-06	-
External irradiation from stream/dry sediment	-	3.16E-11	-	6.14E-10
Total	4.13E-03	5.86E-08	2.54E-02	1.26E-06

* PAHs, metals, and radionuclides are the only COCs in stream/dry sediment. Dermal absorption of metals and radionuclides is considered insignificant. EPA has stated that it is inappropriate to assess dermal absorption of PAHs using the oral slope factor (EPA 1989a).

\- Exposure pathway is not relevant for COCs (e.g., COCs have carcinogenic, but no non-carcinogenic, affects)

TABLE J8-4
SUMMARY OF RISK
AOC NO. 4

Pathway	Central Tendency Hazard Index	Central Tendency Cancer Risk	Reasonable Maximum Hazard Index	Reasonable Maximum Cancer Risk
Future Ecological Worker				
Ingestion of pond sediment	2.61E-04	8.15E-09	3.11E-03	9.70E-08
Ingestion of stream/dry sediment	4.78E-06	3.49E-10	5.69E-05	4.48E-09
Inhalation of particulates from stream/dry sediment	-	4.12E-13	-	7.06E-13
Dermal contact with pond sediment	3.32E-03	1.84E-08	3.17E-02	1.75E-07
Dermal contact with stream/dry sediment*	-	-	-	-
Ingestion of surface water	1.34E-06	4.65E-11	1.15E-05	1.52E-10
Dermal contact with surface water	7.49E-05	8.24E-10	1.28E-04	1.41E-09
External irradiation from stream/dry sediment	-	3.48E-11	-	7.54E-11
Total	3.67E-03	2.78E-08	3.50E-02	2.78E-07
Future Open Space Recreational Use				
Ingestion of pond sediment by a child	1.21E-02	-	6.06E-02	-
Ingestion of pond sediment by an adult	1.30E-03	-	6.49E-03	-
Carcinogenic effects of ingestion of pond sediment	-	2.05E-07	-	3.32E-06
Ingestion of stream/dry sediment by a child	2.22E-04	-	1.11E-03	-
Ingestion of stream/dry sediment by an adult	2.38E-05	-	1.19E-04	-
Carcinogenic effects of ingestion of stream/dry sediment	-	1.67E-08	-	2.62E-07
Inhalation of particulates from stream/dry sediment	-	1.32E-12	-	6.18E-11
Dermal contact with pond sediment	5.70E-04	1.13E-08	3.78E-02	2.50E-06
Dermal contact with stream/dry sediment*	-	-	-	-
Ingestion of surface water	1.20E-06	5.72E-11	1.44E-05	2.29E-09
Dermal contact with surface water	1.35E-05	5.19E-10	1.61E-04	2.12E-08
External irradiation from stream/dry sediment	-	6.58E-11	-	1.28E-09
Total	1.42E-02	2.34E-07	1.06E-01	6.10E-06

*PAHs, metals and radionuclides are the only COCs in stream/dry sediment. Dermal absorption of metals and radionuclides is considered insignificant. EPA has stated that it is inappropriate to assess dermal absorption of PAHs using the oral slope factor (EPA 1989a).

- Exposure pathway is not relevant for COCs (e.g., COCs have carcinogenic, but no non-carcinogenic, affects)

In this chapter, total radiation doses for one year of exposure (expressed as total effective dose equivalents, in mrem/year) were estimated for receptors exposed to radionuclides in soil, air, and other media by the ingestion, inhalation, and external irradiation pathways. The estimated doses are compared to DOE radiation standards for protection of public health, also expressed in mrem/year (DOE 1990).

J9.1 METHODOLOGY

This section defines the terms used in estimating annual radiation doses, explains how the doses are calculated, and describes the national annual radiation protection standards that are used for comparison to the calculated doses.

J9.1.1 Definitions

Ionizing Radiation: Ionizing radiation is radiation that has sufficient energy to cause ionization of matter (removing electrons from atoms). Ionization and excitation (raising electrons to a higher energy state) of atoms in cells and tissues from absorption of ionizing radiation can result in damage to those cells and tissues (EPA 1989a).

Absorbed Dose (in grays): Radiation dose may be expressed in terms of an internal (absorbed) dose, defined as the average energy imparted by ionizing radiation per unit mass of exposed tissue. The unit for absorbed dose is the gray (Gy), equal to 1 joule of energy delivered per kilogram of tissue (EPA 1989a).

Dose Equivalent (in rems or sieverts): Different types of radiation can produce more or less tissue damage at the same absorbed dose level. Thus, absorbed dose (in grays) does not provide an adequate estimate of potential for biological effects. The dose equivalent is an expression of internal dose that is normalized for different biological effects produced by different types of radiation. The dose equivalent is based on absorbed dose, type of energy released by different radionuclides, and other modifying factors. The dose equivalent

provides a better correlation between radiation dose and potential for biological effects than does the absorbed dose. Units for the dose equivalent are the rem or the sievert (Sv), equal to 100 rem (EPA 1989a).

Effective Dose Equivalent (EDE) (in rems or Sv): The EDE, equal to the weighted sums of organ-specific dose equivalents, normalizes radiation doses and effects on a whole body basis (EPA 1989a).

Committed Effective Dose Equivalent (CEDE) (in rems or Sv): Because internal doses delivered to tissues by radionuclides continue long after intake of the radionuclide has ceased, internal doses to specific tissues and organs are usually reported in terms of the committed dose equivalent, which is defined as the integral of the dose equivalent in a particular tissue for 50 years after intake. The sum of committed dose equivalents weighted for specific tissues in the body is the CEDE, also expressed in rems or Sv. The CEDE represents a dose to the whole body integrated over a 50-year period (EPA 1989a).

CEDE only applies to pathways resulting in an internalized dose and therefore does not apply to the external irradiation pathway. Radiation doses from the external irradiation pathway are expressed in terms of EDEs.

Total Effective Dose Equivalent (TEDE) (in rems or Sv): The TEDE is the sum of doses from pathways that result in an internalized dose (expressed as CEDE) and doses from pathways that result in an external dose, such as external irradiation (expressed as EDE).

Dose Coefficients: Dose coefficients, also known as dose conversion factors, are radionuclide-specific constants that are used to convert total intake of radionuclides to dose equivalents. Committed effective dose coefficients are constants used to convert total intake of radionuclides to CEDEs (EPA 1989a).

Total Annual Radiation Dose (in rems/year or Sv/year): Total annual radiation dose is equal to the TEDE for one year of exposure. Annual radiation doses for specific pathways are equal to the CEDE or EDE for that pathway for one year of exposure. These doses are calculated using site-specific estimates of annual radionuclide intake from potentially contaminated media and radionuclide-specific committed effective dose coefficients and

effective dose coefficients (EPA 1989a). The total annual radiation dose is the sum of CEDEs and EDEs for all pathways for one year of exposure. Total annual radiation dose can be compared to annual radiation protection standards, also expressed as the TEDE for one year of exposure (DOE 1990). Note: DOE's annual radiation protection standards are currently termed EDEs, but they are actually TEDEs equal to the sum of CEDEs and EDEs.

J9.1.2 Calculating Annual Radiation Doses

Selection of Dose Coefficients: Radionuclide-specific committed effective dose coefficients were used in the calculation of CEDEs for the ingestion and inhalation routes of exposure. Radionuclide-specific effective dose coefficients were used to calculate EDEs for the external irradiation route of exposure. These values were obtained from EPA's "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion" (EPA 1988) for the inhalation and ingestion route of exposure and from DOE's "External Dose-Rate Conversion Factors for Calculation of Dose to the Public" (DOE 1988) for external irradiation.

For some radionuclides, committed effective dose coefficients vary based on the chemical species (e.g., oxidation state or mineralized form) of the radionuclide. Differences in committed effective dose coefficients for the ingestion route of exposure reflect differences in fractional uptake (f_i) of radionuclide species from the small intestine to blood (Table J9-1). Less soluble radionuclide forms have smaller committed dose coefficients than more soluble forms because the less soluble forms are absorbed to a lesser degree from the gastrointestinal tract into the bloodstream (EPA 1988).

It is probable that plutonium in the soils of RFETS is in a relatively insoluble PuO_2 form. Pu in most natural environments is stable in two oxidation states, Pu III or Pu IV. In acidic environments, Pu III is the dominant species, whereas under alkaline or oxidizing conditions the dominant species is Pu IV (solid plutonium dioxide, PuO_2) (Brookins 1988). As discussed in Section 5.2 of the RFI/RI Report, the alkaline and oxidizing conditions in soil at OU6 favor the Pu IV species, suggesting that solid plutonium dioxide is the primary phase of plutonium in OU6. Pu IV has very low solubility at near-neutral and oxidizing conditions (NRC 1983).

Additional studies at RFETS have demonstrated low extraction of plutonium from soil, suggesting the presence of an insoluble species (EPA 1990b). EPA states that "analyses of soil samples from Rocky Flats have shown the presence of discrete particles of plutonium (probably the oxide) attached to larger soil particles." EPA further states that, because of the stability of Pu IV relative to other forms of plutonium "most if not all plutonium in environmental ... systems is in the Pu IV state."

The committed effective dose coefficient for plutonium for the ingestion route was selected assuming that the predominant species at RFETS is the less soluble PuO_2 (See Section 5.0). Therefore, plutonium isotopes were assigned a fractional uptake (f_i) of 1E-05, and the committed effective dose coefficient for plutonium was selected corresponding to this fractional uptake estimate (Table J9-1). Only one committed effective dose coefficient is available for Am-241, corresponding to an f_i of 1E-03.

Committed effective dose coefficients for the inhalation route of exposure also vary based on the chemical species of the radionuclide. The different committed effective dose coefficients reflect differences in the rates that radionuclide species are cleared from the lungs, with lung clearance rates classified as days (D), weeks (W), or years (Y). In general, less soluble forms of the radionuclide are cleared from the lungs more slowly than more soluble forms. The committed effective dose coefficient for plutonium for the inhalation route of exposure was selected assuming that the predominant species of Pu isotopes is the less soluble form, associated with a lung clearance class of Y (years).

For simplicity in selecting the committed effective dose coefficients for uranium, it was also assumed that uranium is present in RFETS soil as the dioxide, UO_2 (i.e., U IV), although it may be present in the more oxidized (and more soluble) U VI state. Assuming the isotopes are present as UO_2, an f_i of 1E-03, a lung clearance class of Y, and the corresponding committed effective dose coefficients were selected (Table J9-1). (In fact, the selection of the committed effective dose coefficients for uranium has little or no impact on the calculation of annual radiation doses in OU6.)

Only one committed effective dose coefficient is available for Am-241, corresponding to a lung clearance class of W (weeks). Committed effective dose coefficients corresponding to these lung clearance classes were selected for the radionuclides in OU6 (Table J9-1).

For the external irradiation route of exposure, a single effective dose coefficient is available for each radionuclide (Table J9-1).

Ingestion and Inhalation Routes of Exposure: For the inhalation and ingestion routes of exposure, annual intake of radionuclides, expressed in pCi/year, is first calculated using the following equation:

$$Intake_{int} = C \times IR \times EF$$

where:

$Intake_{int}$	=	Annual radionuclide intake via inhalation or ingestion (pCi/year)
C	=	Activity concentration of a radionuclide at the exposure point (pCi/m^3, pCi/L, or pCi/g)
IR	=	Intake rate (m^3/day, L/day, or mg/day)
EF	=	Exposure frequency (days/year)

Exposure factors used in calculating annual radionuclide intake for specific receptors and pathways are presented in Attachment J2. The annual intake of each radionuclide in pCi/year is multiplied by the committed effective dose coefficient (mrem/pCi) from Table J9-1 to estimate the CEDE for one year of exposure (mrem/year).

External Irradiation: For the external irradiation route of exposure, an areal activity concentration in soil (pCi/m^2) adjusted for a gamma shielding factor and an exposure time factor is first calculated.

$$AC = C \times \frac{10^3 g}{kg} \times SD \times D \times (1 - Se) \times Te$$

where:

AC	=	Areal activity concentration in soil, adjusted for a gamma shielding factor and an exposure time factor (pCi/m^2)
C	=	Mass activity concentration of a radionuclide at the exposure point (pCi/g soil)

SD	=	soil density at RFETs (1.84E+03 kg/m^3)
D	=	soil depth (0.0508 m) (2 inches)
Se	=	gamma shielding factor (unitless)
Te	=	gamma exposure time factor (unitless)

Exposure factors used in calculating annual radionuclide intake for specific receptors and pathways are presented in Attachment J2. The areal activity concentration of each radionuclide in soil is multiplied by the number of hours of exposure per year to obtain the annual external irradiation exposure (pCi-hr/m^2-year). The annual radiation exposure is then multiplied by the effective dose coefficient for external irradiation (mrem/hr per pCi/m^2) (Table J9-1) to estimate the EDE (mrem/year) for each radionuclide for one year of exposure.

