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U.S. Department of Energy

Oakland Operations Office, Oakland, California

DRAFT FINAL DETERMINATION OF RISK-BASED ACTION STANDARDS FOR DOE AREAS VOLUME I

For the

LABORATORY FOR ENERGY-RELATED HEALTH RESEARCH UNIVERSITY OF CALIFORNIA AT DAVIS, CALIFORNIA

Prepared for:

United States Department of Energy
Oakland Operations Office
1301 Clay Street
Oakland, California 95612

Prepared by:

Weiss Associates
5500 Shellmound Street
Emeryville, California 94608

August 4, 1997
Rev. C

DOE Oakland Operations Office, Contract DE-AC03-96SF20686

Approvals Page

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for the

Laboratory for Energy-Related Health Research
University of California at Davis, California

Prepared by:

Weiss Associates
5500 Shellmound Street
Emeryville, California 94608-2411

August 4, 1997
Rev. C

Approved by: _____ Date: _____

Mary Stallard, RG
Project Quality Assurance Manager
Weiss Associates

Approved by: _____ Date: _____

Robert O. Devany, RG
Project Manager
Weiss Associates

Approved by: _____ Date: _____

Michael D. Dresen, RG
Program Manager
Weiss Associates

Approved by: _____ Date: _____

Carolyn Atwood
Project Task Leader
Weiss Associates

Approved by: _____ Date: _____

Timothy Utterback
Environmental Scientist
Weiss Associates

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1. EXECUTIVE SUMMARY

This report presents the results of risk-based action standard calculations conducted as part of the ongoing CERCLA activities at the former Laboratory for Energy-Related Health Research (Site) and the South Campus Disposal Site (SCDC), together referred to herein as the Site, at the University of California, Davis (UC Davis), California. Action standards apply only to those areas for which the U.S. Department of Energy (DOE) is taking responsibility, based on the Memorandum of Agreement (MOA) (DOE/UC Davis 1997) between the DOE and UC Davis. Table 1-1 below shows a summary of DOE Areas at the Site. For consistency with previous documents and reports, this report uses the Operable Unit (OU) designations shown in Table 1-1 below. However, the reader should be aware that these are not formal CERCLA OU designations, and that the OU designations are likely to change in the future when the Federal Facilities Agreement is signed at this site.

Table 1-1. Summary of DOE Areas at the Site.

Operable Unit	Investigative Area	Description
OU-1	Southwest Trenches	Disposal trenches and chemical dispensing area in the southwest corner of the Site.
OU-1	DOE Disposal box	Subsurface disposal area bounded by metal matting located between the two sets of dog pens.
OU-2	Radium Treatment System	Radium-226 treatment tank and associated leach field
OU-2	Strontium Treatment System	Strontium-90 treatment tank and associated leach field and dry wells.
OU-3	Dog Pen Areas	Western and eastern dog pens, including the southern portion of the area currently occupied by the Cellular Biology Lab.
OU-4	Domestic Septic Systems	Seven domestic septic tanks at the site.

The overall objective of this evaluation is to determine action standards for contaminated soil in the DOE Areas, for both chemical and radiological constituents of concern (COCs). Action standards for carcinogenic compounds are calculated for the incremental risk range of 10^{-4} to 10^{-6} established in the National Contingency Plan, 40 CFR part 300. Action standards for non-carcinogens are based on a hazard quotient of 1.0, consistent with EPA guidance. The action standards calculated here represent single constituent concentrations, which, if present throughout the horizontal and vertical extent of each of the DOE Areas, might theoretically result in the specified maximum individual excess risk level to an exposed individual. It should be emphasized that because the calculation methodologies used herein are conservative, so are the calculated action standards. The actual excess risk to an exposed individual resulting from contaminant being present at the site at the action standard could be negligible or even zero.

DOE and the regulatory agencies plan to use the results provided herein to choose appropriate standards to guide removal action(s). A subsequent site-wide cumulative risk assessment, if necessary, is planned to follow DOE and UC Davis removal actions.

Three exposure scenarios were selected for evaluation in this assessment. Scenario 1, Onsite Researcher, represents potential onsite workers that may be exposed to source area soil through external radiation from ground surface radionuclides (for radionuclides only), ingestion, inhalation and dermal exposure. Scenario 2, the East Side Residential Farmer, involves potential offsite residential farmers that may be exposed to potentially impacted ground water, potentially impacted surface water (via recreational use), and via external radiation from ground surface radionuclides (for radionuclides only), inhalation of fugitive dust, soil ingestion, and agricultural foods potentially impacted by fugitive dust migration from the onsite source areas. Scenario 3, the South Side Residential Farmer, is identical to Scenario 2 except that exposure to impacted ground water is not included, since ground water flow is generally toward the east, away from this receptor location, and ground water contamination (if any) does not impact Putah Creek. At the request of the regulatory agencies, an onsite residential scenario has also been included, in which the action standards are set equal to those established in the *USEPA Region 9 August 1996 Preliminary Remediation Goals (PRGs)* for chemical constituents and the *USEPA Region 9 December 1996 PRGs* for radionuclides. This latter scenario is included for comparison purposes only; future land use planning by UC Davis does not indicate any possibility of future residential land use at this time. Rather, continued use as a research facility is anticipated for the foreseeable future.

The approach for establishing action standards for site soil consisted of the following general process. First, chemical and radionuclide contaminants of potential concern were identified as those present in DOE OU site soil above site-specific background levels. Next, action standards for these contaminants were calculated using the Argonne National Laboratory computer code RESRAD for radionuclides and a *Risk Assessment Guidance for Superfund (RAGS)*-based approach for chemical constituents. To complete the back calculations, it was necessary to relate DOE OU source area soil concentrations to concentrations in exposure media at the receptor location for each scenario. Fate and transport modeling was conducted to establish these relationships for each COC. For chemical constituents, chemical dose, or intake, was then calculated using the intake equations presented in *the Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (Part A)* (EPA 1989a). Incremental human health risk was then calculated using toxicological parameters from the *USEPA Region IX August 1996 Preliminary Remedial Goals* tabulation and the EPA's *Integrated Risk Information System* online database. The action standard for source soil was then determined by iterative back calculation to determine the source soil concentration that yields the target incremental cancer risk (or target hazard quotient (HQ)) value. The target incremental cancer risk (or target HQ) is a sum of risk (or HQ) across all pathways for a particular chemical and a particular exposure scenario. Radionuclide action standards were similarly calculated using RESRAD Version 5.62, which uses the USEPA dose conversion factors from the 1995 Health Effects Assessment Summary Tables. For each radionuclide, the target risk is equivalent to a specific radiologic dose to the receptor.

For chemical and radiological constituents, this approach closely parallels that devised in *RAGS Part B - Development of Risk-Based Preliminary Remediation Goals* (EPA 1991), in which soil concentrations equivalent to action standards are back-calculated based on a target risk

level, rather than a forward calculation approach in which measured concentrations in environmental media are used to estimate risk.

The resulting action standards for chemicals and radionuclides in each scenario for 10^{-4}, 10^{-5} and 10^{-6} incremental cancer risk levels and a 1.0 HQ are presented in Section 5. In the event that the calculated action standard is below the site-specific background level for a given contaminant, the action standard is set equal to the site specific background level. Site soil concentration data summaries in each OU, including reasonable maximum exposure (RME) soil concentration calculations, and site-specific background concentrations are presented in Attachments A and B respectively for comparison with the action standards. This information is tabulated in Section 6.

In general, comparison of the action standards to the measured Site soil concentrations indicates that only a few action standards are exceeded in the Ra/Sr treatment system area, the Dog Pens area, and in the Domestic Septic Systems. The number of compounds that exceed the action standards in the Southwest Trenches for 10^{-4} target risk is approximately 1/4 of the number at the 10^{-6} target risk level. A brief comparison of chemical and radionuclide site soil concentrations to risk-based action standards is presented in turn for 10^{-4}, 10^{-5} and 10^{-6} target risk and an HQ of 1.0 as follows:

- At the 10^{-4} target incremental carcinogenic risk level, three non-radionuclide carcinogenic chemicals in the Southwest Trenches (OU1) exceed the action standards determined in this assessment. These chemicals are benzo(a)anthracene, benzo(a)pyrene and carbazole. Lead also exceeds the action standrad. No carcinogenic chemicals in the other DOE Areas exceed the risk-based action standards. The radionuclide radium-226 the Southwest Trenches exceeds the action standards at 10^{-4} target risk. For radium-226, the action standard is set at the site-specific background concentration, because the calculated action standard is less than background.
- At the 10^{-5} target incremental carcinogenic risk level, the action standards for six polynuclear aromatic compounds (PNAs), carbazole, lead and six radionuclides including radium-226 and strontium-90 are exceeded in the Southwest Trenches. In OU2, radium-226 and two PNAs exceed the calculated action standards. Radium-226 in OU3 is above the action standard for 10^{-5} target risk. No radionuclides or carcinogenic chemicals in OU4 are above the calculated action standard. For radium-226, thorium-228, and thorium-232, the action standard is the site-specific background concentration, because the calculated action standard is less than background.
- At the 10^{-6} target carcinogenic risk level, additional carcinogenic chemicals and radionuclides exceed the action standards. In OU1, seven PNAs, six radionuclides including radium-226 and strontium-90, the pesticides chlordane and dieledrin, lead, arochlor 1260, and two semivolatile organic compounds (SVOCs) were above the action standards. In OU2, six PNAs, radium-226 and benzene were above the action standards. Radium-226,

chlordane[1] and alpha BHC were above the action standards in OU3. No compounds were present above the action standard in OU4. For radium-226, thorium-228, and throrium-232, the action standard is the site-specific background concentration, because the calculated action standard is less than background.

- At the 10^{-6} target incremental risk level, estimated single compound radionuclide dose (mrem/yr) ranges from 0.03 mrem/yr for tritium to 4.3 mrem/yr for carbon-14, with all compounds of concern except tritium below 1 mrem/yr. The total dose for each compound differs based on the differing contributions from each exposure pathway, and differing dose conversion factors between toxic endpoints for the same compound. At the 10^{-4} target incremental risk level, the corresponding mrem/yr dose ranges from 3 to 430 mrem/yr. At the 10^{-6} target risk level, the corresponding dose for each radionuclide of concern is well below the 15 mrem/yr limit specified by draft 40 CFR 196 or the 25 mrem/yr limit routinely used as an ARAR at other CERCLA sites.
- Based on a hazard quotient of 1.0, the non-carcinogenic action standards for seven PNAs, five metals including cadmium and mercury, and one SVOC are exceeded in OU1. In OU2 exceeds the action standards. Mercury is above the action standard in OU3. Barium is above the action standard in OU4.

Section 6 provides a complete tabulation of the action standard calculation results, the OU-specific RME soil concentration values, and the site-specific background values, and identifies by OU which COCs exceed the action standards at each target risk level.

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[11] The accuracy of the RME concentration for chlordane in IU3 is in question. The sample holding times were exceeded and the contract laboratory program analytical method for pesticides was not used. However, chlordane was positively identified by the pesticide analysis method used according to the USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review.

2. INTRODUCTION, OBJECTIVES AND GENERAL APPROACH

2.1 Introduction

This report presents the results of risk-based action standard calculations conducted as part of the ongoing CERCLA activities at the former Laboratory for Energy-Related Health Research and the South Campus Disposal Site (SCDC), together referred to as the Site, at the University of California, Davis (UC Davis), California. Action standards apply only to those areas for which the U.S. Department of Energy is taking responsibility, based on the Memorandum of Agreement (MOA) between the DOE and UC Davis (DOE/UC Davis 1997). The areas for which DOE is responsible were summarized in Table 1-1 and are shown in Figure 2-1 (located at the end of Section 2). DOE is not responsible for restoration of surface water and ground water, currently grouped as OU6. However, because OU-6 encompasses media that could result in potentially complete exposure pathways with respect to the DOE Areas, they were included to the extent necessary to do a complete evaluation.

Figure 2-1 shows the general site configuration and identifies the DOE Areas. Locations for each of the exposure scenarios are also shown on this figure. These exposure scenarios are discussed in the next section. Figure 2-2 shows the Site surface water and storm water monitoring locations.

The process and technical details of calculating risk-based action standards were discussed in the following meeting and document:

- Remedial Project Managers (RPM) meeting of Jan 30, 1997 at the Site
- Draft Risk Assessment Protocol, Weiss Associates (WA) March 15, 1997

2.2 Objectives

The overall objective of this evaluation is to determine action standards for contaminated soil in the DOE Operable Units (DOE Areas), for both chemical and radiological constituents of concern (COCs). Action standards for carcinogenic compounds are calculated for the incremental risk range of 10^{-4} to 10^{-6} established in the 40 CFR Section 300.430(e)(i)(A)(2), the National Contingency Plan. Action standards for non-carcinogens are based on a hazard quotient of 1.0.

DOE and the regulatory agencies plan to use the results provided herein to choose appropriate standards to guide removal action(s).

Specifically, this assessment was conducted to determine:

- Background levels for constituents in soil;
- Contaminants of potential concern within each OU;
- The exposure scenarios appropriate for this site;
- Complete exposure pathways to be evaluated in each scenario;
- Appropriate scenario and pathway-specific exposure parameter values;
- The toxicological data necessary to calculate action standards;
- The relationship between contaminant concentrations in soil onsite and soil, air, and ground water concentrations at offsite receptor locations; and,
- Single-constituent action standards for site soil.

2.3 General Approach

The general approach for establishing action standards for site soil is shown in Figure 2-3. First, chemical and radionuclide contaminants of potential concern were identified as those present in DOE OU site soil above site-specific background levels. Next, action standards for these contaminants were calculated using the Argonne National Laboratory computer code RESRAD for radionuclides and a *Risk Assessment Guidance for Superfund (RAGS)*-based approach for chemical constituents. To complete the back calculations, is was necessary to relate DOE OU source area soil concentrations to concentrations in exposure media at the receptor location for each scenario. Fate and transport modeling was conducted to establish these relationships for each COC. For chemical constituents, chemical dose, or intake, was then calculated using the intake equations presented in the *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (Part A)* (EPA 1989a). Incremental human health risk was then estimated using toxicological parameters from the *USEPA Region 9 August 1996 Preliminary Remedial Goals* tabulation and the EPA's *Integrated Risk Information System* online database. The action standard for source soil was then determined by iterative back calculation to determine the source soil concentration that yields the target incremental cancer risk (or target hazard quotient (HQ)) value. The target incremental cancer risk (or target HQ) is a sum of risk (or HQ) across all pathways for a particular chemical and a particular exposure scenario. Radionuclide action standards were similarly calculated using RESRAD Version 5.62, that uses the USEPA dose conversion factors from *the 1995 Health Effects Assessment Summary Tables*. For each radionuclide, the target risk is equivalent to a specific radiologic effective dose to the receptor.

For chemical and radiological constituents, this approach closely parallels that devised in *RAGS Part B - Development of Risk-Based Preliminary Remediation Goals* (EPA 1991), in which soil concentrations equivalent to action standards are back-calculated based on a target risk level, rather than a forward calculation approach in which measured concentrations in environmental media are used to estimate risk.

Three exposure scenarios were selected for evaluation in this assessment. Scenario 1 represents potential onsite workers that may be exposed to source area soil through irradiation

from ground surface or near surface radionuclides, ingestion, inhalation and dermal exposure. Scenario 2, the East Side Residential Farmer, involves potential offsite residential farmers that may be exposed to potentially impacted ground water, potentially impacted surface water (via recreational use), and via irradiation from ground surface radionuclides (for radionuclides only), inhalation of fugitive dust, soil ingestion, and agricultural foods potentially impacted by fugitive dust migration from the onsite source areas. Scenario 3, the South Side Residential Farmer, is identical to Scenario 2 with the exception that exposure to impacted ground water is not included, since ground water flow is generally toward the east, away from this receptor location, and ground water contamination (if any) does not impact Putah Creek. At the request of the regulatory agencies, an onsite residential scenario has also been included, in which the action standards are set equal to those established in the USEPA Region IX August 1996 Preliminary Remediation Goals (PRGs) for chemical constituents and the USEPA Region IX December 1996 PRGs for radionuclides. This latter scenario is included for comparison purposes only; future land use planning by UC Davis does not indicate any possibility of future residential land use at this time. Rather, continued use as a research facility is anticipated for the foreseeable future.

Fate and transport modeling has been conducted to correlate source area soil concentrations to concentrations in exposure media for each scenario (receptor location). The results of the fate and transport modeling are presented here in attachments. Five modeling approaches have been used to determine the ratios between concentrations of contaminants in environmental media at the receptor locations and onsite soil concentration:

- An air particulate emission model coupled with a particulate dispersion model was used to estimate particulate emissions from contaminated onsite surface soil, and estimate their transport to outdoor air (onsite and offsite) and deposition to offsite soil. Offsite contaminated soil concentration was then calculated as a function of on-site surface soil concentration.
- A storm water runoff model was used to determine the contribution to Putah Creek surface water of contaminants in storm water runoff from onsite surface soil in OU1 and OU2 and then discharged into Putah Creek. Based on the design of the surface water drainage system, OU1 and OU2 surface soil is the only surface soil within the DOE Areas that is capable of contacting surface water that discharges to Putah Creek.
- A vadose zone fate and transport model (NUFT) to determine worst case contaminant transport from source area soil to ground water directly beneath the source area, coupled with a two dimensional transport model (SOLUTE 2D) to estimate concentrations at the offsite receptor location for Scenario 2.
- A subsurface diffusion model was applied to indoor and outdoor air box models to determine volatile organic compound (VOC) concentrations in onsite air from source area soil (for volatile compounds in Scenario 1).
- A bioconcentration model for fish media and biouptake models for meat, milk and vegetation media models were used to determine the concentration of contaminants in agricultural food media as a function of source area soil fugitive dust dispersion and deposition.

For chemical contaminants, the fate and transport results were coupled with standard EPA RAGS Part A equations for intake for each pathway of concern, such that the starting soil concentration (or action standard) can be calculated for each target risk or hazard quotient level.

For radionuclides, both the intake calculations and the fate and transport models for the vadose zone, volatilization, and food pathway mechanisms are built directly into the RESRAD code. However, the code can only calculate action standards for receptors that are assumed to be directly at the source location. Therefore, for scenarios 2 and 3, the results of the particulate modeling, the surface water modeling, and the ground water modeling to estimate the ratio between offsite and onsite contaminant concentrations, were used to develop correction factors that are applied to the Scenario 2 and 3 action standards calculated directly by RESRAD. In this way, the resultant final action standard reflects the level at the Site that would result in the offsite action standard calculated by RESRAD. In other words, RESRAD calculated the action standard at the receptor location, and the correction factors were then applied to calculate the corresponding action standard at the Site.

The resulting values represent a single compound action standard, which, if the contaminant were present throughout the horizontal and vertical extent of all DOE Areas, would be theoretically predicted to result in the target risk level at the receptor of concern. It is important to underscore the latter key assumption in the backcalculation approach: this approach assumes that the contaminant is present site-wide, in each OU, at the action standard. This assumption is extremely conservative since none of the contaminants of concern can reasonably be assumed to be homogeneously dispersed throughout the DOE Areas in this manner based on the investigation data available for the site. Therefore, it is not appropriate to use the calculated action standards, in comparison to OU-specific soil concentration data, to make a forward calculation of human health risk at the site. Rather, site data will be compared to action standards in the EE/CA portion of the CERCLA process to determine which contaminants in which DOE Areas may warrant remedial action. The methodology for evaluating post-remedial attainment of the action standards will also be developed during the EE/CA process. A site-wide human health risk evaluation will then be conducted, if necessary, after remedial activities are underway or complete, based on actual data regarding residual contaminant levels and extent within the DOE Areas.

The following sections provide more detailed information regarding the data evaluation, the exposure assessment, and the calculation of action standards.

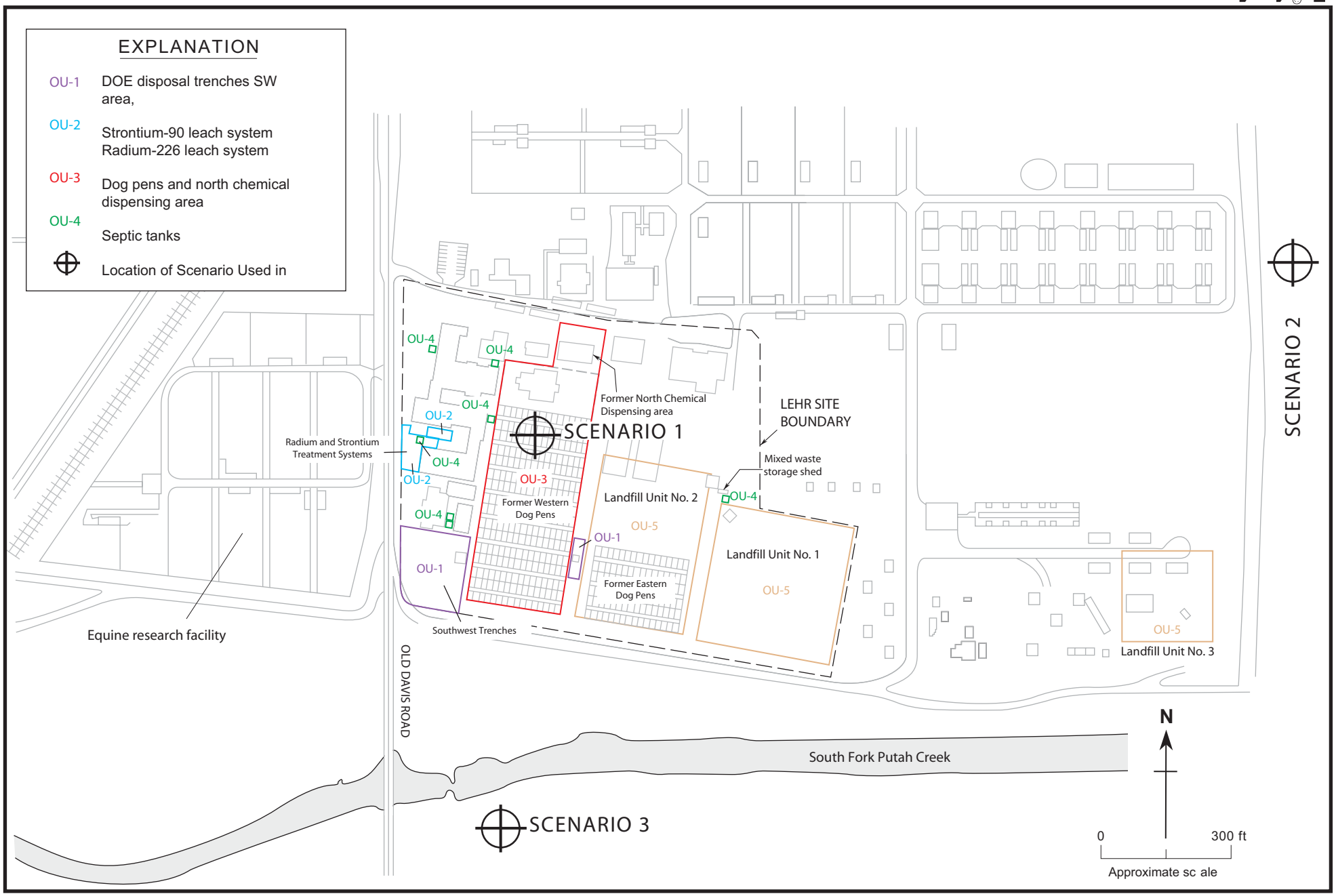


Figure 2-1. Site Map and Exposure Scenarios for Risk -Based Action Level Determination, LEHR Facility, Davis, California.

