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The Hanford nuclear reservation in Washington state was initially created during World War II for the production of plutonium to be used in atomic bombs. A perceived need for a large increase in the number of nuclear weapons spurred expansions in production facilities at Hanford through the 1960's, and production was continued through the mid 1980's. The production process included irradiation of uranium fuel in reactors followed by chemical separation of the plutonium from the other fuel constituents, and finally transformation of plutonium nitrate to plutonium metal. The various steps in the process produced large amounts of radioactive as well as chemical hazardous waste. Some of this waste was released to the environment either through deliberate disposal methods or by leaks in transfer and storage systems. As a result, the soil at many areas of Hanford is contaminated to a point at which it would be unsafe for human contact for more than a short period of time. The current focus of efforts at Hanford is cleanup of the environment as well as decommissioning of the facilities. As part of the cleanup process, future land use must be determined

which will then affect the scale of the remediation effort. The proposed land use will determine the residual contamination which will be left after all remediation is complete and access is allowed to the site. This document details the process for determining the residual contamination levels associated with various land use options. Some possible land use options are explained in the form of exposure scenarios. These scenarios give data in the form of exposure factors which describe the possible exposure level of an individual to contaminated media. Once the exposure factors are determined, they can be used in the equations outlined in the Hanford Site Risk Assessment Methodology to calculate preliminary remediation goals. These goals are presented as contaminant concentrations in environmental media which are the maximum allowable in order to meet regulatory limits. The limits are expressed either as a risk for carcinogens, or as a hazard quotient for non-carcinogens.