Estimating Annual Radiation Dose: TEDEs are equal to the sum of CEDEs and EDEs for all radionuclides and all exposure pathways. Total annual radiation dose is equal to the TEDE for one year of exposure and can be compared to annual radiation protection standards (also in terms of TEDEs for one year of exposure).

Annual radiation doses were estimated for all receptors and exposure areas (Attachment J4); results are summarized and compared to radiation protection standards in the following subsections.

J9.1.3 Radiation Protection Standards

The DOE occupational limit for radiological workers is 50 mSv/year (5,000 mrem/year) (DOE 1993). The DOE annual radiation dose limit for members of the public is 1 mSv/year (100 mrem/year) for all routes of exposure (DOE 1990). The occupational limit for general employees (i.e., those not considered to be radiological workers) may be 100 or 5,000 mrem/year depending on employment circumstances. DOE states: "The radiological worker dose limits ... also apply to general employees. However, general employees who have not completed Radiological Worker I or II Training are not permitted unescorted access to any area in which they are expected to receive doses in excess of 100 mrem in one year. General employees who have not received Radiological Worker I or II training are not normally expected to exceed 100 mrem in a year" (DOE 1994g). These values are for

radiation doses received in addition to that from natural background radiation (U.S. average background radiation is approximately 300 mrem/year, including exposure from radon; NCRP 1987) and that received from routine medical treatments (U.S. average is approximately 50 mrem/year; NCRP 1987). Background levels in the Denver area are estimated to range from 350 to 700 mrem/year; these levels are higher than the national average because of high natural levels of radium, thorium, and radon in native rock and soils and because cosmic radiation exposure increases with increased altitude (NCRP 1987).

J9.2 AOC NO. 1

Annual radiation doses in terms of mrem/year were calculated for onsite receptors in AOC No.1, AOC No. 2, the 30-acre maximum exposure area in AOC No. 2, AOC No. 3, and AOC No. 4. Results are summarized in Tables J9-2 through J9-5 and calculations are shown in Attachment J4.

Onsite receptors are current workers, future office workers, future ecological workers, future open space recreational users, and future construction workers.

This section describes the results of annual radiation dose estimates for receptors in AOC No.1. AOC No.1 is the North Spray Field Area and is approximately 10 acres in areal extent. The total annual radiation doses, in terms of TEDE for one year of exposure for current and future onsite receptors in AOC No. 1 are 0.02 mrem/year or less for the average and RME conditions, which is well below the DOE limit of 100 mrem/year for members of the public.

Current Worker: Radionuclide exposure pathways evaluated for the current worker were:

- Inhalation of airborne particulates
- Ingestion of surface soil
- External irradiation from radionuclides in surface soil

The total annual radiation dose for the current worker in AOC No. 1 is 0.007 mrem/year for the CT exposure condition and 0.02 mrem/year for the RME condition (Table J9-2). These values are well below the DOE limit of 100 mrem/year for members of the public.

Future Office Worker: Radionuclide exposure pathways evaluated for the future office worker were the same as for the current worker. The total annual radiation dose for the future office worker in AOC No. 1 is 0.006 mrem/year for the CT exposure condition and 0.02 mrem/year for the RME condition (Table J9-2).

Future Ecological Worker: Radionuclide exposure pathways evaluated for the ecological worker in AOC No. 1 were the same as for the current industrial worker and future office worker. The total annual radiation dose for the ecological worker in AOC No. 1 is 0.003 mrem/year for the CT exposure condition and 0.007 mrem/year for the RME condition (Table J9-2).

Future Open Space Recreational Use: Radionuclide exposure pathways evaluated for the open space recreational user in AOC No. 1 were the same as for the other receptors. The total annual radiation dose for the open space recreational user in AOC No. 1 is 0.0002 mrem/year for the CT exposure condition and 0.001 for the RME condition (Table J9-2).

Future Construction Worker: The future construction worker was evaluated for the following exposure pathways:

- Subsurface soil ingestion
- Inhalation of airborne particulates from subsurface and surface soil
- External irradiation from radionuclides in subsurface soil

The total annual radiation dose for the construction worker in AOC No. 1 is 0.001 mrem/year for the average exposure condition and 0.002 mrem/year for the RME condition (Table J9-2).

J9.3 AOC NO. 2

AOC No. 2 includes the Sludge Dispersal Area, Triangle Area, and Soil Dump Area and is approximately 50 acres in areal extent. Onsite receptors evaluated in this AOC include current workers, future ecological workers, future open space recreational users, and future construction workers. Annual radiation doses for future office workers were evaluated in a 30-acre maximum exposure area in AOC No. 2, which includes all of the Sludge Dispersal

Area and Triangle Area and approximately half of the Soil Dump Area. Annual radiation doses for all receptors in AOC No. 2 are summarized in Table J9-3 and detailed in Attachment J4.

Exposure pathways evaluated for current and future onsite receptors in AOC No. 2 were the same as those evaluated in AOC No. 1. The total annual radiation doses, in terms of TEDE for one year of exposure, for current and future onsite receptors in AOC No. 2 are 0.1 mrem/year or less for the average and RME conditions, which is well below the DOE limit of 100 mrem/year for members of the public. Radiation dose results for each receptor are discussed below.

Current Worker: The total annual radiation dose for the current worker in AOC No. 2 is 0.04 mrem/year for the average exposure condition and 0.1 mrem/year for the RME condition.

Future Office Worker: The total annual radiation dose for the future office worker in the 30-acre maximum exposure area is 0.05 mrem/year for the average exposure condition and 0.1 mrem/year for the RME condition.

Future Ecological Worker: The total annual radiation dose for the future ecological worker in AOC No. 2 is 0.02 mrem/year for the average exposure condition and 0.05 mrem/year for the RME condition.

Future Open Space Recreational User: The total annual radiation dose for the future open space recreational user in AOC No. 2 is 0.002 mrem/year for the average exposure condition and 0.009 mrem/year for the RME condition.

Future Construction Worker: The total annual radiation dose for the future construction worker in AOC No. 2 is 0.0008 mrem/year for the average exposure condition and 0.002 mrem/year for the RME condition.

J9.4 AOC NO. 3

AOC No. 3 includes Ponds A-1, A-2, and A-3 and the interconnecting stream segments; AOC No. 3 is approximately 50 acres in areal extent. Onsite receptors evaluated in AOC No. 3 include future ecological workers and future open space recreational users. Annual radiation doses for these receptors are summarized in Table J9-4 and detailed in Attachment J4.

The total annual radiation doses, in terms of TEDE for one year of exposure, for future onsite receptors in AOC No. 3 are 0.06 mrem/year or less for the average and RME conditions, which is well below the DOE limit of 100 mrem/year for members of the public. Radiation dose results for each receptor are discussed below.

Future Ecological Worker: Exposure pathways evaluated for the future ecological worker were:

- Inhalation of airborne particulates from stream/dry sediment
- Ingestion of pond sediment and stream/dry sediment
- Ingestion of surface water
- External irradiation from decay of radionuclides in stream/dry sediment

The total annual radiation doses for the future ecological worker in AOC No. 3 are 0.002 mrem/year for the average exposure condition and 0.02 mrem/year for the RME condition.

Future Open Space Recreational User: Exposure pathways evaluated for the future open space recreational user were the same as for the future ecological worker with the addition of soil ingestion by young children. The total annual radiation doses for the open space recreational user in AOC No. 3 are 0.01 mrem/year for the average exposure condition and 0.06 mrem/year for the RME condition.

J9.5 AOC NO. 4

AOC No. 4 includes Ponds B-1, B-2, B-3, and B-4 and the interconnecting stream segments; AOC No. 4 is approximately 50 acres in areal extent. Onsite receptors evaluated in AOC No. 4 include future ecological workers and future open space recreatioanl users. Annual radiation doses for these receptors are summarized in Table J9-5 and detailed in Attachment J4.

The total annual radiation doses, in terms of TEDE for one year of exposure, for future onsite receptors in AOC No. 4 are 0.6 mrem/year or less for the average and RME conditions, which is well below the DOE limit of 100 mrem/year for members of the public. Radiation dose results for each receptor are discussed below.

Future Ecological Worker: Exposure pathways evaluated for the future ecological worker were the same as those described in Section J9.4. The total annual radiation doses are 0.02 mrem/year for the average exposure condition and 0.2 mrem/year for the RME condition.

Future Open Space Recreational Use: Exposure pathways evaluated for the future open space recreational user were the same as those described in Section J9.4. The total annual radiation doses are 0.1 mrem/year for the average exposure condition and 0.6 mrem/year for the RME condition.

J9.6 SUMMARY OF RESULTS

Annual radiation dose calculations were performed for five onsite receptors in four AOCs in RFETS OU6. Results are summarized in Tables J9-2 through J9-5 and detailed in Attachment J4.

Exposure pathways evaluated for all receptors were soil ingestion, inhalation of particulates from soil, and external irradiation from soil. Additional pathways evaluated for the future ecological worker and future open space recreational user were sediment ingestion, inhalation of particulates from stream/dry sediment, surface water ingestion, and external irradiation from stream/dry sediment. Exposure of current and future onsite receptors to OU6 groundwater is an incomplete pathway because it is expected that drinking water will

continue to be provided from a public water supply. Therefore, ingestion of groundwater was not included in estimating radiation dose.

Total annual radiation doses for all receptors in all areas were 0.6 mrem/year or less, which is well below the DOE limit of 100 mrem/year for members of the public and indicates that exposure to radionuclides in OU6 is negligible.

TABLE J9-1
EFFECTIVE DOSE COEFFICIENTS FOR RADIONUCLIDES

Radionuclide	f_i [1]	Ingestion (Sv/Bq)	Class [2]	Inhalation (Sv/Bq)	External [3]
Americium-241	1.00E-03	9.84E-07	W	1.20E-04	2.99E+00
Plutonium-239	1.00E-03	9.56E-07	W	1.16E-04	3.78E-02
	1.00E-04	9.96E-08	Y	8.33E-05	
	1.00E-05	1.40E-08			
Uranium-234[4]	5.00E-02	7.66E-08	D	7.37E-07	8.07E-02
	2.00E-03	7.06E-09	W	2.13E-06	
			Y	3.58E-05	
Uranium-238	5.00E-02	6.88E-08	D	6.62E-07	6.46E-02
	2.00E-03	6.42E-09	W	1.90E-06	
			Y	3.20E-05	

[1] Fractional uptake from small intestine to blood.

[2] Lung clearance class: D = days; W = weeks; Y = years

[3] In units of millirem/yr per microcurie/square meters.

[4] Used to evaluate U-233/234.

