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Standard Human Health Risk Assessment Scenarios

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Produced by the Environmental Restoration Project

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STANDARD HUMAN HEALTH RISK ASSESSMENT SCENARIOS

PURPOSE

The standard exposure scenarios presented here are a point of departure for risk assessors performing baseline risk assessments in support of the Laboratory's ER Project. The scenarios represent assemblages of exposure pathways that reasonably bound potential avenues for human exposure to nonradiological and radiological contaminants in the environment. The values of the input parameters represent default values that may be used if site-specific values are not available. The risk assessor must apply professional judgment when determining which scenarios, pathways, and parameters are appropriate in the context of site-specific conditions and the objectives of the risk assessment.

INTRODUCTION

The Integrated Technical Strategy (LANL 1999, 63491.1) developed by the Laboratory's Environmental Restoration (ER) Project is intended to provide general guidelines for the areas of investigation required to determine if a site or aggregate has been adequately characterized. One component of this Strategy is the description of the present-day human health risk associated with a site or aggregate. The basic elements of the human health risk assessment need to be representative and uniform in order to provide the risk assessor and risk manager with a common point of departure. The ER Project's basic approach to human health risk assessment is consistent with the process described in the Environmental Protection Agency's (EPA's) Risk Assessment Guidance for Superfund (RAGS), Volume 1 Human Health Evaluation Manual (Part A) (EPA 1989, 08021) as outlined in the 2000 Draft Installation Work Plan (LANL 2000, 64361.4). It is the intent of this paper to define and describe the fundamental land use scenarios, exposure pathways, and exposure parameters that can be incorporated into a baseline risk assessment. It is not meant to restrict the risk assessor in conducting a baseline risk assessment if different land use scenarios are applicable, site-specific information is available, or additional or fewer exposure pathways are appropriate. For example, if a risk assessment is to be conducted for a residential scenario and site-specific information is available about the age distribution of children, the risk assessor can refer to the 1997 EPA Exposure Factors Handbook (EPA 1997a, 66596; 1997b, 66597; 1997c, 66598) for parameters related to different age groups of children. If, however, no such site-specific information is available, the risk assessor can use the parameters for children presented in this paper. The elements presented herein have been developed to encourage a consistent approach to assessing risk when there is a lack of site-specific data or consensus on which parameter value to use, given a range of possibilities. The scenarios, pathways, and parameters combine upper bound and mid-range exposure factors so that the estimated risk represents an exposure that is both protective and reasonable and not the worst possible case.

The human health endpoints for which present-day risk is estimated are systemic effects or hazards (noncarcinogens), incremental lifetime cancer risk (carcinogens), and effective dose equivalents (radionuclides). The exposure scenarios that are commonly encountered at Laboratory sites and under which a human health risk assessment might be conducted include residential (adult and child), industrial (site worker and construction worker), recreational (adult and child trail user), and a resource user. Other scenarios and/or exposure parameters have been developed and incorporated into risk screening assessments for several ER Project investigations, including the model used to calculate preliminary remediation goals (PRGs) in the canyons reach reports (Perona et al. 1998, 62049) and the screening assessment presented in the Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) of potential release site (PRS) 16-021(c) (LANL 1998, 59891.3). The scenarios and parameters used in these assessments have been approved by the Administrative Authority (AA) and could be used in a baseline risk assessment for these and other sites, if appropriate. These assessments also serve as examples of the types of site-specific approaches that depart from typical generic assessments using default parameters. However, any site-specific scenarios, pathways, and parameters must be justified, documented, and approved by the AA prior to use in a risk assessment. The common exposure pathways for these scenarios for nonradionuclide exposure include the ingestion of soil, inhalation of particulates and/or vapors, and dermal contact with soil and/or water. The common exposure pathways for these scenarios for radionuclide exposure include ingestion of soil, inhalation of particulates and radon, and external irradiation from soil. Additional pathways of ingestion of plant material (fruits and vegetables), ingestion of meat, and incidental ingestion of water may also be considered depending upon the site and the receptors. Standard default parameter values obtained from EPA guidance documents are used in the exposure scenarios, where available. These values are consistent with the objective of estimating present-day risk under reasonable maximum exposure conditions. Where EPA values are not available, assumptions are made in selecting values or other sources are utilized, e.g., Laboratory specific information.

ESTIMATION OF NONRADIONUCLIDE RISK

An estimation of risk begins with the characterization of the site and subsequently an assessment of the exposure to the contamination. The exposure assessment includes estimates of the magnitude of actual or potential human exposures, the frequency and duration of the exposure, and the pathways by which humans might be exposed. As part of the exposure assessment, the reasonable maximum estimate of the contaminant(s) concentration is developed for current land-use assumptions and is one of several parameters needed to estimate the contaminant intake by an individual. The reasonable maximum exposure (RME) concentration is the maximum exposure that is reasonably expected to occur at the site and does not reflect the maximum concentration that could be contacted at any given time. Because of the uncertainty associated with estimating the true average concentration at a site, the 95% upper confidence limit (UCL) of the arithmetic mean is often used as the RME exposure point concentration and is recommended in EPA (1989, 08021). Other approaches for estimating an exposure point concentration may also be used, including use of the maximum detected concentration, the mean concentration, the weighted average, and the median concentration, as long as value used is representative of potential exposure and justified by the available data. The mean concentration is considered to represent the most likely exposure (MLE) rather than the maximum exposure and is less (i.e., less conservative) than the RME. The calculation of the RME concentration is described in EPA's Supplemental Guidance to RAGS: Calculating the Concentration Term (EPA 1992a, 59182.1). The exposure to a contaminant normalized for time and body weight is the intake and is expressed as mg chemical per kg body weight-day. The basic equation (EPA 1989, 08021) for calculating intake is:

$$\text{Intake} = \frac{C \times CR \times EF \times ED}{BW \times AT}$$

where,

C	=	chemical concentration in exposure medium (mg/kg soil or mg/L water)
CR	=	contact rate (mg soil/day or liters/day)
EF	=	exposure frequency (hours/day or days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time; time over which exposure is averaged (days)

The intake or dose averaged over time [i.e., the average daily dose (ADD) for noncarcinogens or lifetime average daily dose (LADD) for carcinogens (EPA 1992b, 55637)] is calculated for a given environmental medium and is based on the exposure pathway and its associated exposure parameters. The estimated LADD is converted to incremental risk of an individual developing cancer by multiplying this value by a slope factor specific for the chemical and intake route. Because the slope factor is generally an upper 95^{th} percentile confidence limit based on laboratory animal data, the carcinogenic risk estimate will generally be an upper-bound estimate, i.e., the actual risk will likely not exceed the estimated risk calculated by this relationship (EPA 1989, 08021). The equation for calculating cancer risk is:

$$ICR = LADD \times SF$$

where,

ICR	=	lifetime incremental cancer risk
LADD	=	chronic daily dose or intake averaged over a lifetime (mg/kg-d)
SF	=	slope factor $(\text{mg/kg-d})^{-1}$

The estimated ADD is converted to the potential for noncarcinogenic effects occurring over a specified time by dividing this value by a reference dose (RfD) specific for the chemical and intake route. The ratio of exposure or intake to the RfD is called a hazard quotient (HQ). The HQ assumes that if the exposure level exceeds a threshold (i.e., HQ>1) there is a potential for adverse systemic effects and that below this threshold it is unlikely that adverse effects will occur even to sensitive populations. Although it is generally interpreted that the greater the HQ, the greater the level of concern, the ratio should not be considered a statistical probability of an effect occurring. The equation for calculating the HQ is:

$$HQ = \frac{ADD}{RfD}$$

where,

HQ	=	hazard quotient
ADD	=	chronic average daily dose or intake (mg/kg-d)
RfD	=	reference dose (mg/kg-d)

When an individual is likely to be exposed to more than one chemical at a site, it is necessary to determine the total estimated cancer risk or hazard. This is accomplished by summing either the individual incremental lifetime cancer risks to obtain a total cancer risk or the individual hazard quotients to obtain a hazard index (HI) for each exposure pathway and/or critical effect.

This approach assumes dose additivity in the absence of information on specific mixtures. Because slope factors are upper 95^{th} percentile estimates and are not strictly additive, the total cancer risk estimate might become artificially more conservative as risks from a number of different carcinogens are summed. In addition, this approach sums all carcinogens equally, giving as much weight to Class B or C carcinogens as to Class A carcinogens, and slope factors derived from animal data the same weight as slope factors derived from human data. With respect to the HI approach, the level of concern does not increase linearly as the reference dose is approached or exceeded because these values do not have equal accuracy or precision and are not based on the same severity of effect. Also, RfDs have varying levels of confidence and will result in a combination of values with different uncertainty adjustments and modifying factors. In both cases, because it is assumed that chemicals induce the same effect by the same mechanism of action, this approach could overestimate the potential for either cancer risk or hazard.

Interactions that alter the toxicity may also occur among chemicals in a mixture, i.e., the potential exists for synergistic effects or antagonistic effects. Synergistic effects occur when the combined effects are greater than the toxicity of each component of a mixture individually, while antagonistic effects occur when the combined effects are less than the toxicity of each component of a mixture individually. Failure to consider potential synergistic or antagonistic effects on toxicity may result in either an underestimation or an overestimation (similar to the assumption of additivity) of the risk, respectively. Because the uncertainties related to exposure to chemical mixtures affect whether the risk is over- or underestimated, it is important to determine the conditions under which additivity versus synergism may occur. For example, EPA (1986, 65403.1) suggested that additivity is likely to occur when mixture components are at low doses and when toxicity occurs via the same mechanism. Seed et al. (1995, 58928.1) indicated that there was no discernible toxic response until the dose levels of the individual components of a mixture approached or exceeded their individual thresholds. An understanding of the toxic effects of mixtures is important in estimating the risk associated with exposure as well as describing the uncertainties related to the potential risk.

An individual might also be exposed to one or more substances through several exposure pathways. The total exposure by either one or several chemicals will equal the sum of the exposures by all pathways. In summing the risk or hazard across pathways, it is important to identify reasonable exposure pathway combinations and whether it is likely that the same individual would consistently be exposed to the RME concentration by more than one pathway. If neither of these conditions apply, then the risks or hazards might not need to be combined. It is also assumed that an individual is exposed through only one scenario, e.g., as a resident. However, in Los Alamos an individual may be exposed not only at home but also at work (site worker at a technical area) and at play (trail user or jogger along canyon trails). Therefore, it may be appropriate to combine some or all of the pathways from different scenarios in order to determine the actual risk or hazard for an individual from all sources and exposures. As mentioned above, there are a number of limitations that should be taken into consideration when presenting the uncertainty surrounding the total cancer risk or noncancer hazard to an individual.

The exposure scenarios routinely encountered and the associated pathways are presented in Table 1. The pathways listed in the table may or may not be relevant for any given exposure scenario. It is up to the discretion of the risk assessor to determine which pathways are representative of the exposure conditions at the site under investigation. For example, if a resident is ingesting homegrown fruits and/or vegetables, then this pathway should be included in the exposure assessment. If, however, this pathway is not representative of the site, then the pathway may be eliminated or included with appropriate assumptions to calculate a reasonable upper bound risk. In both cases, a discussion of the uncertainties related to the pathway as well as the relevance of the pathway should be included. Figures 1 through 4 present a general site conceptual model for each of the scenarios with the pathways illustrated as either primary (common) in bold capital letters, secondary (occasional) in bold letters, or unlikely/no pathway in normal script. The exact site conceptual model for a given potential release site, aggregate of sites, or watershed may be different depending on the scenario and site conditions.

Table 1
Exposure Scenarios and Pathways[a,b]

Pathways	**Exposure Scenarios**				
	Residential	Site Worker	Construction Worker	Trail User	Resource User
Inhalation of Dust/VOCs	**X**	**X**	**X**	**X**	**X**
Ingestion of Soil	**X**	**X**	**X**	**X**	**X**
Dermal Contact w/Soil	**X**	**X**	**X**	**X**	**X**
Ingestion of Fruits and Vegetables	**x**	-	-	-	**X**
Ingestion of Meat	-	-	-	-	**X**
Dermal Contact w/Surface Water	**x**	-	-	**x**	**x**
Ingestion of Drinking Water	**x**	-	-	**x**	**x**
External Irradiation	**X**	**X**	**X**	**X**	**X**

[a] An exposure scenario for an environmental worker has also been presented in the RFI report for PRS 16-021(c) (260 Outfall).
[b] Pathways with a large X are considered to be common pathways (those routinely incorporated into a risk assessment), those with a small x are considered to be less likely (those occasionally incorporated into the risk assessment), and those with a – are considered to be unlikely or no pathways for that scenario.

The intake equations and parameters for the exposure pathways associated with each scenario to determine nonradionuclide intakes at a site are presented in Tables 2 through 21. Parameters for external irradiation are included in the list of parameters for RESRAD (Table 22). The parameters provided in the tables are from several sources, including EPA's Exposure Factors Handbook, Volumes 1,2,3 (EPA 1997a, 66596; 1997b, 66597; 1997c, 66598), RAGS, Part A (EPA 1989, 08021), the standard default exposure factors document (EPA 1991, 56140.1), and the dermal exposure assessment manual (EPA 1992c, 59184.1). Many of the factors are default values designed to derive MLE and RME (EPA 1991, 56140.1), including the exposure frequencies and exposure durations, and are generally the same for each pathway in a scenario. The parameters of adult body weight and adult lifetime have historically been assumed to be 70 kg and 70 years, respectively. The current version of the Exposure Factors Handbook (EPA 1997a, 66596; 1997b, 66597; 1997c, 66598) has indicated that the mean body weight for adults is 71.8 kg and that life expectancy is 75 years. The tables presented in this document incorporate the values that have been historically assumed in EPA risk assessments (70 kg and 70 years) rather than the more recent values. The reason for retaining the former values is that in calculating the slope factors on the basis of animal or human data, a standard exposure scenario has been assumed that has included a body weight of 70 kg and a lifetime of 70 years. Therefore, if values other than those traditionally used are utilized, the dose-response relationship and as a result the slope factor or unit risk should be adjusted as described in Appendix 1, Chapter 1 of Volume 1 of EPA's Exposure Factors Handbook (EPA 1997a, 66596). The modification of parameters and inclusion or exclusion of pathways is at the discretion of the risk assessor and should be based on the site-specific conditions. Parameters that may often be modified on a site-specific basis, include inhalation rate, ingestion rates (soil, water, fruits, vegetables, and meat), surface areas, exposure times, and fraction of obtained from contaminated area. These parameters might be more prone to change because each site may have different potentially exposed individuals with varying levels of activity and/or different sensitive populations. Exposure frequencies and durations may also be changed based on available information and best professional judgment of the risk assessor.