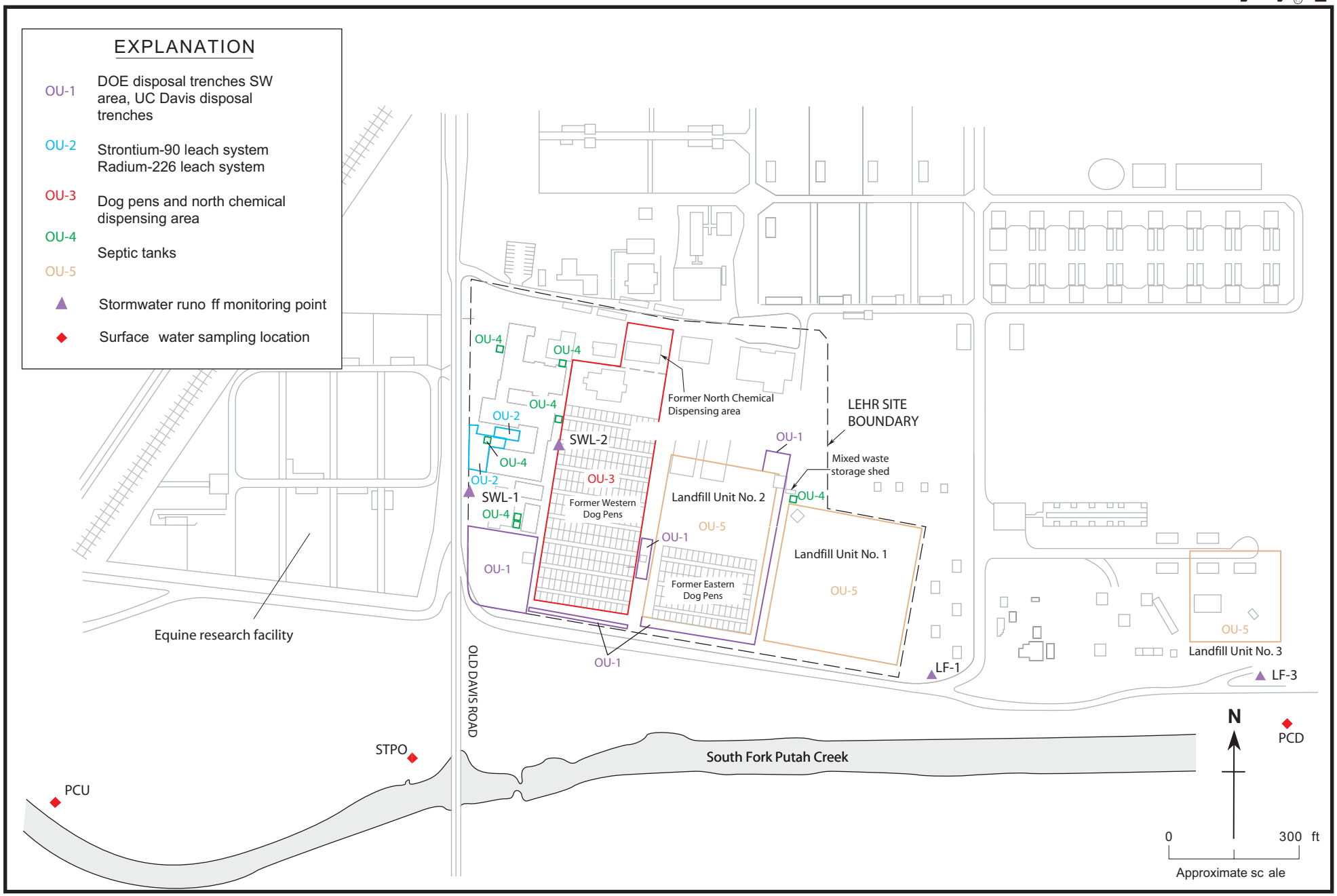


Figure 2-2. LEHR Operable Unit Locations,Storm Water Runoff Monitoring Points and Surface Watering Points, Davis, California

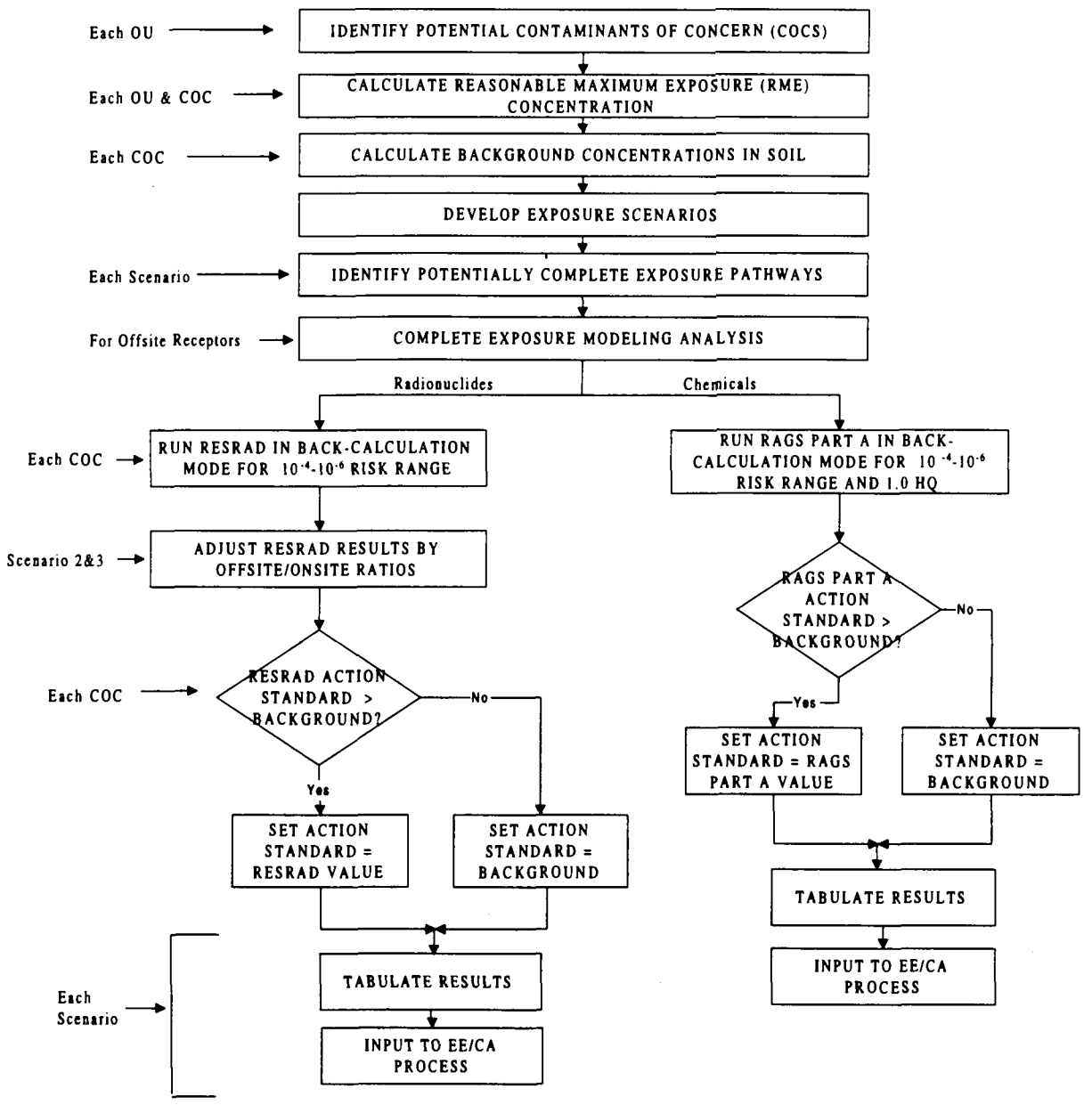


FIGURE 2-3. General Approach to Develop Soil Action Standards for Radionuclides & Chemical Constituents for DOE Areas

3. DATA EVALUATION

The procedures and criteria used to select the chemical data set to be used determine contaminants of concern, establish reasonable maximum exposure concentrations and determine background concentrations are presented in Sections 3.1 through 3.4 below.

3.1 Selection of Chemical Data Set

The data set used in this evaluation consists of all data that were collected and analyzed at the Site by appropriate procedures and methodologies, validated by established EPA data validation procedures, and recorded in the Site database with no substantial errors or omissions. Data collection procedures are outlined in the RI/FS Workplan for Site Environmental Restoration (Dames and Moore, 1994). Sample analysis methodologies are certified procedures as established by the EPA Contract Laboratory Program (CLP). Data validation procedures are from the EPA CLP national functional guidelines for data review outlined in the RI/FS Workplan. Data containing substantial untraceable omissions or errors were removed from the database before proceeding to identify COCs and determine the reasonable maximum exposure (RME) concentration terms.

In general, the data for DOE OU surface and subsurface soil was collected during the 1996 Limited Field Investigation (LFI), the December 1994 soil investigation and 3 surface soil samples collected from OU-1 in June 1995.

Data from the Phase II Site Characterization Report dated, February, 1993, were not used in this assessment for the following reasons:

- The Phase II Data were analyzed by SW 846 analytical methods rather than EPA CLP methods;
- The Phase II Data were not validated using the EPA CLP national functional guidelines for data review; and,
- The Phase II data were not available in electronic form in the Site database.

The following specific data were used for this evaluation:

- OU-1 surface soil: Eight soil samples collected during the LFI between July 23, 1996 and August 2, 1996, and three soil samples collected on June 1, 1995;
- OU-1 subsurface soil: 60 soil samples collected during the LFI, between July 23, 1996, and August 27, 1996;
- OU-2 shallow soil: Four soil samples collected during the LFI, on August 27, 1996;

- OU-2 subsurface soil: 58 soil samples collected during the LFI, between August 6, 1996 and August 21, 1996;
- OU-3 shallow soil: 18 soil samples collected during the December 1994 soil investigation, inclusive dates December 7, 1994 to December 14, 1994. In addition, 15 soil samples collected on July 31, 1996;
- OU-3 subsurface soil: 26 soil samples collected during the December 1994 soil investigation, inclusive dates December 7, 1994 to December 14, 1994;
- OU-4 shallow soil: One soil sample collected on June 9, 1995. Note: OU4 sources are all subsurface so this does not represent a data gap with respect to the risk evaluation;
- OU-4 subsurface soil: seven samples collected during the LFI, between August 16, 1996 and August 19, 1996;
- Surface water: Putah Creek stations PCU, and, PCD and UC Davis Treatment Plant Outfall line (STPO): 26, 25 and 27 quarterly monitoring samples, respectively, collected from each station between November 9, 1990 and May 29, 1996; and
- Storm water runoff sampling locations SWL-1 and SWL-2: Eight water samples collected between November 15, 1994 and March 12, 1996.

3.2 Selection of Potential COCs by Operable Unit and Exposure Pathway

The flowchart for determining potential COCs in site soil and their corresponding concentration terms is shown in Figure 3-1. The assembled database consists of samples from all data collection efforts conforming to the criteria discussed in section 2.1.1 and from all OU locations for which the DOE is responsible. Soil sample data were sorted by OU and chemical. All chemical results with no detections in soil were evaluated through historical records and data from other media to determine whether the compound was likely to be present. If less than ten[2] samples contained detectable concentrations, the maximum detected concentration was selected as the concentration term. Otherwise, the 95% upper confidence limit on the mean was calculated to determine the concentration term, using EPA procedures (EPA, 1992c). A background comparison was conducted to eliminate contaminants present below site-specific background. The remaining concentration terms for soil in each DOE OU were carried forward into the evaluation as COCs.

Some compounds were below laboratory detection limits for all soil samples collected from the DOE Areas. Compounds that were not detected in soil in any of the DOE Areas and were not believed to exist at the Site from historical review of previous site activities were eliminated from the data set and were not included as potential COCs. For radionuclides, the entire data set, including concentrations reported below the sample-specific Minimum Detectable

[2] Sampling data from Superfund sites have shown that data sets with fewer than 10 samples per exposure area provide poor estimates of the mean concentration (EPA, 1992c). Thus, the maximum concentration is selected to represent the data set.

Activity (MDA) was used in calculating the concentration terms, following DOE guidance (DOE, 1991).

Compounds that were detected in soil in any of the DOE Areas were selected as potential COCs in ground water-related pathways. VOCs detected in soil in any of the DOE Areas were selected as COCs in indoor and outdoor air for Scenario 1. VOCs were not considered COCs for Scenarios 2 and 3 (excluding the ground water pathway in Scenario 2) because contaminant transport is through fugitive dust dispersion and deposition. VOCs are not capable of remaining adsorbed to fugitive dust particulates during dispersion and deposition transport process due to rapid volatilizaiton.

All compounds except VOCs detected in soil in the DOE Areas were selected as COCs in fugitive dust emissions and soil deposited after Offsite transport to receptor locations in Scenarios 2 and 3. Non-volatile contaminants present in fugitive dust, and therefore possibly present in offsite soil as a function of deposition, were also selected as COCs in milk, meat and fruit/vegetable media due to possible contaminant uptake for Scenarios 2 and 3.

Figure 3-2 shows the methodology for selecting COCs for surface water-related pathways. Compounds that were detected in both DOE OU soil and storm water runoff were selected as COCs in storm water. The method detection limit (MDL) was compared to EPA fresh water ambient water quality criteria or California Inland Surface Water criteria for compounds that were detected in soil and not detected in storm water run off. If the MDL was above ambient water quality criteria the compound was selected as a potential COC in surface water.

Attachment A contains tables summarizing the data used in this evaluation. Tables 1 through 8 include the results of the identification of chemical and radiological COCs in surface and subsurface soil by OU. Table 9 is a consolidated listing of COCs in site soil. Table 10 is a consolidated list of chemical and radionuclide COCs in surface water, including the ambient water quality criteria and the COC selection criteria. Tables 11 through 14 include a summary of the surface water and storm water sampling data at each location.

3.2.1 Use of Qualified Data

The use of qualified data followed the procedures outlined in RAGS Part A (EPA, 1989). Unqualified and qualified data were used in calculations to determine the concentration term for soil in each DOE OU. Data with R (rejected) or Uz (laboratory contamination) qualifiers were not used. "R" qualifiers are typically applied to data with substantial analytical failures or grossly exceeded holding times. Uz qualifiers indicate potential false-positives. No outlier data were removed.

Chlordane data for 15 samples collected from shallow soil in OU3 were included in the database without validation or proper sample analysis methodology (EPA SW 846 rather than EPA CLP) and exceeding the RI/FS holding time requirements. However, chlordane was detected in all 15 shallow soil samples. According to the EPA CLP National Functional Guidelines for Organic Data Review, a J flag would be applied to these samples if validated. A J flag indicates the compound is present but the analytical accuracy is questionable. The data were

included in the database with a caution that the accuracy of the reasonable maximum exposure (RME) concentration determined from these data may not be accurate.

3.2.2 Evaluation of Tentatively Identified Compounds

The use of tentatively identified compounds (TICs) followed the procedures outlined in RAGS Part A (EPA, 1989). Most of the in soil and water samples at the Site were unidentified hydrocarbons with mass spectra typical of saturated hydrocarbon chains. The dominant ions present indicated the presence of straight chain hydrocarbon structures typical of common fats and oils. No convincingly positive identifications of compounds or classes of compounds of toxicological significance were made. The analytical response of most TICs was near or below the quantitation limit of compound in the target compound list. Saturated hydrocarbon compounds response for a mass spectral detector should not be significantly different than the response to the internal standards used in the EPA CLP methods. The only other TIC consistently found in Site samples was an aldol condensation product which is due to laboratory sample preparation chemicals.

3.2.3 Elimination of Background Metals and Radionuclides

Metal and radionuclide concentration terms for soil in DOE Areas were evaluated against background data on an OU by OU basis. Metals and radionuclides whose concentration terms were above background were carried forward as COCs. All other chemicals detected in soil were carried forward as COCs because no background value was available. Metals and radionuclides whose concentration terms were below background were eliminated as COCs.

3.2.4 No Elimination of Contaminants with Limited Detection

In response to RPMs following review of the Protocol, no chemicals or radionuclides were eliminated based on a limited number of detections. All contaminants positively detected in one or more samples in a specific OU were identified as COCs.

3.3 Establishing RME Concentrations in Soil for Each OU

3.3.1 Definition of Surface vs. Subsurface Soil

Surface and subsurface soil data were divided at a depth of three feet below ground surface (bgs) into two groups. Three ft depth was selected as a reasonable definition of soils that might be disturbed by tilling for rodent control or typical trenching/construction activities. Soil from shallower depths than three feet bgs was classified as surface soil and soil from depths of three feet to the deepest depth explored in each DOE OU was classified as subsurface soil.

3.3.2 Determination of Data Distributions

All data were assumed to be normally distributed for OU soil based on observation of the data set for a limited number of compounds. Due to the relatively large number of compounds present in DOE OU site soil, and in some cases the limited number of samples available, it was not feasible to statistically test each distribution. Typically, however, an assumption of normal versus log-normal distribution results in a conservative (higher) estimate of the 95% UCL on the mean.

3.3.3 Selection of Maximum vs. 95% UCL as RME Concentration

The maximum detected concentration was selected as the RME concentration term for data sets with less than 10 detected data points. The 95% UCL of the mean was calculated to determine the RME concentration term for data sets with 10 or more detected data points. The 95% UCL of the mean was calculated as presented in the *Supplemental Guidance to RAGS: Calculating the Concentration Term* (EPA, 1992) using the equation presented in Highlight 6 for normally distributed data.

3.3.4 Handling Data Below the Detection Limit in Statistical Calculations

For chemical constituents, only positively detected sample results were used in the 95% UCL calculations, biasing the 95% UCL values positively due to truncating the chemical data sets in this manner. The bias is towards larger positive values making the 95% UCL a more conservative estimate of the mean. Other techniques such as replacing the non-detect results with values equal to one-half the detection limit result in less conservative estimates of the mean. In other words, the resulting RME values are higher that they would have been if non-detects were included in the data set for calculation.

All radiological results were used in 95% UCL calculations including negative values, zero values and results below the MDA. All radiological data were used to avoid bias in the 95% UCL value (Gilbert, 1987, DOE, 1991).

3.4 Determination of Background Concentrations

3.4.1 Background Data Sets

In 1995, a background investigation was conducted involving the collection of 26 background samples at depths of 0, 4, 19, and 39 ft bgs at six locations outside, but within one-half mile, of the Site. The samples were analyzed for radionuclides, metals, and inorganic compounds (e.g., salts), and were validated. Attachment B presents the background range of values for metals and radionuclides obtained from this study.

For purposes of this evaluation, the sample set consisting of 26 discrete samples from the 1995 investigation has been used to calculate background concentrations for inorganic and radionuclide constituents. Support for the selection of the background data set for this analysis has been previously submitted to the RPMs, as requested. No comments on the background submittal have been received from the RPMs as of the date of publication of this document; therefore, concurrence with the background data set selection has been assumed.

3.4.2 Calculation Method

The 80% lower confidence limit on the 95th quantile of background soil sample data was selected to represent background, as agreed with the RPMs and based on their comments on the Protocol. The complete calculation methodology and results are included in Attachment B.

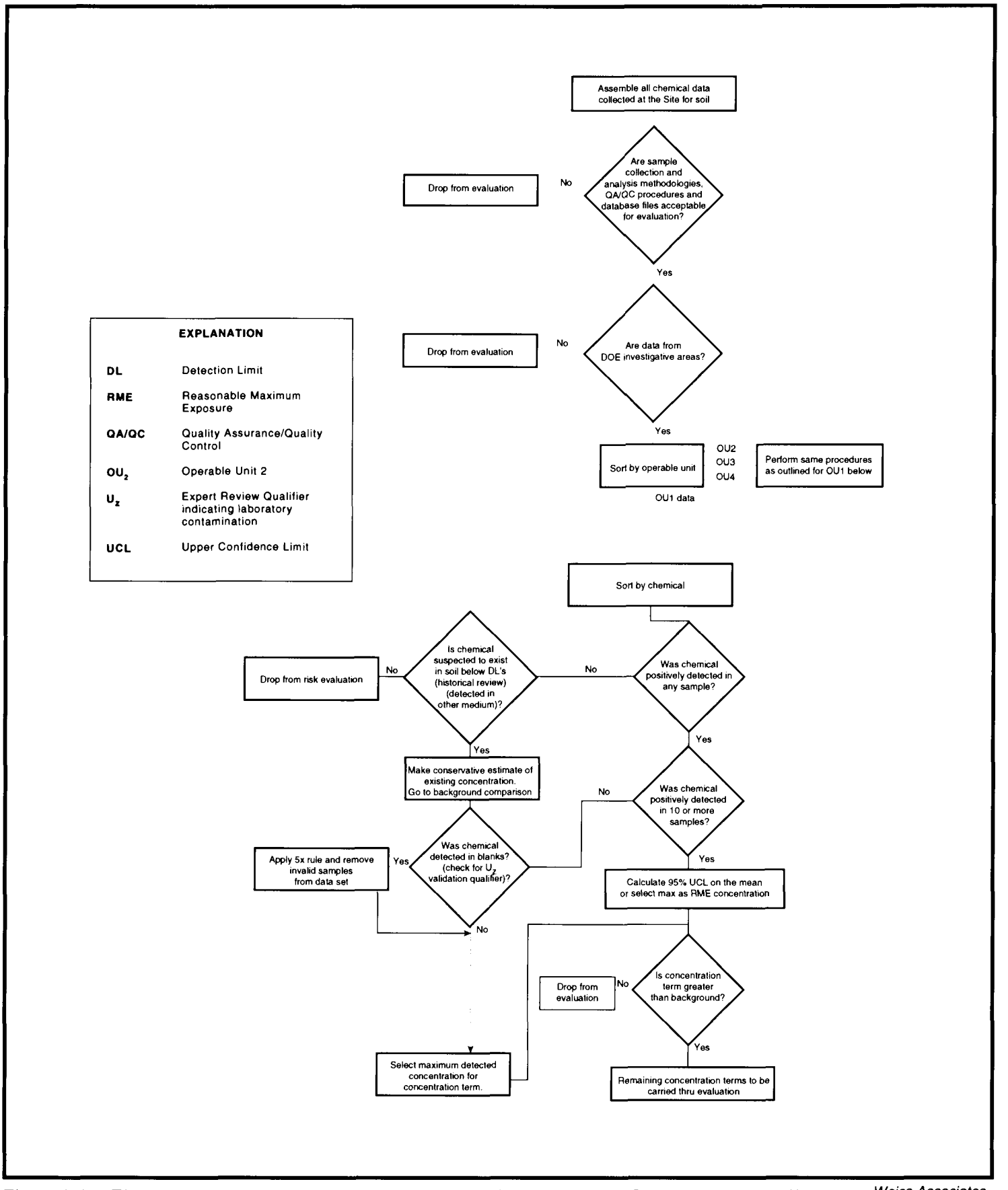
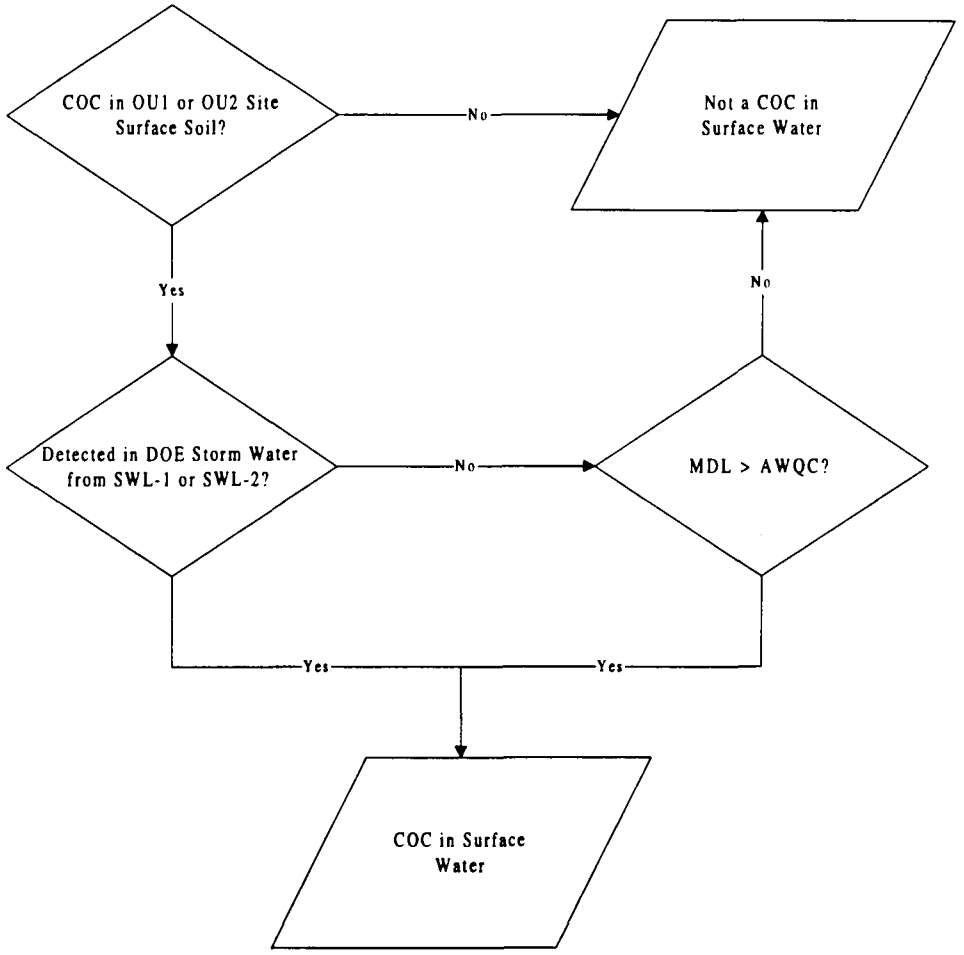


Figure 3-1. Flowchart for Determining the Reasonable Maximum Exposure Concentration in soil.

Weiss Associates



MDL = Method Detection Limit
COC = Contaminant of Concern
AWQC = Ambient Water Quality Criteria (instantaneous or one hour average limits) from US Federal AWQC for the Protection of Aquatic Life, or California SWRCB Numerical Water Quality Objectives for Inland Surface Water.

Figure 3-2. Flowchart for Identifying DOE Area-derived COCs in Surface Water.

J:\DOE\4000\A1C\PROTOCOLS\DRAWINGS\FIG3_2.VSD 06/10/97

4. EXPOSURE ASSESSMENT

This exposure assessment contains qualitative evaluations to identify exposure pathways and scenarios and quantitative determinations to relate onsite COC concentrations in soil to concentrations in exposure media. The Site physical setting is described in Section 4.1 to orient the reader to the site and surrounding area. The exposure scenarios are presented in Section 4.2 followed by the exposure pathway analysis in Section 4.3. The physical fate and transport models that were used to determine the relationship between COCs in soil in DOE Areas and exposure media in each scenario are described in Section 4.4. Finally, the intake calculations, exposure parameters, toxicological parameters and physical constants used to calculate risk are presented in Sections 4.5 and 4.6.

4.1 Physical Setting

The Site is located in a rural area in the Sacramento Valley. The land within a one-mile radius of the site is owned both privately and by UC Davis, and is used for animal research, agriculture, and recreation. Immediately adjacent to the Site to the east and west are UC Davis-owned research facilities. Privately-owned lands within one mile to the south and east of the site include permanent residences and support some crops. Approximately 75 percent of the surrounding land in the general vicinity of the Site is used for agriculture. Major crops include fruits, nuts, and grains. Approximately 40 percent of the agricultural land in the Site vicinity is irrigated, and some of the nearby lands are used for cattle grazing (DOE, 1988).

Climate - The climate is temperate with mild winters and warm summers. The mean winter and summer temperatures are 46.9 degrees Fahrenheit (°F) and 73.0 °F respectively. The average daily minimum in winter is 37.6 °F and the average daily maximum in summer is 92.3 °F (NOAA, 1985; DOE, 1988). The mean annual precipitation at the Davis 2 WSW station located northwest of the Site was 17.0 inches based on data collected between 1908 and 1990 (National Climactic Data Center).

Meteorology - The dominant wind direction is from the south with most wind directions along a south - north axis. Winds from the north are almost as common as winds from the south, with the 180-degree change a result of seasonal variation. Northeast and southeast wind directions also occur. Most wind speeds are in the 1 to 3 mile per hour (mph) and 4 to 7 mph ranges (PNNL, 1996).