TABLE J9-2
SUMMARY OF ANNUAL RADIATION DOSE
AOC NO. 1

Pathway	Annual Radiation Dose Central Tendency (mrem/yr)	Annual Radiation Dose Reasonable Maximum (mrem/yr)
Current Worker		
Ingestion of surface soil	1.11E-03	7.05E-03
Inhalation of particulates from surface soil	1.86E-03	2.36E-03
External irradiation from surface soil	3.90E-03	7.12E-03
Total	6.87E-03	1.65E-02
Future Office Worker		
Ingestion of surface soil	5.56E-04	7.05E-03
Inhalation of particulates from surface soil	1.41E-03	2.36E-03
External irradiation from surface soil	3.90E-03	7.12E-03
Total	5.87E-03	1.65E-02
Future Ecological Worker		
Ingestion of surface soil	1.09E-03	3.89E-03
Inhalation of particulates from surface soil	5.51E-04	1.03E-03
External irradiation from surface soil	1.85E-03	2.32E-03
Total	3.49E-03	7.24E-03
Future Open Space Recreational Use		
Ingestion of surface soil	1.72E-04	8.47E-04
Inhalation of particulates from surface soil	1.77E-05	2.48E-04
External irradiation from surface soil	4.75E-05	2.85E-04
Total	2.37E-04	1.38E-03
Future Construction Worker		
Ingestion of subsurface soil	2.72E-04	1.53E-03
Inhalation of particulates from surface and subsurface soil	3.84E-04	4.78E-04
External irradiation from subsurface soil	3.76E-04	4.70E-04
Total	1.03E-03	2.47E-03

TABLE J9-3
SUMMARY OF ANNUAL RADIATION DOSE
AOC NO. 2

Pathway	Annual Radiation Dose Central Tendency (mrem/yr)	Annual Radiation Dose Reasonable Maximum (mrem/yr)
Future Office Worker, 30-acre area		
Ingestion of surface soil	4.71E-03	5.98E-02
Inhalation of particulates from surface soil	1.54E-02	2.57E-02
External irradiation from surface soil	3.30E-02	6.03E-02
Total	5.31E-02	1.46E-01
Current Worker		
Ingestion of surface soil	9.18E-03	5.82E-02
Inhalation of particulates from surface soil	1.94E-04	2.46E-04
External irradiation from surface soil	3.22E-02	5.88E-02
Total	4.15E-02	1.17E-01
Future Ecological Worker		
Ingestion of surface soil	8.99E-03	3.21E-02
Inhalation of particulates from surface soil	5.75E-05	1.08E-04
External irradiation from surface soil	1.53E-02	1.91E-02
Total	2.43E-02	5.13E-02
Future Open Space Recreational Use		
Ingestion of surface soil	1.42E-03	6.99E-03
Inhalation of particulates from surface soil	1.84E-06	2.59E-05
External irradiation from surface soil	3.92E-04	2.35E-03
Total	1.81E-03	9.36E-03
Future Construction Worker		
Ingestion of subsurface soil	3.53E-04	1.98E-03
Inhalation of particulates from surface and subsurface soil	4.05E-05	5.04E-05
External irradiation from subsurface soil	3.60E-04	4.50E-04
Total Annual Radiation Exposure (mrem/yr)	7.53E-04	2.48E-03

TABLE J9-4
SUMMARY OF ANNUAL RADIATION DOSE
AOC NO. 3

Pathway	Annual Radiation Dose Central Tendency (mrem/yr)	Annual Radiation Dose Reasonable Maximum (mrem/yr)
Future Ecological Worker		
Ingestion of pond sediment	1.78E-03	2.12E-02
Ingestion of stream/dry sediment	6.36E-05	7.58E-04
Inhalation of particulates from stream/dry sediment	8.47E-07	1.45E-06
Ingestion of surface water	3.72E-06	3.19E-05
External irradiation from stream/dry sediment	4.42E-04	9.48E-04
Total	2.29E-03	2.29E-02
Future Open Space Recreational Use		
Ingestion of pond sediment	1.08E-02	5.29E-02
Ingestion of stream/dry sediment	3.85E-04	1.89E-03
Inhalation of particulates from stream/dry sediment	7.52E-07	1.06E-05
Ingestion of surface water	3.32E-05	3.99E-05
External irradiation from stream/dry sediment	1.05E-04	7.90E-04
Total	1.13E-02	5.57E-02

TABLE J9-5
SUMMARY OF ANNUAL RADIATION DOSE
AOC NO. 4

Pathway	Annual Radiation Dose Central Tendency (mrem/yr)	Annual Radiation Dose Reasonable Maximum (mrem/yr)
Future Ecological Worker		
Ingestion of pond sediment	1.84E-02	2.19E-01
Ingestion of stream/dry sediment	3.76E-04	1.48E-03
Inhalation of particulates from stream/dry sediment	6.68E-07	1.14E-06
Ingestion of surface water	4.28E-05	3.67E-04
External irradiation from stream/dry sediment	8.74E-04	1.09E-03
Total	1.97E-02	2.22E-01
Future Open Space Recreational Use		
Ingestion of pond sediment	1.12E-01	5.48E-01
Ingestion of stream/dry sediment	2.28E-03	1.48E-03
Inhalation of particulates from stream/dry sediment	5.94E-07	8.35E-06
Ingestion of surface water	3.82E-04	4.59E-04
External irradiation from stream/dry sediment	2.08E-04	1.56E-03
Total	1.15E-01	5.52E-01

J10.0
UNCERTAINTIES AND LIMITATIONS

This section discusses the chief uncertainties and limitations of the risk assessment and how they affect the results and conclusions. It also provides an assessment of risk from exposure to special-case COCs and COIs and discusses their potential contribution to overall site risk.

Uncertainties and limitations are inherent in the risk assessment process. The level of certainty associated with the conclusions of the risk assessment are conditional upon the quality of data and models used to identify COCs and estimate chemical concentrations, the assumptions made in estimating exposure conditions, the conservatism of the methods used to develop toxicity values, and the conservatism of methods used to characterize risk. At all stages of this risk assessment, however, reasonable conservative assumptions were made so as not to underestimate potential risk. Furthermore, estimates of toxicity and carcinogenicity (RfDs and SFs) are very conservative and may result in an overestimate of risk. Therefore, the conclusions regarding identification of chief COCs and levels of potential health risk associated with direct and indirect exposures are considered reliable.

The chief sources of uncertainty are discussed in Section J10.1. An evaluation of risk from special-case COCs and COIs is presented in Sections J10.2 and J10.3, respectively.

J10.1 CHIEF UNCERTAINTIES

Uncertainties in the human health risk assessment for OU6 at RFETS lie chiefly in the identification of COCs, the estimation of exposure point concentrations, the media not evaluated, the assumptions regarding human exposure scenarios at RFETS, and in the assessment of toxicity. Each of these is discussed below.

J10.1.1 Identification of COCs

Samples of soil, sediment, groundwater, and surface water were collected in and near IHSSs in OU6 according to approved work plans, and chemical analytical results were validated by a validation subcontractor in accordance with EPA and RFETS data validation guidelines.

Summaries of the work plans are presented in Section 1.0 of the RFI/RI report, and the chemical analytical database and data review are described in Appendix E, Quality Assurance. All detected analytes were screened to identify a subset of chemicals to evaluate in the risk assessment. The screening process is intended to identify all analytes whose concentrations were high enough that there may be concern for potential health hazards. The screening process included a background comparison for inorganic analytes, a frequency test (analytes detected at less than 5 percent frequency were excluded as potential OU-wide contaminants because exposure potential is minimal), and concentration toxicity screens that estimate the relative contribution to overall risk based on maximum detected concentrations. Concentration/toxicity screens have the potential for eliminating chemicals that could contribute significantly to overall risk if the relative magnitude of maximum concentrations differs from the relative magnitude of exposure concentrations (95% UCLs of the mean). However, the results of the risk assessment demonstrate that the selection process was sufficiently conservative so that potentially significant sources of health risk were not overlooked.

COCs in soil, groundwater, sediments, and surface water were those identified in concentration/toxicity screens as contributing at least 1 percent of an overall "risk factor," based on maximum detected concentrations. Of the chemicals retained as COCs on the basis of the screen, only two or three COCs were found to contribute the majority of total estimated risk, and other COCs evaluated in the quantitative risk assessment contributed relatively insignificantly to total risk. This is borne out by several examples, discussed below.

In subsurface soil, for example, barium was the only analyte identified as a noncarcinogenic COC based on the concentration/toxicity screen because the inhalation RfD for barium, which is 500 times lower than the oral RfD, was used in the screen. Consequently, barium contributed nearly 100 percent of the RME HI of 0.0006 for the soil ingestion and inhalation pathways. Analytes excluded by the concentration/toxicity screen for noncarcinogens included vanadium, zinc, strontium, and chromium. Of these, vanadium had the highest combination of maximum concentration and toxicity. However, even at the maximum concentration of 118 mg/kg, vanadium would result in an RME HI of only 0.005 for soil ingestion and inhalation, which, while higher than the HI for barium, is still much less than

1. This shows that compounds excluded by the screen would have contributed insignificantly to overall risk from exposure to subsurface soil.

For carcinogenic effects in pond sediment, Am-241, Pu-239/240, and Aroclor-1254 together contributed 93 percent of the estimated total RME cancer risk from ingestion of sediment under the open space recreational use scenario. Other COCs in pond sediment [benzo(a)pyrene, benzo(b)fluoranthene, and bis(2-ethylhexyl)phthalate] contributed the remaining 7 percent of the total risk from ingestion. Compounds excluded by the screen were several other PAHs, methylene chloride, and benzene. Of these, benzo(a)anthracene had the highest combination of maximum concentration and toxicity. Even at the maximum concentration of 1.1 mg/kg, benzo(a)anthracene would result in an ingestion RME cancer risk of only 4.5E-08 for the open space recreational user, (calculation not shown), compared to the total cancer risk from ingestion of 3E-06 (see Table J8-4). This shows that compounds excluded by this screen would have contributed insignificantly to the total estimated risk from ingestion of pond sediment.

J10.1.2 Exposure Point Concentrations

The chief uncertainties in estimating exposure point concentrations of COCs lie in the numerical estimate of an average exposure concentration and in the modeling assumptions used to estimate concentrations in pond sediment, surface water, and air. The uncertainties can result in either an underestimate or overestimate of the average exposure concentration; however, conservative approaches were taken so as not to underestimate average exposure concentrations for the exposure scenarios and areas being evaluated in the risk assessment.

Estimating the Concentration Term: Concentration terms were either the 95% UCLs of the mean (normal or lognormal distribution) or the maximum detected concentrations. The 95% UCL is used rather than the arithmetic mean concentration to provide an additional level of conservatism in accounting for the uncertainties involved in estimating the true mean from a relatively small data set. Although small sample size, variability in sample results, extreme values, and accounting for negative or zero values add to the uncertainty in estimating the mean, these uncertainties usually result in a high, rather than a low, bias to the estimate. Therefore, the uncertainties in the statistical evaluation of the data are not expected to result in an underestimation of exposure or risk.

Modeled Exposure Concentrations: Modeling was performed to estimate (1) future concentrations of chemical constituents in the A- and B-series ponds resulting from surface runoff, (2) outdoor air concentrations of COCs associated with PM_{10}, and (3) indoor air concentrations of VOCs from soil gas. A combination of average and reasonable maximum values for input parameters were used to produce conservative estimates of average exposure concentrations.

The modeled concentrations used in risk assessment were conservative (protective) because:

- Maximum modeled concentrations of antimony, Am-241, and Pu-239/240 in pond sediment and surface water within each AOC (A- or B-series ponds) were used in risk assessment. The maximum modeled concentrations probably significantly overestimate average exposure concentration because the highest modeled concentrations were as much as 1,000 times higher than modeled concentrations in the other ponds (see Table J5-13).

- The maximum annual average air concentrations of COCs associated with PM_{10}, based on five years of meteorological data were used as the exposure terms. Other input parameters in air modeling included conservative estimates of mixing heights for onsite box models, conservative estimates of emission rates during construction, and site-specific estimates of threshold wind speed.

- Maximum VOC concentrations in groundwater and conservative estimates of transport through soil and through a porous building foundation yield conservative estimates of average "basement air" concentrations of VOCs.

J10.1.3 Media Not Evaluated

As discussed in Section J1.4, IHSSs Evaluated in the HHRA, and in Section J3.4.2, Groundwater COCs Evaluated in the HHRA, groundwater near Trenches A, B, and C that appears to contain constituents related to potential releases from the Landfill (OU7) were not evaluated in the OU6 HHRA because potential groundwater contamination in this area is expected to be evaluated in OU7 and OU6 IHSSs are not the source of the detected analytes

in groundwater. In addition, nitrates detected in some wells upgradient of the A-series ponds were not evaluated in the HHRA, primarily because the source of the plume is in OU4 (Solar Ponds). Therefore, potential migration of nitrates could not be quantitatively evaluated in the OU6 RFI/RI Report because source concentrations necessary for modeling cannot be defined using OU6 sampling results. Furthermore, ingestion of groundwater was not a complete exposure pathway for any exposure scenario evaluated under current or future use conditions.

J10.1.4 Exposure Scenarios and Pathways

The chief uncertainty in the exposure assessment is future land use at RFETS. Because of the uncertainty in future land use, several possible scenarios were developed, ranging from commercial through open space recreational use and construction worker exposure to subsurface soil. In addition, CT and RME exposure factors were developed for each scenario using EPA values and best estimates based on site-specific or local information. Therefore, the uncertainty in future land use and exposure conditions at RFETS is addressed by the range of scenarios evaluated.

Among the exposure scenarios that were considered possible at RFETS, the future office worker is the maximum exposed individual at AOC No. 1 and AOC No. 2 and provides the reasonable maximum estimated risk associated with exposure to the media encountered at those two AOCs. This receptor was evaluated for exposure to surface soil (ingestion, inhalation, and dermal contact pathways), external irradiation from radionuclides in surface soil, and inhalation of VOCs migrating from groundwater into a building.