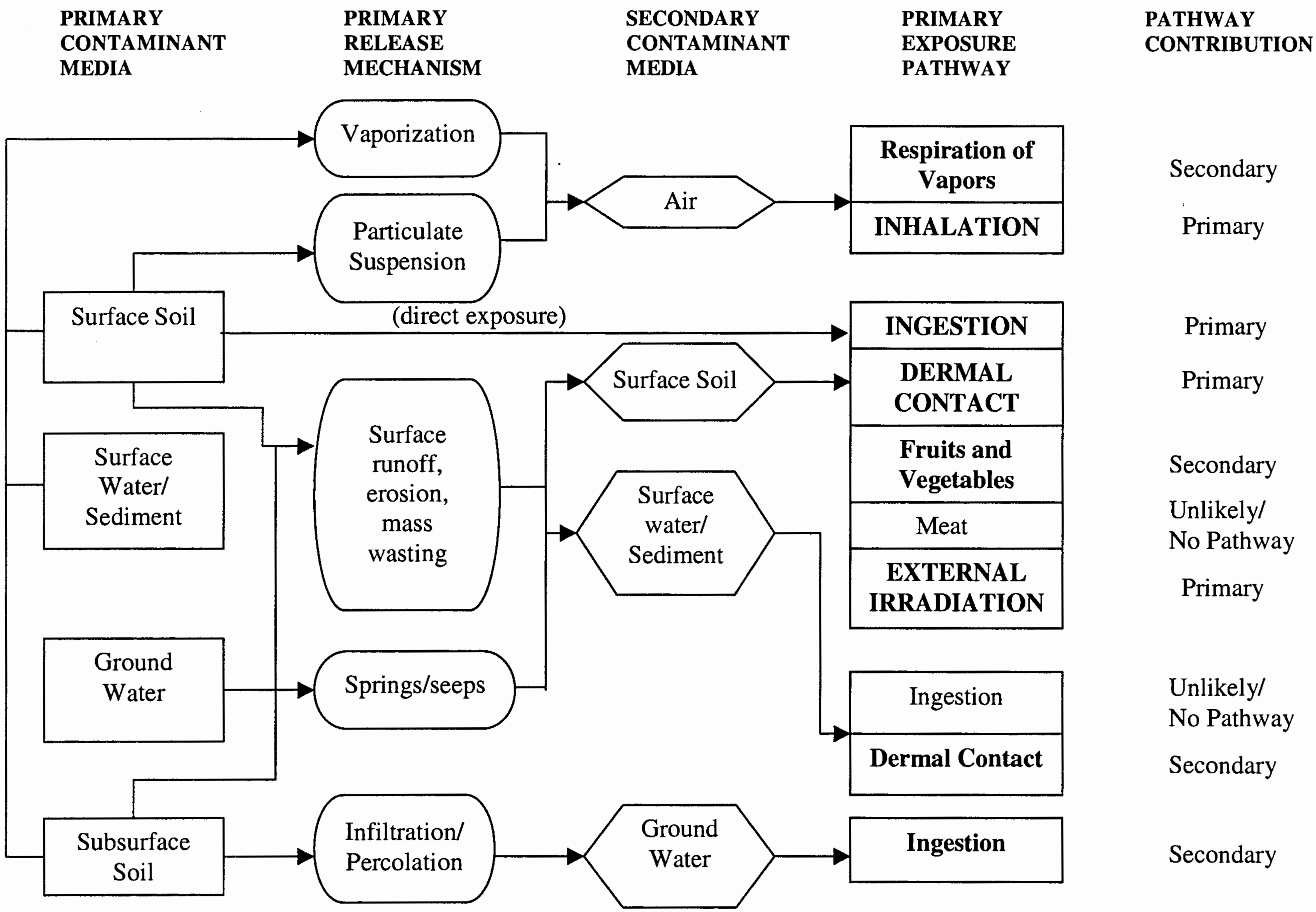

Figure 1. Conceptual Site Model for Residential Scenario.

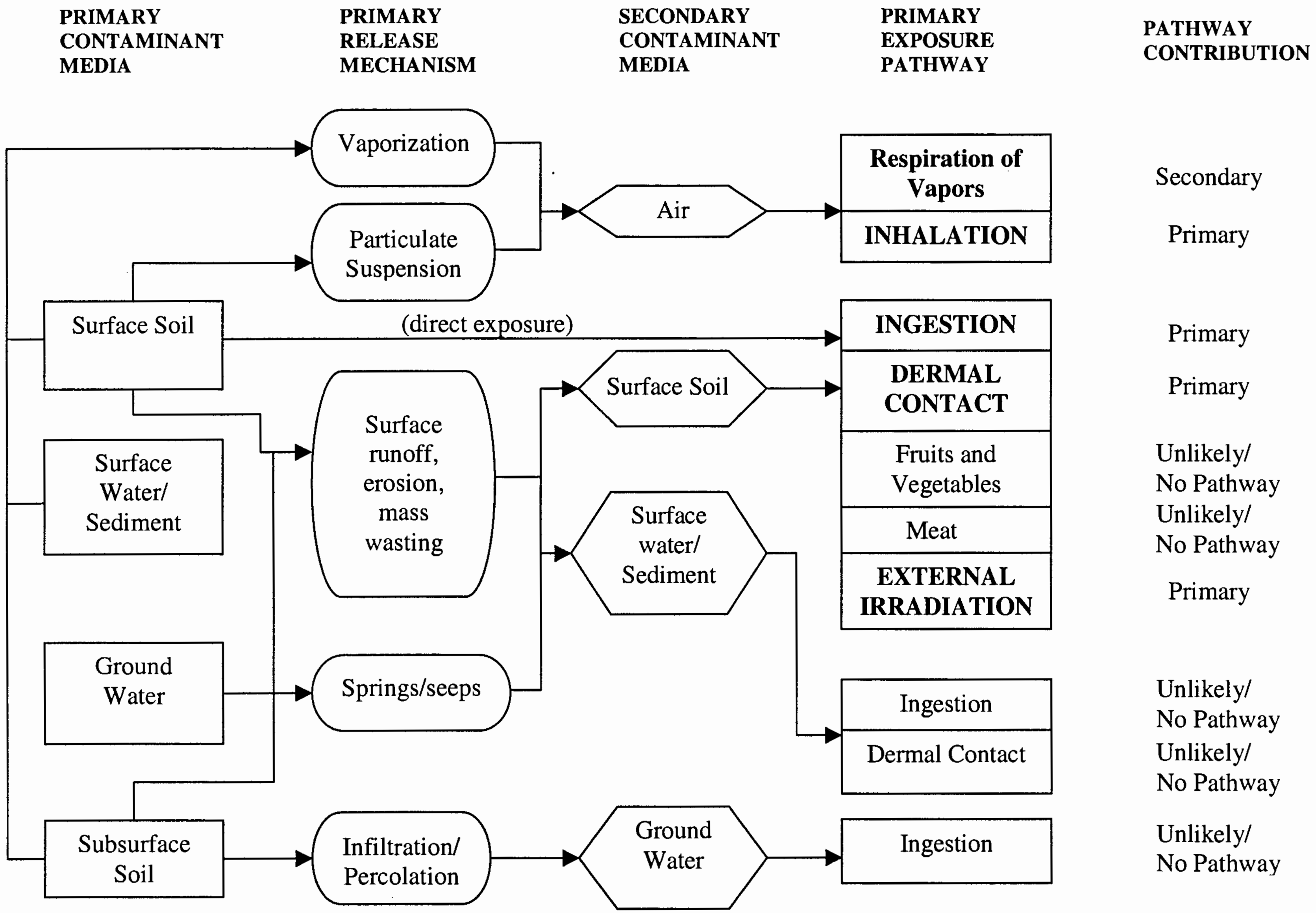

Figure 2. Conceptual Site Model for Industrial Scenario.

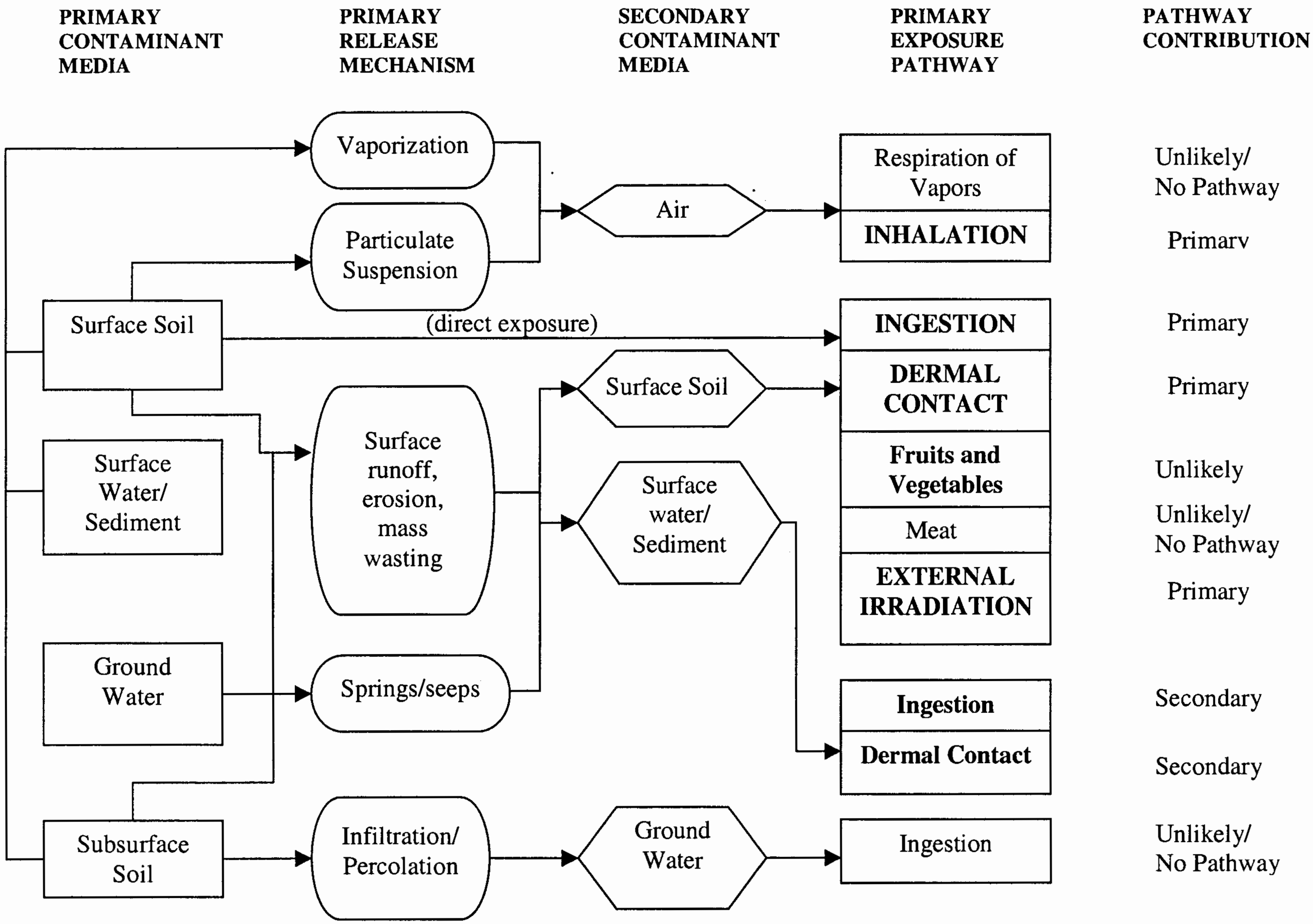

Figure 3. Conceptual Site Model for Recreational Scenario.

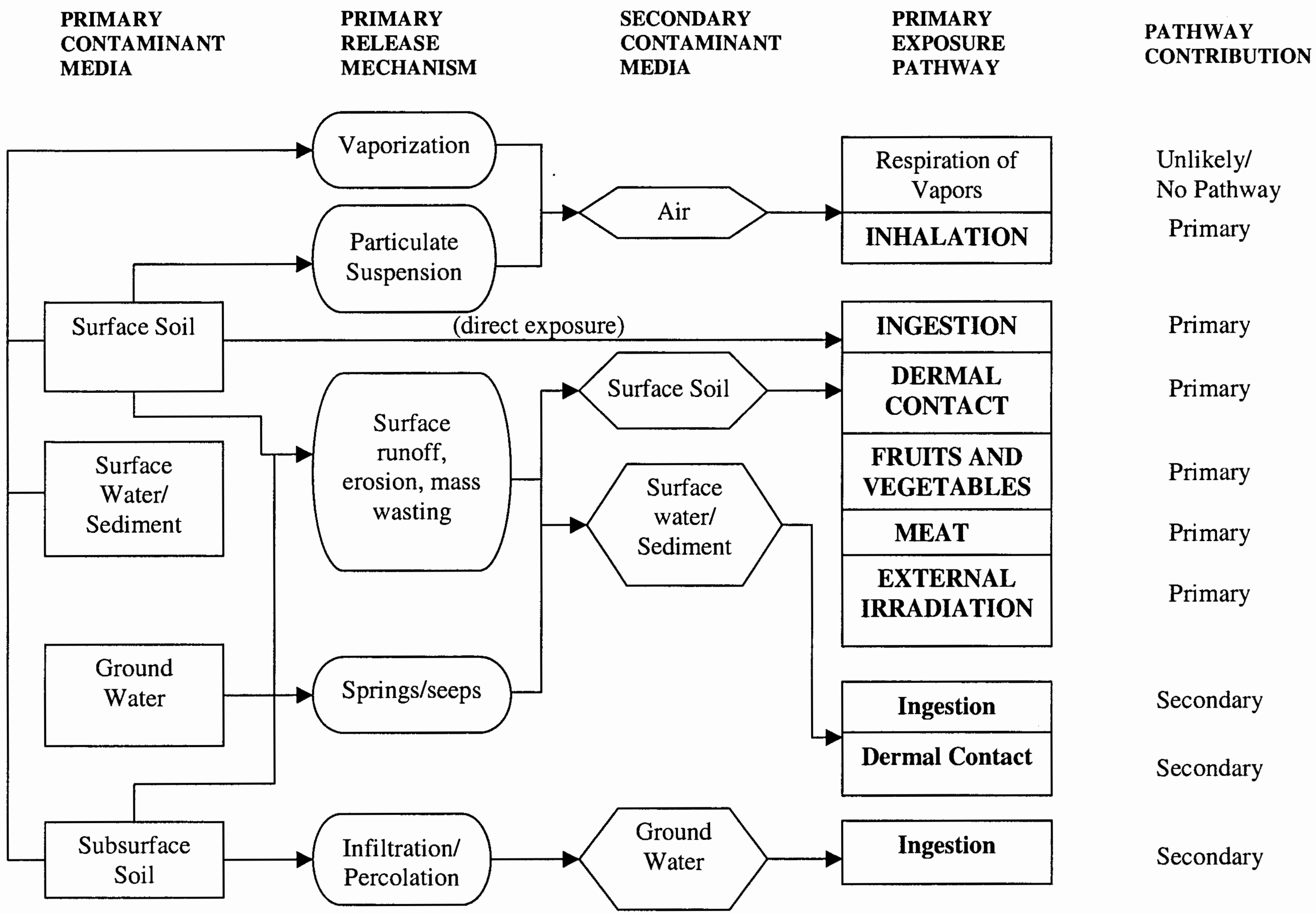

Figure 4. Conceptual Site Model for Resource User Scenario.

Residential Scenario

A residential scenario is used to evaluate areas where there are occupied residences on or adjacent to a potential release site as well as sites that may be developed as residential areas. Under this land use, present-day risk for residents is expected to result from frequent, repeated contact with contaminated media. The contamination is the present day condition and not what may migrate to or from the site in the future. The assumptions in this scenario account for daily exposure over a long period of time and generally result in the maximum potential exposure and risk to an individual. The exposure pathways related to this scenario that are routinely evaluated include incidental ingestion of soil, inhalation of particulates and/or vapors, dermal contact, and, if appropriate, consumption of home grown fruits and vegetables. An exposure pathway for the ingestion of drinking water is also included for this scenario, although this is a minor or unlikely pathway under most circumstances. Residential developments in and around Laboratory property, i.e., Los Alamos and White Rock, New Mexico, rarely include activities related to rearing livestock. The ingestion of fruits and vegetables is generally a minor pathway because overall only a small portion of the total amount of fruits and vegetables consumed probably come from home gardens. The proximity of residential developments to bodies of water is also rare or nonexistent so pathways for dermal contact or ingestion of surface water are considered unlikely or nonexistent. The residential scenario considers both child and adult receptors, although the age of the receptor is dependent on the exposure pathway and the toxicological endpoint.

The exposure parameters and intake equations for each of the pathways for residential exposure, except for external irradiation, are presented in Tables 2 to 6. The inhalation rates for adults are recommended values for the general population average daily inhalation rates for long-term exposure (EPA 1997a, 66596) (Table 2). The higher rate is for males and the lower rate for females. These values are different from the 20 m^3/day commonly assumed in past EPA risk assessments. The inhalation rates for children are the highest rates presented in EPA (1997a, 66596) for long-term exposure for children (Table 2). These values are for children 15-18 years of age (males and females) and may not be representative if the exposed population is comprised of younger children. EPA (1997a, 66596) provides inhalation rates for various age groups and activity levels, which might be used to accurately reflect the exposed population. The mean soil ingestion rates for adults and children are those recommended in EPA (1997a, 66596) (Table 3). The higher rates presented as upper bound values were estimates recommended in EPA (1991, 56140.1) (Table 3). The higher values for inhalation and soil ingestion are recommended for the RME because they probably better reflect conditions in this area of the country where vegetation is sparse, winds are prevalent, activities occur at higher altitudes so metabolism is higher, and more time is spent outdoors.