Determining Preliminary Remediation Goals for Contaminated Hanford Sites

by

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Darin R. Hekkala, Author

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CHAPTER 1. INTRODUCTION

1.1 Hanford Overview

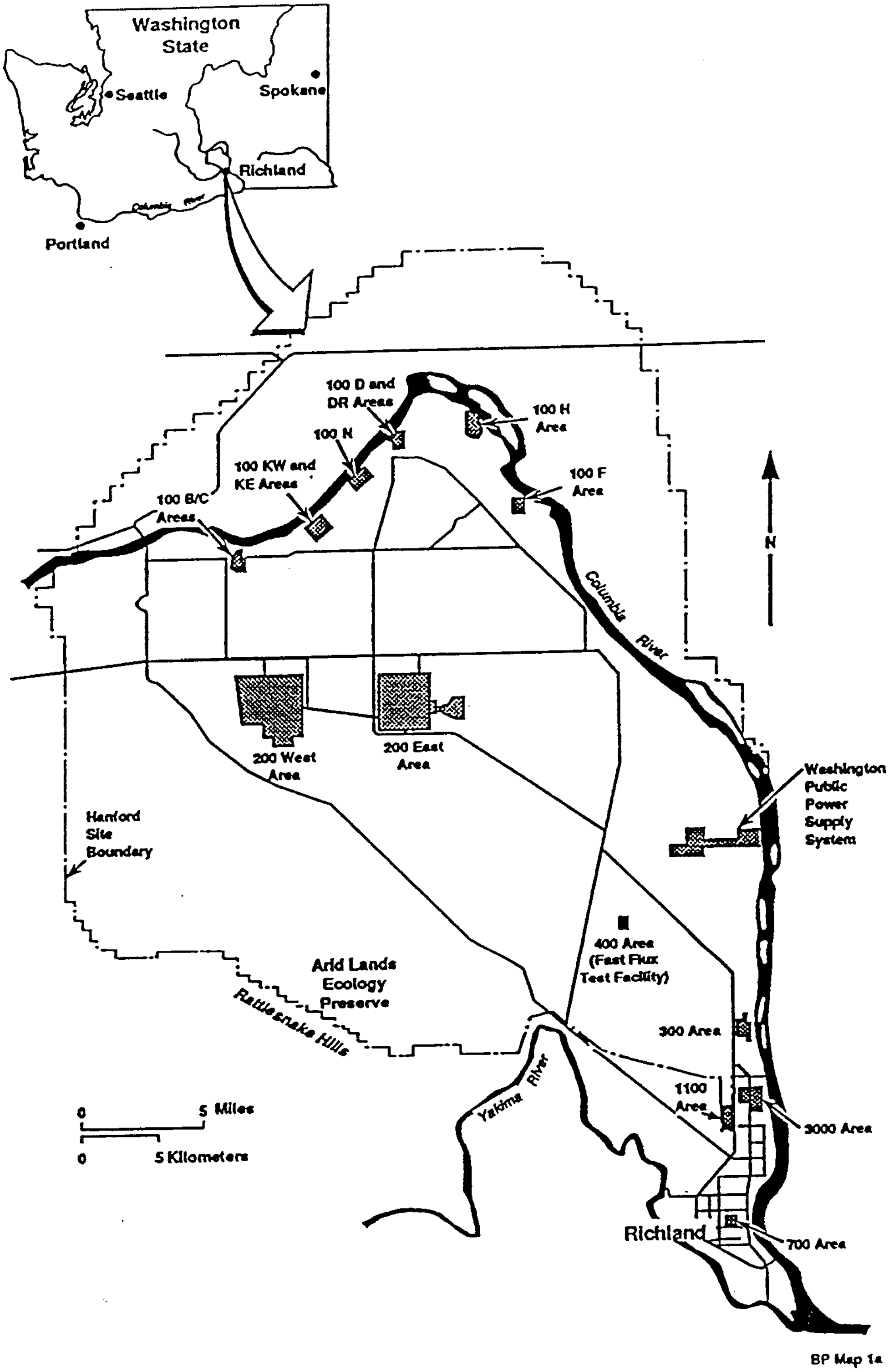
1.1.1 Hanford Beginning

In 1942 a search was conducted to locate an area to build a complex for the purpose of production of plutonium for nuclear weapons. The area selected, currently known as Hanford, was chosen for its isolation, large clean water supply, and abundant electrical power. It is located in central Washington state along the Columbia River in an area known as the Columbia Basin (Figure 1.). Construction began in 1943 and within 30 months 554 buildings dedicated directly or indirectly to plutonium production were constructed. The reactors B, D, and F were constructed during this period as well as the T, B, and U, processing plants. For storing high-level radioactive waste, 64 underground storage tanks were built.

1.1.2 1947 to 1949 Expansion

From 1947 to 1949 a large expansion of the Hanford industrial complex occurred. H and DR reactors were built during this period as well as the Z plant, which is commonly known as the Plutonium Finishing Plant. The Plutonium Finishing Plant allowed the conversion of plutonium nitrate to plutonium metal, a step which was previously performed at Los Alamos. Forty-two more underground storage tanks

Figure 1.1: Location and Regional Map of the Hanford Site (Gerber 1992)



were completed during this period, and the previously incomplete C Plant was finished for the newly developed reduction oxidation (REDOX) process. The REDOX chemical processing technique was developed to scavenge uranium which was not recovered during the original bismuth-phosphate processing.

1.1.3 1950 to 1955 Expansions

Another expansion took place from 1950 to 1952, mostly in response to a nationwide fear of communist aggression brought on by the Soviet Union's detonation of an atomic bomb (Gerber 1992). Some of the facilities constructed during this period include C Reactor, two evaporators, and 18 single-shell storage tanks. Close on the heels of this expansion another expansion occurred due to the influence of President Eisenhower. He believed that atomic weapons were an economical solution to national defense. This expansion saw the completion of the two K Reactors in 1955 as well as the PUREX Plant which was the most advanced method of extracting the valuable plutonium and uranium from the spent fuel. At this point there were eight reactors operating at Hanford which subsequently resulted in large quantities of hazardous chemical and radioactive material being released to the environment. In addition, the PUREX Plant itself was the source of 6.5 million gallons of low level liquid waste which was discarded directly to the ground. The groundwater mounds caused by the 200 Area disposal are still present to this day. This increased relative groundwater height contributes to contaminant movement because groundwater movement rates depend on the gradient described by the groundwater level.

1.1.4 Peak Production at Hanford

The period from 1956 to 1963 saw the most intensive period of plutonium production at Hanford, but compared to earlier periods, little new construction took place. In addition to plutonium, other isotopes such as cerium, cesium, strontium, promethium, and others, were separated for the military and NASA. The escalation of the Cold War was the impetus for the increased activity as U.S. leaders observed the Soviet Union's advances in space exploration. Tensions resulting from attempts to place missiles in Cuba, as well as the Berlin crisis also fueled Cold War production. The most significant new structure constructed at Hanford during this period was N Reactor. It had the dual purpose of electricity production as well as the creation of plutonium.