The open space recreational user is the maximum exposed receptor at AOC No. 3 and AOC No. 4 and provides the reasonable maximum estimated risk associated with exposure to the media encountered at those two AOCs. This receptor was evaluated for exposure to pond and stream/dry sediment (ingestion and dermal contact pathways), inhalation of particulates from wind erosion of stream/dry sediment, surface water ingestion and dermal contact, and external irradiation from radionuclides in stream/dry sediment. The sediment ingestion pathway for open space recreational use includes child and adult exposure, which is much more conservative than adult exposure only. In addition, this receptor was assumed to be exposed to the sediment and surface water intermittently for 30 years in contrast to the 2.5 year exposure duration of the ecological worker.

Subsurface soil exposures: Risk from exposure to subsurface soil was evaluated for a construction worker scenario, assuming excavation in AOC No. 1 and AOC No. 2. Chemical intake was estimated using an exposure duration of 30 days and ingestion rates of 95 mg/day (CT) or 480 mg/day (RME). Health risks for this exposure scenario were well below levels of potential concern. For example, the highest RME cancer risk estimate for this scenario was 1E-08 (AOC No. 2).

Longer exposure to subsurface soil in AOC No. 2 (for example, under an industrial exposure scenario if construction activities brought subsurface soil to the surface) would not be expected to result in unacceptable risk. RME cancer risk estimates for subsurface soil exposure could increase by roughly a factor of 100 for ingestion and inhalation, based on comparing RME intake factors for the construction worker and office worker. This would result in an estimated cancer risk of 100 x 1E-08, or 1E-06. The office worker intake factors assume an 8-hour/day exposure to outdoor air PM_{10}, 50 mg/day soil ingestion, and no landscaping or paving to reduce contact with soil. These are conservative assumptions that are likely to overestimate risk for an office worker.

Finally, four of the five receptors evaluated in the risk assessment are assumed to be exposed to a 30 or 50-acre area, corresponding to an industrial park or open space. However, AOC No. 1 is approximately 10 acres in areal extent. The assumption that a current industrial worker, ecological worker, open space recreational user, or construction worker spends all of their time in a 10-acre area results in an overestimation of potential risk to those receptors in AOC No. 1.

J10.1.5 Toxicity Assessment

Toxicity values (RfDs and cancer SFs) derived by EPA are conservative upperbound estimates of potential toxicity or carcinogenicity of chemicals, and their use in risk assessment tends to result in an overestimate of potential risk. However, several detected compounds do not have EPA-established toxicity factors (see Table J3-1). Therefore, they could not be evaluated in a quantitative risk assessment. Some of the compounds were detected at low frequency (<5 percent) and at low concentrations. The exclusion of infrequently detected compounds from risk assessment is not expected to contribute to an

underestimation of potential risk because generally their concentrations and frequency of occurrence are trivial compared to concentrations of OU-wide COCs.

However, several analytes without EPA toxicity factors were detected at greater than five percent frequency. These are discussed below.

Lead in surface and subsurface soil: Potential risk from exposure to lead in surface and subsurface soil was addressed in Section J8.7.

Copper in surface soil: Copper was considered to be different from background since it failed three of the four statistical tests and seven samples exceeded the background $UTL_{99/99}$ in surface soil. The maximum concentration of copper (61.6 mg/kg) is within the same range of concentrations (e.g., 44 mg/kg to 706 mg/kg) of the metals that are COCs in surface soil in OU6. Since copper is generally considered to have relatively low toxicity for humans, and because its maximum concentration is comparable to maximum concentrations of COCs in surface soil and those COCs did not result in unacceptable risk, the exclusion of copper from the quantitative risk assessment would have no effect on the estimate of site risk.

Copper in pond sediment: Copper in pond sediment was considered different from background because it failed the Gehan test. However, the maximum concentration of copper (125 mg/kg) was below the background maximum (178 mg/kg). Because copper levels in pond sediment are relatively low and appear to be within background range, and because copper is generally considered to have relatively low toxicity for humans, its exclusion from quantitative risk assessment would have no effect on the estimate of site risk.

Phenanthrene and benzo(ghi)perylene in subsurface soil, pond sediment, and stream/dry sediment: Phenanthrene and benzo(ghi)perylene were detected at frequencies above 5 percent in subsurface soil, pond sediment, and stream/dry sediment. The maximum concentrations of phenanthrene (2.6 mg/kg in pond sediment, 0.75 in stream/dry sediment) in those media were similar to other PAHs detected. Inadequate data are available to assess toxicity of these compounds (EPA 1994b), and they are likely to have lower toxicity than benzo(a)pyrene (which is among the most carcinogenic of the organic COCs in these media). Since benzo(a)pyrene did not cause unacceptable risk to any receptors in these media, the

exclusion of phenanthrene and benzo(ghi)perylene from quantitative risk assessment would have no effect on the estimate of site risk.

Dibenzofuran in stream/dry sediment: HEAST (EPA 1994b) states that data available for dibenzofuran are inadequate for quantitative risk assessment. Exposure to a total of 10 different COCs in stream/dry sediment was estimated to result in negligible risk to potential receptors (Tables J8-3 and J8-4). Dibenzofuran was detected at a low frequency and low concentrations relative to other organic COCs in stream sediment. Thus, dibenzofuran is not expected to contribute significantly to an estimate of site risk.

J10.2 EVALUATION OF RISK ASSOCIATED WITH SPECIAL-CASE COCs

Special-case COCs are compounds that were infrequently detected (<5 percent) but that exceeded 1000 times the RBC (see detailed presentation in DOE [1994c]). Hazard/risk results for special-case COCs are summarized in Table J10-1 and detailed in Attachment J3.

Vinyl chloride in groundwater was the only chemical identified as a special-case COC based on low frequency of detection (3 percent) and high toxicity (the maximum concentration of 860 μg/L exceeded a screening level equivalent to 1,000 times the RBC of 0.028 μg/L for residential use). Risks associated with vinyl chloride were evaluated for the residential ingestion pathway, even though residential development is not a reasonable future use scenario.

Vinyl chloride was detected in only one well in OU6 in concentrations ranging over time from 200 μg/L to 860 μg/L. Because vinyl chloride was only detected in one well, it is not practical to calculate an area-wide exposure concentration. Therefore, the cancer risk estimate was calculated using the arithmetic mean concentration from that well (0.461 mg/L) and assuming long-term residential groundwater ingestion. The estimates were calculated using an intake factor for residential ingestion of carcinogens in groundwater (1.17E-02 L/kg-day), the oral slope factor for vinyl chloride of 1.9 $(mg/kg\text{-}day)^{-1}$, and the arithmetic mean concentration from well 3586 (0.461 mg/L).

The cancer risk level for hypothetical residential ingestion of vinyl chloride in groundwater is 1E-02, which exceeds EPA's target risk range of 1E-06 to 1E-04 (EPA 1989a).

Vinyl chloride in well 3586 would pose unacceptable risk to humans if ingested daily for many years. However, vinyl chloride was not detected in any other well, nor in any medium such as surface water that is downgradient from well 3586. Since onsite use of groundwater is unlikely under any of the assumed exposure scenarios, current and future receptors are not expected to be exposed to vinyl chloride in groundwater. An evaluation of migration potential of vinyl chloride in groundwater is presented in Appendix G of the RFI/RI report.

J10.3 EVALUATION OF RISK ASSOCIATED WITH CHEMICALS OF INTEREST (COIs)

Chemicals of interest (COIs) are compounds that are probably not environmental contaminants (i.e., they are probably naturally occurring), but were retained for separate consideration because of their potential toxicity at environmental levels. Hazard/risk results for COIs are summarized in Table J10-1 and detailed in Attachment J3.

J10.3.1 Metals in Groundwater in OU6

Four metals were selected for separate evaluation of potential hazard/risk associated with hypothetical residential ingestion of groundwater: antimony, arsenic, beryllium, and manganese. None of these metals was identified as a COC in OU6 groundwater, primarily because they do not appear to be potential contaminants but rather are associated with high concentrations of TSS in unfiltered groundwater samples. Because of their potential toxicity at environmental levels, those metals were retained as COIs for separate evaluation in the uncertainties section of the risk assessment, assuming hypothetical residential use of groundwater (CDPHE 1994b; EPA Region VIII 1994; DOE 1994e), even though groundwater exposure pathways are not complete, because UHSU groundwater at OU6 is not currently used and is not expected to be used in the future.

Hazard/risk results for ingestion of these four metals in groundwater, assuming hypothetical residential use of groundwater in AOC No. 2, are shown in Table J10-1 and detailed in Attachment J3. Results from unfiltered samples were used in the risk evaluation. Results are discussed in the paragraph below.

Noncarcinogenic Hazard Index: The total HIs for noncarcinogenic health effects from exposure to these four metals in groundwater in AOC No. 2 are 1 and 9 for the average and RME conditions, respectively (Table J10-1). Manganese contributes most to the total HIs. HQs for the other metals were near or less than 1.

As stated above, the magnitude of the HIs are driven by manganese. However, the HIs may not be a sound guide to potential health hazards (assuming unfiltered groundwater is ingested chronically) because significant uncertainty exists with regard to the toxicity of manganese ingested in water. The toxicity value for manganese in water, represented by the RfD (0.0005 mg/kg-day, EPA 1995b), is probably significantly overestimated. This RfD is 28-times smaller than the RfD for manganese in food (0.14 mg/kg-day, EPA 1995b); it is an order of magnitude less than the "Estimated Safe and Adequate Daily Dietary Intake" of 0.03 to 0.07 mg Mn/kg-day (manganese is an essential element) recommended by the National Research Council (NRC 1989); and it is well below the dose (0.129 mg/kg/day) considered by the World Health Organization (WHO) to be "perfectly safe" (WHO 1973).

Because of the conservatism in establishing toxicity factors for manganese, because groundwater use is unlikely in OU6, and because UHSU groundwater is not present in OU6 in significant quantities for household or drinking water use (see Sections 3.0 and 5.0 of the RFI/RI Report), further evaluation or action in OU6 related to potential noncarcinogenic effects of manganese and other metals in groundwater is probably not warranted.

Carcinogenic Risk: The excess lifetime cancer risks for hypothetical onsite residents ingesting arsenic and beryllium in unfiltered groundwater at AOC No. 2 are 4E-06 and 1E-04 in the CT and RME cases, respectively. For the RME condition, the cancer risk estimate is at the upperbound limit of the EPA target risk range of 1E-06 to 1E-04 (1 in 1 million to 1 in 10,000). Both arsenic and beryllium contributed significantly to the total cancer risk estimates. Since the cancer risk associated with ingestion of these metals in groundwater is within the EPA target risk range, and since groundwater in OU6 is not expected to be ingested, especially under residential conditions, further evaluation or action in OU6 is probably not warranted.

J10.3.2 Risk at Background Levels of Metals in Groundwater

As a comparison to risk estimates for metals in unfiltered OU6 groundwater samples and to help support the conclusion drawn in the COC TM (DOE 1994c) that metals in OU6 groundwater are naturally occurring, hazard/risk levels were also estimated for background levels of arsenic, antimony, beryllium, and manganese in groundwater using 95% UCLs of the background means as the exposure concentrations. The results are shown in Table J10-1. Sample results used in the calculation of the exposure terms are shown in Attachment J1 and detailed risk calculations are shown in Attachment J3.

Noncarcinogenic Hazard Index: The total HIs for noncarcinogenic health effects from ingestion of background levels of the four metals in groundwater are 0.4 and 3.0 for the CT exposure and RME conditions, respectively (Table J10-1). HQs for antimony, arsenic, and beryllium in background are very similar to those in OU6. Only the HQs for manganese were lower in background samples, resulting in lower total HIs. As discussed in Appendix C of the COC TM (DOE 1994c), local geochemical characteristics are highly variable, and background wells were not located in areas of high manganese and iron, whereas OU6 wells are located in areas characterized by elevated manganese and iron.

Carcinogenic Risk: The lifetime excess cancer risks associated with ingesting background concentrations of arsenic and beryllium in groundwater are 8E-06 (8 in 1 million) and 2E-04 (2 in 10,000) for the CT exposure and RME conditions, respectively (Table J10-1). Cancer risk from the RME condition for exposure to background levels of metals in groundwater slightly exceeds EPA's target risk range of 1E-06 to 1E-04 (1 in 1 million to 1 in 10,000). The risks at background levels are actually higher than those in OU6.

The results indicate that hazard/cancer risk estimates from hypothetical residential exposure to naturally occurring metals in groundwater exceed EPA target values for health hazard indexes and cancer risk. Cancer risk estimates for COIs in OU6 were similar to or less than cancer risk estimates for exposure to background levels. Since the cancer risk estimate for hypothetical consumption of metals in groundwater is not significantly different from the cancer risk estimate at background levels, this suggests that COIs in groundwater samples in OU6 are naturally occurring and are not due to environmental contamination.