Geologic Setting - Sediments below the Site and vicinity consist primarily of silt and clay with localized interfingered coarse grained sediments to a depth of approximately 180 ft bgs (Weiss Associates, 1996). The depths and major types of sedimentary units encountered below the site are:

- 0 to 80 feet bgs: Interbedded silt, clay and sand with some sand and gravel channel deposits;
- 80 to 135 feet bgs: Cobbles and gravels; and,
- 135 to 143 feet bgs: Clay with some silt.

Ground Water Hydrology - Ground water generally flows from the Sacramento Valley sides towards the valley axis. In the vicinity of the Site, regional ground water generally flows east from the Coast Ranges towards the Sacramento River (Dames & Moore, 1990).

At various depths beneath the valley floor, fresh water gives way to saline water entrapped during the deposition of sediments in a marine environment. The depth to the base of fresh water in the Sacramento Valley varies from 400 ft to over 3,000 ft, and is 2,600 to 3,100 ft bgs at Davis (California Department of Oil & Gas, 1982).

The uppermost aquifer beneath the Site has been divided into two hydrostratigraphic units (HSUs), based on the stratigraphy of the sediments at the site, and the associated ground water flow and contaminant migration characteristics. HSU-1 consists predominantly of fine-grained sediments and extends from the water table down to approximately 80 ft bgs. HSU-2 consists of cobbles and gravel and extends from 80 to 135 ft bgs. Well drillers' logs indicate that a 90-foot-thick clay unit separates HSU-2 from a second aquifer (or third HSU) below (Dames & Moore, 1994).

Ground water levels in 1996 varied from approximately 28 ft bgs in winter to 48 ft bgs in summer. Generally, there is a 20- to 30-foot seasonal fluctuation in the depth-to-ground water beneath the Site caused predominantly by the net agricultural extraction in the summer.

The lateral gradient into HSU-1 across the Site varies from approximately 0.0001 to 0.0015 ft/ft, and is predominantly northeast. The lateral gradient across the site within HSU-2 typically ranges from 0.0004 ft/ft to 0.0015 ft/ft and is predominantly northeast, although it can occasionally be east-southeast. Vertical groundwater gradients have been observed to vary from an upward gradient of 0.075 ft/ft to a downward gradient of 0.01 ft/ft (at different locations at the Site) (as reported in WA 1996 Site Characterization Report). Vertical gradients vary both temporally and spatially. The magnitude of the vertical gradient is greatest when ground water elevations are rising or falling sharply. Short term activities such as local agricultural pumping can produce downward vertical gradients during periods of an otherwise rising water table.

Surface Water - The east-flowing South Fork of the Putah Creek borders the southern portion of the Site and is separated from the site by the north levee of the creek. In 1948, the U.S. Army Corps of Engineers modified the South Fork and dammed the North Fork, so that all water in Putah Creek now flows in the South Fork. Putah Creek is a "losing" stream in the Site vicinity. Therefore, Putah Creek water may impact shallow ground water beneath the site, but not vice-versa. (DOE, 1996).

Flow in the South Fork of Putah Creek is regulated by releases from Monticello Dam at Lake Berryessa and from the Putah Diversion Dam, located about 18 and 14 miles west of the Site, respectively. Based on data from 1980 through 1991, flows several miles upstream from the Site typically range from 0.1 cubic ft per second (cfs) to about 3 cfs, although flows as high as 15,500 cfs in March 1983 have been reported (Dames & Moore, 1994). In the reach bordering

the Site, flow in the South Fork of Putah Creek is supplemented by discharge from the UC Davis Wastewater Treatment Plant. Based on data from the gauge near Old Davis Road, flow rates for the reach bordering the Site ranged from 0.17 to 148 cfs from 1989 to 1993. Flows have not changed substantially since 1993 (personal communication, 1996, Roland Sanford, Solano County Water Resources Agency). Data from the Putah Creek gauging station for 1994 and 1995 obtained from the Water Resources Agency were used in the evaluation of potential risks via surface-water related pathways.

As shown on federal flood maps, the 100-year flood is confined within the Putah Creek levees south of the Site. The Site lies in the Federal Emergency Management Administration (FEMA) Zone C, the area expected to experience minimal flooding.

4.2 Exposure Scenarios

Three scenarios were selected for evaluation in this assessment. The locations of receptors for these three scenarios is shown in Figure 2-1. These scenarios, as discussed in the September 1996 RPM meeting at the Site, at the January 1997 RPM meeting, and in the Protocol, are:

- Scenario 1, the Onsite Researcher. This scenario represents potential onsite workers that may be exposed to contaminants in source area soil through external radiation (for radionuclides only), ingestion, inhalation and dermal exposure.
- Scenario 2, the East Side Residential Farmer. This scenario assumes a residential farm is located immediately east of the UC Davis property boundary. This location represents the nearest reasonable downgradient (with respect to ground water) location for an offsite receptor. The exposure evaluation involves potential offsite residential farmers that may be exposed to 1) potentially impacted ground water, 2) potentially impacted surface water (via recreational use), 3) potential external radiation (for radionuclides only), 4) inhalation of potentially impacted fugitive dust, 5) ingestion of potentially impacted soil, and 6) agricultural foods potentially impacted by fugitive dust migration from the onsite source areas.
- Scenario 3, the South Side Residential Farmer. This scenario assumes a residential farm is located immediately south of the UC Davis property boundary and Putah Creek. This location represents the nearest reasonable downwind location for an offsite receptor. The exposure analysis is similar to Scenario 2 except that exposure to impacted ground water is not included, since ground water flow is generally toward the east, away from this receptor location, and Putah Creek is a losing stream, meaning that ground water does not recharge the creek.

Based on RPM comments on the Draft Protocol (Weiss Associates, 1997), an onsite residential scenario has also been included, in which the action standards were set equal to those established in the EPA Region IX August 1996 Preliminary Remediation Goals (PRGs) for chemical constituents, and the EPA Region IX December 1996 PRGs for radionuclides. This

latter scenario is included for comparison purposes only; future land use planning by the UC Davis does not indicate any possibility of future residential land use at this time. Rather, continued use as a research facility is anticipated for the foreseeable future. [reference to come]

4.3 Exposure Pathway Analysis

Figures 4-1, 4-2 and 4-3 show the exposure pathways that were identified as potentially complete for Scenarios 1, 2, and 3, respectively, along with the rationale for inclusion or exclusion of each possible pathway, or contaminant group within a pathway. It is important to note that certain exposure pathways are not complete for every potential COC.

In developing the exposure pathway analysis, careful consideration was given to RPM comments on the Protocol with respect to inclusion or exclusion of the surface water-related pathways. Section 2 discussed the selection of COCs for surface water pathways, and the list of surface water COCs and the rationale for inclusion or exclusion of each is included in Tables 10a and 10b in Attachment A. Significant uncertainty, as discussed in Section 5, is associated with the surface water-related pathways. Specifically, only a small portion of OU1 and some portions of OU2 surface soil comprise the source term for storm water runoff from the site. The drainage area that sheds runoff to Putah Creek does, however, encompass a number of paved parking areas and buildings. Review of the data indicates that, for some constituents (specifically including lead), the presence of contaminants in storm water as indicated by analytical results from SWL-1 and SWL-2 may not be indicative of the presence of these contaminants in OU surface soil. Specifically, the concentration of lead in OU2 surface soils does not exceed the site-specific background concentration, indicating that concentrations expected in runoff from OU2 would not be expected to be elevated. In OU1, lead is present in surface soils at about two times the background level. However, review of the site drainage map included in Attachment E shows that only a small portion of OU1 surface soils actually contribute runoff that flows to Putah Creek. The rest ponds and infiltrates. Therefore, it is probable that another source of lead exists to account for the concentration in lead in the surface water runoff from these areas.

4.4 Determination of Relationships Between On-Site Soil and Receptor Location Exposure Concentrations

Onsite soil is the medium of concern for the DOE Areas, and as such represents the source term for every exposure pathway. Fate and transport modeling has been conducted to correlate source area soil concentrations to concentrations in exposure media at the receptor location for each scenario. The correlation is carried into the action standard calculation as a ratio of exposure media concentration at the receptor location to source soil concentration.

Each fate and transport modeling technique is briefly described below. Detailed descriptions of the approaches and modeling outputs are presented in Attachments C, D, E, F and G.

4.4.1 Chemical Constituents

4.4.1.1 Air Pathway – On-Site Outdoor Air Models for Volatile Organic Compounds

Transport of contaminants through site soil, followed by flux from the ground surface into ambient air, is a mechanism by which onsite inhalation exposure to volatile contaminants may occur in Scenario 1. A simple one-dimensional diffusive vapor transport model was used to determine vapor flux from soil to the ground surface using the equations presented in the Air/Superfund National Technical Guidance Series (EPA, 1992). Concentrations of VOCs in outdoor air were determined by applying outdoor air box models to the vapor flux rate. In a box model, contaminants fluxing from the subsurface are assumed to mix within a "box" defined by the physical limits of the DOE Areas and a height set at 1.6 meters (a typical person's height), with air inflow/outflow from the box determined as a function of average wind speed at the site.

Outdoor air models were run for a subset of the VOCs detected in soil based on the ratio of Henry's Law constant (H) and the soil/water partition coefficient (K_d). To limit the number of modeling runs required and provide worst case (most conservative) estimates of air exposure media concentrations. The H/K_d ratio is the driving parameter that defines the diffusive vapor transport equation. Physical parameters for the most conservative (largest) H/K_d compound were used to calculate diffusive transport for all compounds within the same H/K_d order of magnitude.

The results of the modeling were then expressed as a ratio of the contaminant concentration in air to a unit concentration in source area soil, for use in the intake equations that form the basis for backcalculation of action standards.

This approach was applied to Scenario 1 only. VOCs were assumed to volatilize from airborne fugitive dust before depositing in the vicinity of Scenarios 2 and 3. Thus, the exposure pathway for VOCs in Scenarios 2 and 3 was assumed to be incomplete. The equations, indoor and outdoor air conceptual models, and modeling results are presented in Attachment C.

4.4.1.2 Air Pathway – On-Site Particulate Loading and Offsite Particulate Dispersion and Deposition Model

Transport of particulates via the air pathway represents the mechanism by which contaminants may be present in onsite air, and at Offsite receptor locations in air and surface soil. A fate and transport analysis was conducted to determine the ratio of exposure point concentrations of contaminants to concentrations in onsite soil. Specifically, fate and transport analysis was used to determine:

- Particulate resuspension rate, or the concentration of contaminants in onsite air (particulate loading) as a function of fugitive dust emissions (wind erosion) from onsite soil. The result is the onsite particulate loading (in mg/m^3) per mg/kg in site soil, to be used in the Scenario 1 air pathway intake calculations for non-volatile contaminants;
- The concentration of particulates in offsite air (particulate loading) as a function of fugitive dust emissions from onsite soil, to be used in the

Scenario 2 and 3 air pathway intake calculations for non-volatile contaminants; and,

- The concentration of contaminants in offsite surface soil as a function of fugitive dust emissions from onsite soil by depositing at the offsite receptor location. The results are expressed as mg contaminant/kg in offsite soil per mg/kg in onsite soil, and are used in the Scenario 2 and 3 intake calculations for offsite soil ingestion, dermal exposure, and food chain pathways (milk/meat/plant uptake).

EPA recommended or approved models as described in Attachment D were used in each step of this process. Site-specific data were used wherever possible, including meteorological conditions and surface conditions. Attachment D provides the methodology, calculations, and results.

4.4.1.3 Surface Water Pathways – The Storm Water Runoff Model

Transport of contaminants from site surface soil into storm water runoff described in Attachment E the mechanism by which site soil contaminants could reach Putah Creek. A storm water runoff model (see Attachment E) was used to calculate the contaminant contribution to Putah Creek from surface soil in DOE Areas. Specifically, fate and transport analysis, coupled with site analytical data for surface soil and storm water and flow data from Putah Creek, were used to:

- Establish the relationship between storm water contaminant concentrations and site soil contaminant concentrations, using analytical data from both media;
- Estimate the storm water runoff flow rate using the site drainage area map, storm event data collected at the Davis 2 WSW Experimental Farm Station for the years 1994 and 1995, and the storm water runoff model described in the Superfund Exposure Assessment Manual (EPA 1988); and,
- Determine a dilution factor by which storm water concentrations are diluted upon reaching Putah Creek, using the storm water runoff estimate above coupled with actual 1994 and 1995 stream flow data from the Putah Creek gauging station.

The ratio of the concentration in storm water to the onsite surface soil concentration was determined from site data in those media. The concentration contributed to Putah Creek was calculated from the storm water flow rate, concentration in storm water, and the Putah Creek flow rate. Flow in Putah Creek was determined from 1994 and 1995 creek gauging data at the Old Davis Road Station. These data were used together to estimate the ratio between contaminant concentrations in Putah Creek surface water and contaminant concentrations in site surface soil. This ratio was then used in the intake calculations that form the basis for the action standard backcalculation. The storm water model equations, input data and results are presented in detail in Attachment E.

4.4.1.4 Ground Water Pathway – Vadose Zone and Ground Water Fate and Transport Models

Transport of contaminants through the unsaturated (vadose) zone to the underlying ground water table the mechanism by which contaminants present in site soil could enter the ground water pathways. Once contaminants have reached the ground water directly beneath the site, they may be transported in the saturated zone to the receptor location in Scenario 2. Specifically, fate and transport analysis was used to predict:

- The maximum concentration of contaminants in ground water directly beneath a source at any time in the future, as a function of site soil concentration. For chemical constituents, the Nonisothermal Unsaturated-Saturated Flow and Transport (NUFT) model (Nitao, 1996) was used with worst-case site-specific data to evaluate transport from the vadose zone to ground water. In every case, contaminants were conservatively assumed to be homogeneously present throughout each OU, to a depth of 15 ft bgs. All organic chemicals detected in soil in the DOE Areas were simulated by NUFT to estimate concentration in ground water as a function of time at the water table. The worst case concentration at any future time was then expressed as ug/l in the ground water per mg/kg in the site soil. NUFT modeling for organic chemicals included loss via volatilization during transport, and therefore used chemical-specific Henry's law constants and Kd values. NUFT modeling for metals was based solely on the soil/water partition coefficient, K_d and not on Henry's constant because metals are typically considered nonvolatile. To limit the number of required runs, metal COCs were grouped by similar K_d, and the worst-case (most conservative) K_d value was assigned to the entire group, providing overly conservative results for some metals. Conservatively, no degradation was assumed for either organics or metals.
- The ratio of contaminant concentration in ground water at the offsite, Scenario 2 receptor location to the onsite concentration in ground water beneath the source was determined using the fate and transport model Solute 3.01 (Colorado School of Mines). No degradation was assumed to occur within the contaminant plume during transport. The result of this modeling calculation was that the offsite ground water concentration is estimated to be 0.19 times the onsite concentration in ground water. Alternatively, the offsite to onsite ratio is 1/5.

The results of the NUFT and Solute 3.01 simulations were combined to determine the concentration ratio between offsite ground water (in the vicinity of Scenario 2) and onsite soil, for use in the chemical intake calculations that form the basis for the action standard back-calculation. It is important to note that the ratio chosen for chemical constituents was the worst case ratio at any time (1,000's to 1,000,000's of years) in the future. Because of this conservative assumption, the action standard calculations for chemicals in Scenario 2 combine maximum ground water exposure (many thousands of years in the future) with exposure risks from other pathways that are predicted to be at a maximum now.

A detailed description of these models is presented in Attachment F. As requested by the RPMs in their review of the Protocol, the contaminant-specific results showing the estimated concentration in onsite ground water as a function of site soil concentration, are shown for each contaminant.

4.4.1.5 Biological Media Models

Offsite transport of onsite contaminants present in site surface soil, via either particulate resuspension and offsite deposition or via storm water runoff to Putah Creek, represents the mechanism by which onsite contaminants are available for uptake in offsite food chain exposure pathways. Biological media calculations were used to determine the ratio of contaminant concentrations in offsite biological media (milk, meat, fish and vegetation) to onsite soil concentrations. Offsite media were assumed to uptake COCs from onsite soil through contact with contaminated particulate matter suspended in air and deposited in soil from the DOE Areas. For the surface water pathways, uptake from impacted Putah Creek surface water forms the basis of intake by human receptors. The concentration in offsite air, soil, or surface water was multiplied by the appropriate biological partition coefficient, uptake coefficient or bioconcentration factor to determine the concentration in the biological media as a function of initial onsite soil concentration. A detailed description of the equations and parameters used and the results of these calculations are presented in Attachment G.

4.4.2 Radionuclides

4.4.2.1 RESRAD

RESRAD was run for each individual radionuclide and each exposure scenario. Like the analysis for chemicals, RESRAD was run using an iterative approach in which the input concentration in soil is varied until the total output risk across all pathways is equal to the target risk (10^{-4}, 10^{-5}, or 10^{-6}).

The derivation of action standards for radionuclide concentrations in soil using RESRAD is based, according to the RESRAD Manual (ANL, 1993), on a pathway analysis method known as the concentration factor method. In the concentration factor method, the relationship between radionuclide concentrations in soil and the dose (or risk) to an exposed individual is expressed as a sum of the products of "pathway factors." Pathway factors correspond to pathway segments connecting exposure routes through which radionuclides can be transported or radiation transmitted. RESRAD automatically accounts for radionuclide decay and daughter products, and their transfer (if any) amongst the pathways selected for inclusion in the analysis. Some environmental media partitioning (equivalent to fate and transport described above), all intake (dose) calculations, and all risk calculations are built directly into RESRAD.

Specifically, the fate and transport models for the vadose zone, volatilization, and food pathway mechanisms are built directly into the RESRAD code. However, the code can only calculate action standards for receptors that are located at the contaminant source. Therefore, for offsite Scenarios 2 and 3, the results of the particulate modeling, surface water modeling, and ground water modeling have been used to develop correction factors that are applied to the Scenario 2 and 3 action standards calculated directly by RESRAD. The correction factors are

expressed as a x/Q value, or a ratio between the offsite concentration in the exposure media of concern (x) and the onsite soil concentration term (Q). The resultant final action standard reflects the radiological activity in soil at the Site that would result in the target risk (10^{-4}, 10^{-5}, 10^{-6}) for receptors located offsite in Scenarios 2 and 3. This is discussed below, and in Section 5.2.

4.4.2.2 Surface Water Pathways

In RESRAD, contaminants are assumed to reach surface water in a three step process: 1) transport of contaminants in soil through the vadose zone to ground water beneath the site; 2) transport in ground water to the surface water (in other words, ground water is postulated to impact surface water via saturated zone transport); and 3) dilution in surface water as a function of the watershed area. At the Site, the hydrologic conditions specific to the Site drive our site conceptual model. At the Site, Putah Creek is known to be a losing stream; i.e., the ground water does not influence the surface water in the stream. Secondly, ground water is known to flow to the northeast, away from Putah Creek. Therefore, RESRAD's surface water algorithm cannot support the site conceptual model. For this reason, the surface water pathways were "turned off" in RESRAD for all of the scenarios. Instead, as described in section 5.2, once the action standard was established for a given radionuclide based on the other complete exposure pathways, radionuclide risk via the surface water pathways was evaluated using the action standard as the starting concentration in soil. Conceptually, if the resulting risk is insignificant (1% or less of the target risk level), it can be shown that the surface water pathways do not influence the action standard. Otherwise, the action standard was adjusted (downward) to ensure the total risk, including the surface water pathways, was equal to the target risk.

4.4.2.3 Inhalation and Soil Pathways – Relationship Between On-Site and Off-Site Concentrations

In RESRAD, the calculated soil action standard represents the soil concentration at the receptor location that could result in the target risk (or dose) specified. As such, the Scenario 2 and 3 results taken directly from RESRAD represent the action standard *at the receptor location.* However, the result desired from this analysis is the action standard at the Site. Therefore, the relationship between onsite and offsite concentration must be accounted for.

Inhalation risk is a function of the particulate loading at the receptor. For Scenario 1, the particulate loading input to RESRAD was the particulate loading value (in ug/m^3 or equivalent g/m^3) calculated by the particulate modeling for the Site. For Scenarios 2 and 3, to accurately reflect the fact that contaminant loading of particulates at the receptor location is a function of contaminated particulates transported from the Site, the offsite particulate loading estimated by the particulate fate and transport analysis was used as input to RESRAD for these scenarios.

Similarly, for Scenarios 2 and 3, offsite soil concentrations are a function of transport from onsite contaminated soil. Contaminated soil also drives the external radiation and food chain intake pathways in RESRAD. As described above, particulate transport modeling has been used to estimate the ratio between offsite onsite soil concentrations. RESRAD is not, however, able to account for this ratio within the model, as it is designed only to calculate action standards at the receptor location. Therefore, where the soil-dependent pathways drive the risk, and therefore the action standard, for radionuclides in Scenarios 2 and 3, a correction factor has been applied to the receptor location action standard such that the final action standard represents the

value in Site soil. The correction factor is the ratio between offsite soil concentration and Site onsite soil concentration. This correction is described again in Section 5.2.

4.4.2.4 Ground Water Pathways

Ground water dependent pathways are complete only for Scenario 2, the East Side Residential Farmer scenario. As described above, contaminant transport is a two step process from the site soil to the receptor location: first, transport from soil through the vadose zone to the ground water table, and second, transport in the saturated zone to the receptor location. RESRAD handles the first step integrally to the model, as described in Attachment E of the RESRAD Manual (ANL, 1993). Radionuclide concentrations in ground water at the site are calculated as a function of time from time zero; the concentration at the time of maximum dose is the concentration applied in the calculation of the soil action standard at the receptor location. In evaluating the ground water pathways for Scenario 2, conservative, Site-specific inputs have been assumed to apply at the offsite location.

As with the soil related pathways, the action standard calculated by RESRAD is *at the receptor location*. Therefore, where the ground water dependent pathways drive the risk, and therefore the action standard for radionuclides in Scenario 2, a correction factor has been applied to the receptor location action standard such that the final action standard for Scenario 2 represents the value in Site soil. The correction factor is the ratio between offsite and onsite ground water concentration. As described above, that value is 1/5. This correction is described again in Section 5.2.

4.5 Intake Calculations and Exposure Parameter Values

4.5.1 Intake calculations

For chemical contaminants, intake, or exposure dose in mg/kg-day, has been calculated for each complete exposure pathway/contaminant pair as a function of the initial onsite soil concentration, using the relationships established in the fate and transport analysis described above. Intake equations for each exposure pathway are the standard equations taken directly from RAGs Part A for chemical contaminants. Intake calculations are included in Attachment I, which shows example supporting calculations for the risk-based action standard determination for each exposure scenario evaluated.

For radionuclides, the RESRAD model has the intake equations for each exposure pathway built directly into the model. Radionuclide intake is expressed in mrem/yr. The RESRAD Guidance Manual (ANL, 1993) contains a complete description of the exposure pathway intake calculations and assumptions.

4.5 2 Exposure Parameter Values

A compilation of the key exposure (intake) parameters that were used for each scenario has been included in Attachments I and J. In general, site-specific values were used whenever available. Site specific parameters are shown in the Attachments to the extent they were established. In general, EPA default values were used for intake and exposure-related parameters. These values were compiled from EPA Region IX PRG guidance, CAL-DTSC Preliminary Endangerment Assessment Guidance (California EPA, 1994), and RAGs (EPA, 1989) and its supplemental guidance documents (EPA, 1991).

To the extent that RESRAD uses equivalent parameters, but with different units, these values were used in RESRAD also. RESRAD also requires a number of additional exposure-related parameters, which were set at RESRAD default values whenever site specific data were not available. The additional exposure parameters used in RESRAD are summarized in Attachment J.

4.6 Toxicological and Physical Constant Data

4.6.1 Chemical Constituents

Toxicological data for COCs were taken from EPA Region 9's most current (August 1996) *Preliminary Remediation Goals (PRGs)*, IRIS online and the California EPA Initial Statement of Reasons For Rulemaking (CalEPA, 1997). The toxicological data contained in the PRGs reflects the most current reference doses (RfDs) and cancer slope factors (CSFs) available from IRIS through July 1996, HEAST through May 1995, and the EPA's National Center for Environmental Assessment (NCEA). Where appropriate, the toxicological data used in this assessment reflect the "CAL-modified" values included in the PRG tables, taken from the most recent CAL-EPA Office of Environmental Health Hazard Assessment *California Cancer Potency Factors: Update* (1995).

Toxicological data were unavailable for delta BHC, endosulfan sulfate, phenanthrene, 2-hexanone and 2-methylnaphthalene. The alpha BHC oral and inhalation cancer slope factors were used for delta BHC due to chemical structure similarity. Endosulfan RfD values were used for endosulfan sulfate for the same reason. Pyrene RfD values were used for phenanthrene due to their chemical similarity as polynuclear aromatic hydrocarbons. Toxicological inferences were not made for 2-hexanone and 2-methylnaphthalene due to the lack of toxicological information available for chemicals of similar structure.

The slope factor for lead was selected from the California EPA Initial Statement of Reasons For Rulemaking (CalEPA, 1997) and is based on the risk of cardiovascular deaths for adults ages 40 to 59. The cardiovascular slope factor for lead was selected instead of the carcinogenic slope factor due to the greater risk of cardiovascular death.

The sources of chemical-specific physical constant data are presented in the Attachments as they were used for each physical model.

4.6.2 Radionuclides

Toxicological and physical constant data for COCs were taken from the database included with the most recent version of RESRAD (V5.62). These data reflect the most current EPA dose conversion factors. Physical constant data were taken from RESRAD v5.62 data tables. The risk per mrem/yr conversion assumed was consistent with current EPA dose conversion factors and slope factors for radiation intake.