N Reactor was a closed loop plant, whereas the other eight reactors were single-pass reactors. In a single-pass reactor, the cooling water which flows through the core only passes through the system one time and is then discharged to the environment. The single-pass design was relatively simple to build and maintain compared to a closed loop, but it resulted in increased releases of contamination. Fuel leaks, and activated impurities in the water, resulted in large amounts of radioactivity being released to the Columbia River as well as to the ground. The average amount of radioactivity released to the Columbia due to reactor discharges was estimated to be 14,500 curies per day by 1960 (Gerber 1992).

Although a great amount of radioactivity was discharged to the river, most of the radioactivity has decayed or has been diluted or immobilized under sediment deposits. The contamination which this document is mainly concerned with is the soil contamination resulting from coolant water disposal or leakage from the single-pass reactors which did not make it into the Columbia, from disposal of low level waste from the 200 areas, underground tank leaks, and miscellaneous dumping of a multitude of materials at all areas.

1.2 Exposure Scenarios

As the land use at the former plutonium production complex of Hanford changes from past industrial activities to the possibility of some form of access by the general public, the potential problem of human exposure to contaminants must be addressed. It will be necessary to limit the exposure to harmful contaminants such that the health risks are within acceptable ranges. Some type of remediation is usually required in order to limit the exposure while allowing access to an area, assuming that the level of contamination is not already low enough that the health effects are negligible under all circumstances. The extent of the remediation activities will depend on the postulated types of uses by the public once the site is released. It is therefore important to develop realistic land use scenarios, not only to ensure public health, but also to efficiently utilize available resources.

Over the last two decades, federal and state governments have promulgated various regulations concerning the handling of hazardous substances which have been released into the environment through accidents, negligence, or accepted industrial practices. These hazardous substances have the possibility of negatively affecting human health. In order to prevent detrimental effects to humans, guidelines and resources were made available for addressing sites where contamination is present. In order to provide guidance for remediation planning, documents titled *Risk Assessment Guidance for Superfund: Volume 1, Human Health Evaluation Manual, Parts A, B, and C* (EPA 1989, 1991a, 1991b) were created The applicable State of Washington statute is the Model Toxics Control Act (MTCA) (WAC 1992).

The hazard to human health from contamination present in the environment depends in large part on the land use. Uses which are not time intensive may prevent the contaminants from becoming a hazard if the exposure rate is too low to deliver a dangerous amount of material to a human body during the time of the exposure. It also may be the case that the activities described do not allow contact with contaminated material due to the location or the form of the contamination. Human health risks are as dependent on the activities of a potentially exposed individual as they are on the characteristics of the contaminant. The selection of scenarios which describe the aforementioned activities as accurately as possible then becomes critical in assessing the human health risks associated with a geographical area.

1.2.1 HSRAM Scenarios

The *Hanford Site Risk Assessment Methodology* (HSRAM) (DOE-RL 1995a) presents four scenarios describing possible human activities. These are referred to as Industrial, Recreational, Residential, and Agricultural. The level of exposure can be characterized as increasing throughout these scenarios in the order they are listed.

Each of these scenarios has a series of exposure parameters which can be used to calculate human risk from contaminants for different exposure pathways. These parameters are tabulated in the HSRAM document along with example calculations and justification of the values selected.

1.2.2 Proposed Scenarios

The infinite variety of human activities is not adequately described by four general scenarios no matter how much thought and research is behind their formulation. With this in mind, a series of scenarios were developed to more completely describe the range of human activities. These scenarios were developed specific to the Hanford area, but many parameters could undoubtedly apply to other geographic locations. Preliminary work developing scenarios is described in the letter report titled *Draft Hanford-Specific Exposure Scenarios for Non-Remedial Activities that Might Occur Under "Restricted Access."* (Harper et al, 1995) This report was prepared by Pacific Northwest Laboratory under contract to the U.S. Department of Energy.

The exposure scenarios were developed based on actual site specific activities which might occur. Scenarios developed up to this point all assume that access to the site will be restricted. The general categories of exposure are identified as Industrial, Wildlife Refuge, and Native American Eco-cultural Preserve. Tabulated parameters are given in Appendix B for land uses applicable to these exposure pathways. Other activities such as those associated with residential use are covered by the scenarios presented in HSRAM.