J10.3.3 Arsenic in Stream/Dry Sediment

Arsenic was selected for separate evaluation of potential hazard/risk associated with ingestion of stream/dry sediment under an open space recreational use scenario. Arsenic was not identified as a COC in OU6 stream/dry sediment primarily because, although it failed one of the four statistical tests in the background comparison, further evaluation of arsenic concentrations in stream sediment and the background samples indicated that arsenic was probably naturally occurring (DOE 1994c). Furthermore, there are no significant sources or historical uses of arsenic at RFETS (DOE 1994c). However, to address concerns that arsenic could pose a health risk under long-term exposure to detected concentrations, parties to the IAG agreed that arsenic would be evaluated separately as a COI in the uncertainties section (DOE 1995c). Hazard/risk results for ingestion of arsenic in stream/dry sediment in OU6 and in background stream sediment by open space recreational users are summarized in Table J10-1 and detailed in Attachment J3.

Exposure concentrations used in the evaluation were 6.5 mg/kg (95% UCL in stream and dry sediment, AOC No. 3), 4.88 mg/kg (95% UCL in stream and dry sediment, AOC No. 4), and 4.9 mg/kg (background mean plus one standard deviation).

Noncarcinogenic Hazard: The total HIs for open space recreational use exposure to arsenic in AOC No. 3 and AOC No. 4 via the sediment ingestion pathway are 0.0055 or less for the average and RME exposure conditions (Table J10-1). The RME HI for ingestion of background levels of arsenic in stream sediment is 0.004. Because the HIs are below 1, no adverse noncarcinogenic health effects are expected for onsite receptors from ingestion of arsenic in stream/dry sediments during recreational exposure. Additionally, there is no substantial difference between HIs calculated for arsenic levels in OU6 AOCs No. 3 and No. 4 and for background levels.

Carcinogenic Risk: The estimated lifetime excess cancer risks for open space recreational use exposure to arsenic in AOC No. 3 and AOC No. 4 via ingestion of stream/dry sediment is 3E-07 or less for average and RME exposure conditions (Table J10-1). The RME cancer risk for ingestion of background levels of arsenic in stream sediment is 2E-07, which does not differ significantly from the risk estimates for OU6 AOCs No. 3 and No. 4. Since these levels are below EPA's target range for acceptable risk and the risks from other COCs at

these locations were at the lower end of EPA's target risk range (1E-06 to 1E-04), incremental risk from ingestion of arsenic would not significantly affect the total cancer risk estimate for exposure to stream/dry sediment.

TABLE J10-1
SUMMARY OF HEALTH RISKS FOR SPECIAL-CASE CHEMICALS OF CONCERN AND CHEMICALS OF INTEREST (COIs)

Exposure Pathway/Receptor	Central Tendency Hazard Index	Central Tendency Carcinogenic Risk	Reasonable Maximum Exposure Hazard Index	Reasonable Maximum Exposure Carcinogenic Risk
Special-Case COC				
Residential Ingestion of Vinyl Chloride in Groundwater				
AOC No. 2				
Vinyl Chloride		4.33E-04		1.03E-02
Chemicals of Interest (COIs)				
Residential Ingestion of Metals in Groundwater				
AOC No. 2				
Antimony	1.59E-01		1.13E+00	
Arsenic	3.18E-02	2.09E-06	2.26E-01	4.95E-05
Beryllium	7.69E-04	2.13E-06	5.48E-03	5.05E-05
Manganese	1.10E+00		7.93E+00	
Total	1.31E+00	4.21E-06	9.30E+00	1.00E-04
Background				
Antimony	3.08E-01		2.19E+00	
Arsenic	2.56E-02	1.68E-06	1.83E-01	3.99E-05
Beryllium	2.31E-03	6.38E-06	1.64E-02	1.51E-04
Manganese	8.23E-02		5.86E-01	
Total	4.18E-01	8.06E-06	2.98E+00	1.91E-04
Ingestion of Arsenic In Stream/Dry Sediment (Open Space Recreational User)				
AOC No. 3				
Arsenic (Child)	1.92E-03		4.94E-03	
Arsenic (Adult)	3.39E-05		5.29E-04	
Arsenic (Carcinogenic)		6.05E-09		3.08E-07
Total	1.95E-03	6.05E-09	5.47E-03	3.08E-07
AOC No. 4				
Arsenic (Child)	1.09E-03		3.71E-03	
Arsenic (Adult)	2.55E-05		3.98E-04	
Arsenic (Carcinogenic)		4.55E-09		2.32E-07
	1.12E-03	4.55E-09	4.11E-03	2.32E-07
Background				
Arsenic (Child)	1.10E-03		3.73E-03	
Arsenic (Adult)	2.56E-05		4.00E-04	
Arsenic (Carcinogenic)		4.56E-09		2.33E-07
Total	1.13E-03	4.56E-09	4.13E-03	2.33E-07

J11.0
SUMMARY AND CONCLUSIONS

This section briefly summarizes the results of the HHRA for OU6 and suggests conclusions that may be drawn from the assessment.

J11.1 SUMMARY

The HHRA for RFETS OU6 estimated health risks and annual radiation doses for current and future onsite receptors who could be exposed directly or indirectly to COCs at or released from sources in OU6. COCs were identified as the chemicals, metals, or radionuclides in soil, groundwater, sediment, or surface water that were likely to contribute at least 1 percent of overall risk. The chief COCs were Am-241 and Pu-239/240 in all media; metals in surface and subsurface soil, pond sediments, and stream/dry sediments; and Aroclor-1254 in pond sediment.

Exposure scenarios evaluated were a current worker (security patrol), a future office worker, a future ecological researcher, future open space recreational user, and a construction worker.

Exposure media evaluated were surface soil, subsurface soil (construction worker only), outdoor and indoor air, pond sediment, pond surface water, and stream/dry sediment.

Risks were estimated for four AOCs in OU6. AOC No. 1 is the North Spray Field Area (IHSS 167.1). AOC No. 2 includes the Sludge Dispersal Area (IHSS 141), Triangle Area (IHSS 165), and Soil Dump Area (IHSS 156.2). AOC No. 3 includes Ponds A-1 through A-3 (IHSSs 142.1, 142.2, and 142.3). AOC No. 4 includes Ponds B-1 through B-4 (IHSSs 142.5, 142.6, 142.7, and 142.8). In addition, risks for the future office worker were evaluated in a 30-acre maximum exposure area in AOC No. 2. Annual radiation doses in units of mrem/year were also estimated for comparison to national radiation standards.

The risk characterization process combines average and reasonable maximum estimates of exposure with upperbound estimates of toxicity to yield conservative (protective) estimates

of health risk. Estimates of health risk for CT and RME conditions are provided so that risk management decisions can be based on a range of potential risk for different exposure scenarios.

Hazard/risk estimates are summarized in Table J11-1. Results of the risk assessment can be described as follows:

- AOC No. 1 and AOC No. 2: Cumulative HIs were below 1 and RME cancer risk estimates were below EPA's target acceptable risk range and 1E-06 to 1E-04 for all receptors. These results indicate that no adverse noncarcinogenic health hazards and negligible cancer risks are expected for all receptors evaluated.

- AOC No. 3 and No. 4: Cumulative HIs were below 1 and RME cancer risk estimates were 6E-06 or below for both receptors (open space recreational user and ecological worker). The maximum cancer risk estimate is within EPA's target acceptable risk range of 1E-06 to 1E-04. Ingestion of maximum modeled concentrations of Am-241 and Pu-239/240 in pond sediment over a 30-year exposure duration by the open space recreational user is the chief contributor to this estimate of cancer risk. Given the conservatism of using maximum concentrations and a 30-year exposure duration, the RME cancer risk estimates for open space exposure very likely overestimate potential risk. The results indicate that there is no unacceptable risk for these receptors.

- Cancer risk estimates based on additional pond sediment samples collected in 1994 were 9E-06 or lower (evaluated in Attachment J5) and support the conclusion of no unacceptable risk for these receptors from exposure to pond sediment.

- Estimated annual radiation doses for onsite receptors were less than 0.6 mrem/year, well below the DOE standard of 100 mrem/year for protection of the public.

- Background and OU6 levels of COIs in unfiltered groundwater (antimony, arsenic, beryllium, and manganese) would pose unacceptable risk if directly ingested under a long-term residential exposures scenario.

- Vinyl chloride in groundwater in well 3586 (evaluated as a special-case COC) would pose unacceptable risk if directly ingested under a long-term residential exposure scenario.

J11.2 CONCLUSIONS

Under possible future land use scenarios at RFETS, none of the receptors evaluated in AOC No. 1 and AOC No. 2 are exposed to unacceptable levels of chemical constituents in surface soil, subsurface soil, and indoor and outdoor air. RME cancer risk estimates for receptors in AOC No. 3 and AOC No. 4 were within or below EPA's target cancer risk range. HIs were also below 1 in AOC No. 3 and AOC No. 4, indicating that no adverse health effects are expected.

In general, cancer risk levels that do not exceed 1E-04, combined with HIs that do not exceed 1, may be used to support a decision that remediation is not warranted for the protection of public health (EPA 1991c). These results suggest that remediation of exposure media evaluated in the OU6 HHRA (surface soil, subsurface soil, pond water and sediment, and stream and dry sediment) may not be necessary for protection of public health.

TABLE J11-1
SUMMARY OF ESTIMATED HEALTH RISKS

	Central Tendency		Reasonable Maximum	
	Hazard Index	Cancer Risk	Hazard Index	Cancer Risk
AOC No. 1				
Current Industrial Worker	1.78E-03	2.01E-09	1.13E-02	5.17E-08
Future Office Worker	8.91E-04	1.30E-09	1.13E-02	5.17E-08
Future Ecological Worker	1.74E-03	8.78E-10	6.21E-03	2.73E-09
Future Open Space Recreational User	2.34E-03	4.12E-10	1.17E-02	7.22E-09
Future Construction Worker	9.28E-05	1.95E-09	5.21E-04	4.03E-09
AOC No. 2				
Current Worker	1.82E-03	1.23E-08	1.15E-02	4.26E-07
Future Ecological Worker	1.78E-03	6.90E-09	6.34E-03	2.29E-08
Future Open Space Recreational User	2.83E-03	3.66E-09	1.19E-02	6.03E-08
Future Construction Worker	1.15E-04	2.69E-09	6.43E-04	1.16E-08
30-acre Maximum Exposure Area				
Future Office Worker	7.90E-04	1.31E-08	1.00E-02	5.18E-07
AOC No. 3				
Future Ecological Worker	5.37E-04	4.60E-09	5.28E-03	4.86E-08
Future Open Space Recreational User	4.13E-03	5.88E-08	2.54E-02	1.26E-06
AOC No. 4				
Future Ecological Worker	3.67E-03	2.78E-08	3.50E-02	2.78E-07
Future Open Space Recreational User	1.43E-02	2.34E-07	1.06E-01	6.10E-06