Figure 4-1. Exposure Pathways Analysis
Scenario #1: Onsite Researcher

Source	Transport Mechanism	Exposure Route	Pathway Complete?	Rationale
Soil Contamination	Direct Contact	Dermal Exposure	Yes	Assumed dermal exposure to soil.
		Direct Ingestion	Yes	Assumed direct ingestion of soil.
	Saturated/ Unsaturated Zone via diffusion, advection, etc.	Ground Water Ingestion	No	Assumed workers do not ingest water from impacted wells (municipal drinking water supply, no onsite wells).
	Subsurface Diffusion/Volatilization	Inhalation of VOCs	Yes	Assumed volatilization of subsurface volatiles to outdoor air. Complete only for VOCs.
	Volatilization, and particulate dispension in air	Inhalation of Particulates	Yes	Assumed inhalation of particulates. Complete for SVOCs, metals, radionuclides.
		Deposition with Dermal Exposure/Direct Ingestion	No	Evaluated under direct contact above.
		Deposition with Impacted Food Ingestion.	No	Assumed workers do not ingest food obtained through farming activities at the site.
	Precipitaion and Surface Water Runoff	Ingestion Via Surface Water	No	Assumed workers do not ingest water from Putah Creek or onsite ponded storm water.
		Dermal Exposure Via Surface Water	No	Assumed workers do not contact surface water for research activities.
		Aquatic Food Ingestion	No	Assumed workers do not ingest aquatic food from Putah Creek.
	Direct Exposure	External Radiation	Yes	Complete only for radionuclides.

Figure 4-2. Exposure Pathways Analysis
Scenario #2: East Residential Farmer Scenario

Source	Transport Mechanism	Exposure Route	Pathway Complete?	Rationale
Soil Contamination	Direct Contact	Dermal Exposure	No	No direct access to onsite soil assumed.
		Direct Ingestion	No	Resident assumed not to cross LEHR site boundary and ingest source soil directly.
	Migration in Saturated/ Unsaturated Zone via diffusion, advection, etc.	Ground Water Ingestion	Yes	Ground water ingestion from residential well assumed. Receptor is downgradient of DOE OUs.
	Subsurface Diffusion/Volatilization	Inhalation of VOC's	No	Air monitoring at perimeter stations has not shown significant levels of volatiles. Volatiles assumed to be lost from particulates prior to offsite transport.
	Dispersion and Deposition of Particulates in Air	Inhalation of Particulates	Yes	Assumed off-site transport of particulates generated on-site. Not complete for volatiles.
		Deposition with Dermal Exposure/Direct Ingestion	Yes	Assumed off-site transport and deposition of particulates followed by direct exposure. Pathway not complete for volatiles.
		Deposition with Impacted Food Ingestion	Yes	Assumed off-site transport and deposition of particulates, followed by food pathway uptake. Pathway not complete for volatiles.
	Precipitation and Surface Water Runoff	Incidental Ingestion of Surface Water	Yes	Incidental ingestion while swimming assumed possible. All pathways complete only for those contaminants present LEHR site surface soils > background, AND present in stormwater runoff from DOE OUs (see Figure 3-2).
		Dermal Exposure to Surface Water	Yes	Dermal contact during swimming assumed.
		Aquatic Food Ingestion	Yes	Residents assumed to ingest aquatic food from Putah Creek.
	Direct Exposure	External Radiation	Yes	Assumed offsite transport of particulates containing radionuclides.

Notes:
Yes = Pathway is Complete
No = Pathway is Incomplete

Figure 4-3. Exposure Pathways Analysis
Scenario #3: South Residential Farmer Scenario

Source	Transport Mechanism	Exposure Route	Pathway Complete?	Rationale
Soil Contamination	Direct Contact	Dermal Exposure	No	Resident assumed not to cross LEHR site boundary and contact source soil directly.
		Direct Ingestion	No	Resident assumed not to cross LEHR site boundary and ingest source soil directly.
	Migration in Saturated/ Unsaturated Zone via Diffusion, Advection, etc.	Ground Water Ingestion	No	Receptor located upgradient and/or crossgradient of site and across Putah Creek, which is a losing stream: no ground water impacts from the site will occur at this location.
	Subsurface Diffusion/Volatilization	Inhalation of VOC's	No	Air monitoring at stations has not shown significant levels of volatiles. Volatiles assumed to be lost from particulates prior to offsite transport.
	Dispersion and Deposition of Particulates in Air	Inhalation of Particulates	Yes	Assumed off-site transport of particulates generated on-site. Not complete for volatiles.
		Deposition with Dermal Exposure/Direct Ingestion	Yes	Assumed off-site transport and deposition of particulates followed by direct exposure. Pathway not complete for volatiles.
		Deposition with Impacted Food Ingestion	Yes	Assumed off-site transport and deposition of particulates, followed by food pathway uptake. Pathway not complete for volatiles.
	Precipitation and Surface Water Runoff	Ingestion Via Surface Water	Yes	Incidental ingestion while swimming assumed possible. All surface water pathways complete only for those contaminants present in LEHR site surface soil > background, AND present in stormwater runoff from DOE OUs (see Figure 3-2).
		Dermal Exposure to Surface Water	Yes	Dermal contact during swimming with surface water from Putah Creek assumed.
		Aquatic Food Ingestion	Yes	Residents assumed to ingest aquatic organisms from Putah Creek.
	Direct Exposure	External Radiation	Yes	Assumed offsite transport of particulates continuing radionculides.

Notes:
Yes = Pathway is Complete
No = Pathway is Incomplete

5. CALCULATION OF ACTION STANDARDS

The calculation process for determining soil action standards for chemicals and radionuclides in Scenarios 1, 2 and 3 is discussed below in sections 5.1 and 5.2. These sections describe the forward calculation and iterative back-calculation process that results in action standards corresponding to the target risk level (10^{-4}, 10^{-5}, 10^{-6}) for each scenario. The results of these calculations are presented in Sections 5.1.1 and 5.2.1 followed by a discussion of uncertainties in Section 5.1.2 and 5.2.3 for chemicals and radionuclides, respectively.

5.1 Calculation of Action Standards for Chemicals

5.1.1 Results

Single-chemical action standards were calculated using the RAGS Part A equations for intake and risk for each complete exposure pathway and each scenario. An initial default value of 100 mg/kg for each COC in soil was input to the equations. Inputs for other source-term concentrations (meat, fish, air, etc.) were entered as a ratio of the default input soil value. For each scenario, the initial output was the total risk per chemical based on the initial default input value. An iterative approach was used to establish the input value in soil for each chemical that results in risk level of concern. Excess cancer risk levels of 10^{-4}, 10^{-5} and 10^{-6} were evaluated, and the level of concern was set at a hazard quotient of 1.0 for noncarcinogens. As described in Section 4, onsite soil action standards were calculated for the two offsite exposure scenarios using the fate and transport results to provide a ratio of onsite to offsite media concentrations. The iterative action standard calculation approaches are presented in Attachment I.

A summary of the calculated action standards for Scenarios 1, 2 and 3 and the onsite residential scenario PRGs for chemical carcinogens is shown in Table 5-1 for each target risk level. Table 5-2 provides the same summary for chemical noncarcinogens at a target hazard quotient of 1.0 for each scenario.

5.1.2 Discussion and Uncertainties

For each chemical in each scenario, it is helpful to understand which pathways (and therefore which key input assumptions) are "driving" the risk, and thus the action standard. This information is provided in Tables 5-3 and 5-4 for Scenario 1, Tables 5-5 and 5-6 for Scenario 2, and 5-7 and 5-8 for Scenario 3. The tables show examples at 10^{-6} risk and 1.0 hazard quotient. The relative contribution to risk for each complete exposure pathway is the same at 10^{-5} and 10^{-4} target risk levels as it is at the 10^{-6} level; therefore this information has been provided only at the 10^{-6} level as an example.

For Scenario 1 carcinogenic compounds, the majority of action standards are driven by soil-dependent pathway risks. Because the cancer slope factors are the same for both soil ingestion and soil adsorption, and because the ratio between these two exposure pathways is constant, independent of the chemical for those chemicals with the same adsorption factor, the ratio between the soil ingestion and soil dermal contact risk is constant for most COCs. For those chemicals with no oral slope factors, the inhalation route drives the risk since the other pathways are not complete. This is true for certain volatiles, and for cadmium and chromium (total and Cr(VI)). Risk fractions[3] for noncarcinogens behave similarly, with the soil-dependent pathways typically driving the hazard quotient. For Scenario 1, uncertainty in the action standards result is therefore primarily a function of uncertainties surrounding the standard exposure factors in the intake equations for the soil-dependent pathways. The only uncertainties introduced by the site-specific fate and transport modeling are those used to estimate the particulate loading for the inhalation pathway. These uncertainties are not of great concern except for those compounds where the action standard is driven by the inhalation pathway. We note, however, that comparison of the calculated action standards for Scenario 1 with EPA Region IX Preliminary Remediation Goals for the corresponding commercial/industrial scenario shows excellent agreement.

The action standards for Scenario 2 are driven almost exclusively by the ground water dependent pathways: ground water ingestion and dermal exposure during showering. The only exceptions are cadmium and chromium, which pose risk via inhalation only, and chlordane, for which the fish ingestion pathway drives the action standard determination, followed closely by ground water ingestion. Therefore, uncertainties for Scenario 2 are primarily due to uncertainties in the very conservative vadose and ground water modeling that was conducted to estimate the ratio between the offsite ground water concentrations and the onsite soil concentrations. Several key conservative assumptions in the ground water fate and transport modeling should be considered when evaluating these results. They include:

- Contaminants were assumed to be present throughout the vertical and lateral extent of every OU at the action standard, and present both in surface soil and in soil to a depth of 15 ft bgs;
- Contaminant transport in the vadose zone was assumed to be a function of the parameters selected to describe OU1 hydrologic and soil characteristics;
- No degradation with time was assumed to occur for any compounds, including organics, in the vadose zone or the saturated zone. Only loss via volatilization was assumed to occur; and,
- The worst-case ground water impact estimated at any time in the future was used to establish the ground water to soil concentration ratios. In most cases, maximum ground water impact concentrations estimated to occur thousands and even tens of thousands of years in the future were used to estimate risk, and therefore action standards.

For lead in Scenario 2, it should be noted that the toxicological values used in the risk calculation must be considered provisional values. Typically, lead action standards are

[3] Equals the calculated risk for one exposure pathway divided by the sum total risk for all exposure pathways.

determined for onsite receptors using an uptake/biokinetic model, with risk quantified as a function of blood-lead level. We have chosen here to use toxicological values adapted from recent documents (CalEPA, 1997) listing lead as a toxic air contaminant.

In Scenario 3, the results are more variable. Action levels for lead, mercury, chlordane and BHC are driven almost exclusively by the fish ingestion pathway. There are two key uncertainties associated with the action standards for these compounds in Scenario 3. First is the relationship between concentrations in site surface soil and concentrations in storm water runoff. Specifically, only a small portion of OU1 and some portions of OU2 surface soil comprise the source term for storm water runoff from the DOE portions of the Site. The drainage area that results in storm water runoff to Putah Creek does, however, encompass a number of paved parking areas and buildings. Review of the data indicates that, for some constituents and lead specifically, the presence of contaminants in storm water as indicated by analytical results from SWL-1 and SWL-2 may not be indicative of the presence of these contaminants in OU surface soil. The second key uncertainty associated with the surface water related pathways is the dilution factor calculated for of contaminants in storm water by Putah Creek flow. The dilution factor calculation is included in Attachment E, and is a function of storm water runoff estimates and flow volume in the creek. It is important to note that gauging data from the creek were not available in the extremely high flow storm months in 1995, as the gauging station was literally overrun. Therefore, these high flow months were not included in the dilution factor calculation, tending to underestimate the dilution factor.

The potential for DOE Area-related exposures to occur via the Putah Creek surface water exposure pathways has been evaluated here in a quantitative fashion, in part because of the recent attention given to surface water-related exposure pathways by the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR (1996) concluded that, with the exception of lead and mercury in fish, chemical and radionuclide contaminant levels in Putah Creek surface water, sediments, and fish do not pose a significant human health risk. As discussed above, contaminants present in surface soil in certain DOE OU's have the potential to migrate to Putah Creek via erosion and runoff during storm events. Therefore, it is relevant to examine here whether the DOE Areas at the Site could be contributing significantly to the lead and mercury concentrations observed by ATSDR in fish.

UC Davis has prepared a site wide drainage map that delineates onsite drainage areas (included in Attachment E). This map indicates that, of the DOE Areas, only surface soil in a portion of OU1, the Southwest Trenches, and a portion of OU-2, the Radium/Strontium treatment areas, shed surface water to Putah Creek. The total drainage area for the DOE portions of the site that results in surface water runoff to Putah Creek was estimated at approximately four acres. This area includes parking lots and buildings outside the boundaries of the DOE Areas. Section 2 of this report identifies lead as a contaminant of concern in OU1 site surface soil, with a maximum concentration of 21 mg/kg (ppm), slightly above the background concentration of around 11 mg/kg. Mercury is also present in OU1 surface soil, but not at concentrations above the naturally-occurring background level. Further, onsite storm water samples collected from this drainage area (at SWL-1 and SWL-2) show lead present at a maximum concentration of about 38 ug/l (ppb), below the 170 ppb water quality criteria from California State Water Resources Control Board Water Quality Plan for Inland Surface Waters (SWRCB, 1991 and 1992). Mercury has not been detected in storm water runoff samples from the DOE Areas, at a detection limit an order of magnitude less than the EPA NAWQC. Based on those data, it

appears that the DOE portions of the site that contribute surface drainage to the creek through Lift Station 1 do not result in any significant contribution of mercury to the creek above that which might be expected in naturally occurring background soil.

To evaluate the significance of the Site contribution of lead to the creek, surface water runoff volume was conservatively estimated using site-specific 1994 and 1995 storm event (rainfall) data coupled with a calculation algorithm from the Superfund Exposure Assessment Manual (EPA, 1988). Putah Creek streamflow data from the Old Davis Road gauging station was obtained from the same period, and an average and worst-case dilution factor were calculated. The dilution factor represents the amount by which Site storm water is diluted upon entering Putah Creek. Comparison of the DOE storm water concentration data, as adjusted by the conservative dilution factor, and the available data for the upstream and downstream Putah Creek surface water sampling locations shows that on a concentration basis, DOE storm water runoff from Lift Station 1 represents less than 10% of the total lead concentration measured in Putah Creek.

More relevant is examination of lead mass loading to the Creek from DOE storm water runoff through Lift Station 1. Putah Creek flow data were coupled with Putah Creek surface water monitoring data from the upstream and downstream locations (PCU and PCD respectively) to calculate total mass loading of lead in the creek on an annual basis for 1994 and 1995. Similarly, DOE storm water lead concentration data were coupled with the conservative estimate of storm water runoff flow to estimate lead mass loading to the creek for both 1994 and 1995. Based on average and maximum concentrations of lead measured in the creek and in storm water from the western Lift Station 1, the DOE OU contribution to lead mass in Putah Creek was calculated as approximately 0.08%. The data and calculations are included in Attachment E. Thus, the contribution of lead from DOE portions of the site (including parking lots and buildings) to Putah Creek via storm water runoff is insignificant based on this analysis.

Further, careful review of the site drainage map included in Attachment E shows that only a limited portion of any of the DOE Areas sheds surface water to Putah Creek. Storm water ponds and infiltrates or evaporates over the majority of the DOE Areas, according to the Site drainage map prepared by Dames & Moore for UC Davis. Only a portion of the surface soil in OU1 and OU2 sheds water resulting in surface runoff. Therefore, specifically for lead, it is possible and even likely that surface soil in the DOE Areas is not the only source of contaminants in the runoff. This review of the data indicates that, for some constituents and specifically lead, the presence of contaminants in storm water as indicated by analytical results from SWL-1 and SWL-2 may not be indicative of the presence of these contaminants in OU surface soil.

Scenario 3 action standards for many other contaminants are driven by the food chain pathways - plant ingestion, meat ingestion, and milk ingestion. Uncertainty for these pathways is probably driven predominantly by the uncertainty in intake amounts, and the fraction of intake that is assumed from contaminated sources. This analysis very conservatively assumes that contaminated sources represent 100% of the assumed intake.

5.2 Calculation of Action Standards for Radionuclides

5.2.1 Results

Single-radionuclide action standards were calculated for those contaminants present above background levels in site soil using the most recent version of RESRAD (v5.62) at input dose levels equivalent to $1x10^{-4}$ risk, $1x10^{-5}$ risk, and $1x10^{-6}$ risk, for those complete exposure pathways identified in Section 4 for each scenario. Table 5-9 shows the results for each of the three scenarios evaluated, and for comparison, shows the EPA Region IX December 1996 PRGs for the residential scenario. Tables 5-10, 5-11, and 5-12 show the calculated action standards, the corresponding dose, and the pathway specific risk contributions and risk fractions for Scenarios 1, 2, and 3, respectively.

5.2.2 Adjustment Procedure for RESRAD-Generated Action Standards for Scenarios 2 and 3

Since Scenario 1 involves an onsite receptor, the RESRAD results have been used directly to establish action standards. To calculate onsite soil action standards for the two offsite exposure scenarios, RESRAD was first run for a hypothetical residential farm assumed to be located at the source. The results generated from RESRAD for Scenarios 2 and 3 therefore represent action standards at the Scenario 2 or 3 location, respectively. RESRAD does not include built-in fate and transport modeling to adjust for the fact that the receptors are actually at an offsite location. In other words, RESRAD can *only* assume that the receptor is at the site of interest. Therefore, to calculate a Site action standard the results of the particulate fate and transport modeling or the ground water modeling described in Section 4 were used, as described below. Further, since RESRAD does not support the site conceptual model for surface water related pathways, the fish ingestion risks have been separately calculated using the adjusted action standards as a starting point, and "added back in." As necessary, a second adjustment to the RESRAD calculated action standards was made to account for risks from this pathway.

Review of the RESRAD generated results for Scenario 2 indicates that the ground water ingestion pathway drives the risk for americium-241, plutonium-241, tritium, and uranium-235 (Table 5-11). For the other radionuclides, at the time of maximum dose RESRAD vadose zone calculations show no breakthrough to the unsaturated zone, and thus no risk via this pathway. The action standard results assume, as described above, that the receptor is at the source location. However, ground water fate and transport modeling indicates that the ratio of offsite ground water concentrations at the Scenario 2 receptor location to the onsite, Site property boundary ground water concentration is predicted to be no more than 1/5. Therefore, the action standards calculated directly by RESRAD have been adjusted by this ratio. The adjusted action standards, corrected in this manner, represent the Site onsite concentrations of each radionuclide that would result in the offsite action standard calculated by RESRAD. For Scenario 3, the ground water pathway is not complete, and only the adjustments described below apply.

The remaining contaminants have risks, and thus action standards, that are driven by soil-dependent pathways (external radiation, soil ingestion, food chain pathways). Similar to the

ground water discussion above, the fate and transport results provide a ratio of the onsite concentration in soil to the offsite concentration in soil at each receptor location, based on site-specific dispersion and deposition. Therefore, the action standards calculated directly by RESRAD have been adjusted by this ratio. The adjusted action standards, corrected in this manner, represent the onsite concentration of each radionuclide that would result in the offsite soil concentration calculated by RESRAD. In the case of the soil-dependent pathways, this adjustment to the RESRAD calculated action standard is substantial based on the very low ratio of offsite concentration in soil to onsite concentration in soil. As the action standard at the Site increases based on the soil-dependent pathway adjustment, the risk via the inhalation pathway also increases and must be accounted for in the action standard determination. Therefore, the inhalation pathway risks have been re-calculated using the adjusted action standard to ensure that the inhalation pathway risk is accurately represented.

Lastly, for each radionuclide the surface water/aquatic food pathway risk was calculated in the forward direction using the adjusted action standard as the starting point for each radionuclide of concern for Scenarios 2 and 3. As discussed earlier, this is necessary since RESRAD is not entirely compatible with the Site conceptual model, and thus this pathway must be addressed separately. In some cases, the resultant calculated risk for the surface water pathway was greater than the target risk, indicating that, at the adjusted action standard, the surface water pathways were driving the risk. This result, when it occurred, necessitated a second adjustment to the calculated Site action standard (downward) such that the total calculated risk across all pathways at the action standard was equal to the target risk. Attachment J shows the procedure for these adjustments.

Following these adjustments, the resulting action standard represents the Site action standard that is predicted to result in the offsite, pathway specific risks shown in Tables 5-11 and 5-12 for Scenarios 2 and 3 respectively.

5.2.3 Discussion and Uncertainties

For Scenario 1, Table 5-10 shows that the calculated action standards are driven by the external radiation pathway for most contaminants. The key site-specific variable driving uncertainty in this pathway is the Site area used to evaluate exposure. As with the chemical constituents, the RESRAD calculations assume that the action standard concentration is present throughout the lateral and vertical extent of each OU, in both surface and subsurface soil. Therefore, the surface area used in the calculations represents the total surface area of all DOE Areas. The exceptions in Scenario 1 are Am-241, C-14, Pb-210, Pu-241, and tritium, which all have action standards driven by direct soil ingestion, and Ra-226 for which radon inhalation drives the action standard determination. Uncertainties for these pathways center around the standard default exposure parameters used to estimate intake, and in general are not site-specific in nature. Specifically, uncertainty regarding the direct ingestion pathway centers on the ingestion rate assumed; this value has been taken from USEPA guidance. Similarly, uncertainty regarding inhalation centers on the inhalation rate assumed and again this value has been taken from USEPA guidance.

In Scenario 2, Table 5-11 shows that the action standards for Am-241, Pu-241, tritium, and U-235 are driven by ground water ingestion. Therefore, uncertainties for Scenario 2 are

primarily in the very conservative vadose and ground water modeling that relates the offsite ground water concentrations and the Site onsite soil concentrations. Several key conservative assumptions in the fate and transport modeling should be considered when evaluating these results. They include:

- Contaminants were assumed to be present throughout the vertical and lateral extent of every OU at the action standard concentration, and present both in surface soil and in soil to a depth of 15 ft bgs;
- Contaminant transport in the vadose zone was assumed to be a function of parameters selected to describe OU1 hydrologic and soil characteristics, and a conservative infiltration rate; and,
- No degradation (or decay) is assumed during saturated zone transport from the Site to the receptor location.

The remaining radionuclides in Scenario 2, with the exception of C-14 and Sr-90, have action standards that are driven by the surface water pathway. The site-specific determination of the estimated ratio between Putah Creek surface water concentration (contributed by DOE Areas) and site surface soil concentration is the key source of uncertainty in this analysis. The approach for calculating this ratio is shown in Attachment E, and is in part a function of the average concentrations of radionuclides in OU1 and OU2 surface soil and the average concentrations of radionuclides in storm water. Evaluation of the data shows significant uncertainty in establishing the relationship between storm water and site soil concentration, in large part because the data set for storm water samples is limited (six total samples available) and the sample results for certain radionuclides are often negative (indicating background concentrations of those radionuclides were greater than measured concentrations in storm water). The additional site-specific uncertainties discussed above in the chemical action standard section also apply here. For C-14 in Scenario 2, the risk is driven by the inhalation pathway. Uncertainty in this result is driven by uncertainties in the particulate emission model and the related air transport assumptions. For Sr-90, risk is driven by the food chain pathways. Significant uncertainties include the intake assumptions for meat, milk, and leafy vegetables, and the conservative assumption of 100% home-grown meat and produce.

In Scenario 3, action standards for C-14 and Pu-241 are driven by the inhalation pathway. Site-specific uncertainty surrounding these results centers on the estimation of onsite fugitive dust emissions, and the estimation of offsite dispersion to the receptor location. These calculations are shown in Attachment D. Key variables include the mean annual windspeed and the surface roughness height. High quality, site-specific data were available to estimate the first parameter, leading to low uncertainty. Surface roughness height has been conservatively estimated, tending to overestimate particulate emissions.

Action levels for remaining radionuclides in Scenario 3 are driven by the surface water pathway. Uncertainties described above for Scenario 2 also apply here.

Table 5-1. Summary of Risk-Based Action Standards for Chemical Carcinogens for 10^{-4} to 10^{-6} Target Incremental Carcinogenic Risk Range.

	Scenario 1 RBASs			Scenario 2 RBASs			Scenario 3 RBASs			1996 PRGs - Residential Soil		
Analyte	10^{-4} Risk (mg/kg)	10^{-5} Risk (mg/kg)	10^{-6} Risk (mg/kg)	10^{-4} Risk (mg/kg)	10^{-5} Risk (mg/kg)	10^{-6} Risk (mg/kg)	10^{-4} Risk (mg/kg)	10^{-5} Risk (mg/kg)	10^{-6} Risk (mg/kg)	10^{-4} Risk (mg/kg)	10^{-5} Risk (mg/kg)	10^{-6} Risk (mg/kg)
4,4'-DDD	790	79	7.9	940	94	9.4	RES	700,000	70,000	190	19	1.9
4,4'-DDE	560	56	5.6	900	90	9.0	RES	610,000	61,000	130	13	1.3
4,4'-DDT	560	56	5.6	3,000	300	30	RES	230,000	23,000	130	13	1.3
Alpha-BHC	30	3.0	0.30	0.75	0.075	0.0075	840,000	84,000	8,400	7.1	0.71	0.071
Alpha-Chlordane	150	15	1.5	80	8.0	0.80	590	59	5.9	34	3.4	0.34
Arochlor-1260	25	2.5	0.25	490	49	4.9	12,000	1,200	120	6.6	0.66	0.066
Benzene	23	2.3	0.23	1.5	0.15	0.015	NC	NC	NC	63	6.3	0.63
Benzo(a)anthracene	260	26	2.6	120	12	1.2	RES	300,000	30,000	61	6.1	0.61
Benzo(a)pyrene	26	2.6	0.26	24	2.4	0.24	130,000	13,000	1,300	6.1	0.61	0.061
Benzo(b)fluoranthene	260	26	2.6	330	33	3.3	RES	120,000	12,000	61	6.1	0.61
Benzo(k)fluoranthene	2600	260	26	2,700	270	27	RES	RES	130,000	610	61	6.1
Bis(2-Ethylhexyl)phthalate	14,000	1,400	136	770	77	7.7	860	86	8.6	3,200	320	32
Cadmium (Cd)	480,000	48,000	4,800	RES	RES	RES	RES	RES	RES	3,800	380	38
Carbazole	9,500	950	95	220	22	2.2	RES	RES	RES	2,200	220	22
Carbon Tetrachloride	22	2.2	0.22	5.5	0.55	0.055	NC	NC	NC	23	2.3	0.23
Chlordane	150	15	1.5	78	7.8	0.78	590	59	5.9	34	3.4	0.34
Chromium (Cr)	72,000	7,200	720	RES	RES	840,000	RES	RES	160,000	21,000	2,100	210
Chromium, Hexavalent (Cr+6)	10,000	1,000	100	RES	RES	120,000	RES	230,000	23,000	20	2.0	0.20
Chrysene	26,000	2,600	260	2,000	200	20	RES	RES	RES	610	61	6.1
Delta-BHC	30	3.0	0.30	1.3	0.13	0.013	21	2.1	0.21	25	2.5	0.25
Dibenzo(a,h)anthracene	26	2.6	0.26	54	5.4	0.54	26,000	2,600	260	6.1	0.61	0.061
Dieldrin	12	1.2	0.12	1.5	0.15	0.015	410,000	41,000	4,100	2.8	0.28	0.028
Formaldehyde	22,000	2,200	220	NC	NC	NC	NC	NC	NC	980,000	98,000	9,800
Gamma-BHC	150	15	1.5	3.0	0.30	0.030	RES	350,000	35,000	34	3.4	0.34
Gamma-Chlordane	150	15	1.5	81	8.1	0.81	640	64	6.4	34	3.4	0.34
Heptachlor	42	4.2	0.42	17	1.7	0.17	RES	140,000	14,000	10	1.0	0.099
Heptachlor Epoxide	21	2.1	0.21	0.057	0.0057	0.00057	180,000	18,000	1,800	4.9	0.49	0.049
Indeno(1,2,3-cd)pyrene	260	26	2.6	490	49	4.9	460,000	46,000	4,600	61	6.1	0.61
Lead (Pb)	300	30	3.0	4.4	0.44	0.044	1,900	190	19	130	130	130
Mercury (Hg)	RES	160,000	16,000	1,500	150	15	54,000	5,400	540	2,300	230	23
Methylene Chloride	720	72	7.2	13	1.3	0.13	NC	NC	NC	780	78	7.8
Pentachlorophenol	1,600	160	16	1,300	130	13	RES	RES	130,000	250	25	2.5

RBAS = Risk Based Action Standard
RES = 10-4 , 10-5 or 10-6 risk not exceeded for pure compound present at any concentration
NC = Exposure pathway incomplete for compound.
PRG = USEPA Region IX Preliminary Remediation Goals, August 1996,
Lead PRG based on Uptake Biokinetic Model.