The values presented for dermal exposures are default values for the adult including the surface area (EPA 1997a, 66596), adherence factors (EPA 1992c, 59184.1), and absorption factors (EPA 1998, 63061.1) (Table 4). The surface area values assume the adult is wearing a short sleeve shirt and shorts. The surface areas for children assume the same situation as the adult, i.e., the child is wearing a short sleeve shirt and shorts. However, the surface areas were calculated from Tables 6-6 and 6-8 in Volume 1 of EPA's Exposure Factors Handbook (EPA 1997a, 66596). These tables provide information from studies on the total mean body surface area of male children for various age groups and the percentage of total body surface area by body part for different age groups, respectively. The values were calculated using the 50th and 95th percentile skin surface area values for children from 2 to 7 years of age and the mean percentage of total body surface area by body part for children between 6 and 7 years of age. The body surface areas for male children were used because they were generally greater than the female values. Different surface area values for children can be calculated from these tables to reflect the potentially exposed population.

The ingestion rates for fruits and vegetables for children and adults were obtained from Tables 9-18 and 9-19 in Volume 2 of EPA's Exposure Factors Handbook (EPA 1997b, 66597). These annual ingestion rates were calculated by converting the highest of the two intake values to kg/day and then multiplying by 365 days (Table 5). The same ingestion rates were used for both the MLE and RME calculations but the fraction ingested that were grown in the contaminated area was changed to reflect different levels of contaminated food intake (Table 5). The ingestion of 100% of fruits and vegetables from the contaminated area is probably not representative of most situations in residential areas but provides a maximum exposure situation and a point of departure for calculating risk where ingestion of fruits and vegetables is relevant.

The intake rates for drinking water for children (ages 1-10) were obtained from Volume 1 of EPA's Exposure Factors Handbook (EPA 1997a, 66596) (Table 6). The intake rate for adults (2 L/day) is the value that has commonly been assumed in EPA risk assessments (EPA 1991, 56140.1). However, the recommended values for adults in EPA (1997a, 66596) are different from the 2 L/day intake rate. When using values other than 2 L/day the risk assessor should consider if the dose estimate will be used to estimate risk by combining with a dose-response relationship that was derived assuming tap water intake of 2L/day. IRIS does not use a tap water intake assumption in the derivation of RfDs, but does make the 2 L/day assumption in the derivation of cancer slope factors and unit risks. If the values recommended in EPA (1997a, 66596) are used, the risk assessor should adjust the dose-response relationship as described in Appendix 1, Chapter 1 of Volume 1 of EPA's Exposure Factors Handbook (EPA 1997a, 66596).

Table 2
Exposure Parameters for Inhalation of VOCs or Fugitive Dust
Residential Scenario

Intake (mg/kg-day) = (C x IR x EF x ED) / (BW x AT)	**Exposure Values**			
	Child		**Adult**	
	MLE	**RME**	**MLE**	**RME**
C = Chemical concentration in ambient air (mg/m^3)	Site-specific [a]	Site-specific [a]	Site-specific [a]	Site-specific [a]
IR = Inhalation rate (m^3/day)	8.3[b]	8.3[c]	15.2[d]	15.2[e]
EF = Exposure frequency (days/year)	350[f]	350[f]	350[f]	350[f]
ED = Exposure duration (years)	6[g]	6[g]	9[h]	30[i]
BW = Body weight (kg)	15[j]	15[j]	70[k]	70[k]
AT = Averaging time (period over which exposure is averaged – days)				
Noncarcinogenic effects	2190[l]	2190[l]	3285[l]	10950[l]
Carcinogenic effects	25550[m]	25550[m]	25550[m]	25550[m]

[a] Mean and 95 % UCL of the mean used for MLE and RME calculations, respectively. Concentrations in fugitive dust calculated from chemical concentrations in soil and particulate concentration in air of 0.00009 g/m^3 (EPG 1990, 0497).

[b] Average inhalation rate based on long-term exposure for 3 to 5 year old children(EPA 1997a, 66596, Table 5-23, page 5-24).

[c] EPA recommends that an upper percentile not be used for this parameter (EPA 1997a, 66596).

[d] Inhalation rate based on long-term exposure for adult males (19-65+) (EPA 1997a, 66596, Table 5-23, page 5-24).

[e] EPA recommends that an upper percentile not be used for this parameter (EPA 1997a, 66596).

[f] Exposure frequency based on days/year spent at home (EPA 1991, 56140.1).

[g] Exposure duration for child from birth to six years of age (EPA 1991, 56140.1).

[h] Exposure duration for adult is national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187).

[i] Exposure duration is national upper bound time (90th percentile) at one residence (EPA 1991, 56140.1).

[j] Average body weight for 1-6 year old child (EPA 1991, 56140.1).

[k] Average body weight for adult (EPA 1991, 56140.1).

[l] Exposure duration multiplied by 365 days (EPA 1989, 08021)

[m] Lifetime exposure (70 years) multiplied by 365 days (EPA 1989, 08021).

Table 3
Exposure Parameters for Ingestion of Soil
Residential Scenario

Intake (mg/kg-day) = (C x IR x CF x FI x EF x ED) / (BW x AT)	Exposure Values			
	Child		Adult	
	MLE	RME	MLE	RME
C = Chemical concentration in soil (mg/kg)	Site-specific [a]	Site-specific [a]	Site-specific [a]	Site-specific [a]
IR = Ingestion rate (mg soil/day)	100[b]	200[c]	50[d]	100[e]
CF = Conversion Factor (kg/mg)	10^{-6}	10^{-6}	10^{-6}	10^{-6}
FI = Fraction ingested from contaminated source	0.5[f]	1[g]	0.5[f]	1[g]
EF = Exposure frequency (days/year)	350[h]	350[h]	350[h]	350[h]
ED = Exposure duration (years)	6[i]	6[i]	9[j]	30[k]
BW = Body weight (kg)	15[l]	15[l]	70[m]	70[m]
AT = Averaging time (period over which exposure is averaged – days)				
Noncarcinogenic effects	2190[n]	2190[n]	3285[n]	10950[n]
Carcinogenic effects	25550[o]	25550[o]	25550[o]	25550[o]

[a] Mean and 95 % UCL of the mean used for MLE and RME calculations, respectively.
[b] Mean amount of soil consumed per day by a child 0-6 years of age (EPA 1997a, 66596, Table 4-23, page 4-25).
[c] Conservative upper bound estimate of the amount of soil consumed per day by a child 0-6 years of age (EPA 1991, 56140.1).
[d] Mean amount of soil consumed per day by an adult (EPA 1997a, 66596, Table 4-23, page 4-25).
[e] Upper bound estimate of soil consumed per day by an adult (EPA 1991, 56140.1).
[f] Assumes 50% of soil ingested comes from the contaminated source.
[g] Assumes 100% of soil ingested is from the contaminated source.
[h] Exposure frequency based on days/year spent at home (EPA 1991, 56140.1).
[i] Exposure duration for child from birth to six years of age (EPA 1991, 56140.1).
[j] Exposure duration for adult is national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187).
[k] Exposure duration is national upper bound time (90th percentile) at one residence (EPA 1991, 56140.1).
[l] Average body weight for 1-6 year old child (EPA 1991, 56140.1).
[m] Average body weight for adult (EPA 1991, 56140.1).
[n] Exposure duration multiplied by 365 days (EPA 1989, 08021).
[o] Lifetime exposure (70 years) multiplied by 365 days (EPA 1989, 08021).

Table 4
Exposure Parameters for Dermal Contact with Soil
Residential Scenario

Absorbed Dose (mg/kg-day) = (C x CF x SA x AF x ABS x EF x ED) / (BW x AT)	**Exposure Values**			
	Child		**Adult**	
	MLE	**RME**	**MLE**	**RME**
C = Chemical concentration in soil (mg/kg)	Site-specific [a]	Site-specific [a]	Site-specific [a]	Site-specific [a]
CF = Conversion Factor (kg/mg)	10^{-6}	10^{-6}	10^{-6}	10^{-6}
SA = Surface area available for contact (cm^2/event)	4300[b]	4700[c]	5000[d]	5800[e]
AF = Soil to skin adherence factor (mg/cm^2)	0.2[f]	1[f]	0.2[f]	1[f]
ABS = Absorption factor (unitless)	0.1/0.01[g]	0.1/0.01[g]	0.1/0.01[g]	0.1/0.01[g]
EF = Exposure frequency (days/year)	350[h]	350[h]	350[h]	350[h]
ED = Exposure duration (years)	6[i]	6[i]	9[j]	30[k]
BW = Body weight (kg)	15[l]	15[l]	70[m]	70[m]
AT = Averaging time (period over which exposure is averaged – days)				
Noncarcinogenic effects	2190[n]	2190[n]	3285[n]	10950[n]
Carcinogenic effects	25550[o]	25550[o]	25550[o]	25550[o]

[a] Mean and 95 % UCL of the mean used for MLE and RME calculations, respectively.

[b] Surface area for child assumes individual is wearing short sleeve shirt, shorts, and shoes so exposed skin area is limited to the head, hands, arms, and legs. The mean (50th percentile) value was obtained from tables of the total body surface area for male children and percent of total body surface area by body part for children in the Exposure Factors Handbook (EPA 1997a, 66596, Tables 6-6 and 6-8, pages 6-15 and 6-16).

[c] Surface area for child assumes individual is wearing short sleeve shirt, shorts, and shoes so exposed skin area is limited to the head, hands, arms, and legs. The upper bound (95th percentile) value was obtained from tables of the total body surface area for male children and percent of total body surface area by body part for children in the Exposure Factors Handbook (EPA 1997a, 66596, Tables 6-6 and 6-8, pages 6-15 and 6-16).

[d] Surface area for adult assumes individual is wearing short sleeve shirt, shorts, and shoes. The mean (50th percentile) exposed skin area is limited to the head, hands, arms, and legs (EPA 1997a, 66596, Table 6-14, page 6-25).

[e] Surface area for adult assumes individual is wearing short sleeve shirt, shorts, and shoes. The upper bound (95th percentile) exposed skin area is limited to the head, hands, arms, and legs (EPA 1997a, 66596, Table 6-14, page 6-25).

[f] Default values for 50th and 95th percentile skin adherence factors (EPA 1992c, 59184.1).

[g] Default values for absorption factors of 0.1 for organics and 0.01 for inorganics are recommended if chemical-specific values are not available (EPA 1998, 63061.1). Site-specific skin absorption factors are available for arsenic (0.03), cadmium (0.001), chlordane (0.04), 2,4-D (0.05), DDT (0.03), lindane (0.04), TCDD (0.030), PAHs (0.13), PCBs (0.14), and pentachlorophenols (0.25).

[h] Exposure frequency based on days/year spent at home (EPA 1991, 56140.1).

[i] Exposure duration for child from birth to six years of age (EPA 1991, 56140.1).

[j] Exposure duration for adult is national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187).

[k] Exposure duration is national upper bound time (90th percentile) at one residence (EPA 1991, 56140.1).

[l] Average body weight for 1-6 year old child (EPA 1991, 56140.1).

[m] Average body weight for adult (EPA 1991, 56140.1).

[n] Exposure duration multiplied by 365 days (EPA 1989, 08021).

[o] Lifetime exposure (70 years) multiplied by 365 days (EPA 1989, 08021).

Table 5
Exposure Parameters for Ingestion of Home Grown Fruits and Vegetables
Residential Scenario

Intake (mg/kg-day) = (C x K x IR x FI x ED) / (BW x AT)	**Exposure Values**			
	Child		**Adult**	
	MLE	**RME**	**MLE**	**RME**
C = Chemical concentration in soil (mg/kg)	Site-specific [a]	Site-specific [a]	Site-specific [a]	Site-specific [a]
K = plant – soil concentration ratio (mg/kg plant per mg/kg soil)	Chemical-specific [b]	Chemical-specific [b]	Chemical-specific [b]	Chemical-specific [b]
IR = Plant ingestion rate (kg/yr)				
Vegetables	30.3[c]	30.3[c]	68.6[e]	68.6[e]
Fruit	84[d]	84[d]	63.1[f]	63.1[f]
FI = Fraction of plants ingested that are grown in contaminated area	0.4[g] 0.3[h]	1[i] 1[i]	0.4[g] 0.3[h]	1[i] 1[i]
ED = Exposure duration (years)	6[j]	6[j]	9[k]	30[l]
BW = Body weight (kg)	15[m]	15[m]	70[n]	70[n]
AT = Averaging time (period over which exposure is averaged – days)				
Noncarcinogenic effects	2190[o]	2190[o]	3285[o]	10950[o]
Carcinogenic effects	25550[p]	25550[p]	25550[p]	25550[p]

[a] Mean and 95 % UCL of the mean used for MLE and RME calculations, respectively. Concentrations to be calculated based on uptake factors for fruits and vegetables. Transfer factors from plant to human may also be incorporated into the calculation of the exposure point concentration if such information is available.

[b] Uptake factors should be obtained from appropriate referenced literature.

[c] The plant ingestion rate for vegetables was the result of a 1994 and 1995 study for mean total vegetable intake (as consumed) per day for children 0-5 years of age (EPA 1997b, 66597, Table 9-19, page 9-35) .

[d] The plant ingestion rate for fruits was the result of a 1994 and 1995 study for mean total fruit intake (as consumed) per day for children 0-5 years of age (EPA 1997b, 66597, Table 9-18, page 9-35) .

[e] The plant ingestion rate for vegetables was the result of a 1994 and 1995 study for mean total vegetable intake (as consumed) per day for adults, all ages (EPA 1997b, 66597, Table 9-19, page 9-35) .

[f] The plant ingestion rate for fruits was the result of a 1994 and 1995 study for mean total fruit intake (as consumed) per day for adults, all ages (EPA 1997b, 66597, Table 9-18, page 9-35) .

[g] Value assumes that 40% of the vegetables ingested are grown in contaminated area (EPA 1991, 56140.1).

[h] Value assumes that 30% of the fruits ingested are grown in contaminated area (EPA 1991, 56140.1).

[i] Value assumes that 100% of the vegetables and fruits ingested are grown in contaminated area (EPA 1991, 56140.1).

[j] Exposure duration for child from birth to six years of age (EPA 1991, 56140.1).

[k] Exposure duration for adult is national median time (50th percentile) at one residence (EPA 1997, 66598c, Table 15-176, page 15-187).

[l] Exposure duration for adult is national upper bound time (90th percentile) at one residence (EPA 1991, 56140.1).

[m] Average body weight for 1-6 year old child (EPA 1991, 56140.1).

[n] Average body weight for adult (EPA 1991, 56140.1).

[o] Exposure duration multiplied by 365 days (EPA 1989, 08021).

[p] Lifetime exposure (70 years) multiplied by 365 days (EPA 1989, 08021).

Table 6
Exposure Parameters for Ingestion of Drinking Water
Residential Scenario

Intake (mg/kg-day) = (C x IR x EF x ED) / (BW x AT)	**Exposure Values**			
	Child		**Adult**	
	MLE	**RME**	**MLE**	**RME**
C = Chemical concentration in water (mg/L)	Site-specific[a]	Site-specific[a]	Site-specific[a]	Site-specific[a]
IR = Ingestion rate (liters of water/day)	0.74[b]	1.5[c]	2.0[d]	2.0[d]
EF = Exposure frequency (days/year)	350[e]	350[e]	350[e]	350[e]
ED = Exposure duration (years)	6[f]	6[f]	9[g]	30[h]
BW = Body weight (kg)	15[i]	15[i]	70[j]	70[j]
AT = Averaging time (period over which exposure is averaged – days)				
Noncarcinogenic effects	2190[k]	2190[k]	3285[k]	10950[k]
Carcinogenic effects	25550[l]	2555[l]	25550[l]	25550[l]

[a] Mean and 95 % UCL of the mean used for MLE and RME calculations, respectively.
[b] Water intake is the mean value for children 1-10 years of age (EPA 1997a, 66596, Table 3-30, page 3-26).
[c] Water intake is the 90[th] percentile value for children 1-10 years of age (EPA 1997a, 66596, Table 3-30, page 3-26).
[d] Water intake for adults is comparable to 8 glasses of water per day and is commonly assumed in EPA risk assessments (EPA 1991, 56140.1).
[e] Exposure frequency based on days/year spent at home (EPA 1991, 56140.1).
[f] Exposure duration for child from birth to six years of age (EPA 1991, 56140.1).
[g] Exposure duration is national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187).
[h] Exposure duration is national upper bound time (90th percentile) at one residence (EPA 1991, 56140.1).
[i] Average body weight for 1-6 year old child (EPA 1991, 56140.1).
[j] Average body weight for adult (EPA 1991, 56140.1).
[k] Exposure duration multiplied by 365 days (EPA 1989, 08021).
[l] Lifetime exposure (70 years) multiplied by 365 days (EPA 1989, 08021).