The industrial scenario in HSRAM was expanded by adding a fish hatchery worker in anticipation of the opening of a fish hatchery in the near future. It was anticipated that this type of use would cause unique exposure circumstances not covered by previous assumptions concerning industrial activities. The most variable parameter between different scenarios is the exposure frequency. The exposure frequency distinguishes the fish hatchery worker from a general industrial worker as described in the HSRAM. The proposed fish hatchery project in the K-basins has site specific parameters for its operation.

Another anticipated exposure scenario is the designation of the area as a wildlife refuge. In the case where the land is designated as a wildlife refuge it was postulated that five types of classifications describing different activities would be possible. These classifications are ranger, hunter, birdwatcher, archeologist, and backpacker. A wildlife refuge will have certain limitations concerning the types of uses which are allowed on the land. For example, no permanent residents will be allowed and no crop production. A similar postulated scenario is the wild and scenic river corridor designation which will result in activities similar, if not identical to the wildlife refuge, but no scenarios were developed for this classification.

The next scenario which is new and specific to the Hanford site is related to Native American activities which may occur at the site. The Native American related activities are subsistence living, hunting and gathering, and cultural activities. The subsistence and hunting/gathering categories include more pathways than most other scenarios because it is assumed that the person exposed receives most of their food and water from the land as well as spending large amounts of time in the area. These can generally be considered the most restrictive of all the new scenarios developed. Cultural activities do not involve as many pathways as subsistence or hunting/gathering and the frequency of exposure is much less.

1.3 Procedure

In addition to presenting future land use scenarios for determining immediate cleanup activities, HSRAM outlines the equations used for calculating preliminary remediation goals (PRG's), intakes, and risk. Equations specific to a variety of pathways are presented in HSRAM, and these were utilized in a spreadsheet in order to perform the calculations. A spreadsheet application was chosen in order to apply additional software for the purpose of performing a monte carlo analysis of the calculations. The monte carlo analysis entails entering distributions for the parameters used in the calculations in order to calculate a distribution of the dose or risk. The parameter distributions are sampled based on a random number generator which selects values based on the probability which is found from the distribution. In this way it is possible to vary many parameters for each calculation and to perform several calculations in a relatively short period of time. The result of the calculations is then a distribution of possible answers, as opposed to a single value which can be misleading since it is based on assumptions and should not be interpreted as exact.

The results from a monte carlo calculation are also based on assumptions, but the effects of the assumptions on the precision of the answer can be quantified.

The PRG's are used as a tool for determining the extent of the remedial activities. For instance, they can be used to calculate the volumes of soil it is necessary to remove in order to achieve the concentrations stated in the PRG's, and subsequently the cost associated with performing the cleanup. The basis for this work is to provide scientific data upon which important fiscal and human health decisions can be based. In the past, decisions were mainly based on protecting human health to the maximum extent feasible and this lead to unnecessary utilization of important resources which could have been used in a more beneficial manner.

CHAPTER 2. LITERATURE REVIEW

2.1 Applicable Regulations

The risk assessment process has been described by regulations and supporting documents and has been put into practice at the Hanford site in accordance with federal requirements. The *100 Area Source Operable Unit focused Feasibility Study* (FFS) (DOE-RL 1995b) is a document which not only describes the HSRAM procedure, but gives results in connection with the 100 Area of the Hanford site. The results include calculated PRG's for the contaminants of potential concern and groundwater contaminant concentrations for several exposure scenarios. The FFS presents five remedial action objectives upon which the PRG's are based. These are:

- Limit exposure of human receptors to contaminated soils
- Limit future impacts to groundwater
- Comply with applicable or relevant and appropriate requirements (ARAR)
- Limit exposure of ecological receptors to contaminants
- Avoid or minimize destruction of natural resources.

In the FFS, the PRG's were based on one scenario classified as occasional use and which also considered the possibility that the groundwater would be used as a drinking water source. The allowable soil contamination, based on the resulting contamination in groundwater, was calculated using the Summers model which describes the transport of contamination from soil to groundwater. Although the

Summers model is a simple model based on the flow rate of the groundwater and chemical specific distribution coefficients, it is more versatile than the method outlined in MTCA which states that the allowed soil concentration is 100x more than the groundwater maximum concentration regardless of the contaminant or hydrogeologic properties. The final PRG's are sometimes based on the groundwater results and other times based on the HSRAM calculations depending on which is more conservative.