Table 5-2. Summary of Risk-Based Action Standards for Chemical Non-Carcinogens at a Hazard Quotient of 1.0

	Risk Based Action Standard			1996 PRGs
	Scenario 1	Scenario 2	Scenario 3	Residential Soil
Analyte	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
2-Butanone (MEK)	710	12	NC	7,100
Acenaphthene	41,000	250	RES	110
Acetone	830	1.7	1,900	2,100
Anthracene	200,000	1,400	RES	5.7
Antimony (Sb)	680	0.30	RES	31
Barium (Ba)	110,000	53	RES	5,300
Benzo(g,h,i)perylene	20,000	9,100	RES	no ref
Cadmium (Cd)	850	0.38	RES	9.0
Chromium (Cr)	RES	760	RES	210
Chromium, Hexavalent (Cr+6)	8,500	3.8	740	0.20
Copper (Cu)	63,000	28	610,000	2,800
Dibenzofuran	2,700	14	RES	140
Diethyl Phthalate	550,000	220	RES	52,000
Di-n-Butylphthalate	68,000	890	3,300	6,500
Di-n-Octylphthalate	14,000	28,000	4,900	1,300
Endosulfan 1	4,100	29	RES	390
Endosulfan Sulfate	4,100	26	RES	no ref
Ethyl Benzene	2,400	10	NC	230
Fluoranthene	27,000	1,800	RES	2,600
Fluorene	27,000	170	RES	90
Formaldehyde	100,000	1.7	10,000	9,800
Manganese (Mn)	52,000	36	RES	3,200
Mercury (Hg)	510	0.22	6.4	23
Methoxychlor	3,400	100	RES	330
Naphthalene	27,000	39	RES	240
Phenanthrene	20,000	1,200	RES	no ref
Pyrene	20,000	490	RES	100
Selenium (Se)	8,500	58	RES	380
Silver (Ag)	8,500	3.8	RES	380
Styrene	710	76	NC	680
Toluene	920	19	NC	790
Xylenes (Total)	1,700	700	NC	320
Zinc (Zn)	510,000	3,400	150,000	23,000

NC = Exposure pathway incomplete for compound.
RES = HQ not exceeded for pure compound
PRG = USEPA Region IX Preliminary Remediation Goals, August 1996, at HQ = 1.
no ref = No PRG reference value listed for this compound.

Table 5-3. **Scenario 1,** Summary of Soil Action Standards and Pathway-Specific Risk Contributions for Chemical Carcinogens at 10^{-6} Target Risk Level.

Analyte	Site Action Standard (mg/kg)	Pathway-Specific Risk at Action Standard				Pathway-Specific Risk Fraction at Action Standard			Risk Fraction Across Pathways
		Inhalation Risk	Soil Ingestion Risk	Soil Adsorption Risk	Risk Across Pathways	Inhalation Fraction	Soil Ingestion Fraction	Soil Adsorption Fraction	
4,4'-DDD	7.9	6.3E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0
4,4'-DDE	5.6	6.3E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0
4,4'-DDT	5.6	6.3E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0
Alpha-BHC	0.30	6.3E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0
Alpha-Chlordane	1.5	6.3E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0
Arochlor-1260	0.25	6.3E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0
Benzene	0.23	9.9E-07	4.1E-09	8.1E-09	1.0E-06	0.988	0.004	0.008	1.0
Benzo(a)anthracene	2.6	6.3E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0
Benzo(a)pyrene	0.26	6.3E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0
Benzo(b)fluoranthene	2.6	6.3E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0
Benzo(k)fluoranthene	26	6.3E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0
Bis(2-Ethylhexyl)phthalate	136	6.3E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0
Cadmium (Cd)	4813	1.0E-06	NC	NC	1.0E-06	1.000	NC	NC	1.0
Carbazole	95	6.3E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0
Carbon Tetrachloride	0.22	9.8E-07	5.0E-09	1.0E-08	1.0E-06	0.985	0.005	0.010	1.0
Chlordane	1.5	6.3E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0
Chromium (Cr)	722	1.0E-06	NC	NC	1.0E-06	1.000	NC	NC	1.0
Chromium, Hexavalent (Cr	105	1.0E-06	NC	NC	1.0E-06	1.000	NC	NC	1.0
Chrysene	261	6.3E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0
Delta-BHC	0.30	6.3E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0
Dibenzo(a,h)anthracene	0.26	6.3E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0
Dieldrin	0.12	6.3E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0
Formaldehyde	218	1.0E-06	NC	NC	1.0E-06	1.000	NC	NC	1.0
Gamma-BHC	1.5	6.3E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0
Gamma-Chlordane	1.5	6.3E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0
Heptachlor	0.42	6.4E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0
Heptachlor Epoxide	0.21	6.3E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0
Indeno(1,2,3-cd)pyrene	2.6	6.3E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0
Lead (Pb)	3.0	1.6E-10	8.3E-07	1.7E-07	1.0E-06	0.000	0.833	0.167	1.0
Mercury (Hg)	15,898	NC	8.3E-07	1.7E-07	1.0E-06	NC	0.833	0.167	1.0
Methylene Chloride	7.2	9.7E-07	9.4E-09	1.9E-08	1.0E-06	0.972	0.009	0.019	1.0
Pentachlorophenol	16	6.3E-11	3.3E-07	6.7E-07	1.0E-06	0.000	0.333	0.667	1.0

NC = Exposure pathway not complete for chemical.

Table 5-4. **Scenario 1,** Summary of Soil Action Standards and Pathway-Specific Hazard Quotients for Chemical Non-Carcinogens at Hazard Quotient of 1.0.

Analyte	Site Action Standard mg/kg	notes	Pathway Specific Hazard Quotient at Action Standard: Inhalation HQ	Soil Ingestion HQ	Soil Adsorption HQ	HQ Across Pathways
2-Butanone (MEK)	712	---	1.0E+00	5.8E-04	1.2E-03	1.0
Acenaphthene	40,877	---	6.3E-05	3.3E-01	6.7E-01	1.0
Acetone	831	---	9.9E-01	4.1E-03	8.1E-03	1.0
Anthracene	204,387	---	6.3E-05	3.3E-01	6.7E-01	1.0
Antimony (Sb)	681	---	1.6E-04	8.3E-01	1.7E-01	1.0
Barium (Ba)	110,539	---	7.3E-02	7.7E-01	1.5E-01	1.0
Benzo(g,h,i)perylene	20,439	---	6.3E-05	3.3E-01	6.7E-01	1.0
Cadmium (Cd)	850	---	1.4E-03	8.3E-01	1.7E-01	1.0
Chromium (Cr)	1,703,333	RES	NC	8.3E-01	1.7E-01	1.0
Chromium, Hexavalent (Cr+6)	8,517	---	NC	8.3E-01	1.7E-01	1.0
Copper (Cu)	63,013	---	1.6E-04	8.3E-01	1.7E-01	1.0
Dibenzofuran	2,725	---	6.3E-05	3.3E-01	6.7E-01	1.0
Diethyl Phthalate	545,032	---	6.3E-05	3.3E-01	6.7E-01	1.0
Di-n-Butylphthalate	68,129	---	6.3E-05	3.3E-01	6.7E-01	1.0
Di-n-Octylphthalate	13,626	---	6.3E-05	3.3E-01	6.7E-01	1.0
Endosulfan I	4,088	---	6.3E-05	3.3E-01	6.7E-01	1.0
Endosulfan Sulfate	4,088	---	6.3E-05	3.3E-01	6.7E-01	1.0
Ethyl Benzene	2,356	---	9.7E-01	1.2E-02	2.3E-02	1.0
Fluoranthene	27,252	---	6.3E-05	3.3E-01	6.7E-01	1.0
Fluorene	27,252	---	6.3E-05	3.3E-01	6.7E-01	1.0
Formaldehyde	102,200	---	NC	3.3E-01	6.7E-01	1.0
Manganese (Mn)	52,390	---	3.5E-01	5.5E-01	1.1E-01	1.0
Mercury (Hg)	511	---	5.5E-04	8.3E-01	1.7E-01	1.0
Methoxychlor	3,406	---	6.3E-05	3.3E-01	6.7E-01	1.0
Naphthalene	27,252	---	6.3E-05	3.3E-01	6.7E-01	1.0
Phenanthrene	20,439	---	6.3E-05	3.3E-01	6.7E-01	1.0
Pyrene	20,439	---	6.3E-05	3.3E-01	6.7E-01	1.0
Selenium (Se)	8,515	---	1.6E-04	8.3E-01	1.7E-01	1.0
Silver (Ag)	8,515	---	1.6E-04	8.3E-01	1.7E-01	1.0
Styrene	709	---	9.9E-01	1.7E-03	3.5E-03	1.0
Toluene	919	---	9.9E-01	2.2E-03	4.5E-03	1.0
Xylenes (Total)	1,681	---	1.0E+00	4.1E-04	8.2E-04	1.0
Zinc (Zn)	510,920	---	1.6E-04	8.3E-01	1.7E-01	1.0

Notes:

RES = Target risk level not exceeded for pure compound.

NC = Exposure pathway not complete for chemical.

HQ = Hazard Quotient

Table 5-5. **Scenario 2,** Summary Soil Action Standards and Pathway-Specific Risk Level Contributions for Chemical Carcinogens at 10^{-6} Risk Levels.

	Site		Pathway-Specific Risk at Action Standard											
Analyte	Action Standard mg/kg	notes	Ground Water Ingestion Risk	Swimming Ingestion Risk	Dermal Swimming Risk	Dermal Showering Risk	Soil Ingestion Risk	Dermal Soil Risk	Inhalation Risk	Fish Ingestion Risk	Plant Ingestion Risk	Meat Ingestion Risk	Milk Ingestion Risk	Risk Across Pathways
4,4'-DDD	9.4	---	4.8E-07	NC	NC	5.2E-07	2.8E-13	1.2E-13	6.4E-14	NC	2.0E-12	1.5E-11	4.4E-12	1.0E-06
4,4'-DDE	9.0	---	5.1E-07	NC	NC	4.9E-07	3.8E-13	1.7E-13	8.7E-14	NC	2.8E-12	1.6E-11	4.7E-12	1.0E-06
4,4'-DDT	30	---	3.7E-07	NC	NC	6.3E-07	1.2E-12	5.5E-13	2.9E-13	NC	8.5E-12	1.5E-10	4.6E-11	1.0E-06
Alpha-BHC	0.0075	---	9.3E-07	NC	NC	6.9E-08	5.8E-15	2.6E-15	1.3E-15	NC	1.0E-13	8.2E-15	2.5E-15	1.0E-06
Alpha-Chlordane	0.80	---	7.3E-07	2.6E-10	1.1E-09	1.3E-07	1.3E-13	5.6E-14	3.0E-14	1.3E-07	9.8E-13	3.4E-12	1.0E-12	1.0E-06
Arochlor-1260	4.9	---	1.8E-07	NC	NC	8.1E-07	4.7E-12	2.1E-12	1.1E-12	NC	3.0E-11	5.0E-09	1.5E-09	1.0E-06
Benzene	0.015	---	7.0E-07	NC	NC	3.0E-07	NC	NC	NC	NC	NC	NC	NC	1.0E-06
Benzo(a)anthracene	1.2	---	2.4E-07	NC	NC	7.6E-07	1.1E-13	4.7E-14	2.5E-14	NC	7.9E-13	4.2E-12	1.3E-12	1.0E-06
Benzo(a)pyrene	0.24	---	1.7E-07	NC	NC	8.3E-07	2.1E-13	9.4E-14	4.9E-14	NC	1.5E-12	2.2E-11	6.5E-12	1.0E-06
Benzo(b)fluoranthene	3.3	---	1.7E-07	NC	NC	8.3E-07	3.0E-13	1.3E-13	7.0E-14	NC	2.1E-12	3.2E-11	9.4E-12	1.0E-06
Benzo(k)fluoranthene	27	---	1.8E-07	NC	NC	8.2E-07	2.4E-13	1.1E-13	5.6E-14	NC	1.7E-12	2.4E-11	7.1E-12	1.0E-06
Ethylhexyl)phthalate	7.7	---	1.0E-07	3.2E-09	9.4E-09	1.3E-08	1.3E-14	5.8E-15	3.0E-15	8.7E-07	1.1E-13	1.6E-13	4.9E-14	1.0E-06
Cadmium (Cd)	5,576,026	RES	NC	NC	NC	NC	NC	NC	1.0E-06	NC	NC	NC	NC	1.0E-06
Carbazole	2.2	---	8.2E-07	NC	NC	1.8E-07	5.5E-15	2.4E-15	1.3E-15	NC	1.4E-13	4.4E-15	1.4E-15	1.0E-06
Carbon Tetrachloride	0.055	---	9.2E-07	NC	NC	8.0E-08	NC	NC	NC	NC	NC	NC	NC	1.0E-06
Chlordane	0.78	---	7.2E-07	2.6E-10	1.2E-09	1.5E-07	1.3E-13	5.5E-14	2.9E-14	1.3E-07	9.6E-13	3.3E-12	9.9E-13	1.0E-06
Chromium (Cr)	836,404	---	NC	NC	NC	NC	NC	NC	1.0E-06	NC	NC	NC	NC	1.0E-06
Chromium, Hexavalent (C	121,134	---	NC	NC	NC	NC	NC	NC	1.0E-06	NC	NC	NC	NC	1.0E-06
Chrysene	20	---	2.4E-07	NC	NC	7.6E-07	1.8E-14	8.0E-15	4.2E-15	NC	1.3E-13	7.1E-13	2.1E-13	1.0E-06
Delta-BHC	0.0125	---	8.5E-07	1.2E-09	2.7E-09	9.0E-08	9.7E-15	4.3E-15	2.2E-15	5.5E-08	1.4E-13	1.9E-14	5.9E-15	1.0E-06
Dibenzo(a,h)anthracene	0.54	---	8.6E-08	NC	NC	9.1E-07	4.8E-13	2.1E-13	1.1E-13	NC	3.2E-12	2.6E-10	7.7E-11	1.0E-06
Dieldrin	0.015	---	9.4E-07	NC	NC	5.9E-08	3.0E-14	1.3E-14	6.9E-15	NC	3.3E-13	1.3E-13	3.9E-14	1.0E-06
Formaldehyde	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Gamma-BHC	0.030	---	9.5E-07	NC	NC	5.2E-08	4.9E-15	2.1E-15	1.1E-15	NC	9.9E-14	5.2E-15	1.6E-15	1.0E-06
Gamma-Chlordane	0.81	---	7.4E-07	2.4E-10	9.9E-10	1.3E-07	1.3E-13	5.7E-14	3.0E-14	1.2E-07	9.9E-13	3.4E-12	1.0E-12	1.0E-06
Heptachlor	0.17	---	9.6E-07	NC	NC	4.1E-08	9.4E-14	4.2E-14	2.2E-14	NC	1.2E-12	2.4E-13	7.4E-14	1.0E-06
Heptachlor Epoxide	0.00057	---	1.0E-06	NC	NC	2.6E-09	6.4E-16	2.8E-16	1.5E-16	NC	3.8E-14	1.9E-16	5.9E-17	1.0E-06
Indeno(1,2,3-cd)pyrene	4.9	---	1.2E-07	NC	NC	8.8E-07	4.4E-13	1.9E-13	1.0E-13	NC	2.9E-12	1.3E-10	3.9E-11	1.0E-06
Lead (Pb)	0.044	---	9.9E-07	4.2E-10	3.7E-11	3.9E-09	8.7E-15	3.8E-16	2.0E-15	1.9E-09	2.1E-14	2.4E-14	8.1E-15	1.0E-06
Mercury (Hg)	15	---	9.7E-07	7.3E-12	6.4E-13	3.8E-09	5.6E-16	2.5E-17	NC	2.8E-08	2.6E-14	3.1E-13	5.1E-15	1.0E-06
Methylene Chloride	0.13	---	9.8E-07	NC	NC	1.7E-08	NC	NC	NC	NC	NC	NC	NC	1.0E-06
Pentachlorophenol	13	---	2.8E-07	NC	NC	7.2E-07	2.0E-13	8.7E-14	4.6E-14	NC	1.4E-12	1.2E-11	3.5E-12	1.0E-06

NC = Exposure pathway not complete for chemical.
RES = 10-6 risk not exceeded for pure compound.

Table 5-5. **Continued Scenario 2,** Summary of Soil Action Standards and Pathway-Specific Risk Contributions for Chemical Carcinogens at 10^{-6} Risk Levels.

Analyte	Site Action Standard mg/kg	notes	Pathway-Specific Risk Fraction: Ground Water Ingestion	Swimming Ingestion	Dermal Swimming	Dermal Showering	Soil Ingestion	Dermal Soil	Inhalation	Fish Ingestion	Plant Ingestion	Meat Ingestion	Milk Ingestion	Risk Fraction Across Pathways
4,4'-DDD	9.4	---	0.476	NC	NC	0.524	0.000	0.000	0.000	NC	0.000	0.000	0.000	1.0
4,4'-DDE	9.0	---	0.514	NC	NC	0.486	0.000	0.000	0.000	NC	0.000	0.000	0.000	1.0
4,4'-DDT	30	---	0.371	NC	NC	0.628	0.000	0.000	0.000	NC	0.000	0.000	0.000	1.0
Alpha-BHC	0.0075	---	0.931	NC	NC	0.069	0.000	0.000	0.000	NC	0.000	0.000	0.000	1.0
Alpha-Chlordane	0.80	---	0.732	0.000	0.001	0.132	0.000	0.000	0.000	0.134	0.000	0.000	0.000	1.0
Arochlor-1260	4.9	---	0.179	NC	NC	0.814	0.000	0.000	0.000	NC	0.000	0.005	0.001	1.0
Benzene	0.015	---	0.698	NC	NC	0.302	NC	NC	NC	NC	NC	NC	NC	1.0
Benzo(a)anthracene	1.2	---	0.239	NC	NC	0.761	0.000	0.000	0.000	NC	0.000	0.000	0.000	1.0
Benzo(a)pyrene	0.24	---	0.175	NC	NC	0.825	0.000	0.000	0.000	NC	0.000	0.000	0.000	1.0
Benzo(b)fluoranthene	3.3	---	0.174	NC	NC	0.826	0.000	0.000	0.000	NC	0.000	0.000	0.000	1.0
Benzo(k)fluoranthene	27	---	0.182	NC	NC	0.818	0.000	0.000	0.000	NC	0.000	0.000	0.000	1.0
Bis(2-Ethylhexyl)phthalate	7.7	---	0.101	0.003	0.009	0.013	0.000	0.000	0.000	0.874	0.000	0.000	0.000	1.0
Cadmium (Cd)	5,576,026	RES	NC	NC	NC	NC	NC	NC	1.000	NC	NC	NC	NC	1.0
Carbazole	2.2	---	0.818	NC	NC	0.182	0.000	0.000	0.000	NC	0.000	0.000	0.000	1.0
Carbon Tetrachloride	0.055	---	0.920	NC	NC	0.080	NC	NC	NC	NC	NC	NC	NC	1.0
Chlordane	0.78	---	0.719	0.000	0.001	0.147	0.000	0.000	0.000	0.132	0.000	0.000	0.000	1.0
Chromium (Cr)	836,404	---	NC	NC	NC	NC	NC	NC	1.000	NC	NC	NC	NC	1.0
Chromium, Hexavalent ((	121,134	---	NC	NC	NC	NC	NC	NC	1.000	NC	NC	NC	NC	1.0
Chrysene	20	---	0.239	NC	NC	0.761	0.000	0.000	0.000	NC	0.000	0.000	0.000	1.0
Delta-BHC	0.0125	---	0.852	0.001	0.003	0.090	0.000	0.000	0.000	0.055	0.000	0.000	0.000	1.0
Dibenzo(a,h)anthracene	0.54	---	0.086	NC	NC	0.914	0.000	0.000	0.000	NC	0.000	0.000	0.000	1.0
Dieldrin	0.015	---	0.941	NC	NC	0.059	0.000	0.000	0.000	NC	0.000	0.000	0.000	1.0
Formaldehyde	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Gamma-BHC	0.030	---	0.948	NC	NC	0.052	0.000	0.000	0.000	NC	0.000	0.000	0.000	1.0
Gamma-Chlordane	0.81	---	0.740	0.000	0.001	0.134	0.000	0.000	0.000	0.125	0.000	0.000	0.000	1.0
Heptachlor	0.17	---	0.959	NC	NC	0.041	0.000	0.000	0.000	NC	0.000	0.000	0.000	1.0
Heptachlor Epoxide	0.00057	---	0.997	NC	NC	0.003	0.000	0.000	0.000	NC	0.000	0.000	0.000	1.0
Indeno(1,2,3-cd)pyrene	4.9	---	0.118	NC	NC	0.882	0.000	0.000	0.000	NC	0.000	0.000	0.000	1.0
Lead (Pb)	0.044	---	0.994	0.000	0.000	0.004	0.000	0.000	0.000	0.002	0.000	0.000	0.000	1.0
Mercury (Hg)	15	---	0.968	0.000	0.000	0.004	0.000	0.000	NC	0.028	0.000	0.000	0.000	1.0
Methylene Chloride	0.13	---	0.983	NC	NC	0.017	NC	NC	NC	NC	NC	NC	NC	1.0
Pentachlorophenol	13	---	0.281	NC	NC	0.719	0.000	0.000	0.000	NC	0.000	0.000	0.000	1.0

NC = Exposure pathway not complete for chemical.
RES = 10-6 Risk level not exceeded for pure compound.

Table 5-6. **Scenario 2,** Summary of Soil Action Standards and Pathway-Specific Hazard Quotients for Chemical Non-Carcinogens at a Hazard Quotient of 1.0.