Industrial Scenario

This scenario evaluates the exposure to individuals that work on or near a potential release site. The contamination is the present day condition and not what may migrate to or from the site in the future. Under this land use, workers are routinely exposed to contaminated media within a commercial area or industrial site. The individuals addressed by this scenario include Laboratory personnel that may work on or near the site including ground crews, maintenance personnel, security staff, firing site personnel, and office workers. It may also provide exposure estimate for a non-Laboratory commercial worker if the area of exposure is not on Laboratory property. The individuals listed are collectively identified as site workers in the following tables and generally involve nonintrusive activities. Other potential receptors addressed by this scenario are collectively labeled construction workers, which include construction personnel, road crews, drillers, and anyone excavating in or near the contaminated area. These individuals generally are involved in intrusive activities. Environmental workers may be included under one or both categories depending on their activities and exposure may be a combination of the two types of industrial workers. An example of approved environmental worker exposure parameters are presented in the RFI report for PRS 16-021(c) (LANL 1998, 59891.3).

The exposure pathways related to this scenario that are routinely evaluated include incidental ingestion of soil, inhalation of particulates and/or vapors, and dermal contact. Because exposure conditions are limited to periods of work, the exposure duration and frequencies are less for this scenario than was presented for a resident. It has been assumed that a construction worker would spend all of his/her time at or in close proximity to the site (i.e., 8 hours per day). The site worker may either spend all of his/her time at a site or part of his/her time at a site (i.e., 4 hours per day). The latter situation may occur if the individual has an office off-site. Additional assumptions are related to the mean exposure frequencies for the construction worker and site worker as well as the mean exposure duration for a construction worker. These assumptions should be evaluated by the risk assessor to determine if they represent conditions at the site being investigated and modified if appropriate. Exposure pathways related to the ingestion of fruits and vegetables, drinking water, and meat as well as dermal contact with surface water are generally not considered viable pathways for this scenario. Some of the pathways may be added if the site conditions warrant their inclusion in the estimation of risk.

The exposure parameter and intake equations for each of the pathways for industrial exposure, except for external irradiation, are presented in Tables 7 to 9. The inhalation rates are those recommended for short-term exposure for either adults or outdoor workers (EPA 1997a, 66596) (Table 7). The RME and MLE values used for a construction worker are the upper bound hourly average for an outdoor worker and the average rate for heavy activities for outdoor workers, respectively. These are the highest inhalation rates recommended for outdoor workers and reflect the high level of activity anticipated with this type of work. The value used to calculate the RME and MLE for a site worker is the average rate for an adult for moderate activities. Although the same value is used for the RME and MLE, the exposure time differs for the different exposures based on whether part or all of the individual's time is spent on-site. As a result, the intake via inhalation for the RME is higher than for the MLE.

The mean soil ingestion rate for site workers is the same as recommended in EPA (1997a, 66596) for industrial settings (Table 8). The higher rate presented as the upper bound value was an estimate recommended in EPA (1991, 56140.1) (Table 8). The soil ingestion rate for construction workers is much higher because of the high level of activity and the large amount of dust generated by this activity (EPA 1991, 56140.1). The values presented for dermal exposures are default values for the adult including the surface area (EPA 1992c, 66598, 59184.1), adherence factors (EPA 1992c, 66598, 59184.1), and absorption factors (EPA 1998, 63061.1) (Table 9). The mean surface area value assumes the worker is wearing a long sleeve shirt and pants, while the upper bound value assumes the worker is wearing a short sleeve short and pants. Assumptions were also made for each pathway regarding the exposure duration and frequency for a construction worker.

Table 7
Exposure Parameters for Inhalation of VOCs or Fugitive Dust
Industrial Scenario

Intake (mg/kg-day) = (C x IR x ET x EF x ED) / (BW x AT)	**Exposure Values**			
	Construction Worker		**Site Worker**	
	MLE	**RME**	**MLE**	**RME**
C = Chemical concentration in ambient air (mg/m^3)	Site-specific [a]	Site-specific [a]	Site-specific [a]	Site-specific [a]
IR = Inhalation rate (m^3/hour)	2.5[b]	3.3[c]	1.6[d]	1.6[e]
ET = Exposure time (hours/day)	8[f]	8[f]	4[g]	8[h]
EF = Exposure frequency (days/year)	90[i]	250[j]	125[k]	250[j]
ED = Exposure duration (years)	1[l]	1[l]	9[m]	30[n]
BW = Body weight (kg)	70[o]	70[o]	70[o]	70[o]
AT = Averaging time (period over which exposure is averaged – days)				
Noncarcinogenic effects	365[p]	365[p]	2409[p]	9125[p]
Carcinogenic effects	25550[q]	25550[q]	25550[q]	25550[q]

[a] Mean and 95 % UCL of the mean used for MLE and RME calculations, respectively. Concentrations in fugitive dust calculated from chemical concentrations in soil and particulate concentration in air of 0.002 g/m^3. This dust loading value is based on extreme cases of mechanical disturbance and is consistent with maximum values from unpublished data obtained by monitoring heavy equipment operators during excavation activities at TA-54.

[b] Inhalation rate based on short-term exposure as the mean (50th percentile) rate for heavy activity for an outdoor worker (EPA 1997a, 66596, Table 5-23, page 5-24).

[c] Inhalation rate based on short-term exposure as the upper bound (95th percentile) hourly average for an outdoor worker (EPA 1997a, 66596, Table 5-23, page 5-24).

[d] Inhalation rate based on short-term exposure as the mean (50th percentile) hourly average for an adult doing moderate activities outdoors (EPA 1997a, 66596, Table 5-23, page 5-24). Assumes similar level of activity for both the MLE and RME but exposure times are different resulting in higher intake for the RME.

[e] Inhalation rate based on short-term exposure as the mean (50th percentile) hourly average for an adult doing moderate activities outdoors (EPA 1997a, 66596, Table 5-23, page 5-24). Assumes similar level of activity for both the MLE and RME but exposure times are different resulting in higher intake for the RME.

[f] Assumes construction worker spends an 8-hour workday on site (EPA 1991, 56140.1).

[g] Assumes site worker averages 4 hours/day working outdoors.

[h] Assumes site worker spends an 8-hour workday on site (EPA 1991, 56140.1).

[i] Assumes that the average length of a construction job is 90 days/year, based on communication with construction personnel.

[j] Exposure frequency based on working outdoors five days a week for 50 weeks per year (EPA 1991, 56140.1).

[k] Assumes worker spends 50% of time working outdoors based on five days a week for 50 weeks per year.

[l] Assumes construction worker is working on-site for one year.

[m] Exposure duration is national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187). Because of the nature of the area it is assumed that exposure duration in the work environment corresponds with the residence time.

[n] Exposure duration is national upper bound time (90th percentile) at one residence (EPA 1991, 56140.1). Because of the nature of the area it is assumed that exposure duration in the work environment corresponds with the residence time.

[o] Average body weight for adult (EPA 1991, 56140.1).

[p] Exposure duration multiplied by 365 days (EPA 1989, 08021).

[q] Lifetime exposure (70 years) multiplied by 365 days (EPA 1989, 08021).

Table 8
Exposure Parameters for Ingestion of Soil
Industrial Scenario

Intake (mg/kg-day) = (C x IR x CF x FI x EF x ED) / (BW x AT)	Exposure Values			
	Construction Worker		Site Worker	
	MLE	RME	MLE	RME
C = Chemical concentration in soil (mg/kg)	Site-specific[a]	Site-specific[a]	Site-specific[a]	Site-specific[a]
IR = Ingestion rate (mg soil/day)	480[b]	480[b]	50[c]	100[d]
CF = Conversion Factor (kg/mg)	10^{-6}	10^{-6}	10^{-6}	10^{-6}
FI = Fraction ingested from contaminated source	1[e]	1[e]	0.5[f]	1[e]
EF = Exposure frequency (days/year)	90[g]	250[h]	125[i]	250[h]
ED = Exposure duration (years)	1[j]	1[j]	9[k]	30[l]
BW = Body weight (kg)	70[m]	70[m]	70[m]	70[m]
AT = Averaging time (period over which exposure is averaged – days)				
Noncarcinogenic effects	365[n]	365[n]	2409[n]	9125[n]
Carcinogenic effects	25550[o]	25550[o]	25550[o]	25550[o]

[a] Mean and 95 % UCL of the mean used for MLE and RME calculations, respectively.

[b] Estimate for exposure through substantial soil contact and potential ingestion of inhaled material that is not retained in lungs. Evaluation is limited to contaminants in soil at depths of 12 ft or less (EPA 1991, 56140.1).

[c] Mean amount of soil consumed per day by an adult (EPA 1997a, 66596, Table 4-23, page 4-25).

[d] Upper bound estimate of soil consumed per day by an adult (EPA 1991, 56140.1).

[e] Assumes 100% of soil ingested is from the contaminated source.

[f] Assumes 50% of soil ingested comes from the contaminated source because only 50% of the time is spent outdoors.

[g] Assumes that the average length of a construction job is 90 days/year, based on personal communication with construction personnel.

[h] Exposure frequency based on working outdoors five days a week for 50 weeks per year (EPA 1991, 56140.1).

[i] Assumes site worker spends 50% of time working outdoors based on five days a week for 50 weeks per year.

[j] Assumes construction worker is working on-site for one year.

[k] Exposure duration is national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187). Because of the nature of the area it is assumed that exposure duration in the work environment corresponds with the residence time.

[l] Exposure duration is national upper bound time (90th percentile) at one residence (EPA 1991, 56140.1). Because of the nature of the area it is assumed that exposure duration in the work environment corresponds with the residence time.

[m] Average body weight for adult (EPA 1991, 56140.1).

[n] Exposure duration multiplied by 365 days (EPA 1989, 08021).

[o] Lifetime exposure (70 years) multiplied by 365 days (EPA 1989, 08021).

Table 9
Exposure Parameters for Dermal Contact with Soil
Industrial Scenario

Absorbed Dose (mg/kg-day) = (C x CF x SA x AF x ABS x EF x ED) / (BW x AT)	**Exposure Values**			
	Construction Worker		**Site Worker**	
	MLE	**RME**	**MLE**	**RME**
C = Chemical concentration in soil (mg/kg)	Site-specific[a]	Site-specific[a]	Site-specific[a]	Site-specific[a]
CF = Conversion Factor (kg/mg)	10^{-6}	10^{-6}	10^{-6}	10^{-6}
SA = Surface area available for contact (cm^2/event)	2000[b]	3200[c]	2000[b]	3200[c]
AF = Soil to skin adherence factor (mg/cm^2)	0.2[d]	1[d]	0.2[d]	1[d]
ABS = Absorption factor (unitless)	0.1/0.01[e]	0.1/0.01[e]	0.1/0.01[e]	0.1/0.01[e]
EF = Exposure frequency (days/year)	90[f]	250[g]	125[h]	250[g]
ED = Exposure duration (years)	1[i]	1[i]	9[j]	30[k]
BW = Body weight (kg)	70[l]	70[l]	70[l]	70[l]
AT = Averaging time (period over which exposure is averaged – days)				
Noncarcinogenic effects	365[m]	365[m]	2409[m]	9125[m]
Carcinogenic effects	25550[n]	25550[n]	25550[n]	25550[n]

[a] Mean and 95 % UCL of the mean used for MLE and RME calculations, respectively.

[b] Surface area assumes individual is wearing long sleeve shirt, pants, and shoes. The mean (50th percentile) exposed skin area is limited to the head and hands (EPA 1992c, 59184.1).

[c] Surface area assumes individual is wearing short sleeve shirt, pants, and shoes. The upper bound (95th percentile) exposed skin area is limited to the head, hands, and arms (EPA 1992c, 59184.1).

[d] Default values for 50th and 95th percentile skin adherence factors (EPA 1992c, 59184.1)

[e] Default values for absorption factors of 0.1 for organics and 0.01 for inorganics are recommended if chemical-specific values are not available (EPA 1998, 63061.1). Site-specific skin absorption factors are available for arsenic (0.03), cadmium (0.001), chlordane (0.04), 2,4-D (0.05), DDT (0.03), lindane (0.04), TCDD (0.030), PAHs (0.13), PCBs (0.14), and pentachlorophenols (0.25).

[f]. Assumes that the average length of a construction job is 90 days/year, based on personal communication with construction personnel.

[g] Exposure frequency based on working outdoors five days a week for 50 weeks per year (EPA 1991, 56140.1).

[h] Assumes site worker spends 50% of time working outdoors based on five days a week for 50 weeks per year.

[i] Assumes construction worker is working on-site for one year.

[j] Exposure duration is national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187). Because of the nature of the area it is assumed that exposure duration in the work environment corresponds with the residence time.

[k] Exposure duration is national upper bound time (90th percentile) at one residence (EPA 1991, 56140.1). Because of the nature of the area it is assumed that exposure duration in the work environment corresponds with the residence time.

[l] Average body weight for adult (EPA 1991, 56140.1).

[m] Exposure duration multiplied by 365 days (EPA 1989, 08021).

[n] Lifetime exposure (70 years) multiplied by 365 days (EPA 1989, 08021).

Recreational Scenario

This scenario pertains to individuals that may be exposed as a result of spending a limited amount of time in outdoor activities on or near a potential release site. Under this land use, activities such as hiking, camping, hunting, and fishing can be addressed. The only recreational activity that might currently take place on Laboratory property is that of a trail user/hiker. This individual may be either a worker or non-worker and might include a child as well as an adult receptor. The trail user scenario may also be used to address a trespasser or visitor exposure condition. The exposure parameters for this scenario may also be modified to incorporate a jogger who would have a higher metabolic rate. Other modifications may be made to reflect more frequent trail use (jogging or hiking) than is depicted by the listed parameters, because of the accessibility to trails and the generally fairer weather that is prevalent in the Los Alamos area. The exposure pathways related to this scenario that are routinely evaluated include incidental ingestion of soil, inhalation of particulates and/or vapors, dermal contact, and, if appropriate, dermal contact with surface waters. An exposure pathway for the ingestion of drinking water is also included for this scenario, although this is a minor or unlikely pathway under most circumstances. A pathway for the ingestion of fruits and vegetables may also be included as a minor under some situations, but is probably an unlikely pathway under most conditions.

The exposure parameters and intake equations for each of the pathways for a recreational exposure are presented in Tables 10 to 14. The RME and MLE inhalation rates are for moderate and light activity levels, respectively, for both the adults and children (Table 10). The mean soil ingestion rates for adults and children are those recommended in EPA (1997a, 66596) (Table 11). The higher rates presented as upper bound values were estimates recommended in EPA (1991, 56140.1) (Table 11). The higher values for inhalation and soil ingestion are recommended for the RME because they probably reflect conditions in this area of the country where vegetation is sparse, winds are prevalent, activities occur at higher altitudes so metabolism is higher, and more time is spent outdoors.

The values presented for dermal exposures to soil are default values for the adult including the surface area (EPA 1997a, 66596), adherence factors (EPA 1992c, 59184.1), and absorption factors (EPA 1998, 63061.1) (Table 12). The surface area values assume the adult is wearing a short sleeve shirt, shorts, and shoes. The surface areas for children assumes the same situation as the adult, i.e., the child is wearing a short sleeve shirt, shorts, and shoes. However, the surface areas were calculated from Tables 6-6 and 6-8 in Volume 1 of EPA's Exposure Factors Handbook (EPA 1997a, 66596). These tables provide information from studies on the total mean body surface area of male children for various age groups and the percentage of total body surface area by body part for different age groups, respectively. The values were calculated using the 50^{th} and 95^{th} percentile skin surface area values for children from 2-7 years of age and the mean percentage of total body surface area by body part for children between 6 and 7 years of age. The surface areas for dermal contact with water for a child were calculated in the same way as for soil except that the total mean body surface area and the percentage total body surface area for feet were included. The body surface areas for male children were used because they were generally greater than the values for females. Different surface area values for children can be calculated from these tables to reflect the potentially exposed population. The adult surface areas for dermal contact with water were calculated by adding the surface area for feet from Table 6-2 in Volume 1 of EPA's Exposure Factors Handbook (EPA 1997a, 66596). This value was added to the adult surface area values of 5800 and 5000 cm^2 used for a resident exposure (Table 13).