2.2 Rocky Flats Environmental Technology Site (RFETS)

The Rocky Flats site in Colorado is undergoing environmental remediation activities similar to the Hanford site. As a former area used for production of nuclear weapons, extensive environmental contamination has occurred which is now the focus of remediation activities. As part of the remediation process, site specific exposure scenarios were developed for the purpose of guiding the remediation process. These scenarios form the basis for the determination of preliminary risk-based remediation goals which are then used in selecting a remediation alternative.

Three general exposure scenarios are listed in a document titled *Technical Memorandum No. 1, Development of Corrective Remedial Action Objectives for Operable Unit No. 2* (EG&G 1995). These are residential, commercial/industrial, and ecological researcher. The commercial/industrial category is further divided into a gravel mine worker scenario and a construction worker scenario for subsurface soil contact. These scenarios are evaluated for three environmental media and several pathways for each media. For surface soil, the pathways considered are direct ingestion of soils, inhalation of particulates, and external exposure to radiation. Subsurface soil contact is only considered for the gravel mine worker scenario and the construction worker scenario. The pathways evaluated are the same as for surface soil contact except that inhalation of volatiles is also considered. Groundwater contact is appraised for the residential scenario only. The pathways for contact are direct ingestion of groundwater and inhalation during domestic use.

Table 2.1 gives the exposure factors used to calculate the PRG's for the given scenarios for comparison with the values determined for the Hanford site. The table gives the factors for the soil/dust ingestion pathway for exposures to an individual in one of five classifications; resident, office worker, construction worker, ecological worker, and gravel mine worker. Two values are given where applicable. One value is for the reasonable maximum exposure (RME) and the other is for the central tendency (CT). The RME exposure level is estimated by combining the 90 - 95th percentile values for some of the exposure parameters and the CT is the arithmetic mean for some of the exposure parameters.

Table 2.1: Exposure Factors for Soil/Dust Ingestion at RFETS

Factors for Potentially Complete Routes of Exposure		Resident	Office Worker	Const. Worker	Eco. Worker	Gr. Mn. Worker
Ingestion Rate	RME	200	NA	NA	NA	NA
Child (mg/day)	CT	100	NA	NA	NA	NA
Ingestion Rate	RME	100	50	480	50	50
Adult (mg/day)	CT	50	5	95	15	10
Exposure Frequency	RME	350	250	30	65	250
(days/yr)	CT	245	219	30	65	219
Exposure Duration	RME	6/24	25	1	2.5	25
Child/Adult (years)	CT	2/7	4	1	2.5	4
Body Weight	RME	15/70	70	70	70	70
Child/Adult (kg)	CT	15/70	70	70	70	70
Averaging Time Child/Adult:	RME	2190/8760	9125	365	915	9125
Non-carcinogen (days)	CT	730/2555	1460	365	915	1460
Averaging Time:	RME	25550	25550	25550	25550	25550
Carcinogen (days)	CT	25550	25550	25550	25550	25550

CHAPTER 3. METHODOLOGY

The determination of the risk levels and the PRG's was based on the equations illustrated in Appendix D of the HSRAM document. The equations for the summary intake factors (SIF) are given in Appendix A of this document and are the same as the intake equations in HSRAM, Appendix D, except that the concentration factor is not considered. The summary intake factors are then used in conjunction with the contaminant specific reference doses or cancer slope factors along with the desired level of risk to calculate the PRG's. The slope factors are from the Health Effects Assessment Summary Tables (EPA 1993). If the contaminant is a carcinogenic substance then the following equation is used to calculate the soil concentration:

$$SC = \frac{TR}{\sum (SIF \times SF)_i}$$

where:

SC	=	concentration in the soil (mg/kg or pCi/g)
TR	=	target risk level
SIF	=	summary intake factor (d^{-1} or g)
SF	=	carcinogenic slope factor $(mg/kg\text{-}d)^{-1}$ or $(pCi)^{-1}$.