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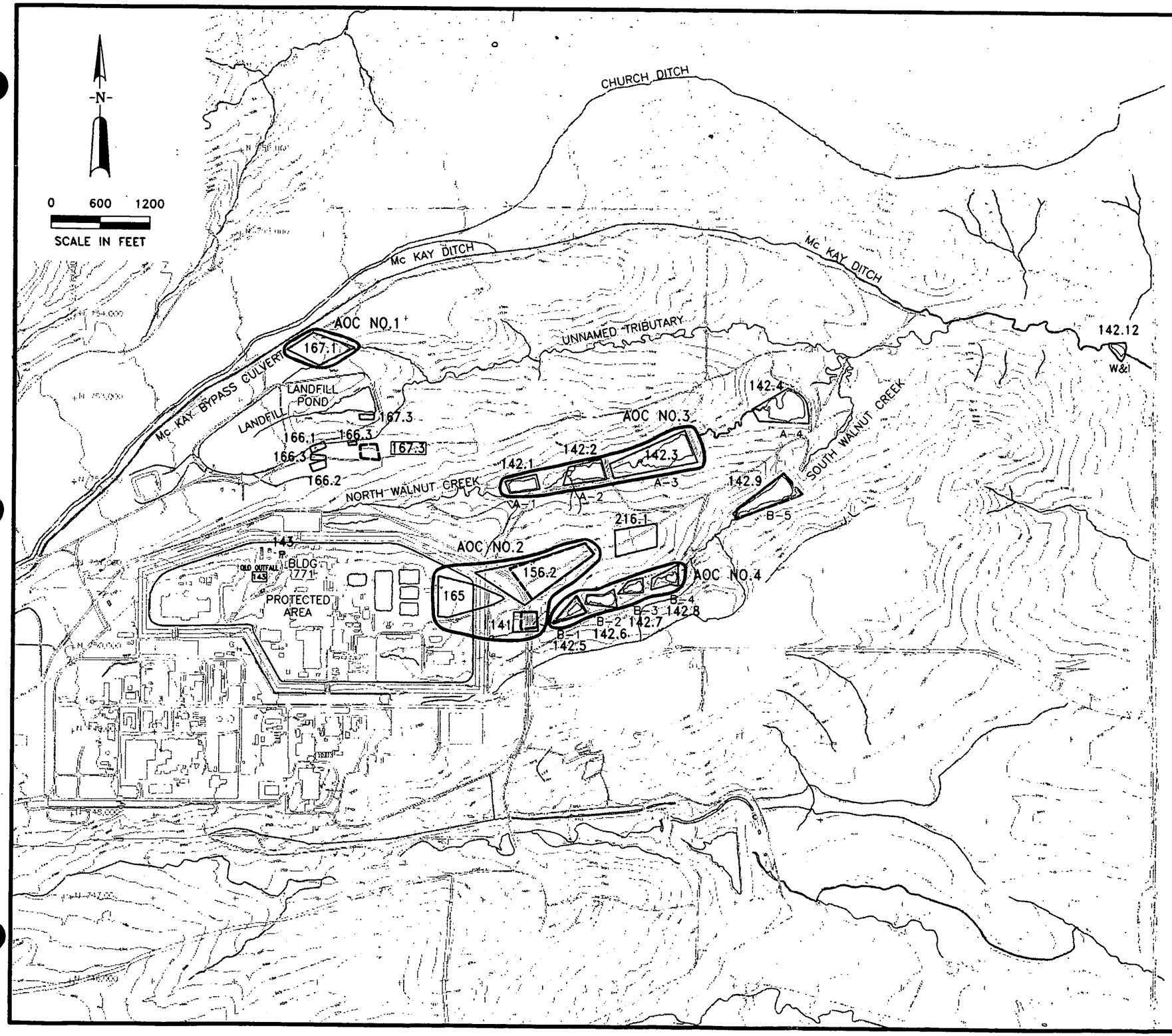

EXPLANATION

PONDS/LAKES

OU6 IHSS'S

142.12

PROTECTED AREA BOUNDARY

167.3 OU6 HISTORICAL IHSS BOUNDARY FOR IHSSs: 141, 142.5, 142.9, 143, AND 156.2

141	SLUDGE DISPERSAL AREA
142	PONDS
143	OLD OUTFALL
156.2	SOIL DUMP AREA
165	TRIANGLE AREA
166.1–166.3	TRENCHES A, B, C
167.1	SPRAY FIELD
216.1	EAST SPRAY FIELDS

IHSS LOCATIONS SHOWN ARE BASED ON REVISED INTERPRETATIONS IN HISTORICAL RELEASE REPORT DOE, JUNE 1992b

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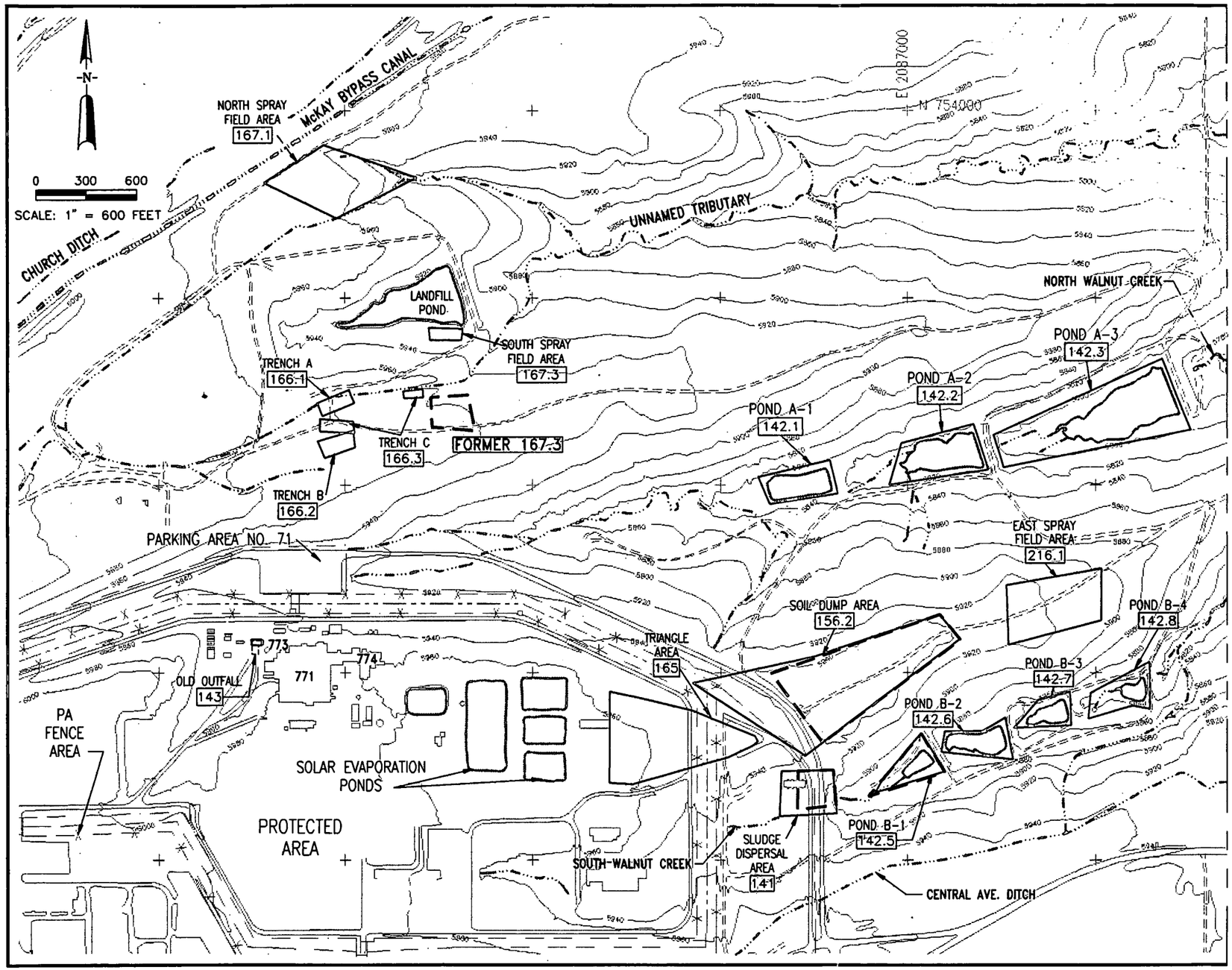
AREAS OF CONCERN
WITHIN OPERABLE UNIT NO. 6

FIGURE J8-1 JUNE 1995

OU6RI299 1=1200



SOURCE: DOE 1992a

EXPLANATION

- INDIVIDUAL HAZARDOUS SUBSTANCE SITE* (IHSS) IN OPERABLE UNIT 6 (OU6)
- 142.3 — IHSS REFERENCE NUMBER
- 167.3 — OU6 HISTORICAL IHSS BOUNDARY (DOE 1987)
- PROTECTED AREA (PA) FENCE
- DIRT ROAD
- INTERMITTENT STREAM

*IHSS LOCATIONS SHOWN ARE BASED ON REVISED INTERPRETATIONS IN HRR (DOE 1992a).

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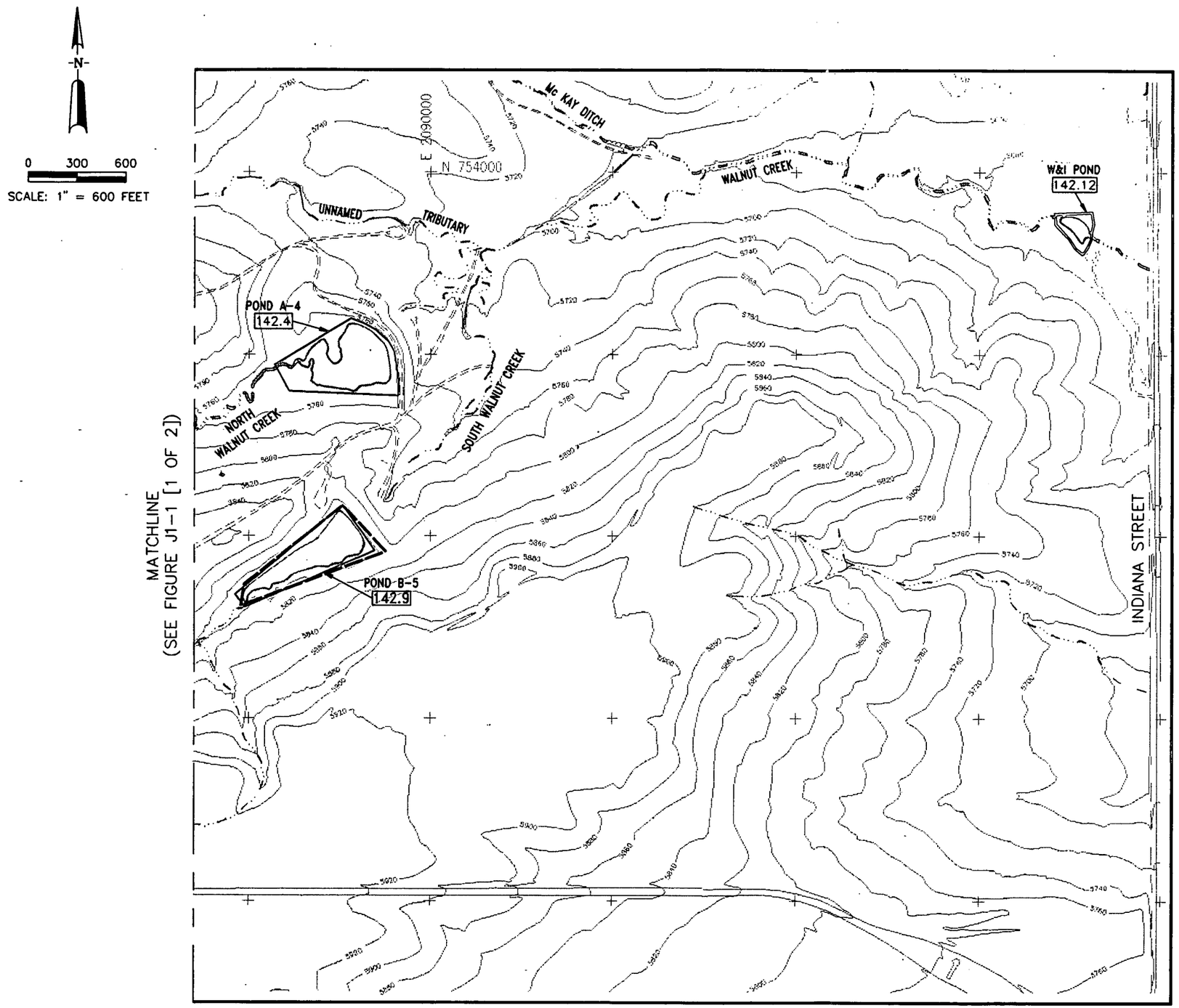
LOCATION AND IDENTIFICATION OF OU6 IHSSs AND DIVERSION STRUCTURES ALONG NORTH & SOUTH WALNUT CREEKS (PAGE 1 OF 2)

FIGURE J1-1 REV. APRIL 1995

8/11/95 OU6RI295 1=600



SOURCE: DOE 1992a

EXPLANATION

INDIVIDUAL HAZARDOUS SUBSTANCE SITE* (IHSS) IN OPERABLE UNIT 6 (OU6)

142.12 IHSS REFERENCE NUMBER

142.9 OU6 HISTORICAL IHSS BOUNDARY (DOE 1987)

DIRT ROAD

INTERMITTENT STREAM

*IHSS LOCATIONS SHOWN ARE BASED ON REVISED INTERPRETATIONS IN HRR (DOE 1992a).