The intake rate for drinking water in adults and children (0.2 L/hr) is the value recommended for medium activity at a temperature of 85°F (EPA 1997a, 66596) (Table 14). Over the exposure time for this pathway (0.75-1.5 hrs for an adult per day and 0.5-1.0 hr for a child per day) this intake is approximately 7-15% and approximately 5-10% of the recommended daily intake of 2 L/day for an adult and child, respectively (EPA 1991, 56140.1). When using values other than 2 L/day the risk assessor should consider if the dose estimate will be used to estimate risk by combining with a dose-response relationship that was derived assuming tap water intake of 2L/day. IRIS does not use a tap water intake assumption in the derivation of RfDs, but does make the 2 L/day assumption in the derivation of cancer slope factors and unit risks. If the values recommended in EPA (1997a, 66596) are used, the risk assessor should adjust the dose-response relationship as described in Appendix 1, Chapter 1 of Volume 1 of EPA's Exposure Factors Handbook (EPA 1997a, 66596).

In addition, assumptions were made with respect to exposure time and exposure frequency for both the RME and MLE values. The assumptions included the total amount of time spent walking and the relative amount of time exposed to the contamination. The time spent walking was based on upper bound values obtained from EPA (1997c, 66598) for adults and children from ages 5-17. It was hypothesized that a reasonable maximum exposure would be for all of the time spent walking, while a more likely exposure would be for half of the time spent walking. The exposure frequency assumes less frequent trail use by children than adults. The frequency is set at once or twice a week for children with two weeks assumed to be spent on vacation away from the area. The frequency for adults is three to five times a week with two assumed to be spent on vacation away from the area and 30 days of inclement weather that would prevent outdoor activities. The exposure frequencies may underestimate the trail use for portions of the population, because some individuals hike and bicycle more frequently due to the accessibility of trails and the generally fair weather. The exposure frequency for dermal contact with surface water assumes more frequent exposure for children than adults. Exposure frequency is assumed to occur approximately half of the time that a child is on the trail versus approximately one-sixth of the time for an adult. The exposure is also restricted to the warmer months of the year for both adults and children. Although the exposure may be under- or overestimated for both groups under site-specific conditions, the intent is to provide a point of departure that is representative of a reasonable maximum exposure for the population. Exposure frequency, exposure time, and other parameters should be modified based on available information of site conditions.

Table 10
Exposure Parameters for Inhalation of VOCs or Fugitive Dust
Recreational Scenario

Intake (mg/kg-day) = (C x IR x ET x EF x ED) / (BW x AT)	Exposure Values			
	Child		Adult	
	MLE	RME	MLE	RME
C = Chemical concentration in ambient air (mg/m^3)	Site-specific [a]	Site-specific [a]	Site-specific [a]	Site-specific [a]
IR = Inhalation rate (m^3/hour)	1.0[b]	1.2[c]	1.0[d]	1.6[e]
ET = Exposure time (hours/day)	0.5[f]	1.0[g]	0.5[h]	1.0[i]
EF = Exposure frequency (days/year)	50[j]	100[k]	100[l]	200[m]
ED = Exposure duration (years)	6[n]	6[n]	9[o]	30[p]
BW = Body weight (kg)	45[q]	45[q]	70[r]	70[r]
AT = Averaging time (period over which exposure is averaged – days)				
Noncarcinogenic effects	2190[s]	2190[s]	3285[s]	10950[s]
Carcinogenic effects	25550[t]	25550[t]	25550[t]	25550[t]

[a] Mean and 95 % UCL of the mean used for MLE and RME calculations, respectively. Concentrations in fugitive dust calculated from chemical concentrations in soil and particulate concentration in air of 0.00009 g/m^3 (EPG 1990, 0497).

[b] Inhalation rate based on short-term exposure as the mean (50th percentile) hourly average for a child doing light activities (EPA 1997a, 66596, Table 5-23, page 5-24).

[c] Inhalation rate based on short-term exposure as the mean (50th percentile) hourly average for a child doing moderate activities (EPA 1997a, 66596, Table 5-23, page 5-24).

[d] Inhalation rate based on short-term exposure as the mean (50th percentile) hourly average for an adult doing light activities (EPA 1997a, 66596, Table 5-23, page 5-24).

[e] Inhalation rate based on short-term exposure as the mean (50th percentile) hourly average for an adult doing moderate activities (EPA 1997a, 66596, Table 5-23, page 5-24).

[f] Assumes one hour of trail use per day, with potential exposure to contaminants occurring over only half of that time. The total time on the trail is comparable to the 90th percentile time spent walking per day for children ages 1 to 11 (EPA 1997c, 66598, Table 15-126, page 15-142).

[g] Assumes one hour of trail use per day, with potential exposure to contaminants occurring over all of that time. The total time on the trail is comparable to the 90th percentile time spent walking per day for children ages 1 to 11 (EPA 1997c, 66598, Table 15-126, page 15-142).

[h] Assumes one hour of trail use per day, with potential exposure to contaminants occurring over only half of that time. The total time on the trail is comparable to the 90th percentile time spent walking per day for adults in the west (EPA 1997c, 66598, Table 15-126, page 15-142).

[i] Assumes one hour of trail use per day, with potential exposure to contaminants occurring over all of that time. The total time on the trail is comparable to the 90th percentile time spent walking per day for adults in the west (EPA 1997c, 66598, Table 15-126, page 15-142).

[j] Assumes exposure frequency occurs for one day per week for 50 weeks per year.

[k] Assumes exposure frequency occurs for two days per week for 50 weeks per year.

[l] Assumes exposure frequency occurs for two days per week for 50 weeks per year.

[m] Assumes exposure frequency occurs for four days per week for 50 weeks per year.

[n] Exposure duration is lifetime of 6-year-old child, which is within the median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187).

[o] Exposure duration is national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187).

[p] Exposure duration is national upper bound time (90th percentile) at one residence (EPA 1991, 56140.1).

[q] Average body weight for a child between 5 and 19 years of age (EPA 1997a, 66596, Table 7-3, page 7-4).

[r] Average body weight for adult (EPA 1991, 56140.1).

[s] Exposure duration multiplied by 365 days (EPA 1989, 08021).

[t] Lifetime exposure (70 years) multiplied by 365 days (EPA 1989, 08021).

Table 11
Exposure Parameters for Ingestion of Soil
Recreational Scenario

Intake (mg/kg-day) = (C x IR x CF x FI x EF x ED) / (BW x AT)	Exposure Values			
	Child		Adult	
	MLE	RME	MLE	RME
C = Chemical concentration in soil (mg/kg)	Site-specific[a]	Site-specific[a]	Site-specific[a]	Site-specific[a]
IR = Ingestion rate (mg soil/day)	100[b]	200[c]	50[d]	100[e]
CF = Conversion Factor (kg/mg)	10^{-6}	10^{-6}	10^{-6}	10^{-6}
FI = Fraction ingested from contaminated source	0.04[f]	0.08[g]	0.04[h]	0.08[i]
EF = Exposure frequency (days/year)	50[j]	100[k]	100[l]	200[m]
ED = Exposure duration (years)	6[n]	6[n]	9[o]	30[p]
BW = Body weight (kg)	45[q]	45[q]	70[r]	70[r]
AT = Averaging time (period over which exposure is averaged – days)				
Noncarcinogenic effects	2190[s]	2190[s]	3285[s]	10950[s]
Carcinogenic effects	25550[t]	25550[t]	25550[t]	25550[t]

[a] Mean and 95 % UCL of the mean used for MLE and RME calculations, respectively.

[b] Mean amount of soil consumed per day by a child 0-6 years of age (EPA 1997a, 66596, Table 4-23, page 4-24).

[c] Conservative estimate of the amount of soil consumed per day by a child 0-6 years of age (EPA 1991, 56140.1).

[d] Mean amount of soil consumed per day by an adult (EPA 1997a, 66596, Table 4-23, page 4-24).

[e] Upper bound estimate of soil consumed per day by an adult (EPA 1991, 56140.1).

[f] Assumes soil ingested from trail is proportional to fraction of time spent on trail exposed to contaminants, i.e., one hour of trail use per day, with potential exposure to contaminants occurring over only half of that time. The fraction ingested from contaminated source is the time exposed on trail divided by portion of day that could be spent on the trail in a day (0.5 hr/12 hr). The total time on the trial is comparable to the time spent walking per day for children ages 1 to 11 (EPA 1997c, 66598, Table 15-126, page 15-142).

[g] Assumes soil ingested from trail is proportional to fraction of time spent on trail exposed to contaminants, i.e., one hour of trail use per day, with potential exposure to contaminants occurring over all of that time. The fraction ingested from contaminated source is the time exposed on trail divided by portion of day that could be spent on the trail in a day (1 hr/12 hr). The total time on the trial is comparable to the time spent walking per day for children ages 1 to 11 (EPA 1997c, 66598, Table 15-126, page 15-142).

[h] Assumes soil ingested from trail is proportional to fraction of time spent on trail exposed to contaminants, i.e., one hour of trail use per day, with potential exposure to contaminants occurring over only half of that time. The fraction ingested from contaminated source is the time exposed on trail divided by portion of day that could be spent on the trail in a day (0.5 hr/12 hr). The total time on the trial is comparable to the time spent walking per day for adults in the west (EPA 1997c, 66598, Table 15-126, page 15-142).

[i] Assumes soil ingested from trail is proportional to fraction of time spent on trail exposed to contaminants, i.e., one hour of trail use per day, with potential exposure to contaminants occurring over all of that time. The fraction ingested from contaminated source is the time exposed on trail divided by portion of day that could be spent on the trail in a day (1 hr/12 hr). The total time on the trial is comparable to the time spent walking per day for adults in the west (EPA 1997c, 66598, Table 15-126, page 15-142).

[j] Assumes exposure frequency occurs for one day per week for 50 weeks per year.

[k] Assumes exposure frequency occurs for two days per week for 50 weeks per year.

[l] Assumes exposure frequency occurs for two days per week for 50 weeks per year.

[m] Assumes exposure frequency occurs for four days per week for 50 weeks per year.

[n] Exposure duration is age of 6-year-old child, which is less than the national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187).

[o] Exposure duration is national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187).

[p] Exposure duration is national upper bound time (90th percentile) at one residence (EPA 1991, 56140.1).

[q] Average body weight for a child between 5 and 19 years of age (EPA 1997a, 66596, Table 7-3, page 7-4).

[r] Average body weight for adult (EPA 1991, 56140.1).

[s] Exposure duration multiplied by 365 days (EPA 1989, 08021).

[t] Lifetime exposure (70 years) multiplied by 365 days (EPA 1989, 08021).

Table 12
Exposure Parameters for Dermal Contact with Soil
Recreational Scenario

Absorbed Dose (mg/kg-day) = **(C x CF x SA x AF x ABS x EF x ED)** / **(BW x AT)**	**Exposure Values**			
	Child		**Adult**	
	MLE	**RME**	**MLE**	**RME**
C = Chemical concentration in soil (mg/kg)	Site-specific[a]	Site-specific[a]	Site-specific[a]	Site-specific[a]
CF = Conversion Factor (kg/mg)	10^{-6}	10^{-6}	10^{-6}	10^{-6}
SA = Surface area available for contact (cm^2/event)	4300[b]	4700[c]	5000[d]	5800[e]
AF = Soil to skin adherence factor (mg/cm^2)	0.2[f]	1[f]	0.2[f]	1[f]
ABS = Absorption factor (unitless)	0.1/0.01[g]	0.1/0.01[g]	0.1/0.01[g]	0.1/0.01[g]
EF = Exposure frequency (events/year)	50[h]	100[i]	100[j]	200[k]
ED = Exposure duration (years)	6[l]	6[l]	9[m]	30[n]
BW = Body weight (kg)	45[o]	45[o]	70[p]	70[p]
AT = Averaging time (period over which exposure is averaged – days)				
Noncarcinogenic effects	2190[q]	2190[q]	3285[q]	10950[q]
Carcinogenic effects	25550[r]	25550[r]	25550[r]	25550[r]

[a] Mean and 95 % UCL of the mean used for MLE and RME calculations, respectively.

[b] Surface area for child assumes individual is wearing short sleeve shirt, shorts, and shoes so exposed skin area is limited to the head, hands, arms, and legs. The mean (50[th] percentile) value was obtained from tables of the total body surface area for male children and percent of total body surface area by body part for children in the Exposure Factors Handbook (EPA 1997a, 66596, Tables 6-6 and 6-8, pages 6-15 and 6-16).

[c] Surface area for child assumes individual is wearing short sleeve shirt, shorts, and shoes so exposed skin area is limited to the head, hands, arms, and legs. The upper bound (95[th] percentile) value was obtained from tables of the total body surface area for male children and percent of total body surface area by body part for children in the Exposure Factors Handbook (EPA 1997a, 66596, Tables 6-6 and 6-8, pages 6-15 and 6-16).

[d] Surface area for adult assumes individual is wearing short sleeve shirt, shorts, and shoes. The mean (50[th] percentile) exposed skin area is limited to the head, hands, arms, and legs (EPA 1997a, 66596, Table 6-14, page 6-25).

[e] Surface area for adult assumes individual is wearing short sleeve shirt, shorts, and shoes. The mean (50[th] percentile) exposed skin area is limited to the head, hands, arms, and legs (EPA 1997a, 66596, table 6-14, page 6-25).

[f] Default values for 50[th] and 95[th] percentile skin adherence factors (EPA 1992c, 59184.1).

[g] Default values for absorption factors of 0.1 for organics and 0.01 for inorganics are recommended if chemical-specific values are not available (EPA 1998, 63061.1). Site-specific skin absorption factors are available for arsenic (0.03), cadmium (0.001), chlordane (0.04), 2,4-D (0.05), DDT (0.03), lindane (0.04), TCDD (0.030), PAHs (0.13), PCBs (0.14), and pentachlorophenols (0.25).

[h] Assumes exposure frequency occurs for one day per week for 50 weeks per year.

[i] Assumes exposure frequency occurs for two days per week for 50 weeks per year.

[j] Assumes exposure frequency occurs for two days per week for 50 weeks per year.

[k] Assumes exposure frequency occurs for four days per week for 50 weeks per year.

[l] Exposure duration is the age of a 6-year-old child, which is less than the national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187).

[m] Exposure duration is national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187).

[n] Exposure duration is national upper bound time (90th percentile) at one residence (EPA 1991, 56140.1).

[o] Average body weight for a child between 5 and 19 years of age (EPA 1997a, 66596, Table 7-3, page 7-4).

[p] Average body weight for adult (EPA 1991, 56140.1).

[q] Exposure duration multiplied by 365 days (EPA 1989, 08021).

[r] Lifetime exposure (70 years) multiplied by 365 days (EPA 1989, 08021).

Table 13
Exposure Parameters for Dermal Contact with Surface Water
Recreational Scenario

Absorbed dose (mg/kg-day) = (C x SA x PC x ET x EF x ED x CF) / (BW x AT)	**Exposure Values**			
	Child		**Adult**	
	MLE	**RME**	**MLE**	**RME**
C = Chemical concentration in water (mg/L)	Site-specific[a]	Site-specific[a]	Site-specific[a]	Site-specific[a]
SA = Surface area available for contact (cm^2/event)	4885[b]	5285[c]	6490[d]	7290[e]
PC = Dermal permeability constant (cm/hour)	1/0.001[f]	1/0.001[f]	1/0.001[f]	1/0.001[f]
ET = Exposure time (hours/day)	0.25[g]	0.5[h]	0.25[g]	0.5[h]
EF = Exposure frequency (days/year)	12[i]	24[j]	32[k]	64[l]
ED = Exposure duration (years)	6[m]	6[m]	9[n]	30[o]
CF = Volumetric conversion factor for water (liters/cm^3)	0.001	0.001	0.001	0.001
BW = Body weight (kg)	45[p]	45[p]	70[q]	70[q]
AT = Averaging time (period over which exposure is averaged – days)				
Noncarcinogenic effects	2190[r]	2190[r]	3285[r]	10950[r]
Carcinogenic effects	25550[s]	25550[s]	25550[s]	25550[s]

[a] Mean and 95 % UCL of the mean used for MLE and RME calculations, respectively.

[b] Surface area for child assumes individual is wearing short sleeve shirt and shorts so exposed skin area is limited to the head, hands, arms, legs, and feet. The mean (50[th] percentile) value was obtained from tables of the total body surface area for male children and percent of total body surface area by body part for children in the Exposure Factors Handbook (EPA 1997a, 66596, Tables 6-6 and 6-8, pages 6-15 and 6-16).