While the noncarcinogenic limiting concentration is expressed in terms of the hazard quotient and reference dose as follows:

$$SC = HQ \times \sum \left(\frac{RfD}{SIF}\right)_i$$

where:

SC	=	concentration in the soil (mg/kg or pCi/g)
HQ	=	hazard quotient (unitless)
RfD	=	reference dose (mg/kg-d)
SIF	=	summary intake factor (d^{-1})

If the contaminant is a radionuclide then radioactive decay has to be taken into account. The following equation is used to determine the soil concentration at the time of remediation for exposure occurring in the future:

$$SC_0 = \frac{TR}{[0.5^{\beta} \times \sum (SIF \times SF)_i]}$$

where:

SC_0	=	soil concentration at time 0 (pCi/g)
TR	=	target risk (unitless)
β	=	calculated as $(time_t - time_0)/T_{0.5}$ ($T_{0.5}$ = radionuclide half-life)
SIF	=	summary intake factor (g)
SF	=	slope factor $(pCi)^{-1}$

These equations, along with the summary intake factor equations, form the basis of the spreadsheet created to calculate risk and preliminary remediation goals.

Some of the parameters which are contaminant specific are the slope factors and reference doses, volatilization and emission factors, radionuclide half lives, and groundwater limits. The following table taken from the spreadsheet template gives the parameters used in the equations which can change depending on the contaminant properties or regulatory requirements in the case of groundwater protection goals.

Table 3.1: Contaminant Specific Factors Used to Calculate PRG's

Oral Slope Factor (SFo)		value	$(mg/kg\text{-}d)^{-1}$ or $(pCi)^{-1}$
Inhalation Slope Factor (SFi)		value	$(mg/kg\text{-}d)^{-1}$ or $(pCi)^{-1}$
External Slope Factor (SFe)		value	$(mg/kg\text{-}d)^{-1}$ or $(pCi)^{-1}$
Oral Reference Dose (RfDo)		value	mg/kg-d
Inhalation Reference Dose (RfDi)		value	mg/kg-d
Particulate Emission Factor (PEF)		value	m^3/kg
Soil Volatilization Factor (VFs)		value	m^3/kg
Water Volatilization Factor (VFwvoc)		value	L/m^3
Absorption Factor (ABS)		value	unitless
Permeability Coefficient (Kp)		value	cm/hr
Radionuclide Half-life		value	y
Decay Factor (DF)		value	unitless
Groundwater Parameters	DCG or MCL	value	pCi/L or µg/L
	Kd	value	mL/g

The groundwater parameters are the derived concentration guides (DCG) for radionuclides or the maximum concentration limits (MCL) for chemical contaminants. The K_d parameter is the soil-water partition coefficient. Although shown in Table 3.1, groundwater based pathways were not considered at this time.

CHAPTER 4: PRESENTATION OF RESULTS

4.1 Exposure Scenario Factors

The new exposure scenarios were developed in order to expand the HSRAM scenarios so that a more realistic set of parameters could be applied to calculating PRG's. The scenarios developed were based on the premise that access to the site would be restricted in some way. Scenarios based on an unrestricted residential or agricultural scenario were not developed at this time. Three categories of restricted use were developed:

- Industrial (non-remedial)
- Wildlife Refuge
- Native American/Eco-cultural Preserve.

The non-remedial designation for the industrial means that exposure during cleanup activities is not considered.

4.1.1 Industrial Scenarios

The industrial category had two new scenarios developed based on fish hatchery activities. The basis of one of the scenarios is the planned fish hatchery in the K-area retention basins. There is currently a fish rearing program in place which is partially maintained by Native American workers, and plans exist for future expansion with increased Native American involvement. Exposure factors were assumed to be similar to those which are based on current activities as given by the

State Hatchery Program. The other scenario developed is based on a current operating hatchery, the Eastbank State Hatchery. This hatchery was chosen because it is estimated that the Hanford hatchery will be approximately the same size.

The pathways included for the fish hatchery worker exposure scenario were soil ingestion, dermal absorption through soil contact, soil inhalation, air inhalation, surface water ingestion, and dermal absorption through surface water contact. These pathways are the same for both the current Hanford operations and the Eastbank hatchery. The exposure factors for the two hatchery scenarios are tabulated in Appendix B. Only adult parameters were used since this is an industrial situation where the exposure only occurs in an occupational setting. The exposure frequency at the Eastbank hatchery is based on current EPA guidelines which suggest 250 days per year. The exposure frequency for current Hanford operations is 138 days per year. This is based on information obtained directly from the project manager.