Analyte	LEHR Site Action Standard mg/kg	Pathway-Specific Hazard Quotient at Action Standards											HQ Across Pathways
		Ground Water Ingestion	Swimming Ingestion	Dermal Swimming	Dermal Showering	Soil Ingestion	Dermal Soil	Inhalation	Fish Ingestion	Plant Ingestion	Meat Ingestion	Milk Ingestion	
2-Butanone (MEK)	12	9.9E-01	NC	NC	5.3E-03	NC	NC	NC	NC	NC	NC	NC	1.0
Acenaphthene	251	5.7E-01	NC	NC	4.3E-01	4.7E-09	1.3E-09	7.3E-10	NC	6.3E-08	6.5E-09	2.0E-09	1.0
Acetone	1.7	1.0E+00	8.4E-04	4.3E-05	2.8E-03	NC	NC	NC	2.0E-05	NC	NC	NC	1.0
Anthracene	1,375	4.8E-01	NC	NC	5.2E-01	5.1E-09	1.4E-09	8.0E-10	NC	5.0E-08	1.5E-08	4.6E-09	1.0
Antimony (Sb)	0.30	1.0E+00	NC	NC	4.9E-03	8.5E-10	2.3E-11	1.3E-10	NC	7.4E-09	4.9E-09	4.8E-10	1.0
Barium (Ba)	53	1.0E+00	NC	NC	4.9E-03	8.5E-10	2.3E-11	6.6E-08	NC	5.6E-09	4.1E-10	1.4E-09	1.0
Benzo(g,h,i)perylene	9,060	2.0E-01	NC	NC	8.0E-01	3.4E-07	9.3E-08	5.3E-08	NC	2.0E-06	2.8E-05	8.2E-06	1.0
Cadmium (Cd)	0.38	1.0E+00	NC	NC	4.9E-03	8.5E-10	2.3E-11	1.2E-09	NC	2.0E-08	3.4E-09	9.6E-09	1.0
Chromium (Cr)	759	1.0E+00	3.9E-07	3.4E-08	4.9E-03	8.5E-10	2.3E-11	NC	4.7E-06	2.8E-10	2.1E-08	3.2E-09	1.0
Chromium, Hexavale	3.8	9.9E-01	3.9E-04	3.5E-05	4.8E-03	8.4E-10	2.3E-11	NC	4.7E-03	2.8E-10	2.1E-08	3.2E-09	1.0
Copper (Cu)	28	1.0E+00	4.0E-06	3.5E-07	4.9E-03	8.5E-10	2.3E-11	1.3E-10	4.1E-05	1.5E-08	1.0E-07	1.1E-08	1.0
Dibenzofuran	14	7.7E-01	NC	NC	2.3E-01	4.0E-09	1.1E-09	6.2E-10	NC	7.8E-08	3.0E-09	9.2E-10	1.0
Diethyl Phthalate	221	9.8E-01	NC	NC	2.3E-02	3.1E-10	8.5E-11	4.8E-11	NC	2.1E-08	5.9E-11	1.9E-11	1.0
Di-n-Butylphthalate	892	6.3E-01	5.1E-03	1.5E-02	1.0E-01	1.0E-08	2.8E-09	1.6E-09	2.5E-01	1.2E-07	1.7E-08	5.2E-09	1.0
Di-n-Octylphthalate	27,501	1.6E-04	NC	NC	6.2E-02	1.5E-06	4.3E-07	2.4E-07	NC	8.2E-06	7.2E-01	2.1E-01	1.0
Endosulfan I	29	9.9E-01	NC	NC	1.0E-02	5.5E-09	1.5E-09	8.5E-10	NC	1.1E-07	3.9E-09	1.2E-09	1.0
Endosulfan Sulfate	26	9.9E-01	NC	NC	1.0E-02	4.8E-09	1.3E-09	7.5E-10	NC	9.5E-08	3.4E-09	1.1E-09	1.0
Ethyl Benzene	10	1.7E-01	NC	NC	8.3E-01	NC	NC	NC	NC	NC	NC	NC	1.0
Fluoranthene	1,782	3.6E-01	NC	NC	6.4E-01	5.0E-08	1.4E-08	7.8E-09	NC	3.8E-07	3.8E-07	1.1E-07	1.0
Fluorene	167	5.3E-01	NC	NC	4.7E-01	4.7E-09	1.3E-09	7.3E-10	NC	5.3E-08	9.0E-09	2.8E-09	1.0
Formaldehyde	1.7	9.9E-01	1.4E-04	2.6E-05	1.1E-02	NC	NC	NC	8.8E-06	NC	NC	NC	1.0
Manganese (Mn)	36	1.0E+00	4.6E-07	4.0E-08	4.9E-03	8.5E-10	2.3E-11	4.5E-07	2.7E-05	9.3E-09	3.9E-09	1.9E-09	1.0
Mercury (Hg)	0.22	9.6E-01	9.0E-06	7.9E-07	4.7E-03	8.2E-10	2.3E-11	4.5E-10	3.4E-02	3.2E-08	3.8E-07	6.3E-09	1.0
Methoxychlor	100	9.2E-01	NC	NC	7.6E-02	2.2E-08	6.2E-09	3.5E-09	NC	2.4E-07	5.1E-08	1.6E-08	1.0
Naphthalene	39	7.5E-01	NC	NC	2.5E-01	1.1E-09	3.0E-10	1.7E-10	NC	2.8E-08	5.5E-10	1.7E-10	1.0
Phenanthrene	1,197	4.3E-01	NC	NC	5.7E-01	4.5E-08	1.2E-08	7.0E-09	NC	4.1E-07	1.6E-07	5.0E-08	1.0
Pyrene	492	2.3E-01	NC	NC	7.7E-01	1.8E-08	5.1E-09	2.9E-09	NC	1.2E-07	2.9E-07	8.8E-08	1.0
Selenium (Se)	58	1.0E+00	NC	NC	4.9E-03	1.3E-08	3.6E-10	2.0E-09	NC	1.4E-08	5.7E-07	1.4E-07	1.0
Silver (Ag)	3.8	1.0E+00	NC	NC	4.9E-03	8.5E-10	2.3E-11	1.3E-10	NC	1.5E-08	2.3E-08	1.5E-07	1.0
Styrene	76	7.9E-01	NC	NC	2.1E-01	NC	NC	NC	NC	NC	NC	NC	1.0
Toluene	19	1.7E-01	NC	NC	8.3E-01	NC	NC	NC	NC	NC	NC	NC	1.0
Xylenes (Total)	697	7.2E-01	NC	NC	2.8E-01	NC	NC	NC	NC	NC	NC	NC	1.0
Zinc (Zn)	3,391	9.7E-01	2.6E-04	2.3E-05	4.8E-03	1.3E-08	3.5E-10	2.0E-09	2.2E-02	8.3E-07	6.9E-05	3.4E-06	1.0

NC = Exposure pathway not complete for chemical.

Table 5-7. **Scenario 3,** Summary of Soil Action Standards and Pathway-Specific Risk Contributions for Chemical Carcinogens at 10^{-6} Risk Level.

Analyte	Site Action Standard mg/kg	notes	Pathway-Specific Risk at Action Standard									Risk Across Pathways
			Swimming Ingestion	Dermal Swimming	Soil Ingestion	Dermal Soil	Inhalation	Fish Ingestion	Plant Ingestion	Meat Ingestion	Milk Ingestion	
4,4'-DDD	70,326	---	NC	NC	1.8E-08	7.8E-09	2.6E-09	NC	8.6E-08	6.9E-07	2.0E-07	1.0E-06
4,4'-DDE	60,568	---	NC	NC	2.2E-08	9.5E-09	3.1E-09	NC	1.1E-07	6.6E-07	1.9E-07	1.0E-06
4,4'-DDT	22,898	---	NC	NC	8.1E-09	3.6E-09	1.2E-09	NC	3.7E-08	7.4E-07	2.1E-07	1.0E-06
Alpha-BHC	8,363	---	NC	NC	5.5E-08	2.4E-08	8.0E-09	NC	8.2E-07	6.8E-08	2.1E-08	1.0E-06
Alpha-Chlordane	5.9	---	1.9E-09	7.8E-09	8.0E-12	3.5E-12	1.2E-12	9.9E-07	4.2E-11	1.6E-10	4.6E-11	1.0E-06
Arochlor-1260	125	---	NC	NC	1.0E-09	4.4E-10	1.5E-10	NC	4.1E-09	7.7E-07	2.2E-07	1.0E-06
Benzene	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Benzo(a)anthracene	29,740	---	NC	NC	2.3E-08	1.0E-08	3.3E-09	NC	1.1E-07	6.6E-07	1.9E-07	1.0E-06
Benzo(a)pyrene	1,283	---	NC	NC	9.8E-09	4.3E-09	1.4E-09	NC	4.5E-08	7.3E-07	2.1E-07	1.0E-06
Benzo(b)fluoranthene	12,475	---	NC	NC	9.5E-09	4.2E-09	1.4E-09	NC	4.3E-08	7.3E-07	2.1E-07	1.0E-06
Benzo(k)fluoranthene	133,899	---	NC	NC	1.0E-08	4.5E-09	1.5E-09	NC	4.7E-08	7.3E-07	2.1E-07	1.0E-06
Bis(2-Ethylhexyl)phthalate	8.6	---	3.6E-09	1.1E-08	1.3E-13	5.6E-14	1.8E-14	9.9E-07	7.8E-13	1.2E-12	3.6E-13	1.0E-06
Cadmium (Cd)	1,043,257	RES	NC	NC	NC	NC	1.0E-06	NC	NC	NC	NC	1.0E-06
Carbazole	1,917,632	RES	NC	NC	4.0E-08	1.8E-08	5.8E-09	NC	9.0E-07	2.9E-08	9.1E-09	1.0E-06
Carbon Tetrachloride	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Chlordane	5.9	---	1.9E-09	8.9E-09	8.0E-12	3.5E-12	1.2E-12	9.9E-07	4.2E-11	1.6E-10	4.6E-11	1.0E-06
Chromium (Cr)	156,488	---	NC	NC	NC	NC	1.0E-06	NC	NC	NC	NC	1.0E-06
Chromium, Hexavalent (Cr+6)	22,664	---	NC	NC	NC	NC	1.0E-06	NC	NC	NC	NC	1.0E-06
Chrysene	2,973,967	RES	NC	NC	2.3E-08	1.0E-08	3.3E-09	NC	1.1E-07	6.6E-07	1.9E-07	1.0E-06
Delta-BHC	0.21	---	2.0E-08	4.7E-08	1.4E-12	6.2E-13	2.1E-13	9.3E-07	1.7E-11	2.4E-12	7.3E-13	1.0E-06
Dibenzo(a,h)anthracene	262	---	NC	NC	2.0E-09	8.8E-10	2.9E-10	NC	8.4E-09	7.7E-07	2.2E-07	1.0E-06
Dieldrin	4,086	---	NC	NC	6.8E-08	3.0E-08	9.9E-09	NC	5.8E-07	2.4E-07	7.1E-08	1.0E-06
Formaldehyde	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Gamma-BHC	35,359	---	NC	NC	4.8E-08	2.1E-08	7.0E-09	NC	8.6E-07	4.6E-08	1.4E-08	1.0E-06
Gamma-Chlordane	6.4	---	1.9E-09	7.8E-09	8.7E-12	3.8E-12	1.3E-12	9.9E-07	4.6E-11	1.7E-10	5.1E-11	1.0E-06
Heptachlor	14,111	---	NC	NC	6.6E-08	2.9E-08	9.9E-09	NC	7.1E-07	1.4E-07	4.4E-08	1.0E-06
Heptachlor Epoxide	1,760	---	NC	NC	1.7E-08	7.4E-09	2.4E-09	NC	9.7E-07	4.8E-09	1.5E-09	1.0E-06
Indeno(1,2,3-cd)pyrene	4,636	---	NC	NC	3.5E-09	1.6E-09	5.1E-10	NC	1.5E-08	7.6E-07	2.2E-07	1.0E-06
Lead (Pb)	19	---	1.8E-07	1.6E-08	3.1E-11	1.4E-12	4.6E-12	8.1E-07	7.4E-11	6.7E-11	2.2E-11	1.0E-06
Mercury (Hg)	540	---	2.6E-10	2.3E-11	1.7E-13	7.4E-15	NC	1.0E-06	7.9E-12	9.0E-11	1.5E-12	1.0E-06
Methylene Chloride	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Pentachlorophenol	126,102	---	NC	NC	1.6E-08	7.0E-09	2.3E-09	NC	7.6E-08	7.0E-07	2.0E-07	1.0E-06

NC = Exposure pathway not complete for chemical.
RES = 10-6 Risk level not exceeded for pure compound.

Table 5-7. **Continued Scenario 3,** Summary of Soil Action Standards and Pathway-Specific Risk Contributions for Chemical Carcinogens at 10^{-6} Risk Levels.

Analyte	Site Action Standard mg/kg	notes	Pathway-Specific Risk Fraction: Swimming Ingestion	Dermal Swimming	Soil Ingestion	Dermal Soil	Inhalation	Fish Ingestion	Plant Ingestion	Meat Ingestion	Milk Ingestion	Risk Fraction Across Pathways
4,4'-DDD	70,326	---	NC	NC	0.018	0.008	0.003	NC	0.086	0.686	0.200	1.0
4,4'-DDE	60,568	---	NC	NC	0.022	0.009	0.003	NC	0.107	0.664	0.194	1.0
4,4'-DDT	22,898	---	NC	NC	0.008	0.004	0.001	NC	0.037	0.736	0.214	1.0
Alpha-BHC	8,363	---	NC	NC	0.055	0.024	0.008	NC	0.824	0.068	0.021	1.0
Alpha-Chlordane	0.44	---	0.002	0.008	0.000	0.000	0.000	0.990	0.000	0.000	0.000	1.0
Arochlor-1260	125	---	NC	NC	0.001	0.000	0.000	NC	0.004	0.771	0.223	1.0
Benzene	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	0.0
Benzo(a)anthracene	29,740	---	NC	NC	0.023	0.010	0.003	NC	0.114	0.657	0.193	1.0
Benzo(a)pyrene	1,283	---	NC	NC	0.010	0.004	0.001	NC	0.045	0.728	0.212	1.0
Benzo(b)fluoranthene	12,475	---	NC	NC	0.010	0.004	0.001	NC	0.043	0.729	0.212	1.0
Benzo(k)fluoranthene	133,899	---	NC	NC	0.010	0.004	0.001	NC	0.047	0.726	0.211	1.0
Bis(2-Ethylhexyl)phthalate	0.65	---	0.004	0.011	0.000	0.000	0.000	0.986	0.000	0.000	0.000	1.0
Cadmium (Cd)	1,043,257	RES	NC	NC	NC	NC	1.000	NC	NC	NC	NC	1.0
Carbazole	1,917,632	RES	NC	NC	0.040	0.018	0.006	NC	0.898	0.029	0.009	1.0
Carbon Tetrachloride	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	0.0
Chlordane	0.44	---	0.002	0.009	0.000	0.000	0.000	0.989	0.000	0.000	0.000	1.0
Chromium (Cr)	156,488	---	NC	NC	NC	NC	1.000	NC	NC	NC	NC	1.0
Chromium, Hexavalent (Cr+6)	22,664	---	NC	NC	NC	NC	1.000	NC	NC	NC	NC	1.0
Chrysene	2,973,967	RES	NC	NC	0.023	0.010	0.003	NC	0.114	0.657	0.193	1.0
Delta-BHC	0.017	---	0.020	0.047	0.000	0.000	0.000	0.934	0.000	0.000	0.000	1.0
Dibenzo(a,h)anthracene	262	---	NC	NC	0.002	0.001	0.000	NC	0.008	0.766	0.222	1.0
Dieldrin	4,086	---	NC	NC	0.068	0.030	0.010	NC	0.583	0.237	0.071	1.0
Formaldehyde	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	0.0
Gamma-BHC	35,359	---	NC	NC	0.048	0.021	0.007	NC	0.863	0.046	0.014	1.0
Gamma-Chlordane	0.48	---	0.002	0.008	0.000	0.000	0.000	0.990	0.000	0.000	0.000	1.0
Heptachlor	14,111	---	NC	NC	0.066	0.029	0.010	NC	0.707	0.144	0.044	1.0
Heptachlor Epoxide	1,760	---	NC	NC	0.017	0.007	0.002	NC	0.967	0.005	0.001	1.0
Indeno(1,2,3-cd)pyrene	4,636	---	NC	NC	0.004	0.002	0.001	NC	0.015	0.759	0.220	1.0
Lead (Pb)	1.697	---	0.179	0.016	0.000	0.000	0.000	0.805	0.000	0.000	0.000	1.0
Mercury (Hg)	40	---	0.000	0.000	0.000	0.000	NC	1.000	0.000	0.000	0.000	1.0
Methylene Chloride	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	0.0
Pentachlorophenol	126,102	---	NC	NC	0.016	0.007	0.002	NC	0.076	0.696	0.203	1.0

NC = Exposure pathway incomplete for chemical.
RES = 10-6 Risk level not exceeded for pure compound.

Table 5-8. **Scenario 3,** Summary of Soil Action Standards and Pathway-Specific Hazard Quotients for Chemical Non-Carcinogens at a Hazard Quotient of 1.0

	Site Action		Pathway-Specific Hazard Quotient at Action Standards									
Analyte	Standard mg/kg	notes	Swimming Ingestion	Dermal Swimming	Soil Ingestion	Dermal Soil	Inhalation	Fish Ingestion	Plant Ingestion	Meat Ingestion	Milk Ingestion	HQ Across Pathways
(MEK)	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Acenaphthene	441,121,321	RES	NC	NC	6.9E-02	1.9E-02	6.9E-03	NC	7.9E-01	8.4E-02	2.6E-02	1.0
Acetone	1,916	---	9.3E-01	4.7E-02	NC	NC	NC	2.2E-02	NC	NC	NC	1.0
Anthracene	2,570,511,404	RES	NC	NC	8.1E-02	2.2E-02	8.0E-03	NC	6.3E-01	2.0E-01	6.0E-02	1.0
Antimony (Sb)	2,733,663	RES	NC	NC	6.5E-02	1.8E-03	6.4E-03	NC	5.7E-01	3.3E-01	3.2E-02	1.0
Barium (Ba)	125,792,236	RES	NC	NC	1.7E-02	4.7E-04	8.4E-01	NC	1.1E-01	7.0E-03	2.4E-02	1.0
Benzo(g,h,i)perylei	38,423,382	RES	NC	NC	1.2E-02	3.4E-03	1.2E-03	NC	4.7E-02	7.3E-01	2.1E-01	1.0
Cadmium (Cd)	1,307,754	RES	NC	NC	2.5E-02	6.9E-04	2.1E-02	NC	6.0E-01	9.4E-02	2.6E-01	1.0
Chromium (Cr)	144,800,279	RES	7.4E-02	6.6E-03	1.4E-03	3.8E-05	NC	8.9E-01	4.5E-04	2.4E-02	3.6E-03	1.0
Chromium, Hexav	737	---	7.6E-02	6.8E-03	1.4E-06	3.9E-08	NC	9.2E-01	4.6E-07	2.5E-05	3.7E-06	1.0
Copper (Cu)	607,712	---	8.7E-02	7.7E-03	1.6E-04	4.3E-06	1.5E-05	8.8E-01	2.7E-03	1.7E-02	1.9E-03	1.0
Dibenzofuran	21,378,345	RES	NC	NC	5.0E-02	1.4E-02	5.0E-03	NC	8.9E-01	3.4E-02	1.1E-02	1.0
Diethyl Phthalate	1,257,818,781	RES	NC	NC	1.5E-02	4.1E-03	1.5E-03	NC	9.8E-01	2.8E-03	8.7E-04	1.0
Di-n-Butylphthalat	3,306	---	1.9E-02	5.6E-02	3.1E-07	8.7E-08	3.1E-08	9.3E-01	3.2E-06	4.6E-07	1.4E-07	1.0
Octylphthalate	4,904	---	NC	NC	2.3E-06	6.4E-07	2.3E-07	NC	7.8E-06	7.8E-01	2.2E-01	1.0
Endosulfan 1	31,426,147	RES	NC	NC	4.9E-02	1.4E-02	4.9E-03	NC	8.9E-01	3.2E-02	1.0E-02	1.0
Endosulfan Sulfate	31,426,147	RES	NC	NC	4.9E-02	1.4E-02	4.9E-03	NC	8.9E-01	3.2E-02	1.0E-02	1.0
Ethyl Benzene	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Fluoranthene	288,069,277	RES	NC	NC	6.8E-02	1.9E-02	6.7E-03	NC	3.8E-01	4.0E-01	1.2E-01	1.0
Fluorene	324,765,793	RES	NC	NC	7.7E-02	2.1E-02	7.6E-03	NC	7.3E-01	1.3E-01	3.8E-02	1.0
Formaldehyde	10,029	---	7.9E-01	1.5E-01	NC	NC	NC	5.2E-02	NC	NC	NC	1.0
Manganese (Mn)	1,171,227	RES	1.5E-02	1.3E-03	2.4E-04	6.5E-06	7.8E-02	9.0E-01	2.6E-03	9.8E-04	4.7E-04	1.0
Mercury (Hg)	6.4	---	2.6E-04	2.3E-05	2.0E-07	5.6E-09	6.9E-08	1.0E+00	7.9E-06	9.0E-05	1.5E-06	1.0
Methoxychlor	41,861,542	RES	NC	NC	7.9E-02	2.2E-02	7.8E-03	NC	6.9E-01	1.5E-01	4.6E-02	1.0
Naphthalene	163,238,767	RES	NC	NC	3.9E-02	1.1E-02	3.8E-03	NC	9.2E-01	1.8E-02	5.7E-03	1.0
Phenanthrene	255,977,232	RES	NC	NC	8.1E-02	2.2E-02	8.0E-03	NC	5.8E-01	2.4E-01	7.2E-02	1.0
Pyrene	145,114,228	RES	NC	NC	4.6E-02	1.3E-02	4.5E-03	NC	2.2E-01	5.6E-01	1.6E-01	1.0
Selenium (Se)	12,097,400	RES	NC	NC	2.3E-02	6.3E-04	2.3E-03	NC	2.5E-02	7.6E-01	1.9E-01	1.0
Silver (Ag)	2,546,453	RES	NC	NC	4.8E-03	1.3E-04	4.8E-04	NC	8.4E-02	1.2E-01	7.9E-01	1.0
Styrene	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Toluene	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Xylenes (Total)	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Zinc (Zn)	147,739	---	1.1E-02	1.0E-03	4.6E-06	1.3E-07	4.6E-07	9.6E-01	3.1E-04	2.5E-02	1.2E-03	1.0

NC = Exposure pathway not complete for chemical. RES = Target hazard quotient not exceeded for pure compound.

Table 5-9. Summary of Risk-Based Action Standards for Radionuclides for 10^{-4} to 10^{-6} Target Incremental Carcinogenic Risk Range

	Scenario 1 RBASs			Scenario 2 RBASs			Scenario 3 RBASs			1996 PRGs - Residential Soil		
Isotope	**10^{-4} Risk (pCi/g)**	**10^{-5} Risk (pCi/g)**	**10^{-6} Risk (pCi/g)**	**10^{-4} Risk (pCi/g)**	**10^{-5} Risk (pCi/g)**	**10^{-6} Risk (pCi/g)**	**10^{-4} Risk (pCi/g)**	**10^{-5} Risk (pCi/g)**	**10^{-6} Risk (pCi/g)**	**10^{-4} Risk (pCi/g)**	**10^{-5} Risk (pCi/g)**	**10^{-6} Risk (pCi/g)**
Americium-241	1,700	170	17	9.2	0.92	0.092	1,600,000	160,000	16,000	190	19	1.9
Bismuth-212 (Th-228 Daugh	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP
Bismuth-214 (Ra-226 Daugh	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP
Carbon-14	420,000	42,000	4,200	950,000	95,000	9,500	700,000	70,000	7,000	77,000	7,700	770
Cesium-137+D	10	1.0	0.10	20,000,000	2,000,000	200,000	2,500,000	250,000	25,000	2.0	0.20	0.020
Cobalt-60	2.2	0.22	0.022	3,200,000	320,000	32,000	580,000	58,000	5,800	0.43	0.043	0.0043
Lead-210+D	960	96	9.6	4,000	400	40	4,000	400	40	78	7.8	0.78
Lead-214 (Ra-226 Daughter)	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP
Plutonium-241 +D	60,000	6,000	600	320	32	3.2	220,000,000	22,000,000	2,200,000	15,000	1,500	150
Radium-223 (U-235 Daughte	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP
Radium-226+D	0.42	0.042	0.0042	110,000	11,000	1,100	110,000	11,000	1,100	0.62	0.062	0.0062
Strontium-90+D	1,000	100	10	29,000,000	2,900,000	290,000	3,400,000	340,000	34,000	1,400	140	14
Thorium-228+D	3.2	0.32	0.032	200,000	20,000	2,000	160,000	16,000	1,600	4.1	0.41	0.041
Thorium-232	2.2	0.22	0.022	380,000	38,000	3,800	220,000	22,000	2,200	2,400	240	24
Thorium-234 (U-238+D)	320	32	3.2	8,800,000	880,000	88,000	6,300,000	630,000	63,000	69	6.9	0.69
Tritium	13,000,000	1,300,000	130,000	540	54	5.4	250,000,000	25,000,000	2,500,000	1,100,000	110,000	11,000
Uranium-235+D	79	7.9	0.79	15	1.5	0.15	3,200,000	320,000	32,000	16	1.6	0.16

RBAS = Risk Based Action Standard
DP = Daughter Product; Standard driven by parent isotope.
PRG = USEPA Region IX Preliminary Remediation Goal, December 1996, at 10^{-4}, 10^{-5} or 10^{-6} Risk.

Table 5-10. **Scenario 1**, Summary of Soil Action Standards and Pathway-Specific Risk Contributions for Radionuclides at 10^{-6} Risk Level

			Pathway-Specific Risk at Action Standard					Pathway-Specific Risk Fraction at Action Standard			
Contaminant	**Site Action Standard (pCi/g)**	**Annual Dose at Action Standard (mrem/yr)**	**Inhalation (excluding Radon)**	**Radon Inhalation**	**Direct Ingestion**	**External Radiation**	**Total Risk at Action Standard**	**Inhalation (excluding Radon)**	**Radon Inhalation**	**Direct Ingestion**	**External Gamma**
Americium-241	17	4.2E-01	2.3E-08	NC	5.9E-07	3.8E-07	1.0E-06	0.023	NC	0.594	0.383
Bismuth-212	Th-228 Daughter[1]										
Bismuth-214	Ra-226 Daughter[1]										
Carbon-14	4,248	4.3E+00	3.5E-07	NC	4.4E-07	2.1E-07	1.0E-06	0.354	NC	0.438	0.208
Cesium-137+D	0.10	6.5E-02	6.8E-14	NC	3.4E-10	1.0E-06	1.0E-06	0.000	NC	0.000	1.000
Cobalt-60	0.022	6.6E-02	5.3E-14	NC	4.3E-11	1.0E-06	1.0E-06	0.000	NC	0.000	1.000
Lead-210+D	9.6	3.0E-01	1.3E-09	NC	9.9E-07	6.9E-09	1.0E-06	0.001	NC	0.992	0.007
Lead-214	Ra-226 Daughter[1]										
Pu-241+D	599	4.2E-01	2.3E-08	NC	6.0E-07	3.8E-07	1.0E-06	0.023	NC	0.601	0.376
Radium-223	U-235 Daughter[1]										
Radium-226+D	0.0042	7.6E-02	3.9E-13	8.7E-07	1.3E-10	1.3E-07	1.0E-06	0.000	0.869	0.000	0.131
Strontium-90+D	10	5.5E-02	2.4E-11	NC	5.8E-08	9.4E-07	1.0E-06	0.000	NC	0.058	0.941
Thorium-228+D	0.032	6.5E-02	1.1E-10	7.1E-08	7.7E-10	9.3E-07	1.0E-06	0.000	0.071	0.001	0.929
Thorium-232	0.022	6.8E-02	8.7E-11	4.7E-08	1.1E-09	9.5E-07	1.0E-06	0.000	0.047	0.001	0.952
Thorium-234 (U-238+D)	3.2	8.5E-02	1.3E-09	0.0E+00	2.0E-08	9.8E-07	1.0E-06	0.001	0.000	0.020	0.978
Tritium	134,600	3.6E-02	6.7E-10	NC	1.0E-06	0.0E+00	1.0E-06	0.001	NC	0.999	0.000
Uranium-235+D	0.79	1.1E-01	3.5E-10	0.0E+00	3.8E-09	1.0E-06	1.0E-06	0.000	0.000	0.004	0.996

D = Daughter products.