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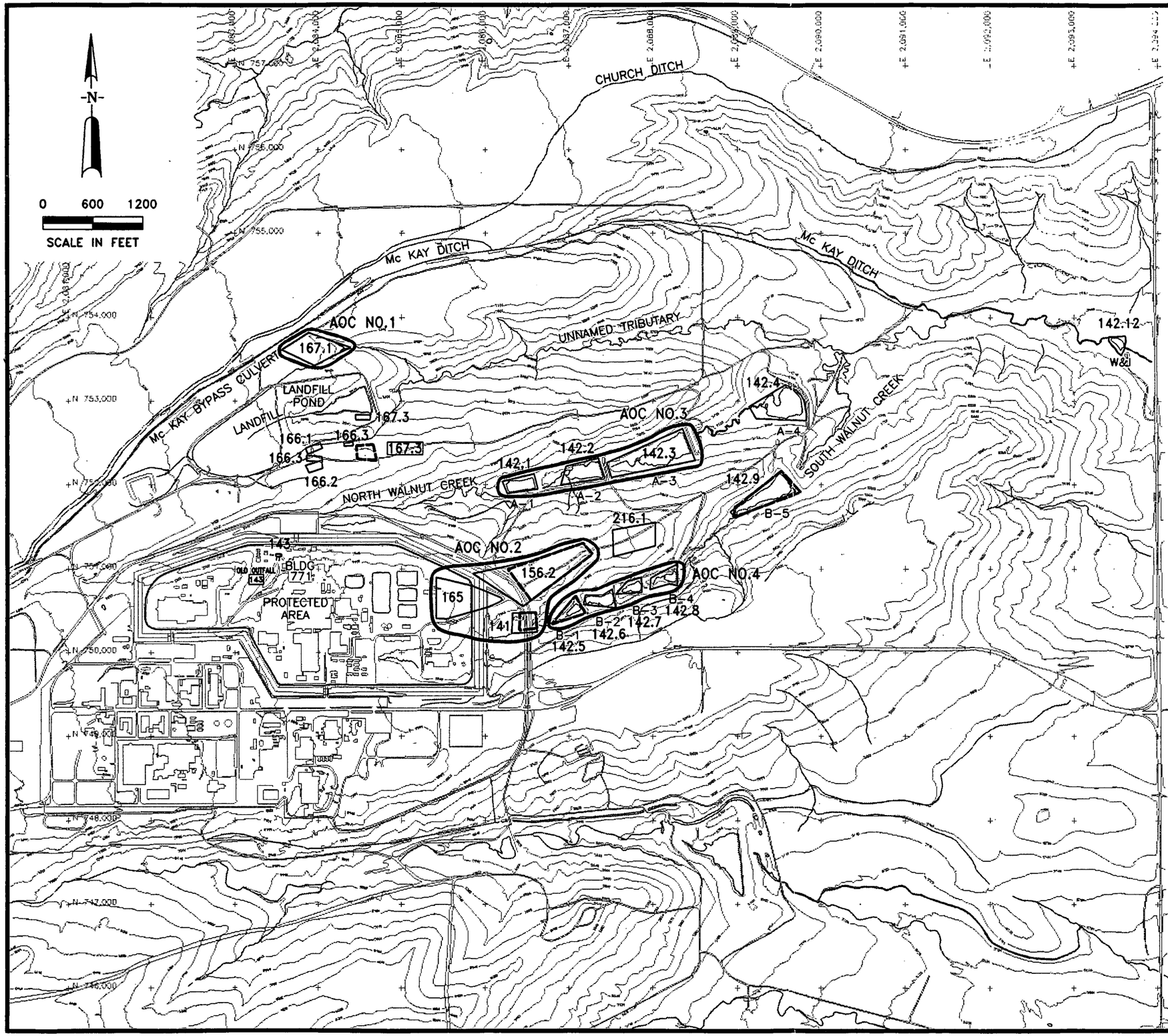
LOCATION AND IDENTIFICATION OF OU6 IHSSs AND DIVERSION STRUCTURES ALONG NORTH & SOUTH WALNUT CREEKS (PAGE 2 OF 2)

FIGURE J1-1 REV. APRIL 1995

8/11/95 OU6RI296 1=600



EXPLANATION

PONDS/LAKES

142.12 OU6 IHSS

PROTECTED AREA BOUNDARY

167.3 OU6 HISTORICAL IHSS BOUNDARY FOR IHSSs: 141,142.5, 142.9, 143, AND 156.2

141	SLUDGE DISPERSAL AREA
142	PONDS
143	OLD OUTFALL
156.2	SOIL DUMP AREA
165	TRIANGLE AREA
166.1–166.3	TRENCHES A, B, C
167.1	SPRAY FIELD
216.1	EAST SPRAY FIELDS

IHSS LOCATIONS SHOWN ARE BASED ON REVISED INTERPRETATIONS IN HISTORICAL RELEASE REPORT DOE, JUNE 1992b

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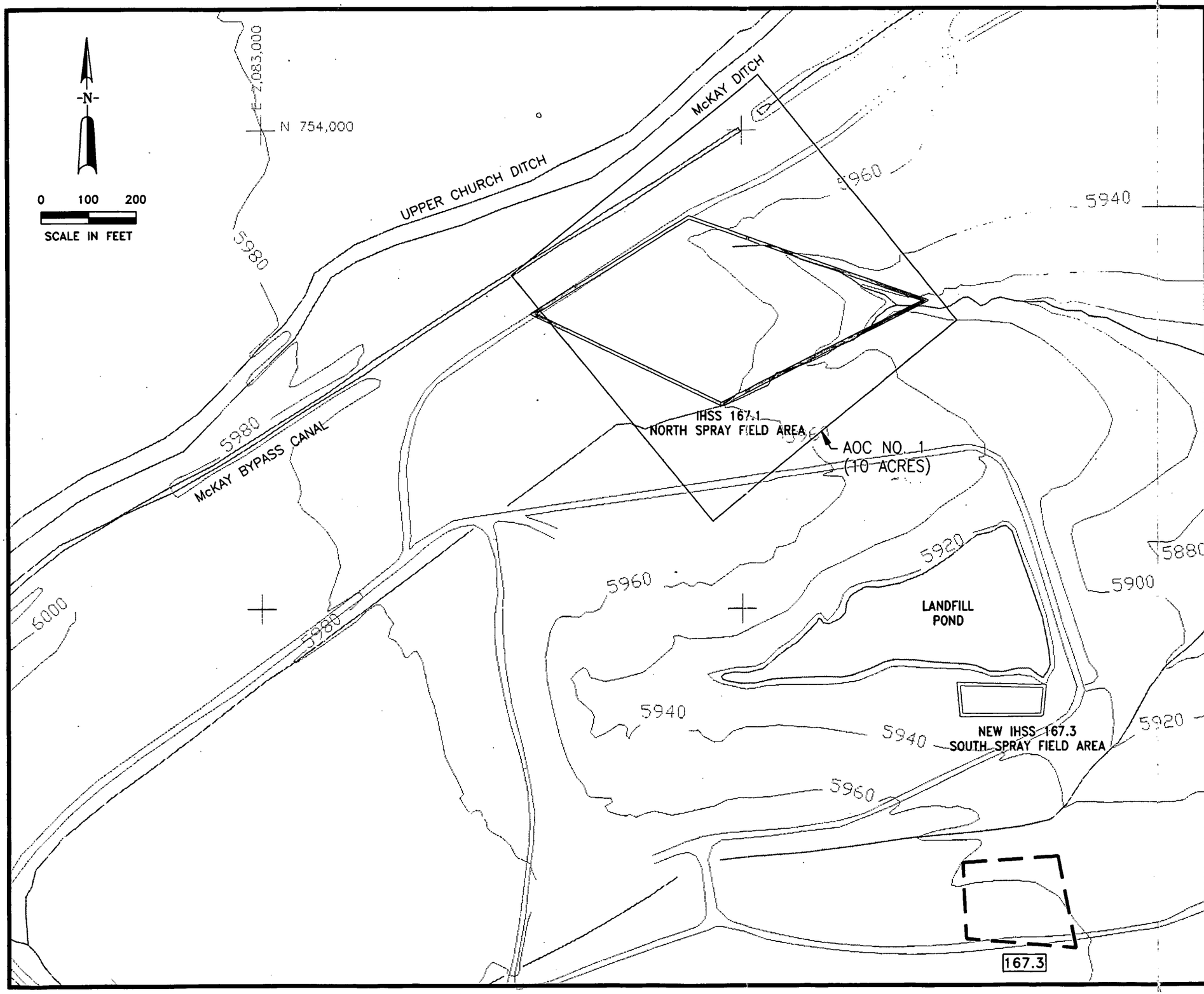
FIGURE J4-1 JUNE 1995

8/11/95 OU6RI299 1=1200



EXPLANATION

INDIVIDUAL HAZARDOUS SUBSTANCE SITES

HISTORICAL IHSS BOUNDARIES DOE 1987

167.3

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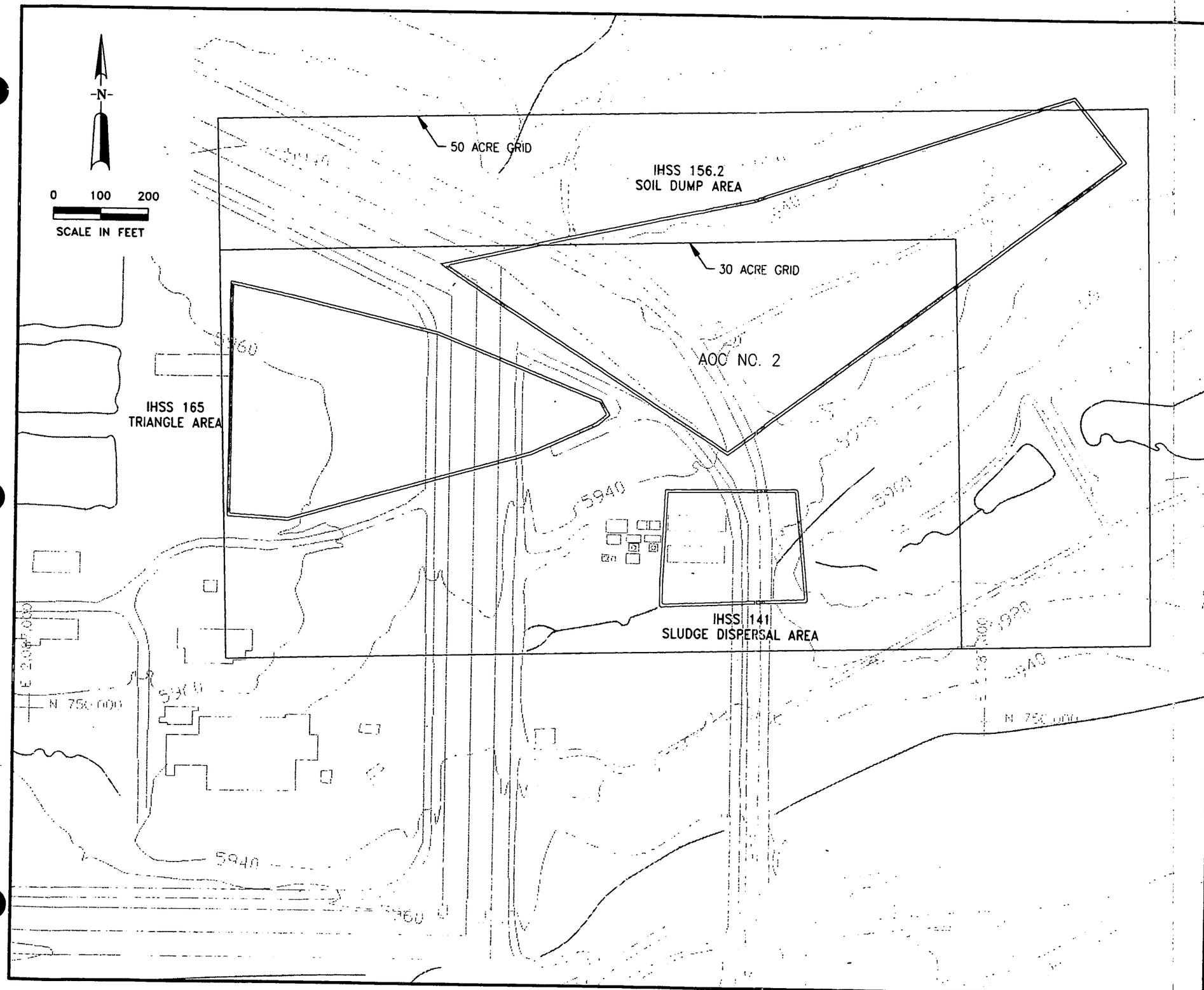
AREA OF CONCERN NO.1