[c] Surface area for child assumes individual is wearing short sleeve shirt and shorts so exposed skin area is limited to the head, hands, arms, legs, and feet. The upper bound (95[th] percentile) value was obtained from tables of the total body surface area for male children and percent of total body surface area by body part for children in the Exposure Factors Handbook (EPA 1997a, 66596, Tables 6-6 and 6-8, pages 6-15 and 6-16).

[d] Surface area for adult assumes individual is wearing short sleeve shirt and shorts so exposed skin area is limited to the head, hands, arms, legs, and feet. The mean (50[th] percentile) value was obtained by adding the surface area for feet from the table for surface area of adult males to the default value of 5000 cm^2 for residential surface area (see Table 4) (EPA 1997a, 66596, Table 6-2, page 6-13).

[e] Surface area for adult assumes individual is wearing short sleeve shirt and shorts so exposed skin area is limited to the head, hands, arms, legs, and feet. The upper bound estimate (95[th] percentile) value was obtained by adding the surface area for feet from the table for surface area of adult males to the default value of 5800 cm^2 for residential surface area (see Table 4) (EPA 1997a, 66596, Table 6-2, page 6-13).

[f] Default values are 1 for organics and $1 x 10^{-3}$ for inorganics if chemical-specific values are not available (EPA 1992c, 59184.1).

[g] Wading activity assumed to be similar to showering activity in that one does not linger for very long. Mean value (50[th] percentile) was obtained from the table of number of minutes spent in the shower for the west region (EPA 1997c, 66598, Table 15-21, page 15-36).

[h] Wading activity assumed to be similar to showering activity in that one does not linger for very long. Upper bound value (95[th] percentile) was obtained from the table of number of minutes spent in the shower for the west region (EPA 1997c, 66598, Table 15-21, page 15-36).

[i] Assumes wading activity for a child occurs one time per week for twelve weeks during the summer months (June – August).

[j] Assumes wading activity for a child occurs two times per week for twelve weeks during the summer months (June – August).

[k] Assumes wading activity for an adult occurs two per week for sixteen weeks during the months of June – September.

[l] Assumes wading activity for an adult occurs four times per week for sixteen weeks during the months of June – September.

[m] Exposure duration is age of 6-year-old child, which is less than the national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187).

[n] Exposure duration is national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187).

[o] Exposure duration is national upper bound time (90th percentile) at one residence (EPA 1991, 56140.1).

[p] Average body weight for a child between 5 and 19 years of age (EPA 1997a, 66596, Table 7-3, page 7-4).

[q] Average body weight for adult (EPA 1991, 56140.1).

[r] Exposure duration multiplied by 365 days (EPA 1989, 08021).

[s] Lifetime exposure (70 years) multiplied by 365 days (EPA 1989, 08021).

Table 14
Exposure Parameters for Ingestion of Drinking Water
Recreational Scenario

Intake (mg/kg-day) = (C x IR x EF x ED) / (BW x AT)	**Exposure Values**			
	Child		**Adult**	
	MLE	**RME**	**MLE**	**RME**
C = Chemical concentration in soil (mg/kg)	Site-specific[a]	Site-specific[a]	Site-specific[a]	Site-specific[a]
IR = Ingestion rate (liters of water/hr)	0.2[b]	0.2[b]	0.2[b]	0.2[b]
EF = Exposure frequency (days/year)	50[c]	100[d]	100[e]	200[f]
ED = Exposure duration (years)	6[g]	6[g]	9[h]	30[i]
BW = Body weight (kg)	45[j]	45[j]	70[k]	70[k]
AT = Averaging time (period over which exposure is averaged – days)				
Noncarcinogenic effects	2190[l]	2190[l]	3285[l]	10950[l]
Carcinogenic effects	25550[m]	25550[m]	25550[m]	25550[m]

[a] Mean and 95 % UCL of the mean used for MLE and RME calculations, respectively.
[b] Water intake based on medium activity level at 85°F (EPA 1997a, 66596, Table 3-27, page 3-22).
[c] Assumes exposure frequency occurs for one day per week for 50 weeks per year.
[d] Assumes exposure frequency occurs for two days per week for 50 weeks per year.
[e] Assumes exposure frequency occurs for two days per week for 50 weeks per year.
[f] Assumes exposure frequency occurs for four days per week for 50 weeks per year.
[g] Exposure duration the age of a 6 year old child, which is less that the national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187).
[h] Exposure duration is national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187).
[i] Exposure duration is national upper bound time (90th percentile) at one residence (EPA 1991, 56140.1).
[j] Average body weight for a child between 5 and 19 years of age (EPA 1997a, 66596, Table 7-3, page 7-4).
[k] Average body weight for adult (EPA 1991, 56140.1).
[l] Exposure duration multiplied by 365 days (EPA 1989, 08021).
[m] Lifetime exposure (70 years) multiplied by 365 days (EPA 1989, 08021).

Resource User

This scenario pertains to individuals that may be exposed as a result of spending time in outdoor activities on or near a potential release site as well as exposed as a result of the transport of materials off-site to biotic and abiotic media. Under this land use, activities involving the utilization of materials either grown or obtained from the land are addressed. The exposed individual would maintain a garden, forage for wild plants and berries as well as hunt and fish to supplement their livelihood. Similar temporal and exposure parameters as proposed for the trail user are presented in this scenario with only an adult receptor considered. Exposure times are assumed to be 2-4 hours per day because the pastimes are not considered full-time activities. The pathway for intake of fruits and vegetables is considered on a routine basis unlike the residential scenario along with a pathway for the ingestion of meat. The other exposure pathways related to this scenario include incidental ingestion of soil, inhalation of particulates and/or vapors, dermal contact with soil, and, if appropriate, dermal contact with surface waters. An exposure pathway for the ingestion of drinking water is also included for this scenario, although this is a minor or unlikely pathway under most circumstances.

The exposure parameters and intake equations for each of the pathways for a resource user are presented in Tables 15 to 21. The inhalation rate used for this scenario is the value recommended for moderate activity by an adult (EPA 1997a, 66596) (Table 15). The mean and upper bound soil ingestion rates for the adult are those recommended by EPA (1997a, 66596 and 1991, 56140.1) (Table 16). The higher values for inhalation and soil ingestion are recommended because they probably reflect conditions in this area of the country where vegetation is sparse, winds are prevalent, activities occur at higher altitudes so metabolism is higher, and more time is spent outdoors.

The values presented for dermal exposures to soil are default values for the adult including the surface area (EPA 1997a, 66596), adherence factors (EPA 1992c, 59184.1), and absorption factors (EPA 1998, 63061.1) (Table 17). The surface area values assume the adult is wearing a short sleeve shirt, shorts, and shoes. The surface area values for soil contact may overestimate the area exposed if an individual is more likely to wear a long sleeve shirt, pants, gloves, and a hat. This is particularly true during the colder months of the year. The risk assessor should evaluate the site conditions to determine if these values are representative of the potential exposure. The adult surface areas for dermal contact with water were calculated by adding the surface area for feet from Table 6-2 in Volume 1 of EPA's Exposure Factors Handbook (EPA 1997a, 66596). This value was added to the adult surface area values of 5800 and 5000 cm^2 used for a resident exposure (Table 20).

The ingestion rates for fruits and vegetables for adults were obtained from Tables 9-18 and 9-19 in Volume 2 of EPA's Exposure Factors Handbook (EPA 1997b, 66597). These annual ingestion rates were calculated by converting the highest of the two intake values to kg/day and then multiplying by 365 days (Table 18). The same ingestion rates were used for both the MLE and RME calculations but the fraction ingested that were grown in the contaminated area was changed to reflect different levels of contaminated food intake (Table 5). The ingestion of 30-40% of fruits and vegetables from the contaminated area is the value recommended by EPA (1991, 56140.1) and is probably representative of this type of scenario since the fruits, vegetables, and berries consumed are considered to be a supplement rather than a sole source (Table 18). The average ingestion rate for meat and the fraction obtained from the contaminated area are values recommended by EPA (1991, 56140.1) (Table 19). The latter value is based on a farming scenario and may overestimate the amount of meat obtained from the contaminated area. However, it is assumed to be a reasonable maximum value and should be evaluated by the risk assessor to determine its relevance.

The intake rate for drinking water in adults (0.2 L/hr) is the value recommended for medium activity at a temperature of 85°F (EPA 1997a, 66596) (Table 21). Over the exposure time for this pathway (2-4 hrs per day) this intake is approximately 20-40% of the recommended daily intake of 2 L/day (EPA 1991, 56140.1). When using values other than 2 L/day the risk assessor should consider if the dose estimate will be used to estimate risk by combining with a dose-response relationship that was derived assuming tap water intake of 2L/day. IRIS does not use a tap water intake assumption in the derivation of RfDs, but does make the 2 L/day assumption in the derivation of cancer slope factors and unit risks. If the values recommended in EPA (1997a, 66596) are used, the risk assessor should adjust the dose-response relationship as described in Appendix 1, Chapter 1 of Volume 1 of EPA's Exposure Factors Handbook (EPA 1997a, 66596).

This scenario contains pathways that may be representative of Native American, Hispanic, or other natural resource users, although input parameters may be adjusted and pathways may be combined with other scenarios' pathways to be more representative of regional specific populations.

Table 15
Exposure Parameters for Inhalation of VOCs or Fugitive Dust
Resource User Scenario

Intake (mg/kg-day) = (C x IR x ET x EF x ED) / (BW x AT)	Exposure Values	
	Adult	
	MLE	RME
C = Chemical concentration in ambient air (mg/m^3)	Site-specific[a]	Site-specific[a]
IR = Inhalation rate (m^3/hour)	1.6[b]	1.6[b]
ET = Exposure time (hours/day)	2.0[c]	4.0[d]
EF = Exposure frequency (days/year)	100[e]	200[f]
ED = Exposure duration (years)	9[g]	30[h]
BW = Body weight (kg)	70[i]	70[I]
AT = Averaging time (period over which exposure is averaged – days)		
Noncarcinogenic effects	3285[j]	10950[j]
Carcinogenic effects	25550[k]	25550[k]

[a] Mean and 95 % UCL of the mean used for MLE and RME calculations, respectively. Concentrations in fugitive dust calculated from chemical concentrations in soil and particulate concentration in air of 0.00009 mg/m^3 (EPG 1990, 0497).

[b] Inhalation rate based on short-term exposure as the mean (50[th] percentile) hourly average for an adult doing moderate activities (EPA 1997a, 66596, Table 5-23, page 5-24).

[c] Assumes four hours of use per day, with potential exposure to contaminants occurring over only half of that time.

[d] Assumes four hours of use per day, with potential exposure to contaminants occurring over all of that time.

[e] Assumes exposure frequency occurs for two days per week for 50 weeks per year.

[f] Assumes exposure frequency occurs for four days per week for 50 weeks per year.

[g] Exposure duration is national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187).

[h] Exposure duration is national upper bound time (90th percentile) at one residence (EPA 1991, 56140.1).

[i] Average body weight for adult (EPA 1991, 56140.1).

[j] Exposure duration multiplied by 365 days (EPA 1989, 08021).

[k] Lifetime exposure (70 years) multiplied by 365 days (EPA 1989, 08021).

Table 16
Exposure Parameters for Ingestion of Soil
Resource User Scenario

Intake (mg/kg-day) = (C x IR x CF x FI x EF x ED) / (BW x AT)	**Exposure Values**	
	Adult	
	MLE	**RME**
C = Chemical concentration in soil (mg/kg)	Site-specific[a]	Site-specific[a]
IR = Ingestion rate (mg soil/day)	50[b]	100[c]
CF = Conversion Factor (kg/mg)	10^{-6}	10^{-6}
FI = Fraction ingested from contaminated source	0.5[d]	1[e]
EF = Exposure frequency (days/year)	100[f]	200[g]
ED = Exposure duration (years)	9[h]	30[i]
BW = Body weight (kg)	70[j]	70[j]
AT = Averaging time (period over which exposure is averaged – days)		
Noncarcinogenic effects	3285[k]	10950[k]
Carcinogenic effects	2555[l]	25550[l]

[a] Mean and 95 % UCL of the mean used for MLE and RME calculations, respectively.
[b] Mean amount of soil consumed per day by an adult (EPA 1997a, 66596, Table 4-23, page 4-25).
[c] Upper bound estimate of soil consumed per day by an adult (EPA 1991, 56140.1).
[d] Assumes 50% of soil ingested comes from the contaminated source.
[e] Assumes 100% of soil ingested is from the contaminated source.
[f] Assumes exposure frequency occurs for two days per week for 50 weeks per year.
[g] Assumes exposure frequency occurs for four days per week for 50 weeks per year.
[h] Exposure duration is national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187).
[i] Exposure duration is national upper bound time (90th percentile) at one residence (EPA 1991, 56140.1).
[j] Average body weight for adult (EPA 1991, 56140.1).
[k] Exposure duration multiplied by 365 days (EPA 1989, 08021).
[l] Lifetime exposure (70 years) multiplied by 365 days (EPA 1989, 08021).

Table 17
Exposure Parameters for Dermal Contact with Soil
Resource User Scenario

Absorbed Dose (mg/kg-day) = (C x CF x SA x AF x ABS x EF x ED) / (BW x AT)	**Exposure Values**	
	Adult	
	MLE	**RME**
C = Chemical concentration in soil (mg/kg)	Site-specific[a]	Site-specific[a]
CF = Conversion Factor (kg/mg)	10^{-6}	10^{-6}
SA = Surface area available for contact (cm^2/event)	5000[b]	5800[c]
AF = Soil to skin adherence factor (mg/cm^2)	0.2[d]	1[d]
ABS = Absorption factor (unitless)	0.1/0.01[e]	0.1/0.01[e]
EF = Exposure frequency (events/year)	100[f]	200[g]
ED = Exposure duration (years)	9[h]	30[i]
BW = Body weight (kg)	70[j]	70[j]
AT = Averaging time (period over which exposure is averaged – days)		
Noncarcinogenic effects	3285[k]	10950[k]
Carcinogenic effects	25550[l]	25550[l]

[a] Mean and 95 % UCL of the mean used for MLE and RME calculations, respectively.

[b] Surface area for adult assumes individual is wearing short sleeve shirt, shorts, and shoes. The mean (50th percentile) exposed skin area is limited to the head, hands, arms, and legs (EPA 1997a, 66596, Table 6-14, page 6-25).

[c] Surface area for adult assumes individual is wearing short sleeve shirt, shorts, and shoes. The upper bound (95th percentile) exposed skin area is limited to the head, hands, arms, and legs (EPA 1997a, 66596, Table 6-14, page 6-25).

[d] Default values for 50th and 95th percentile skin adherence factors (EPA 1992c, 59184.1).

[e] Default values for absorption factors of 0.1 for organics and 0.01 for inorganics are recommended if chemical-specific values are not available (EPA 1998, 63061.1). Site-specific skin absorption factors are available for arsenic (0.03), cadmium (0.001), chlordane (0.04), 2,4-D (0.05), DDT (0.03), lindane (0.04), TCDD (0.030), PAHs (0.13), PCBs (0.14), and pentachlorophenols (0.25).

[f] Assumes exposure frequency occurs for two days per week for 50 weeks per year.

[g] Assumes exposure frequency occurs for four days per week for 50 weeks per year.

[h] Exposure duration is national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187).

[i] Exposure duration is national upper bound time (90th percentile) at one residence (EPA 1991, 56140.1).

[j] Average body weight for adult (EPA 1991, 56140.1).

[k] Exposure duration multiplied by 365 days (EPA 1989, 08021).

[l] Lifetime exposure (70 years) multiplied by 365 days (EPA 1989, 08021).

Table 18
Exposure Parameters for Ingestion of Home Grown Fruits and Vegetables
Resource User Scenario

Intake (mg/kg-day) = (C x K x IR x FI x ED) / (BW x AT)	**Exposure Values**	
	Adult	
	MLE	**RME**
C = Chemical concentration in soil (mg/kg)	Site-specific[a]	Site-specific[a]
K = plant – soil concentration ratio (mg/kg plant per mg/kg soil)	Chemical-specific[b]	Chemical-specific[b]
IR = Plant ingestion rate (kg/yr)		
Vegetables	68.6[c]	68.6[c]
Fruit	63.1[d]	63.1[d]
FI = Fraction of plants ingested that are grown in contaminated area	0.2[e] 0.1[f]	0.4[g] 0.3[g]
ED = Exposure duration (years)	9[h]	30[i]
BW = Body weight (kg)	70[j]	70[j]
AT = Averaging time (period over which exposure is averaged – days)		
Noncarcinogenic effects	3285[k]	10950[k]
Carcinogenic effects	25550[l]	25550[l]

[a] Mean and 95 % UCL of the mean used for MLE and RME calculations, respectively. Concentrations to be calculated based on uptake factors for fruits and vegetables. Transfer factors from plant to human may also be incorporated into the calculation of the exposure point concentration if such information is available.