NC = Exposure pathway is not complete for radionuclide.

(1) These radionuclides are daughter products of others; no separate action standard is calculated for daughter products.

Table 5-11. **Scenario 2,** Summary of Soil Action Standards and Pathway Specific Risk Contributions at 10^{-6} Risk Level

			Pathway-Specific Risk at Site Action Standard									
Contaminant	**Site Action Standard (pCi/g)**	**Annual Dose at Action Standard (mrem/yr)**	**Inhalation (excluding Radon)**	**Radon Inhalation**	**Direct Soil Ingestion**	**External Radiation**	**Groundwater Ingestion**	**Plant Ingestion**	**Meat Ingestion**	**Milk Ingestion**	**Surface Water/Aquatic Foods**	**Total Risk at Action Standard**
Americium-241	0.092	3.7E-01	5.7E-14	NC	5.6E-16	1.9E-16	1.0E-06	4.7E-16	1.7E-16	1.2E-17	4.2E-12	1.0E-06
Bismuth-212	Th-228 Daughter[1]											
Bismuth-214	Ra-226 Daughter[1]											
Carbon-14	9,486	7.0E-02	9.5E-07	NC	7.8E-13	1.9E-13	0.0E+00	1.0E-08	3.1E-08	6.1E-09	4.7E-09	1.0E-06
Cesium-137+D	197,247	5.4E-02	2.7E-10	NC	5.2E-10	7.7E-07	0.0E+00	1.7E-08	1.3E-07	2.0E-08	6.6E-08	1.0E-06
Cobalt-60	32,387	5.5E-02	1.6E-10	NC	5.1E-11	5.9E-07	0.0E+00	3.4E-09	1.5E-08	8.7E-10	3.9E-07	1.0E-06
Lead-210+D	40	2.4E-01	1.1E-11	NC	3.3E-12	1.2E-14	0.0E+00	2.8E-11	8.2E-12	1.9E-12	1.0E-06	1.0E-06
Lead-214	Ra-226 Daughter[1]											
Pu-241+D	3.2	3.7E-01	6.1E-14	NC	6.0E-16	2.0E-16	1.0E-06	5.1E-16	1.8E-16	1.2E-17	2.1E-14	1.0E-06
Radium-223	U-235 Daughter[1]											
Radium-226+D	1,098	6.6E-02	3.7E-10	8.8E-08	7.6E-11	1.3E-08	0.0E+00	1.3E-09	3.5E-10	1.6E-10	9.0E-07	1.0E-06
Strontium-90+D	286,159	9.1E-02	1.4E-09	NC	1.3E-09	1.1E-08	0.0E+00	3.3E-07	5.7E-07	8.0E-08	1.3E-09	1.0E-06
Thorium-228+D	1,982	5.4E-02	1.4E-08	1.7E-09	3.8E-11	2.3E-08	0.0E+00	3.1E-11	5.4E-12	1.8E-13	9.6E-07	1.0E-06
Thorium-232	3,801	6.4E-02	3.2E-08	3.3E-09	1.6E-10	6.7E-08	0.0E+00	2.7E-09	6.7E-10	3.7E-10	8.9E-07	1.0E-06
Thorium-234 (U-23	87,937	8.1E-02	7.5E-08	0.0E+00	4.5E-10	1.1E-08	0.0E+00	9.4E-10	2.7E-10	3.1E-10	9.1E-07	1.0E-06
Tritium	5.4	3.0E-02	8.5E-18	NC	4.9E-18	0.0E+00	1.0E-06	1.4E-14	3.2E-14	3.1E-14	4.5E-19	1.0E-06
Uranium-235+D	0.15	8.0E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E-06	0.0E+00	1.2E-15	6.4E-16	3.6E-12	1.0E-06

D = Daughter products.

NC = Exposure pathway not complete for radionuclide.

(1) These radionuclides are daughter products of others; no separate action standard is calculated for daughter products.

Table 5-11. Continued **Scenario 2**, Summary of Soil Action Standards and Pathway Specific Risk Contributions at 10^{-6} Risk Level

		Pathway-Specific Risk Fraction at Site Action Standard									
Contaminant	**Site Action Standard (pCi/g)**	**Inhalation (excluding Radon)**	**Radon Inhalation**	**Direct Soil Ingestion**	**External Radiation**	**Groundwater Ingestion**	**Plant Ingestion**	**Meat Ingestion**	**Milk Ingestion**	**Surface Water/Aquatic Foods**	**Total Risk Fraction**
Americium-241	0.092	0.000	NC	0.000	0.000	1.000	0.000	0.000	0.000	0.000	1.0
Bismuth-212	Th-228 Daughter[1]										
Bismuth-214	Ra-226 Daughter[1]										
Carbon-14	9,486	0.949	NC	0.000	0.000	0.000	0.010	0.031	0.006	0.005	1.0
Cesium-137+D	197,247	0.000	NC	0.001	0.766	0.000	0.017	0.131	0.020	0.066	1.0
Cobalt-60	32,387	0.000	NC	0.000	0.589	0.000	0.003	0.015	0.001	0.391	1.0
Lead-210+D	40	0.000	NC	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.0
Lead-214	Ra-226 Daughter[1]										
Pu-241+D	3.2	0.000	NC	0.000	0.000	1.000	0.000	0.000	0.000	0.000	1.0
Radium-223	U-235 Daughter[1]										
Radium-226+D	1,098	0.000	0.088	0.000	0.013	0.000	0.001	0.000	0.000	0.896	1.0
Strontium-90+D	286,159	0.001	NC	0.001	0.011	0.000	0.332	0.574	0.080	0.001	1.0
Thorium-228+D	1,982	0.014	0.002	0.000	0.023	0.000	0.000	0.000	0.000	0.962	1.0
Thorium-232	3,801	0.032	0.003	0.000	0.067	0.000	0.003	0.001	0.000	0.894	1.0
Thorium-234 (U-23	87,937	0.075	0.000	0.000	0.011	0.000	0.001	0.000	0.000	0.912	1.0
Tritium	5.4	0.000	NC	0.000	0.000	1.000	0.000	0.000	0.000	0.000	1.0
Uranium-235+D	0.15	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	1.0

D = Daughter products.

NC = Exposure pathway not complete for radionuclide.

(1) These radionuclides are daughter products of others; no separate action standard is calculated for daughter products.

Table 5-12. **Scenario 3**, Summary of Soil Action Standards and Pathway Specific Risk Contributions at 10^{-6} Risk Level

			Pathway-Specific Risk at Site Action Standard								
Contaminant	**Site Action Standard (pCi/g)**	**Annual Dose at Action Standard (mrem/yr)**	**Inhalation (excluding Radon)**	**Radon Inhalation**	**Direct Soil Ingestion**	**External Radiation**	**Plant Ingestion**	**Meat Ingestion**	**Milk Ingestion**	**Surface Water/ Aquatic Foods**	**Total Risk at Action Standard**
Americium-241	16,329	3.6E-01	2.4E-07	NC	3.8E-09	1.2E-09	3.1E-09	2.8E-10	7.4E-12	7.5E-07	1.0E-06
Bismuth-212	Th-228 Daughter[1]										
Bismuth-214	Ra-226 Daughter[1]										
Carbon-14	7,033	7.0E-02	7.0E-07	NC	4.9E-12	1.2E-12	6.3E-08	1.9E-07	3.8E-08	3.5E-09	1.0E-06
Cesium-137+D	24,734	5.4E-02	1.8E-10	NC	5.5E-10	8.1E-07	1.8E-08	1.4E-07	2.1E-08	8.2E-09	1.0E-06
Cobalt-60	5,838	5.5E-02	1.5E-10	NC	7.8E-11	9.0E-07	5.2E-09	2.3E-08	1.3E-09	7.0E-08	1.0E-06
Lead-210+D	40	2.4E-01	6.0E-11	NC	2.8E-11	9.9E-14	2.4E-10	6.9E-11	1.6E-11	1.0E-06	1.0E-06
Lead-214	Ra-226 Daughter[1]										
Pu-241+D	2,224,245	3.6E-01	9.5E-07	NC	1.5E-08	4.7E-09	1.3E-08	1.2E-09	2.9E-11	1.5E-08	1.0E-06
Radium-223	U-235 Daughter[1]										
Radium-226+D	1,068	6.6E-02	1.9E-09	0.0E+00	5.9E-10	1.1E-07	1.0E-08	2.8E-09	1.3E-09	8.7E-07	1.0E-06
Strontium-90+D	33,864	9.1E-02	8.9E-10	NC	1.3E-09	1.1E-08	3.3E-07	5.7E-07	8.0E-08	1.5E-10	1.0E-06
Thorium-228+D	1,594	5.4E-02	5.9E-08	1.2E-08	2.6E-10	1.6E-07	2.1E-10	3.7E-11	1.3E-12	7.7E-07	1.0E-06
Thorium-232	2,247	6.4E-02	1.0E-07	1.7E-08	8.1E-10	3.4E-07	1.4E-08	3.4E-09	1.9E-09	5.3E-07	1.0E-06
Thorium-234 (U-238+	62,548	8.1E-02	2.8E-07	0.0E+00	2.7E-09	6.3E-08	5.7E-09	1.6E-09	1.8E-09	6.5E-07	1.0E-06
Tritium	2,520,075	3.0E-02	1.4E-10	NC	1.3E-10	0.0E+00	3.7E-07	4.5E-07	1.9E-07	2.1E-13	1.0E-06
Uranium-235+D	31,742	1.3E-01	1.3E-07	0.0E+00	1.1E-09	1.1E-07	2.7E-09	1.5E-09	5.0E-10	7.5E-07	1.0E-06

D = Daughter products.

NC = Exposure pathway not complete for radionuclide.

([1]) These radionuclides are daughter products of others; no separate action standard is calculated for daughter products.

Table 5-12. Continued **Scenario 3**, Summary of Soil Action Standards and Pathway Specific Risk Contributions at 10^{-6} Risk Level

		Pathway-Specific Risk Fraction at Site Action Standard								
Contaminant	**Site Action Standard (pCi/g)**	**Inhalation (excluding Radon)**	**Radon Inhalation**	**Direct Ingestion**	**External Radiation**	**Plant Ingestion**	**Meat Ingestion**	**Milk Ingestion**	**Surface Water/ Aquatic Foods**	**Total Risk Fraction**
Americium-241	16,329	0.242	NC	0.004	0.001	0.003	0.000	0.000	0.749	1.0
Bismuth-212	Th-228 Daughter[1]									
Bismuth-214	Ra-226 Daughter[1]									
Carbon-14	7,033	0.703	NC	0.000	0.000	0.063	0.192	0.038	0.003	1.0
Cesium-137+D	24,734	0.000	NC	0.001	0.813	0.018	0.139	0.021	0.008	1.0
Cobalt-60	5,838	0.000	NC	0.000	0.899	0.005	0.023	0.001	0.070	1.0
Lead-210+D	40	0.000	NC	0.000	0.000	0.000	0.000	0.000	1.000	1.0
Lead-214	Ra-226 Daughter[1]									
Pu-241+D	2,224,245	0.952	NC	0.015	0.005	0.013	0.001	0.000	0.015	1.0
Radium-223	U-235 Daughter[1]									
Radium-226+D	1,068	0.002	0.000	0.001	0.111	0.010	0.003	0.001	0.872	1.0
Strontium-90+D	33,864	0.001	NC	0.001	0.011	0.332	0.575	0.080	0.000	1.0
Thorium-228+D	1,594	0.059	0.012	0.000	0.156	0.000	0.000	0.000	0.773	1.0
Thorium-232	2,247	0.100	0.017	0.001	0.335	0.014	0.003	0.002	0.528	1.0
Thorium-234 (U-238+	62,548	0.277	0.000	0.003	0.063	0.006	0.002	0.002	0.649	1.0
Tritium	2,520,075	0.000	NC	0.000	0.000	0.369	0.446	0.185	0.000	1.0
Uranium-235+D	31,742	0.135	0.000	0.001	0.105	0.003	0.001	0.001	0.755	1.0

D = Daughter products.
NC = Exposure pathway not complete for radionuclide.
([1]) These radionuclides are daughter products of others; no separate action standard is calculated for daughter products.

6. SUMMARY AND CONCLUSION

Action standards for chemicals and radionuclides in each scenario for 10^{-4}, 10^{-5} and 10^{-6} risk are summarized in Tables 6-1, 6-2 and 6-3 respectively. Table 6-4 shows the same information for chemical non-carcinogens, based on a single constituent target hazard quotient of 1.0. A summary of site soil concentration data in each OU and site-specific background concentrations is presented for comparison with the action standards. The minimum risk-based action standard across the three exposure scenarios was compared with the background concentration to determine the action standard for a given target risk. When the minimum action standard for a particular risk target level was less than the background concentration, the action standard for that contaminant was set equal to the calculated background concentration. The residential scenario PRGs have not been considered in the selection of the action standards, since, as discussed earlier, these have been included for comparison only. For each DOE OU, chemical compounds and radionuclides whose reasonable maximum exposure (RME) soil concentration is greater than the selected action standards have been flagged with a "YES" in the summary tables, indicating the action standard is exceeded in an OU at the specified risk level.

In general, comparison of the action standards to the Site soil concentrations determined for each OU indicates that only a few action standards are exceeded in OU2, OU3 and OU4. The number of compounds that exceed the action standards in OU1 for 10^{-4} target risk is approximately 1/4 of the number at the 10^{-6} target risk level. A brief comparison of chemical and radionuclide site soil concentrations to risk based action standards is presented in turn for 10^{-4}, 10^{-5} and 10^{-6} target risk and an HQ of 1.0 as follows:

- At the 10^{-4} target incremental carcinogenic risk level, three non-radionuclide carcinogenic chemicals in the Southwest Trenches exceed the action standards determined in this assessment. These chemicals are benzo(a)anthracene, benzo(a)pyrene and carbazole. Lead also exceeds the action standard in the Southwest Trenches No carcinogenic chemicals in OU2, OU3, or OU4 exceed the risk based action standards. The radionuclide radium-226 in the Southwest Trenches exceeds the action standard at 10^{-4} target risk. For radium-226, the action standard is the site-specific background concentration, because the calculated action standard is less than background.
- At the 10^{-5} target incremental carcinogenic risk level, the action standards for six polynuclear aromatic compounds (PNAs), carbazole, lead and six radionuclides including radium-226 and strontium-90 are exceeded in OU1. In OU2, radium-226 and two PNAs exceed the calculated action standards. Radium-226 in OU3 is above the action standard for 10^{-5} target risk. No radionuclides or carcinogenic chemicals in OU4 are above the calculated action standards. For radium-226, thorium-228, and thorium-232, the action standard is the site-specific background concentration, because the calculated action standard is less than background.

- At the 10^{-6} target incremental carcinogenic risk level, additional carcinogenic chemicals and radionuclides exceed the action standards. In OU1, seven PNAs, six radionuclides including radium-226 and strontium-90, the pesticides chlordane and dieldrin, lead, arochlor 1260 and two semivolatile organic compounds (SVOCs) were above the action standards. In OU2, six PNAs, carbazole, and radium-226 were above the action standards. Radium-226, chlordane[4] and alpha BHC were above the action standards in OU3. No compounds were present above the action standards in OU4. For radium-226, thorium-228, and throrium-232, the action standard is the site-specific background concentration, because the calculated action standard is less than background.
- At the 10-6 target incremental carcinogenic risk level, estimated single compound radionuclide dose (mrem/yr) ranges from 0.03 mrem/yr for tritium to 4.3 mrem/yr for carbon-14, with all compounds of concern except tritium below 1 mrem/yr. The total dose for each compound differs based on the differing contributions from each exposure pathway, and differing dose conversion factors between toxic endpoints for the same compound. At the 10-4 target incremental risk level, the corresponding mrem/yr dose ranges from 3 to 430 mrem/yr. At the 10-6 target risk level, the corresponding dose for each radionuclide of concern is well below the 15 mrem/yr limit specified by draft 40 CFR 196 and the 25 mrem/yr limit routinely used as an ARAR at other CERCLA sites.
- Based on a hazard quotient of 1.0, the non-carcinogenic action standards for seven PNAs, five metals including cadmium and mercury, and one SVOC are exceeded in OU1. In OU2, copper exceeds the action standard. Mercury is above the action standard in OU3. Barium is above the action standard in OU4.

[4] The accuracy of the RME concentration for chlordane in OU3 is in question. The sample holding times were exceeded and the contract laboratory program analytical method for pesticides was not used. However, chlordane was positively identified by the pesticide analysis method used according to the USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review.

Table 6-1A. Summary of Risk-Based Action Standards vs Site Data for Chemical Carcinogens at 10^{-4} Target Risk Level.

Analyte	Selected Action Standard (mg/kg)	Action Standard Exceeded (Yes/No) OU1 ? (YES/n)	OU2 ? (YES/n)	OU3 ? (YES/n)	OU4 ? (YES/n)	Risk Based Action Standards Scenario 1 RBAS (mg/kg)	Scenario 2 RBAS (mg/kg)	Scenario 3 RBAS (mg/kg)	1996 PRGs Residential Soil (mg/kg)	Background (mg/kg)	Reasonable Maximum Exposure Concentration In Soil OU1 (mg/kg)	OU2 (mg/kg)	OU3 (mg/kg)	OU4 (mg/kg)
4,4'-DDD	790	n	n	n/a	n/a	790	940	RES	190	none	0.24	0.00032	ND	ND
4,4'-DDE	560	n	n/a	n	n/a	560	900	RES	130	none	0.014	ND	0.0013	ND
4,4'-DDT	560	n	n	n/a	n/a	560	3,000	RES	130	none	0.0037	0.0018	ND	ND
Alpha-BHC	0.75	n/a	n/a	n	n/a	30	0.75	840,000	7.1	none	ND	ND	0.011	ND
Alpha-Chlordane	80	n	n/a	n	n/a	150	80	590	34	none	0.8	ND	0.23	ND
Arochlor-1260	25	n	n/a	n/a	n/a	25	490	12,000	6.6	none	1.3	ND	ND	ND
Benzene	1.5	n	n	n/a	n/a	23	1.5	n/a	63	none	0.001	0.005	ND	ND
Benzo(a)anthracene	120	YES	n	n/a	n/a	260	120	RES	61	none	660	25	ND	ND
Benzo(a)pyrene	24	YES	n	n/a	n/a	26	24	130,000	6.1	none	140	22	ND	ND
Benzo(b)fluoranthene	260	n	n	n/a	n/a	260	330	RES	61	none	96	15	ND	ND
Benzo(k)fluoranthene	2,600	n	n	n/a	n/a	2,600	2,700	RES	610	none	36	20	ND	ND
Bis(2-Ethylhexyl)phthalate	770	n	n	n	n/a	14,000	770	860	3,200	none	1.7	0.82	0.065	ND
Cadmium (Cd)	480,000	n	n/a	n/a	n/a	480,000	RES	RES	3,800	0.46	7.1	ND	ND	ND
Carbazole	220	YES	n	n/a	n/a	9,500	220	RES	2,200	none	410	2.4	ND	ND
Carbon Tetrachloride	5.5	n	n/a	n/a	n/a	22	5.5	n/a	23	none	0.004	ND	ND	ND
Chlordane	78	n/a	n/a	n	n/a	150	78	590	34	none	ND	ND	3	ND
Chromium (Cr)	72,000	n	n	n/a	n/a	72,000	RES	RES	21,000	178	230	230	<BKG	<BKG
Chromium, Hexavalent (Cr+6)	10,000	n	n/a	n	n/a	10,000	RES	RES	20	0.099	0.22	ND	0.16	ND
Chrysene	2,000	n	n	n/a	n/a	26,000	2,000	RES	610	none	630	28	ND	ND
Delta-BHC	1.30	n/a	n/a	n	n/a	30	1.3	21	25	none	ND	ND	0.0014	ND
Dibenzo(a,h)anthracene	26	n	n	n/a	n/a	26	54	26,000	6.1	none	18	1.9	ND	ND
Dieldrin	1.5	n	n/a	n/a	n/a	12	1.5	410,000	2.8	none	0.07	ND	ND	ND
Formaldehyde	22,000	n	n/a	n/a	n	22,000	n/a	n/a	980,000	none	1.6	ND	ND	2.2
Gamma-BHC	3.0	n/a	n/a	n	n/a	150	3.0	RES	34	none	ND	ND	0.0018	ND
Gamma-Chlordane	81	n	n/a	n	n/a	150	81	640	34	none	0.74	ND	0.26	ND
Heptachlor	17	n	n/a	n	n/a	42	17	RES	10	none	0.096	ND	0.0066	ND
Heptachlor Epoxide	0.057	n	n/a	n/a	n/a	21	0.057	180,000	4.9	none	0.0013	ND	ND	ND
Indeno(1,2,3-cd)pyrene	260	n	n	n/a	n/a	260	490	460,000	61	none	27	8.5	ND	ND
Lead (Pb)	4.4	YES	n/a	n/a	n/a	300	4.4	1,900	130	10.1	21	<BKG	<BKG	<BKG
Mercury (Hg)	1,500	n	n/a	n	n/a	RES	1,500	54,000	2,300	0.49	0.65	<BKG	1	<BKG
Methylene Chloride	13	n	n/a	n/a	n/a	720	13	n/a	780	none	0.004	ND	ND	ND
Pentachlorophenol	1,300	n	n/a	n/a	n/a	1,600	1,300	RES	250	none	0.66	ND	ND	ND

Reasonable Maximum Exposure Concentration = Highest value in surface or subsurface data sets expressed as the 95% upper confidence limit (or maximum detected value if less than 10 detected results).
RBAS = Risk Based Action Standard.
ND = Analyte not detected in OU.
<BKG = Concentration below background in OU.
RES = 10^{-4} risk level not exceeded for pure compound present at any concentration.
n/a = Exposure pathway incomplete for compound.
none = No background value established for this compound.
3 mg/kg RME value for chlordane in OU3 is of questionable accuracy.
PRG = USEPA Region IX Preliminary Remediation Goals, August 1996, at 10^{-4} Risk.

Table 6-1B. Summary of Risk Based Action Standards vs Site Data for Radionuclides at 10^{-4} Target Risk Level.

Isotope	Selected Action Standard (pCi/g)	Action Standard Exceeded (Yes/No) OU1 ? (YES/n)	OU2 ? (YES/n)	OU3 ? (YES/n)	OU4 ? (YES/n)	Risk Based Action Standard Scenario 1 RBAS (pCi/g)	Scenario 2 RBAS (pCi/g)	Scenario 3 RBAS (pCi/g)	1996 PRGs Residential Soil (pCi/g)	Background (pCi/g)	Reasonable Maximum Exposure Concentration In Soil OU1 (pCi/g)	OU2 (pCi/g)	OU3 (pCi/g)	OU4 (pCi/g)
Americium-241	9.2	n	n	n/a	n/a	1,700	9.2	1,600,000	190	none	0.027	0.024	<BKG	<BKG
Bismuth-212 (Th-228 Daughter)	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP	0.35	0.42	0.4	0.44
Bismuth-214 (Ra-226 Daughter)	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP	<BKG	1.5	<BKG	<BKG
Carbon-14	420,000	n	n	n	n	420,000	950,000	700,000	77,000	0.87	3.3	2.5	3.6	2.9
Cesium-137+D	10	n	n	n/a	n/a	10	20,000,000	2,500,000	2.0	0.053	5.8	0.054	<BKG	<BKG
Cobalt-60	2.2	n/a	n/a	n/a	n/a	2.2	3,200,000	580,000	0.43	0.016	<BKG	<BKG	<BKG	<BKG
Lead-210+D	960	n	n	n	n	960	4,000	4,000	78	none	3.3	3.0	1	5.5
Lead-214 (Ra-226 Daughter)	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP	0.76	1.7	<BKG	<BKG
Plutonium-241 +D	320	n	n	n/a	n/a	60,000	320	220,000,000	15,000	none	0.30	1.5	NDA	NDA
Radium-223 (U-235 Daughter)	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP	0.47	0.05	0.04	0.16
Radium-226+D	BKG	YES	YES	YES	n/a	0.42	110,000	110,000	0.62	0.77	17	4.6	1.3	<BKG
Strontium-90+D	1,000	n	n	n	n	1,000	28,000,000	3,400,000	1,400	0.36	850	8.9	1.5	0.45
Thorium-228+D	3.2	n	n/a	n/a	n/a	3.2	200,000	160,000	4.1	0.71	0.76	NDA	NDA	NDA
Thorium-232	2.2	n	n/a	n/a	n/a	2.2	380,000	220,000	2,400	0.64	0.71	NDA	NDA	NDA
Thorium-234 (U-238+D)	320	n	n	n	n	320	8,800,000	6,300,000	69	none	2.3	0.69	0.85	0.51
Tritium	540	n	n/a	n/a	n/a	13,000,000	54,000	250,000,000	1,100,000	none	91	NDA	NDA	NDA
Uranium-235+D	15	n	n	n/a	n	79	15	3,200,000	16	0.071	0.12	0.12	<BKG	0.10

Selected Action Standard = Minimum RBAS or Background if Background > Min RBAS.
DP = Daughter Product; Cleanup driven by parent isotope.
BKG = Background value selected as action standard.
PRG = USEPA Region IX Preliminary Remediation Goals, December 1996, at 10-4 Risk.
none = No value available.
<BKG = Concentration below background in OU.
NDA = No data available for this radionuclide.
Reasonable Maximum Exposure Concentration = 95% upper confidence level on the mean (or the maximum activity if less than 10 sample results were available) for surface and subsurface data sets.
n/a = not applicable.