FIGURE J4-2 JUNE 1995

3/11/95 OU6RI300 1=200



EXPLANATION

INDIVIDUAL HAZARDOUS SUBSTANCE SITES

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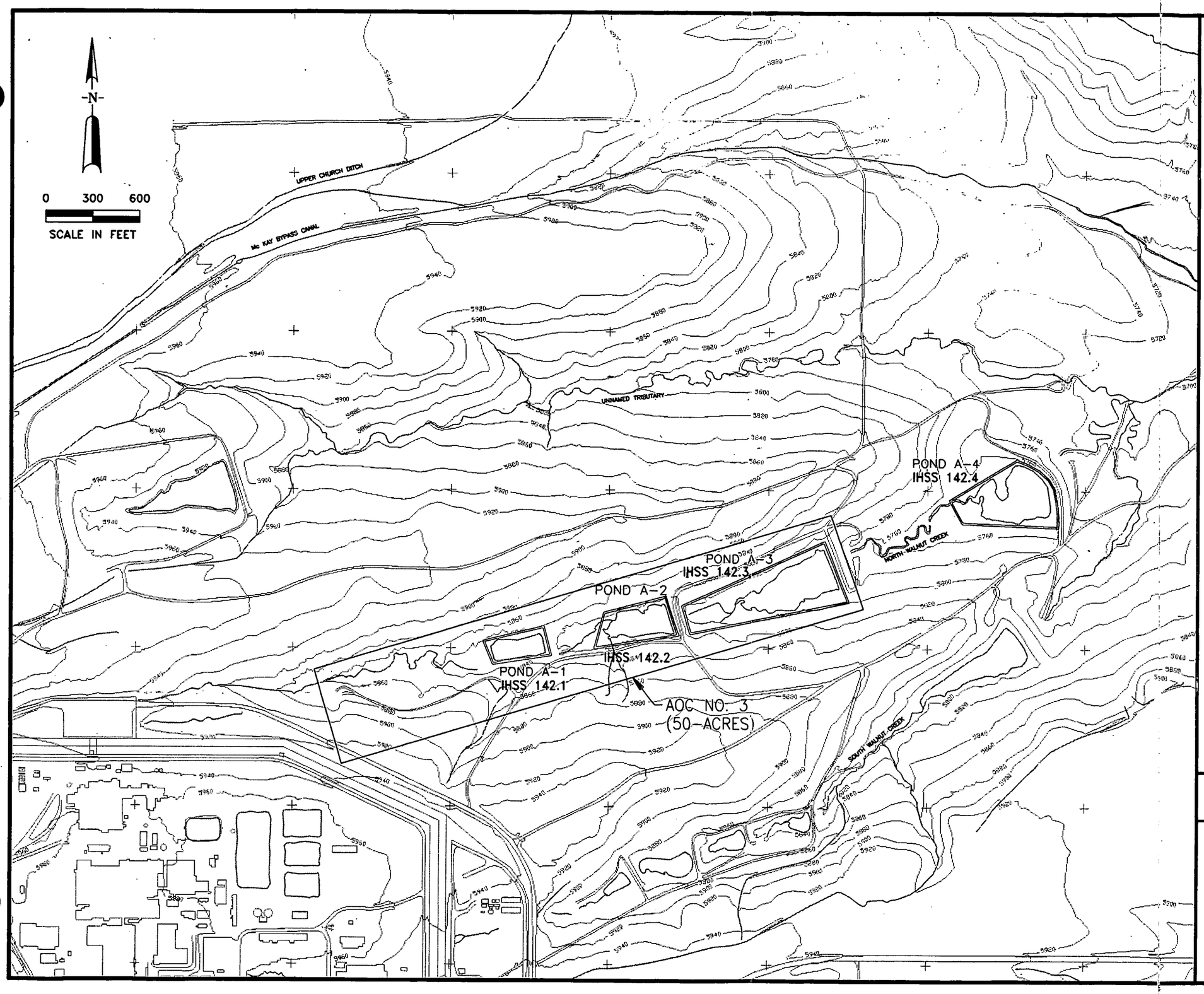
AREA OF CONCERN NO.2
AND 30 ACRE
MAXIMUM EXPOSURE AREA

FIGURE J4-3

JUNE 1995

OU6RI301 1=200



EXPLANATION

INDIVIDUAL HAZARDOUS SUBSTANCE SITES

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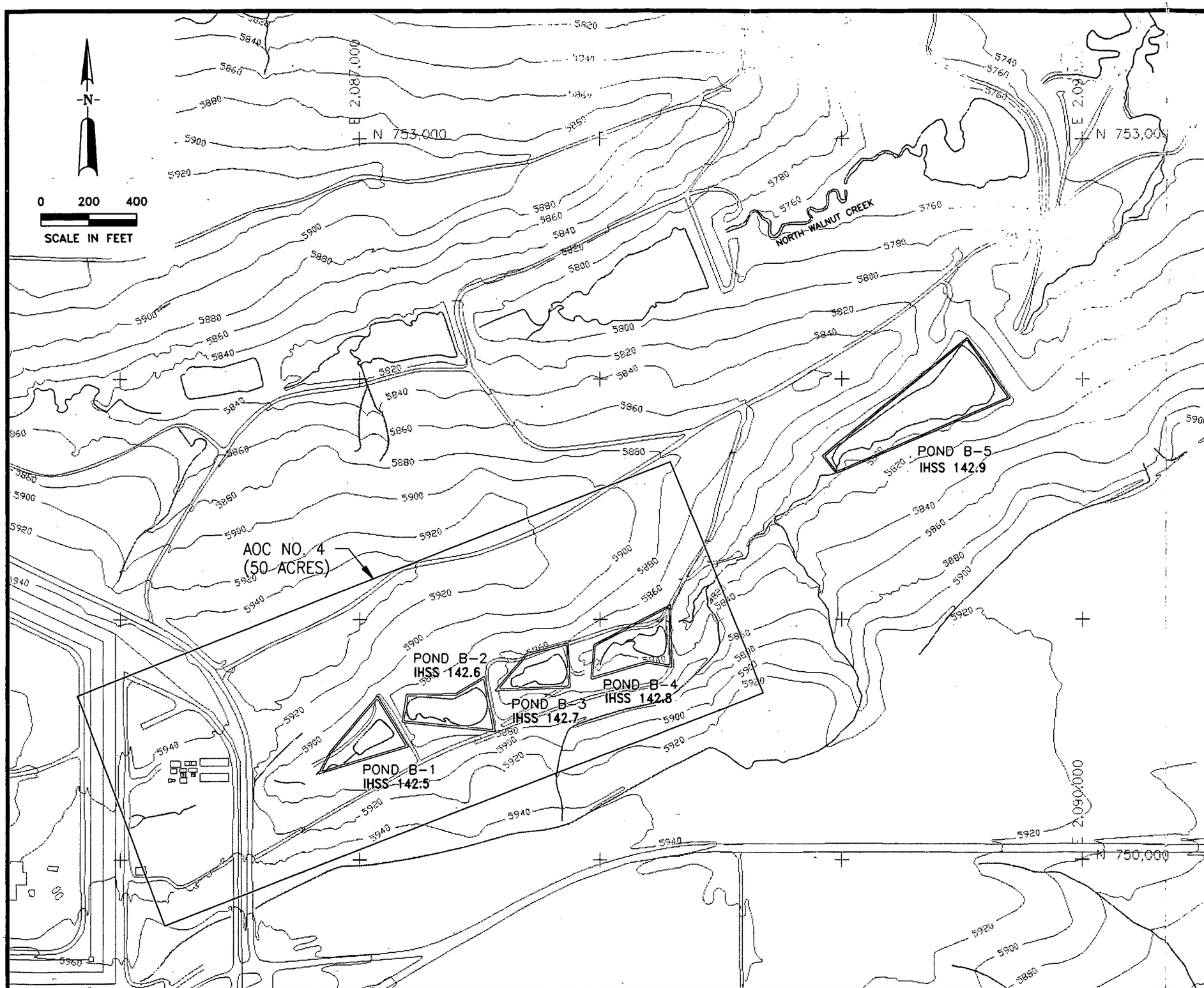
AREA OF CONCERN NO.3

FIGURE J4-4 JUNE 1995

9/11/95 OU6RI302 1=600



EXPLANATION

INDIVIDUAL HAZARDOUS SUBSTANCE SITES

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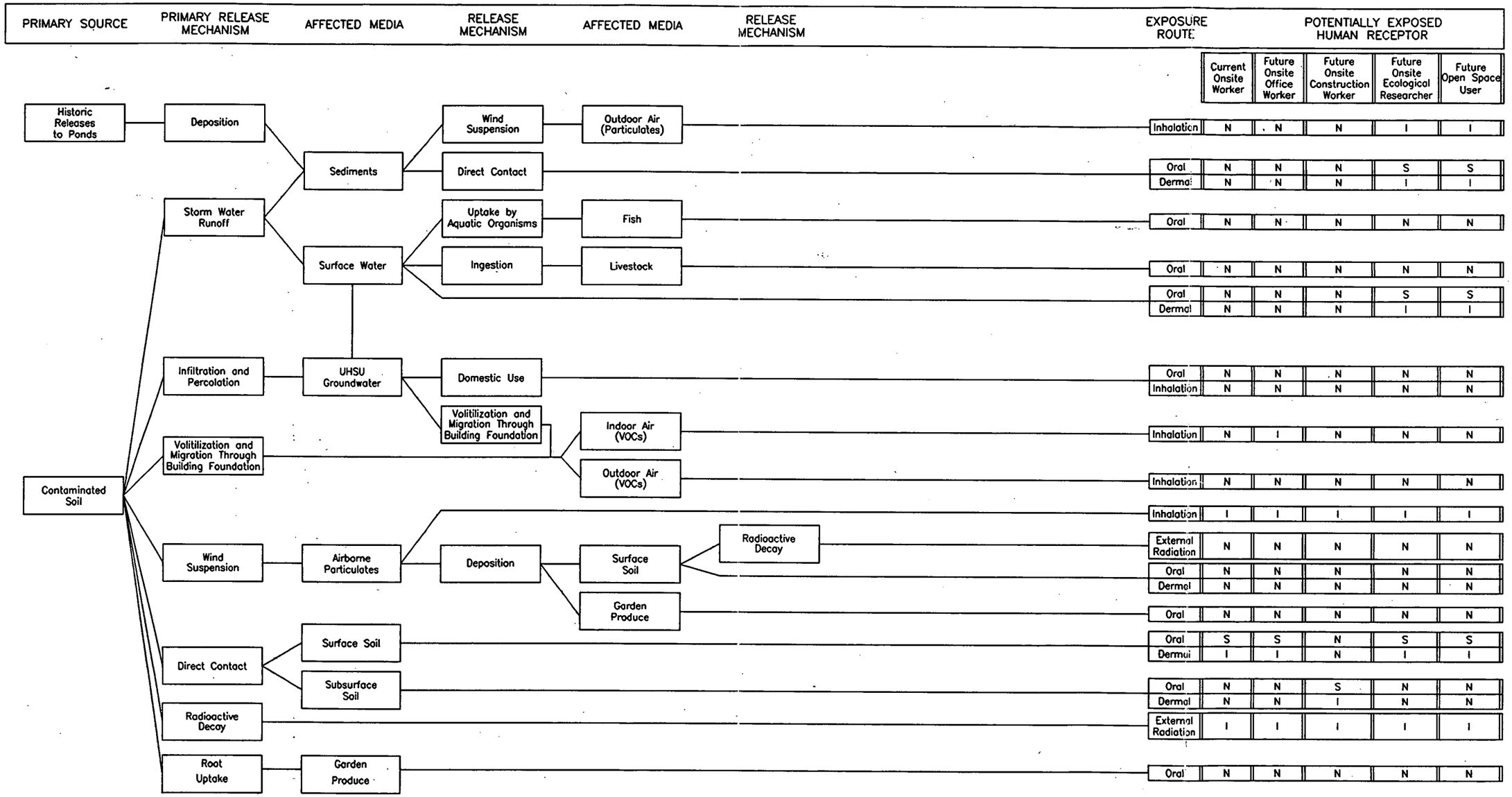
AREA OF CONCERN NO.4

FIGURE J4-5 JUNE 1995

OU6RI303 1=400



LEGEND

S Potentially Complete Exposure Pathway (Evaluated, May Be Significant)
I Potentially Complete Exposure Pathway (Evaluated, Probably Insignificant)
N Not Evaluated (Either Incomplete Or Potentially Complete But Not Assessed)
UHSU Upper Hydrostratigraphic Unit

Note: Pathways that were potentially complete but not assessed did not warrant quantitative evaluation because they would not contribute measurably to the estimate of overall risk (see text).

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CONCEPTUAL SITE MODEL
FOR HUMAN EXPOSURE PATHWAYS

FIGURE J4-6 APRIL 1995

OU6RI298 1=1