[b] Uptake factors should be obtained from appropriate referenced literature.

[c] The plant ingestion rate for vegetables was the result of a 1994 and 1995 study for mean total vegetable intake (as consumed) per day for adults, all ages (EPA 1997b, 66597, Table 9-19, page 9-35) .

[d] The plant ingestion rate for fruits was the result of a 1994 and 1995 study for mean total fruit intake (as consumed) per day for adults, all ages (EPA 1997b, 66597, Table 9-18, page 9-35) .

[e] Value assumes that 20% of the vegetables ingested are grown in contaminated area. Value is 50% of RME.

[f] Value assumes that 10% of the fruits ingested are grown in contaminated area. Value is approximately 50% of RME.

[g] Value assumes that 40% of the vegetables and 30% of the fruits ingested are grown in contaminated area (EPA 1991, 56140.1).

[h] Exposure duration is national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187).

[i] Exposure duration is national upper bound time (90th percentile) at one residence (EPA 1991, 56140.1).

[j] Average body weight for adult (EPA 1991, 56140.1).

[k] Exposure duration multiplied by 365 days (EPA 1989, 08021).

[l] Lifetime exposure (70 years) multiplied by 365 days (EPA 1989, 08021).

Table 19
Exposure Parameters for Ingestion of Meat
Resource User Scenario

Intake (mg/kg-day) = $\frac{C \times TF \times [(UR_f \times K) + UR_s] \times IR \times FI \times ED}{BW \times AT}$	Exposure Values Adult	
	MLE	**RME**
C = Chemical concentration in soil (mg/kg)	Site-specific[a]	Site-specific[a]
TF = Soil to meat transfer factor (mg/kg_{meat} per mg/day)	Chemical-specific[b]	Chemical-specific[b]
UR_f = Uptake rate of feed by animal (kg/day)	25[c]	50[d]
K = feed – soil concentration ratio (mg/kg feed per mg/kg soil)	Chemical-specific[e]	Chemical-specific[e]
UR_s = Uptake rate of soil by animal (kg/day)	0.5[f]	0.5[f]
IR = Meat ingestion rate (kg/yr)	36.5[g]	36.5[g]
FI = Fraction of meat ingested that is raised in contaminated area	0.5[h]	0.75[i]
ED = Exposure duration (years)	9[j]	30[k]
BW = Body weight (kg)	70[l]	70[l]
AT = Averaging time (period over which exposure is averaged – days)		
Noncarcinogenic effects	3285[m]	10950[m]
Carcinogenic effects	25550[n]	25550[n]

[a] Mean and 95 % UCL of the mean used for MLE and RME calculations, respectively. Concentrations to be calculated based on uptake factor for soil to feed and the transfer factor from soil to meat.
[b] Uptake factors should be obtained from appropriate referenced literature.
[c] Value assumed to be 50% of the RME value obtained from Baes et al. (1984, 59788.1).
[d] Value obtained from Baes et al. (1984, 59788.1).
[e] Transfer factors from soil to meat should be obtained from appropriate referenced literature.
[f] Value is based on the livestock soil intake default parameter for RESRAD (Yu et al. 1993, 58695).
[g] Average ingestion rate for beef (EPA 1991, 56140.1).
[h] Value assumes that 50% of the meat ingested is obtained in contaminated area.
[i] Value assumes that 75% of the meat ingested is obtained in contaminated area (EPA 1991, 56140.1).
[j] Exposure duration is national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187).
[k] Exposure duration is national upper bound time (90th percentile) at one residence (EPA 1991, 56140.1).
[l] Average body weight for adult (EPA 1991, 56140.1).
[m] Exposure duration multiplied by 365 days (EPA 1989, 08021).
[n] Lifetime exposure (70 years) multiplied by 365 days (EPA 1989, 08021).

Table 20
Exposure Parameters for Dermal Contact with Surface Water
Resource User Scenario

Absorbed dose (mg/kg-day) = $\frac{\text{(C x SA x PC x ET x EF x ED x CF)}}{\text{(BW x AT)}}$	**Exposure Values** **Adult**	
	MLE	**RME**
C = Chemical concentration in water (mg/L)	Site-specific[a]	Site-specific[a]
SA = Surface area available for contact (cm^2/event)	6490[b]	7290[c]
PC = Dermal permeability constant (cm/hour)	1/0.001[d]	1/0.001[d]
ET = Exposure time (hours/day)	0.25[e]	0.5[f]
EF = Exposure frequency (days/year)	16[g]	32[h]
ED = Exposure duration (years)	9[i]	30[j]
CF = Volumetric conversion factor for water (liters/cm^3)	0.001	0.001
BW = Body weight (kg)	70[k]	70[k]
AT = Averaging time (period over which exposure is averaged – days)		
Noncarcinogenic effects	3285[l]	10950[l]
Carcinogenic effects	25550[m]	25550[m]

[a] Mean and 95 % UCL of the mean used for MLE and RME calculations, respectively.

[b] Surface area for adult assumes individual is wearing short sleeve shirt and shorts so exposed skin area is limited to the head, hands, arms, legs, and feet. The mean (50[th] percentile) was obtained by adding the surface area for feet from the table for surface area of adult males to the default value of 5000 cm^2 for residential surface area (see Table 3) (EPA 1997a, 66596, Table 6-2, page 6-13).

[c] Surface area for adult assumes individual is wearing short sleeve shirt and shorts so exposed skin area is limited to the head, hands, arms, legs, and feet. The upper bound estimate (95[th] percentile) was obtained by adding the surface area for feet from the table for surface area of adult males to the default value of 5800 cm^2 for residential surface area (see Table 3) (EPA 1997a, 66596, Table 6-2, page 6-13).

[d] Default values are 1 for organics and 1x 10^{-3} for inorganics if chemical-specific values are not available (EPA 1992c, 59184.1).

[e] Wading activity assumed to be similar to showering activity in that one does not linger for very long. Mean value (50[th] percentile) was obtained from the table of number of minutes spent in the shower for the west region (EPA 1997c, 66598, Table 15-21, page 15-36).

[f] Wading activity assumed to be similar to showering activity in that one does not linger for very long. Upper bound value (95[th] percentile) was obtained from the table of number of minutes spent in the shower for the west region (EPA 1997c, 66598, Table 15-21, page 15-36).

[g] Assumes wading activity for an adult occurs once per week for sixteen weeks during the months of June – September.

[h] Assumes wading activity for an adult occurs two times per week for sixteen weeks during the months of June – September.

[i] Exposure duration is national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187).

[j] Exposure duration is national upper bound (90th percentile) at one residence (EPA 1991, 56140.1).

[k] Average body weight for adult (EPA 1991, 56140.1).

[l] Exposure duration multiplied by 365 days (EPA 1989, 08021).

[m] Lifetime exposure (70 years) multiplied by 365 days (EPA 1989, 08021).

Table 21
Exposure Parameters for Ingestion of Drinking Water
Resource User Scenario

Intake (mg/kg-day) = (C x IR x EF x ED) / (BW x AT)	**Exposure Values**	
	Adult	
	MLE	**RME**
C = Chemical concentration in water (mg/L)	Site-specific[a]	Site-specific[a]
IR = Ingestion rate (liters of water/hr)	0.2[b]	0.2[b]
EF = Exposure frequency (days/year)	100[c]	200[d]
ED = Exposure duration (years)	9[e]	30[f]
BW = Body weight (kg)	70[g]	70[g]
AT = Averaging time (period over which exposure is averaged – days)		
Noncarcinogenic effects	3285[h]	10950[h]
Carcinogenic effects	2555[i]	25550[i]

[a] Mean and 95 % UCL of the mean used for MLE and RME calculations, respectively.

[b] Water intake based on medium activity level at 85°F (EPA 1997a, 66596, Table 3-27, page 3-22).

[c] Assumes exposure frequency occurs for two days per week for 50 weeks per year.

[d] Assumes exposure frequency occurs for four days per week for 50 weeks per year.

[e] Exposure duration is national median time (50th percentile) at one residence (EPA 1997c, 66598, Table 15-176, page 15-187).

[f] Exposure duration is national upper bound time (90th percentile) at one residence (EPA 1991, 56140.1).

[g] Average body weight for adult (EPA 1991, 56140.1).

[h] Exposure duration multiplied by 365 days (EPA 1989, 08021).

[i] Lifetime exposure (70 years) multiplied by 365 days (EPA 198, 08021).

ESTIMATION OF RADIONUCLIDE DOSE

The exposure assessment for radionuclides is similar to that for nonradionuclide chemicals in that each involves the characterization of the exposure setting, the identification of the exposure pathways, and the quantification of exposure. However, exposure is fundamentally different for radionuclides as compared to chemicals. Radionuclides that enter through the internal exposure pathways may become systemically incorporated and emit radiation within a tissue or organ. Radionuclides can also have adverse effects without being taken into or brought in contact with the body. This is because high-energy beta particles and gamma rays from radioactive contamination can travel distances before depositing their energy in tissues. Intake estimates for radionuclides are not a function of body weight and averaging time as with nonradionuclides and are typically expressed in units of activity rather than mass.

As mentioned previously, an individual is likely to be exposed to more than one contaminant at a site. Therefore, it might be necessary to determine the total estimated dose equivalent to an individual at a site. This is accomplished by summing the individual dose equivalents for each radionuclide of concern for each exposure pathway. Subsequently, the sum of the doses from all radionuclides across all pathways produces the annual dose equivalent from all exposures.

The radiological dose to humans from exposure to radionuclides is estimated using the residual radioactive (RESRAD) computer code. This computer code was developed by Argonne National Laboratory for the Department of Energy (DOE) for implementing DOE's requirement for residual radioactive material. The DOE guidelines were incorporated into DOE Order 5400.5 in February 1990 and were included in proposed Title 10, Part 834 of the Code of Federal regulations (March 1993). Radiological dose can be estimated for the same exposure scenarios as described above for nonradionuclide chemicals. The exposure pathways for these scenarios are also similar except that external contact with water is not considered.

Suggested values for some parameters to be entered into RESRAD for calculating dose are provided in Table 22. These parameters were selected to result in a reasonable maximum exposure for a receptor evaluated for each scenario, i.e., a most likely exposure condition is not calculated. The parameters are either RESRAD default parameters or Laboratory/area-wide parameters. Other site-specific values may be substituted if the information is available and it is determined that the suggested values are not representative of site conditions, e.g., area of contamination and thickness of contaminated zone. Certain parameters such as area of contamination, thickness of contaminated zone, erosion rate of contaminated zone, evapotranspiration coefficient, and soil particulate concentration in air are critical to the manner in which dose is estimated. In addition, the length of time over which the radionuclide is evaluated can influence the dose level for certain radionuclides associated with ingrowth of radioactive progeny. References and rationale for certain parameter values are provided in the following text. Parameter values not presented below are RESRAD default values for the appropriate scenario. Parameters listed in Table 22 may be substituted for site-specific values if information is available.

Radiation dose limit - Dose limit is 15 mrem/yr above background for free release of land to the public (i.e., residential, recreational, and resource user). The RESRAD default value of 30 mrem/yr is used for sites involving continued Laboratory and commercial/industrial use (i.e., site worker and construction worker).

Area of contaminated zone - The RESRAD default value of 10000 m^2 is adopted because it maximizes dose via external irradiation and soil ingestion pathways, and represents an effectively infinite source for modeling dose via the inhalation exposure route. Area of the site being investigated should be substituted for this default value.

Thickness of the contaminated zone - The value of 3 m represents an effectively infinite source for a modeling period of 1000 years. The thickness of contaminated zone for the site being investigated should be substituted for this default value if this is known.

Length parallel to aquifer flow - The value of 100 m represents the square root of the area of the contaminated zone. If sites-specific area is used, this value should change accordingly.

Time since placement of material - This parameter is used in the calculation of site-specific distribution coefficients and is set at zero for calculating generic guidelines.

Cover depth - The value of zero maximizes on-site exposure. Site-specific information may be substituted, if appropriate.

Density of contaminated zone - 1.6 g/cm^3, based on the best professional judgment of ER Project technical staff.

Contaminated zone erosion rate - The RESRAD default of 0.001 m/yr is adopted. At this rate, the depth of the contaminated zone is effectively infinite over the 1000-year modeling period because 2 m of contaminated soil will remain at the end of 1000 years.

Contaminated zone total porosity - The RESRAD default of 0.4 is adopted with concurrence of ER Project technical staff.

Contaminated zone effective porosity - The RESRAD default of 0.2 is adopted with the concurrence of ER Project technical staff.

Evapotranspiration coefficient - The RESRAD maximum value of 0.999 is selected to effectively defeat infiltration of water through the contaminated zone. Because leaching of radionuclides from the contaminated zone is eliminated the on-site dose over time is maximized. Realistic evapotranspiration coefficients will generally be smaller (thus allowing for plant growth) but must be derived on a site-specific basis.

Inhalation rate - For the residential scenario, the value is calculated using the default inhalation rate of 15.2 m^3/day published in EPA (1997a, 66596, Table 5-23, page 5-24) based on long-term exposure for adult males (19-65+). For the commercial/industrial (site worker) scenario, the value is calculated based on short-term exposure (hourly average of 1.6 m^3/hr) for an adult doing moderate activity, as defined in EPA (1997a, 66596, Table 5-23, page 5-24), while for the commercial/industrial scenario (construction worker) it is based on the upper bound (95th percentile) hourly average for an outdoor worker (EPA 1997a, 66596, Table 5-23, page 5-24). For the recreational and resource user scenarios, the values were calculated assuming a moderate (1.6 m^3/hr) level of activity, as defined in EPA (1997a, 66596, Table 5-23, page 5-24). Site-specific and scenario specific values may be substituted, if available.

Mass loading for inhalation - For the residential, commercial/industrial (site worker), recreational, and resource user scenarios, a value of 0.00009 g/m^3 is used based on the highest 24-hr average total suspended particulate concentration reported in the Environmental Surveillance Report for 1989 (EPG 1990, 0497). For the commercial/industrial (construction worker) scenario a value of 0.002 g/m^3 is used because of the generation of higher local dust loading by activities associated with this scenario. Site-specific and scenario specific values may be substituted, if available.

Dilution rate for airborne dust - The RESRAD default value of 3 m, which represents a conservatively biased estimate from national meteorological data, is used.

Exposure duration – For residential, recreational, and resource user scenarios, the exposure duration for an adult is the national upper bound (90th percentile) spent at one residence (EPA 1991, 56140.1). For the commercial/industrial scenario, the exposure duration for a site worker is also assumed to be the national upper bound time (90th percentile) at one residence (EPA 1991, 56140.1) because in general the exposure duration of work at the Laboratory corresponds with the residence time. The exposure duration for a construction worker assumes the individual is working on-site for one year. Site-specific and scenario specific values may be substituted, if available.

Fraction of time spent indoors each year - The exposure frequency for a resident is assumed to be 350 days/year (EPA 1991, 56140.1). The Exposure Factors Handbook (EPA 1997c, 66598, Table 15-176, page 15-187) indicates that the average amount of time spent at home is 76.7% (18.4 hours/day). Approximately 89% of the 18.4 hours, or 16.4 hours, are assumed to be spent indoors, which is 66% of the year. For the site worker, construction worker, recreational, and resource user activities, the exposure is assumed to be exclusively outdoors. Site-specific and scenario specific values may be substituted, if available.

Fraction of time spent outdoors each year - The time spent outside of the home for a resident is 2 hours/day or approximately 8% of the year. For the commercial/industrial scenarios, the exposure frequency is assumed to be 8 hours/day, 250 days/year with all of the time spent outdoors (EPA 1991, 56140.1), which is 23% of the year. For the recreational scenario, a receptor is assumed to spend 200 days in the contaminated area for 1 hour/day or 2.2% of the year. The resource user is assumed to spend 200 days per year in the contaminated zone for 4 hours/day or 9% of the year. The exposure time estimates for the trail user and resource user are based on best professional judgment and are intended to represent a reasonable maximum exposure time. Site-specific and scenario specific values may be substituted, if available.