Table 6-2A. Summary of Risk Based Action Standards vs Site Data for Chemical Carcinogens, 10^{-5} Target Risk Level

Analyte	Selected Action Standard (mg/kg)	Action Standard Exceeded (Yes/No) OU1 ? (YES/n)	OU2 ? (YES/n)	OU3 ? (YES/n)	OU4 ? (YES/n)	Risk Based Action Levels Scenario 1 RBAS (mg/kg)	Scenario 2 RBAS (mg/kg)	Scenario 3 RBAS (mg/kg)	1996 PRGs Residential Soil (mg/kg)	Background (mg/kg)	Reasonable Maximum Exposure Concentration In Soil OU1 (mg/kg)	OU2 (mg/kg)	OU3 (mg/kg)	OU4 (mg/kg)
4,4'-DDD	79	n	n	n/a	n/a	79	94	700,000	19	none	0.24	0.00032	ND	ND
4,4'-DDE	56	n	n/a	n	n/a	56	90	610,000	13	none	0.014	ND	0.0013	ND
4,4'-DDT	56	n	n	n/a	n/a	56	300	230,000	13	none	0.0037	0.0018	ND	ND
Alpha-BHC	0.075	n/a	n/a	n	n/a	3.0	0.075	84,000	0.71	none	ND	ND	0.011	ND
Alpha-Chlordane	8.0	n	n/a	n	n/a	15	8.0	59	3.4	none	0.8	ND	0.23	ND
Arochlor-1260	2.5	n	n/a	n/a	n/a	2.5	49	1,200	0.66	none	1.3	ND	ND	ND
Benzene	0.15	n	n	n/a	n/a	2.3	0.15	n/a	6.3	none	0.001	0.005	ND	ND
Benzo(a)anthracene	12	YES	YES	n/a	n/a	26	12	300,000	6.1	none	660	25	ND	ND
Benzo(a)pyrene	2.4	YES	YES	n/a	n/a	2.6	2.4	13,000	0.61	none	140	22	ND	ND
Benzo(b)fluoranthene	26	YES	n	n/a	n/a	26	33	120,000	6.1	none	96	15	ND	ND
Benzo(k)fluoranthene	260	n	n	n/a	n/a	260	270	RES	61	none	36	20	ND	ND
Bis(2-Ethylhexyl)phthalate	77	n	n	n	n/a	1,400	77	86	320	none	1.7	0.82	0.065	ND
Cadmium (Cd)	48,000	n	n/a	n/a	n/a	48,000	RES	RES	380	0.46	7.1	ND	ND	ND
Carbazole	22	YES	n	n/a	n/a	950	22	RES	220	none	410	2.4	ND	ND
Carbon Tetrachloride	0.55	n	n/a	n/a	n/a	2.2	0.55	n/a	2.3	none	0.004	ND	ND	ND
Chlordane	7.8	n/a	n/a	n	n/a	15	7.8	59	3.4	none	ND	ND	3	ND
Chromium (Cr)	7200	n	n	n/a	n/a	7,200	RES	RES	2,100	178	230	230	<BKG	<BKG
Chromium, Hexavalent (Cr+6)	1000	n	n/a	n	n/a	1,000	RES	230,000	2.0	0.099	0.22	ND	0.16	ND
Chrysene	200	YES	n	n/a	n/a	2,600	200	RES	61	none	630	28	ND	ND
Delta-BHC	0.13	n/a	n/a	n	n/a	3.0	0.13	2.1	2.5	none	ND	ND	0.0014	ND
Dibenzo(a,h)anthracene	2.6	YES	n	n/a	n/a	2.6	5.4	2,600	0.61	none	18	1.9	ND	ND
Dieldrin	0.15	n	n/a	n/a	n/a	1.2	0.15	41,000	0.28	none	0.07	ND	ND	ND
Formaldehyde	2,200	n	n/a	n/a	n	2200	n/a	n/a	98,000	none	1.6	ND	ND	2.2
Gamma-BHC	0.30	n/a	n/a	n	n/a	15	0.30	350,000	3.4	none	ND	ND	0.0018	ND
Gamma-Chlordane	8.1	n	n/a	n	n/a	15	8.1	64	3.4	none	0.74	ND	0.26	ND
Heptachlor	1.7	n	n/a	n	n/a	4.2	1.7	140,000	1.0	none	0.096	ND	0.0066	ND
Heptachlor Epoxide	0.0057	n	n/a	n/a	n/a	2.1	0.0057	18,000	0.49	none	0.0013	ND	ND	ND
Indeno(1,2,3-cd)pyrene	26	YES	n	n/a	n/a	26	49	46,000	6.1	none	27	8.5	ND	ND
Lead (Pb)	0.44	YES	n/a	n/a	n/a	30	0.44	190	130	10.1	21	<BKG	<BKG	<BKG
Mercury (Hg)	150	n	n/a	n	n/a	160,000	150	5,400	230	0.49	0.65	<BKG	1	<BKG
Methylene Chloride	1.3	n	n/a	n/a	n/a	72	1.3	n/a	78	none	0.004	ND	ND	ND
Pentachlorophenol	130	n	n/a	n/a	n/a	160	130	RES	25	none	0.66	ND	ND	ND

Reasonable Maximum Exposure Concentration = Highest value in surface or subsurface data sets expressed as the 95% upper confidence limit (or maximum detected value if less than 10 detected results).

RBAS = Risk Based Action Standard.

ND = Analyte not detected in OU.

<BKG = Concentration below background in OU.

RES = 10-5 risk level not exceeded for pure compound present at any concentration.

n/a = Exposure pathway incomplete for compound.

none = No background value established for this compound.

3 mg/kg RME Value for Chlordane in OU3 is of Questionable Accuracy.

PRG = USEPA Region IX Preliminary Remediation Goals, August 1996, at 10^{-5} Risk.

Table 6-2B. Summary of Risk Based Action Standards vs Site Data for Radionuclides at 10^{-5} Target Risk Level

Isotope	Selected Action Standard (pCi/g)	Action Standard Exceeded (Yes/No) OU1 ? (YES/n)	OU2 ? (YES/n)	OU3 ? (YES/n)	OU4 ? (YES/n)	Risk Based Action Standards Scenario 1 RBAS (pCi/g)	Scenario 2 RBAS (pCi/g)	Scenario 3 RBAS (pCi/g)	1996 PRGs Residential Soil (pCi/g)	Background (pCi/g)	Reasonable Maximum Exposure Concentration In Soil OU1 (pCi/g)	OU2 (pCi/g)	OU3 (pCi/g)	OU4 (pCi/g)
Americium-241	0.92	n	n	n/a	n/a	170	0.92	160,000	19	none	0.027	0.024	<BKG	<BKG
Bismuth-212 (Th-228 Daughter)	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP	0.35	0.42	0.4	0.44
Bismuth-214 (Ra-226 Daughter)	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP	<BKG	1.5	<BKG	<BKG
Carbon-14	42,000	n	n	n	n	42,000	95,000	70,000	7,700	0.87	3.3	2.5	3.6	2.9
Cesium-137+D	1.0	YES	n	n/a	n/a	1.0	2,000,000	250,000	0.20	0.053	5.8	0.054	<BKG	<BKG
Cobalt-60	0.22	n/a	n/a	n/a	n/a	0.22	320,000	58,000	0.043	0.016	<BKG	<BKG	<BKG	<BKG
Lead-210+D	96	n	n	n	n	96	400	400	7.8	none	3.3	3.0	1	5.5
Lead-214 (Ra-226 Daughter)	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP	0.76	1.7	<BKG	<BKG
Plutonium-241 +D	32	n	n	n/a	n/a	6,000	32	22,000,000	1,500	none	0.30	1.5	NDA	NDA
Radium-223 (U-235 Daughter)	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP	0.47	0.05	0.04	0.16
Radium-226+D	BKG	YES	YES	YES	n/a	0.042	11,000	11,000	0.062	0.77	17	4.6	1.3	<BKG
Strontium-90+D	100	YES	n	n	n	100	2,800,000	340,000	140	0.36	850	8.9	1.5	0.45
Thorium-228+D	BKG	YES	n/a	n/a	n/a	0.32	20,000	16,000	0.41	0.71	0.76	NDA	NDA	NDA
Thorium-232	BKG	YES	n/a	n/a	n/a	0.22	38,000	22,000	240	0.64	0.71	NDA	NDA	NDA
Thorium-234 (U-238+D)	32	n	n	n	n	32	880,000	630,000	6.9	none	2.3	0.69	0.85	0.51
Tritium	54	YES	n/a	n/a	n/a	1,300,000	5,400	25,000,000	110,000	none	91	NDA	NDA	NDA
Uranium-235+D	1.5	n	n	n/a	n	7.9	1.5	320,000	1.6	0.071	0.12	0.12	<BKG	0.10

Selected Action Standard = Minimum RBAS or Background if Background > Min RBAS.
DP = Daughter Product; Cleanup driven by parent isotope.
BKG = Background value selected as action level.
TBD = Result to be Determined.
PRG = USEPA Region IX Preliminary Remediation Goals, December 1996, at 10-5 Risk.
none = No value available.
<BKG = Concentration below background in OU.
NDA = No data available for this radionuclide.
Reasonable Maximum Exposure Concentration = 95% upper confidence level on the mean (or the maximum activity if less than 10 sample results were available) for surface and subsurface data sets.
n/a = not applicable.

Table 6-3A. Summary of Risk-Based Soil Action Standards vs Site Data for Chemical Carcinogens at 10^{-6} Target Risk Level

Analyte	Selected Action Standard (mg/kg)	Action Standard Exceeded (Yes/No) OU1 ? (YES/n)	OU2 ? (YES/n)	OU3 ? (YES/n)	OU4 ? (YES/n)	Risk Based Action Standards Scenario 1 RBAS (mg/kg)	Scenario 2 RBAS (mg/kg)	Scenario 3 RBAS (mg/kg)	1996 PRGs Residential Soil (mg/kg)	Background (mg/kg)	Reasonable Maximum Exposure Concentration In Soil OU1 (mg/kg)	OU2 (mg/kg)	OU3 (mg/kg)	OU4 (mg/kg)
4,4'-DDD	7.9	n	n	n/a	n/a	7.9	9.4	70,000	1.9	none	0.24	0.00032	ND	ND
4,4'-DDE	5.6	n	n/a	n	n/a	5.6	9.0	61,000	1.3	none	0.014	ND	0.0013	ND
4,4'-DDT	5.6	n	n	n/a	n/a	5.6	30	23,000	1.3	none	0.0037	0.0018	ND	ND
Alpha-BHC	0.0075	n/a	n/a	YES	n/a	0.30	0.0075	8,400	0.071	none	ND	ND	0.011	ND
Alpha-Chlordane	0.80	YES	n/a	n	n/a	1.5	0.80	5.9	0.34	none	0.8	ND	0.23	ND
Arochlor-1260	0.25	YES	n/a	n/a	n/a	0.25	4.9	120	0.066	none	1.3	ND	ND	ND
Benzene	0.015	n	n	n/a	n/a	0.23	0.015	n/a	0.63	none	0.001	0.005	ND	ND
Benzo(a)anthracene	1.2	YES	YES	n/a	n/a	2.6	1.2	30,000	0.61	none	660	25	ND	ND
Benzo(a)pyrene	0.24	YES	YES	n/a	n/a	0.26	0.24	1,300	0.061	none	140	22	ND	ND
Benzo(b)fluoranthene	2.6	YES	YES	n/a	n/a	2.6	3.3	12,000	0.61	none	96	15	ND	ND
Benzo(k)fluoranthene	26	YES	n	n/a	n/a	26	27	130,000	6.1	none	36	20	ND	ND
Bis(2-Ethylhexyl)phthalate	7.7	n	n	n	n/a	136	7.7	8.6	32	none	1.7	0.82	0.065	ND
Cadmium (Cd)	4800	n	n/a	n/a	n/a	4,800	RES	RES	38	0.46	7.1	ND	ND	ND
Carbazole	2.2	YES	YES	n/a	n/a	95	2.2	RES	22	none	410	2.4	ND	ND
Carbon Tetrachloride	0.055	n	n/a	n/a	n/a	0.22	0.055	n/a	0.23	none	0.004	ND	ND	ND
Chlordane	0.78	n/a	n/a	YES	n/a	1.5	0.78	5.9	0.34	none	ND	ND	3	ND
Chromium (Cr)	722	n	n	n/a	n/a	722	840,000	160,000	210	178	230	230	<BKG	<BKG
Chromium, Hexavalent (Cr+6)	105	n	n/a	n	n/a	105	120,000	23,000	0.20	0.099	0.22	ND	0.16	ND
Chrysene	20	YES	YES	n/a	n/a	261	20	RES	6.1	none	630	28	ND	ND
Delta-BHC	0.013	n/a	n/a	n	n/a	0.30	0.013	0.21	0.25	none	ND	ND	0.0014	ND
Dibenzo(a,h)anthracene	0.26	YES	YES	n/a	n/a	0.26	0.54	260	0.061	none	18	1.9	ND	ND
Dieldrin	0.015	YES	n/a	n/a	n/a	0.12	0.015	4,100	0.028	none	0.07	ND	ND	ND
Formaldehyde	220	n	n/a	n/a	n	220	n/a	n/a	9,800	none	1.6	ND	ND	2.2
Gamma-BHC	0.030	n/a	n/a	n	n/a	1.5	0.030	35,000	0.34	none	ND	ND	0.0018	ND
Gamma-Chlordane	0.81	n	n/a	n	n/a	1.5	0.81	6.4	0.34	none	0.74	ND	0.26	ND
Heptachlor	0.17	n	n/a	n	n/a	0.42	0.17	14,000	0.099	none	0.096	ND	0.0066	ND
Heptachlor Epoxide	0.00057	YES	n/a	n/a	n/a	0.21	0.00057	1,800	0.049	none	0.0013	ND	ND	ND
Indeno(1,2,3-cd)pyrene	2.6	YES	YES	n/a	n/a	2.6	4.9	4,600	0.61	none	27	8.5	ND	ND
Lead (Pb)	0.044	YES	n/a	n/a	n/a	3.0	0.044	19	130	10.1	21	<BKG	<BKG	<BKG
Mercury (Hg)	15	n	n/a	n	n/a	15,898	15	540	23	0.49	0.65	<BKG	1	<BKG
Methylene Chloride	0.13	n	n/a	n/a	n/a	7.2	0.13	n/a	7.8	none	0.004	ND	ND	ND
Pentachlorophenol	13	n	n/a	n/a	n/a	16	13	130,000	2.5	none	0.66	ND	ND	ND

Reasonable Maximum Exposure Concentration = Highest value in subsurface data sets expressed as the 95% upper confidence limit (or maximum detected value if less than 10 detected results).
RBAS = Risk Based Action Standard.
ND = Analyte not detected in OU
<BKG = Concentration below background in OU
RES = 10-6 risk level not exceeded for pure compound present at any concentration
n/a = exposure pathway not applicable for compound.
none = No background value established for this compound.
3 mg/kg RME Value for Chlordane in OU3 is of Questionable Accuracy.
PRG = USEPA Region IX Preliminary Remediation Goals, August 1996, at 10-6 Risk.

Table 6-3B. Summary of Risk-Based Action Standards vs Site Data for Radionuclides, at 10^{-6} Target Risk Level

Isotope	Selected Action Standard (pCi/g)	Action Level Exceeded (Yes/No) OU1 ? (YES/n)	OU2 ? (YES/n)	OU3 ? (YES/n)	OU4 ? (YES/n)	Risk Based Action Standards Scenario 1 RBAS (pCi/g)	Scenario 2 RBAS (pCi/g)	Scenario 3 RBAS (pCi/g)	1996 PRGs Residential Soil (pCi/g)	Background (pCi/g)	Reasonable Maximum Exposure Concentration In Soil OU1 (pCi/g)	OU2 (pCi/g)	OU3 (pCi/g)	OU4 (pCi/g)
Americium-241	0.092	n	n	n/a	n/a	17	0.092	16,000	1.9	none	0.027	0.024	<BKG	<BKG
Bismuth-212 (Th-228 Daughter)	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP	0.35	0.42	0.4	0.44
Bismuth-214 (Ra-226 Daughter)	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP	<BKG	1.5	<BKG	<BKG
Carbon-14	4,200	n	n	n	n	4,200	9,500	7,000	770	0.87	3.3	2.5	3.6	2.9
Cesium-137+D	0.10	YES	n	n/a	n/a	0.10	200,000	25,000	0.020	0.053	5.8	0.054	<BKG	<BKG
Cobalt-60	0.022	n/a	n/a	n/a	n/a	0.022	32,000	5,800	0.0043	0.016	<BKG	<BKG	<BKG	<BKG
Lead-210+D	9.6	n	n	n	n	9.6	40.0	40.0	0.78	none	3.3	3.0	1	5.5
Lead-214 (Ra-226 Daughter)	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP	0.76	1.7	<BKG	<BKG
Plutonium-241 +D	3.2	n	n	n/a	n/a	600	3.2	2,200,000	150	none	0.30	1.5	NDA	NDA
Radium-223 (U-235 Daughter)	DP	DP	DP	DP	DP	DP	DP	DP	DP	DP	0.47	0.05	0.04	0.16
Radium-226+D	BKG	YES	YES	YES	n/a	0.0042	1,100	1,100	0.0062	0.77	17	4.6	1.3	<BKG
Strontium-90+D	10	YES	n	n	n	10	280,000	34,000	14	0.36	850	8.9	1.5	0.45
Thorium-228+D	BKG	YES	n/a	n/a	n/a	0.032	2,000	1,600	0.041	0.71	0.76	NDA	NDA	NDA
Thorium-232	BKG	YES	n/a	n/a	n/a	0.022	3,800	2,200	24	0.64	0.71	NDA	NDA	NDA
Thorium-234 (U-238+D)	3.2	n	n	n	n	3.2	88,000	63,000	0.69	none	2.3	0.69	0.85	0.51
Tritium	5.4	YES	n/a	n/a	n/a	130,000	540	2,500,000	11,000	none	91	NDA	NDA	NDA
Uranium-235+D	0.15	n	n	n/a	n	0.79	0.15	32,000	0.16	0.071	0.12	0.12	<BKG	0.10

Selected Action Level = Minimum RBAS or Background if Background > Min RBAS.
DP = Daughter Product; Cleanup driven by parent isotope.
BKG = Background value selected as action level.
TBD = Result to be Determined.
PRG = USEPA Region IX Preliminary Remediation Goals, December 1996, at 10^{-6} Risk.
none = No value available.
<BKG = Concentration below background in OU.
NDA = No data available for this radionuclide.
Reasonable Maximum Exposure Concentration = 95% upper confidence level on the mean (or the maximum activity if less than 10 sample results were available) for surface and subsurface data sets.

Table 6-4. Summary of Risk-Based Action Standards vs Site Data for Non-Carcinogens at a Hazard Quotient of 1

Analyte	Selected Action Standard (mg/kg)	Action Standard Exceeded (Yes/No) OU1 ? (YES/n)	OU2 ? (YES/n)	OU3 ? (YES/n)	OU4 ? (YES/n)	HQ Based Action Standards Scenario 1 HQBAS (mg/kg)	Scenario 2 HQBAS (mg/kg)	Scenario 3 HQBAS (mg/kg)	1996 PRGs Residential Soil (mg/kg)	Background (mg/kg)	Reasonable Maximum Exposure Concentration In Soil OU1 (mg/kg)	OU2 (mg/kg)	OU3 (mg/kg)	OU4 (mg/kg)
2-Butanone (MEK)	12	n	n	n/a	n/a	710	12	n/a	7,100	none	0.006	0.008	ND	ND
Acenaphthene	250	YES	n	n/a	n/a	41,000	250	RES	110	none	3,300	5.8	ND	ND
Acetone	1.7	n	n	n	n/a	830	1.7	1,900	2,100	none	0.23	0.02	0.032	ND
Anthracene	1,400	YES	n	n/a	n/a	200,000	1,400	RES	5.7	none	1,500	5.6	ND	ND
Antimony (Sb)	BKG	YES	n/a	n/a	n/a	680	0.30	RES	31	0.74	0.94	ND	ND	ND
Barium (Ba)	BKG	n/a	n/a	n/a	YES	110,000	53	RES	5,300	237	<BKG	<BKG	<BKG	270
Benzo(g,h,i)perylene	9,100	n	n	n/a	n/a	20,000	9,100	RES	no ref	none	0.49	8.8	ND	ND
Cadmium (Cd)	BKG	YES	n/a	n/a	n/a	850	0.38	RES	9.0	0.46	7.1	ND	ND	ND
Chromium (Cr)	760	n	n	n/a	n/a	RES	760	RES	210	178	230	230	<BKG	<BKG
Chromium, Hexavalent (Cr+6)	3.8	n	n/a	n	n/a	8,500	3.8	740	0.20	0.099	0.22	ND	0.16	ND
Copper (Cu)	BKG	YES	YES	n/a	n/a	63,000	28	610,000	2,800	50	62	89	<BKG	<BKG
Dibenzofuran	14	YES	n	n/a	n/a	2,700	14	RES	140	none	2,100	0.6	ND	ND
Diethyl Phthalate	220	n/a	n	n/a	n/a	550,000	220	RES	52,000	none	ND	0.12	ND	ND
Di-n-Butylphthalate	890	n	n/a	n	n/a	68,000	890	3,300	6,500	none	0.031	ND	0.16	ND
Di-n-Octylphthalate	4,900	n	n/a	n/a	n/a	14,000	28,000	4,900	1,300	none	0.037	ND	ND	ND
Endosulfan I	29	n	n/a	n/a	n/a	4,100	29	RES	390	none	0.002	ND	ND	ND
Endosulfan Sulfate	26	n	n/a	n/a	n/a	4,100	26	RES	no ref	none	0.011	ND	ND	ND
Ethyl Benzene	10	n	n/a	n/a	n/a	2,400	10	n/a	230	none	1.2	ND	ND	ND
Fluoranthene	1,800	YES	n	n/a	n/a	27,000	1,800	RES	2,600	none	4,000	35	ND	ND
Fluorene	170	YES	n	n/a	n/a	27,000	170	RES	90	none	3,100	1	ND	ND
Formaldehyde	1.7	n	n/a	n/a	n	100,000	1.7	10,000	9,800	none	1.6	ND	ND	0.35
Manganese (Mn)	BKG	YES	n/a	n/a	n/a	52,000	36	RES	3,200	720	880	<BKG	<BKG	<BKG
Mercury (Hg)	BKG	YES	n/a	YES	n/a	510	0.22	6.4	23	0.49	0.65	<BKG	1	<BKG
Methoxychlor	100	n	n/a	n/a	n/a	3,400	100	RES	330	none	0.0011	ND	ND	ND
Naphthalene	39	YES	n	n/a	n/a	27,000	39	RES	240	none	2,600	1.1	ND	ND
Phenanthrene	1,200	YES	n	n/a	n/a	20,000	1,200	RES	no ref	none	9,500	17	ND	ND
Pyrene	490	YES	n	n/a	n/a	20,000	490	RES	100	none	3,900	43	ND	ND
Selenium (Se)	58	n	n/a	n/a	n/a	8,500	58	RES	380	1	1	ND	<BKG	<BKG
Silver (Ag)	3.8	n	n/a	n/a	n/a	8,500	3.8	RES	380	0.52	2.7	ND	ND	ND
Styrene	76	n	n/a	n/a	n/a	710	76	n/a	680	none	0.8	ND	ND	ND
Toluene	19	n	n	n/a	n/a	920	19	n/a	790	none	0.49	0.004	ND	ND
Xylenes (Total)	700	n	n	n/a	n/a	1,700	700	n/a	320	none	6.2	0.003	ND	ND
Zinc (Zn)	3,400	n	n	n/a	n/a	510,000	3,400	150,000	23,000	82	140	160	<BKG	<BKG

HQ = Hazard Quotient.
BKG = Background concentration selected as action level.
n/a = Exposure pathway incomplete for compound.
HQBAL = Hazard Quotient Based Action Standard.
RES = HQ not exceeded for pure compound present at any concentration.
PRG = USEPA Region IX Preliminary Remediation Goals, August 1996, at HQ = 1.

no ref = No PRG reference value listed for this compound.
none = No background value established for this compound.
<BKG = Concentration below background in OU.
ND = Analyte not detected in OU.
Reasonable Maximum Exposure Concentration = Highest value in surface or subsurface data sets expressed as the 95% upper confidence limit (or maximum detected value if less than 10 detected results).

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ACKNOWLEDGMENTS

The following Project personnel worked on the Draft Final Determination of Risk-Based Action Standards for DOE Areas:

Name and Position	Responsibility
Michael Dresen Program Manager, WA	Senior guidance and review, and quality assurance
Robert Devany Project Manager, WA	Project management, guidance and review.
Salem Attiga Principal, EMS	Senior review
Betsy Codding Quality Assurance, WA	Quality assurance
Carolyn Atwood Task Manager, WA	Task Manager, task coordination and technical direction
Tim Utterback Environmental Scientist, WA	Task technical performance, report writing
Pleasant McNeel Environmental Scientist, WA	Task technical performance, report writing
Malieka Bundy Database Technician, WA	Database management
Elizabeth Carrier Project Administrator	Word processing, report coordination
Craig Adams Production Personnel, WA	Graphics and report production

LIST OF ACRONYMS

ALARA	As Low as Reasonably Achievable
ANL	Argonne National Laboratory
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	Ambient Water Quality Criteria
CalEPA	California Environmental Protection Agency
CERCLA	Comprehensive Environmental Response, Compensation and Liabilities Act
CFR	Code of Federal Regulations
COCs	Contaminants of Concern
DOE	U. S. Department of Energy
EPA	U.S. Environmental Protection Agency
g	Gram
Kg	Kilogram
L	Liter
Site	Laboratory for Energy-Related Health Research
m	Meter
MDA	Minimum Detectable Activity
MDL	Method Detection Limit
mg	milligram
mrem	Millirem
NCRCPD	National Conference of Radiation Control Program Directors
NPL	National Priorities List
pCi/g	Picocurie per Gram
PNNL	Pacific Northwest National Laboratory (Battelle)
PRG	Preliminary Remediation Goal
RAGS	Risk Assessment Guidance for Superfund
RESRAD	Residual Radioactive Material Guideline computer program
RBAS	Risk-Based Action Standard
RME	Reasonable Maximum Exposure
SARA	Superfund Amendments and Reauthorization Act
UC Davis	University of California at Davis
UCL	Upper Confidence Limit
TICs	Tentatively Identified Compound
Yr	Year