Shape factor, external gamma - This value should be set at one because the assumed contaminated area of 10000 m^2 represents an effectively infinite area source for gamma irradiation in the RESRAD code. Site-specific values may be substituted, if available.

Fruits, vegetables, and grain consumption - The value of 132 kg/yr for the residential and resource user scenarios is based on the reasonable maximum value presented in EPA (1997b, 66597, Tables 9-18 and 9-19, page 9-35) for ingestion of fruits and vegetables. Consumption of homegrown grain products is considered to be unlikely for the Los Alamos area based on current land use. Site-specific and scenario specific values may be substituted, if available.

Leafy vegetable consumption - The RESRAD default value of 14 kg/yr is adopted for the residential and resource user scenarios. Site-specific and scenario specific values may be substituted, if available.

Meat and poultry consumption – The value is based on the average ingestion rate for beef (EPA 1991, 56140.1). Site-specific and scenario specific values may be substituted, if available.

Contamination fraction of plant food - The value of 1.0 for the residential scenario is considered the reasonable worst case. The value of 0.4 (EPA 1991, 56140.1) for the resource user is based on the upper bound value for the fraction that homegrown vegetables comprise of total yearly intakes. Site-specific and scenario specific values may be substituted, if available.

Contamination fraction of meat - Value assumes that 75% of the meat ingested is obtained in contaminated area (EPA 1991, 56140.1). Site-specific and scenario specific values may be substituted, if available.

Soil ingestion rate - The value used for the residential, recreational, site worker, and resource user scenarios is based on the adult daily soil ingestion rate of 100 mg/d recommended by EPA (1991, 56140.1) over the exposure period, e.g., 350 days/year for a resident. For the construction worker a daily soil ingestion rate of 480 mg/day recommended by EPA (1991, 56140.1) over the exposure period of 250 days/year was used. A soil ingestion rate for children is not incorporated into the RESRAD value because the dose conversion factors are based on an adult. Site-specific and scenario specific values may be substituted, if available.

Drinking water intake – The value for a resident is based on the adult daily intake of 2 L/day for 350 days a year (EPA 1991, 56140.1). Water intake for a recreational exposure is 0.2 liters/hour based on medium activity level at 85°F (EPA 1997c, 66598) for 1.5 hours per day for 200 days per year. Water intake for a resource user is 0.2 liters/hour based on medium activity level at 85°F (EPA 1997c, 66598, Table 3-27, page 3-22) for 4 hours per day for 200 days per year. Site-specific and scenario specific values may be substituted, if available.

Contamination fraction of drinking water – The value is the RESRAD default and assumes 100% of the contamination is from the drinking water at the residence. The value assumes approximately 10% of the contamination is from the drinking water obtained along the trail for the recreational exposure. The value assumes approximately 30% of the contamination is from the drinking water obtained from the natural sources for the resource user exposure. Site-specific and scenario specific values may be substituted, if available.

Mass loading for foliar deposition – Same value used as given for mass loading of inhalation.

Drinking water fraction from ground water – RESRAD default of 1 assumes all drinking water from ground water. Applicable primarily for canyon residents. The value assumes that approximately 10% and 30% of the drinking water is from ground water for the recreational and resource users, respectively. Site-specific and scenario specific values may be substituted, if available.

Storage time for fruits, vegetables, and grain - The RESRAD default value of 14 days is used for this parameter.

Storage time for leafy vegetables - The RESRAD default value of 1 day is used for this parameter.

Table 22
Suggested Values for RME Scenario-Specific RESRAD Parameters

Parameter	Units	Resident[a]	Site Worker[b]	Construction Worker[c]	Recreational User[d]	Resource User[e]
radiation dose limit	mrem/y	15	30	30	15	15
area of contaminated zone	m^2	Site-specific	Site-specific	Site-specific	Site-specific	Site-specific
thickness of contaminated zone	m	Site-specific	Site-specific	Site-specific	Site-specific	Site-specific
length parallel to aquifer flow	m	100	100	100	100	100
time since placement of material	yr	0	0	0	0	0
cover depth	m	0	0	0	0	0
density of contaminated zone	g/m^3	1.6	1.6	1.6	1.6	1.6
contaminated zone erosion rate	m/yr	0.001	0.001	0.001	0.001	0.001
contaminated zone total porosity	-	0.4	0.4	0.4	0.4	0.4
contaminated zone effective porosity	-	0.2	0.2	0.2	0.2	0.2
contaminated zone hydraulic conductivity	m/yr	440	440	440	440	440
contaminated zone b parameter	-	4.05	4.05	4.05	4.05	4.05
humidity in air	g/m^3	5	5	5	5	5
evapotranspiration coefficient[f]	-	0.999	0.999	0.999	0.999	0.999
precipitation	m/yr	0.48	0.48	0.48	0.48	0.48
runoff coefficient	-	0.52	0.52	0.52	0.52	0.52
watershed area	m^2	2.7E+07	2.7E+07	2.7E+07	2.7E+07	2.7E+07
accuracy for water/soil computations	-	0.001	0.001	0.001	0.001	0.001
density of saturated zone	g/m^3	1.6	1.6	1.6	1.6	1.6
saturated zone total porosity	-	0.3	0.3	0.3	0.3	0.3
saturated zone effective porosity	-	0.3	0.3	0.3	0.3	0.3
saturated zone hydraulic conductivity	m/yr	100	100	100	100	100
saturated zone hydraulic gradient	-	0.02	0.02	0.02	0.02	0.02
saturated zone b parameter	-	4.05	4.05	4.05	4.05	4.05
water table drop rate	m/yr	0.3	0.3	0.3	0.3	0.3
well pump intake depth below water table	m	10	10	10	10	10
model: nondispersion (ND) mass balance	-	ND	ND	ND	ND	ND
well pumping rate	m^3/yr	250	250	250	250	250
number of unsaturated zone strata	-	2	2	2	2	2
unsat. zone 1 thickness	m	260	260	260	260	260
unsat. zone 1 soil density	g/m^3	1.6	1.6	1.6	1.6	1.6
unsat. zone 1 total porosity	-	0.5	0.5	0.5	0.5	0.5
unsat. zone 1 effective porosity	-	0.4	0.4	0.4	0.4	0.4
unsat. zone 1 soil-specific b parameter	-	4.05	4.05	4.05	4.05	4.05
unsat. zone 1 hydraulic conductivity	m/yr	3	3	3	3	3
unsat. zone 2 thickness	m	100	100	100	100	100
unsat. zone 2 soil density	g/m^3	1.6	1.6	1.6	1.6	1.6
unsat. zone 2 total porosity	-	0.5	0.5	0.5	0.5	0.5
unsat. zone 2 effective porosity	-	0.4	0.4	0.4	0.4	0.4
unsat. zone 2 soil-specific b parameter	-	4.05	4.05	4.05	4.05	4.05
unsat. zone 2 hydraulic conductivity	m/yr	370	370	370	370	370
inhalation rate	m^3/yr	5548	14016	28908	14016	14016
mass loading for inhalation	g/m^3	9E-05	9E-05	0.002	9E-05	9E-05
exposure duration	yr	30	30	1	30	30
fraction of time spent indoors each year	-	0.85	0	0	0	0
fraction of time spent outdoors	-	0.08	0.23	0.23	0.022	0.09
shape factor, external gamma	-	1	1	1	1	1
fruits, vegetables and grain consumption	kg/yr	132	-	-	-	132
leafy vegetable consumption	kg/yr	14	-	-	-	14
meat and poultry consumption	kg/yr	-	-	-	-	36.5
livestock fodder intake for meat	kg/yr	-	-	-	-	68
livestock water intake for meat	L/yr	-	-	-	-	50
livestock soil intake	kg/day	-	-	-	-	0.5
mass loading for foliar deposition	g/m^3	9E-05	-	-	-	9E-05

Table 22 (concluded)

Parameter	Unit	Resident[a]	Site Worker[b]	Construction Worker[c]	Recreational User[d]	Resource User[e]
soil ingestion rate	g/yr	35	25	120	20	20
drinking water fraction from groundwater	-	1	-	-	0.1	0.3
household fraction from ground water	-	0	-	-	-	-
wet weight crop yield for non-leafy	kg/m	0.7	-	-	-	0.7
wet weight crop yield for leafy	kg/m	1.5	-	-	-	1.5
wet weight crop yield for fodder	kg/m	-	-	-	-	1.1
growing season for non-leafy	years	0.17	-	-	-	0.17
growing season for leafy	years	0.25	-	-	-	0.25
growing season for fodder	years	-	-	-	-	0.08
translocation factor for non-leafy	-	0.1	-	-	-	0.1
translocation factor for leafy	-	1	-	-	-	1
translocation factor for fodder	-	-	-	-	-	1
dry foliar interception fraction for non-	-	0.25	-	-	-	0.25
dry foliar interception fraction for leafy	-	0.25	-	-	-	0.25
dry foliar interception fraction for fodder	-	-	-	-	-	0.25
wet foliar interception fraction for non-	-	0.25	-	-	-	0.25
wet foliar interception fraction for leafy	-	0.25	-	-	-	0.25
wet foliar interception fraction fodder	-	-	-	-	-	0.25
weathering removal constant for	-	20	-	-	-	20
C-12 concentration in water	g/cm³	2E-05	2E-05	2E-05	2E-05	2E-05
C-12 concentration in contaminated soil	g/g	0.03	0.03	0.03	0.03	0.03
fraction of vegetation carbon from soil	-	0.02	-	-	0.02	0.02
fraction of vegetation carbon from air	-	0.98	-	-	0.98	0.98
C-14 evasion layer thickness	m	0.3	0.3	0.3	0.3	0.3
C-14 evasion flux rate from soil	1/sec	7E-07	7E-07	7E-07	7E-07	7E-07
C-12 evasion flux rate from soil	1/sec	1E-10	1E-10	1E-10	1E-10	1E-10
thickness of building foundation	m	0.15	0.15	0.15	-	-
bulk density of building foundation	g/m³	2.4	2.4	2.4	-	-
total porosity of cover material	-	0.4	0.4	0.4	0.4	0.4
total porosity of building foundation	-	0.1	0.1	0.1	-	-
volumetric water content of cover	-	0.05	0.05	0.05	0.05	0.05
volumetric water content of foundation	-	0.03	0.03	0.03	-	-
diffusion coefficient for radon in cover	m/sec	2E-06	2E-06	2E-06	2E-06	2E-06
diffusion coefficient for radon in	m/sec	3E-07	3E-07	3E-07	-	-
diffusion coefficient for radon in soil	m/sec	2E-06	2E-06	2E-06	2E-06	2E-06
radon vertical dimension of mixing	m	2	2	2	2	2
average annual wind speed	m/sec	3	3	3	3	3
average building air exchange rate	1/hr	1	1	1	-	-
height of building interior	m	2.5	2.5	2.5	-	-
building interior area factor	-	0	0	0	-	-
building depth below ground surface	-	-1	-1	-1	-	-
emanating power of Rn-222 gas	-	0.25	0.25	0.25	0.25	0.25
emanating power of Rn-220 gas	-	0.15	0.15	0.15	0.15	0.15

a Pathways evaluated include soil ingestion, dust inhalation, plant ingestion, radon inhalation, and external gamma.

b This is for an industrial scenario and the pathways evaluated include soil ingestion, dust inhalation, radon inhalation, and external gamma.

c Pathways evaluated include soil ingestion, dust inhalation, radon inhalation, and external gamma.

d Pathways evaluated include soil ingestion, dust inhalation, radon inhalation, and external gamma.

e Pathways and parameters are the same as for the trail user except plant ingestion, meat ingestion, and drinking water exposures are added.

f No infiltration is predicted because the evapotranspiration coefficient is >1, therefore, the hydrogeological parameters that follow have no impact on dose rates.

REFERENCES

Baes, C.F., Sharp, R.D., Sjoreen, A.L., and Shor, R.W., September 1984. "A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture." Prepared by the U.S Department of Energy (DOE), Health and Safety research Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee. (Baes et al., 1984, 59788.1)

EPA (U.S. Environmental Protection Agency), 1986. "Guidelines for the Health Risk Assessment of Chemical Mixtures," Federal Register Vol. 51, No. 185, p. 34014-34025. (EPA 1986, 65403.1)

EPA (U.S. Environmental Protection Agency), December 1989. "Risk Assessment Guidance for Superfund (RAGS), Volume 1, Human Health Evaluation Manual (Part A)," Interim Final, EPA 540/1-89/002, OSWER Directive 9285.7-01A. Office of Emergency and Remedial Response, Washington, D.C. (EPA 1989, 08021)

EPA (U.S. Environmental Protection Agency), March 1991. "Risk Assessment Guidance for Superfund (RAGS), Volume 1, Human Health Evaluation Manual Supplemental Guidance: Standard Default Exposure Factors," OSWER Directive 9285.6-03. Office of Emergency and Remedial Response, Washington, D.C. (EPA 1991, 56140.1)

EPA (U.S. Environmental Protection Agency), May 1992a. "Supplemental Guidance to RAGS: Calculating the Concentration Term," Publication Number 9285.7-08I, Office of Solid Waste and Emergency Response, Washington, D.C. (EPA 1992a, 59182.1)

EPA (U.S. Environmental Protection Agency), May 1992b. "Guidelines for Exposure Assessment," Federal Register Vol. 57, No. 104, p. 22888. (EPA 1992b, 55637)

EPA (U.S. Environmental Protection Agency), January 1992c. "Dermal Exposure Assessment: Principles and Applications," EPA 600/8-91/011B, Office of Health and Environmental Assessment, Washington, D.C. (EPA 1992c, 59184.1)

EPA (U.S. Environmental Protection Agency), August 1997a. "Exposure Factors Handbook, Volume I, General Factors," EPA 600/P-95/002Fa, Office of Health and Environmental Assessment, Washington, D.C. (EPA 1997a, 66596)

EPA (U.S. Environmental Protection Agency), August 1997b. "Exposure Factors Handbook, Volume II, Food Ingestion Factors," EPA 600/P-95/002Fb, Office of Health and Environmental Assessment, Washington, D.C. (EPA 1997b, 66597)

EPA (U.S. Environmental Protection Agency), August 1997c. "Exposure Factors Handbook, Volume III, Activity Factors," EPA 600/P-95/002Fc, Office of Health and Environmental Assessment, Washington, D.C. (EPA 1997c, 66598)

EPA (U.S. Environmental Protection Agency) Region IX (EPA Region IX), June 1998. *Region IX Preliminary Remediation Goals (PRGs) 1998*. www.epa.gov/region 09/. (EPA 1998, 63061.1)

EPG (Environmental Protection Group), December 1990. "Environmental Surveillance at Los Alamos During 1989," Los Alamos National Laboratory Report LA-12000-ENV, Los Alamos, New Mexico. (EPG 1990, 0497)

LANL (Los Alamos National Laboratory), September 1, 1998. "RFI Report for Potential Release site 16-021(c), Volume 1 of 3," Los Alamos National Laboratory Report LA-UR-98-4101, Los Alamos, New Mexico. (LANL 1998, 59891.3)

LANL (Los Alamos National Laboratory), March 1, 2000. "Integrated Installation Work Plan," Draft Los Alamos National Laboratory Report LA-UR-00-1336, Los Alamos, New Mexico. (LANL 2000, 64361.4)

Perona, R., R. Ryti, and M. Tardiff, December 1998. "Documentation of the Canyons Human Health Risk Screening Model," Los Alamos National Laboratory Report LA-UR-98-5523, Los Alamos, New Mexico. (Perona et al. 1998, 62049)

Seed, J., R.P. Brown, S.S. Olin, and J.A. Foran, 1995. "Chemical Mixtures: Current Risk Assessment Methodologies and Future Directions," Regulatory Toxicology and Pharmacology 22: 76-94. (Seed et al. 1995, 58928.1)

Yu, C., Zielen, A.J., Cheng, J.J., Yuan, Y.C., Jones, L.G., LePoire, D.J., Wang, Y.Y., Loueiro, C.O., Gnanapragasam, E., Faillace, E., Wallo III, A., Williams, W.A., and Peterson, H., September 1993. "A Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD," Version 5.0, ANL/EAD/LD-2, DOE/CH/8901, Environmental Assessment Division, Argonne National Laboratory, Argonne, Illinois. (Yu et al. 1993, 58695)