4.1.2 Wildlife Refuge Scenarios

The next set of scenarios are related to the possible designation of Hanford as a wildlife refuge. Five different classifications were developed for a wildlife refuge based on postulated activities and each has its own unique pathways and factors describing human exposure. These five classifications were a ranger, hunter, bird watcher, archeologist, and a backpacker. It was decided that these would adequately describe most activities taking place on a wildlife refuge in the area.

The refuge ranger is assumed to work three days per week on the site while spending all other working hours off-site (Harper et. al. 1995). During time spent on the site the ranger may visit any area so it is assumed that time is spent equally between boating, shoreline activities, and upland activities. Possible exposure pathways for the ranger are soil/sediment ingestion and dermal contact, soil inhalation, airborne contaminant inhalation, and external exposure to radiation.

The same pathways are considered for the hunter scenario but with biota ingestion pathways included. This takes into account the possibility of consuming contaminated game. The ingestion and inhalation rates are the same as for the ranger but the time spent on the site is different. The total number of days spent hunting birds and deer is taken to be 70 per year (Harper et. al. 1995). The average success rate for waterfowl is 2 birds per day, and for upland birds it is 0.5 per day with the total season success rate being 10 times the average. This results in a final consumption rate for a hunters family of 9 g/day for each member for upland birds and 35 g/day for waterfowl. For deer, the consumption rate comes to 15 g/day for each family member.

The bird watcher scenario is similar to the ranger in that the same pathways are considered. There is no consumption of biota, so all internal exposure is due to inadvertent dust ingestion and inhalation as well as inhalation of airborne contaminants. Although the pathways are familiar, the intake rates are dissimilar from the scenarios already discussed. The soil/sediment ingestion rate is taken to be 25 g/day, which is only one fourth of the ranger or hunter intake. Also, the inhalation rate is halved to 5 m^3/day. These changes are based on the decreased activity and exposure time for bird watching.

Archeological investigations have been proposed for the site, so an exposure scenario was developed which includes factors describing the activities of an archeologist. This scenario is very simple in that it only includes five different pathways. These are; soil ingestion, soil inhalation, soil dermal exposure, and airborne contaminant inhalation. Soil based intakes are increased in relation to other scenarios due to the increased time in contact with the soil as well as the increased soil resuspension caused by excavation. As an example, the soil ingestion rate is set to 200 mg/day which is twice the normal value. The time at the site is also relatively high although the duration in terms of years is low.

The last scenario developed under the wildlife refuge classification describes the possible exposure to a backpacker. This scenario includes groundwater ingestion and fish ingestion as well as the soil and sediment pathways previously discussed for other scenarios. It is assumed that the backpacker will need to replenish water supplies from springs and that consumption of freshly caught fish will be common. A fish ingestion rate of 250 g/day is used, but the exposure frequency is only 15 days per year. A higher than normal soil ingestion rate is used (20 mg/day) due to the increased soil contact which results from extended hiking.

4.2.3 Native American Scenarios

The first scenario developed based on postulated Native American activities was the full subsistence scenario. This scenario assumes full time residence on the site as well as derivation of all food from the site. As can be expected, more pathways are applicable to this scenario than in the others. The pathways include various media such as soil, sediment, groundwater, surface water, and air. In addition, five different biota ingestion pathways are considered. These are fish, fruit and vegetation, meat, upland birds, and waterfowl. The reason so many pathways are included is as stated earlier, assuming a subsistence lifestyle on the site means that not only is all food gathered from possible contaminated sources, but all time is also spent on site. This is also the first scenario to include child specific factors.

The next Native American based scenario is hunting/gathering. In this scenario it is assumed that time spent on the site is only for the purpose of obtaining food, either through the acquisition of plants, hunting game, or fishing. The biota ingestion based pathways are the same as in the subsistence scenario, and the other pathways are identical except that no surface water inhalation is accounted for. The exposure frequency for this scenario is obviously lower than the subsistence scenario because it is assumed that the primary residence is away from the site.

The final Native American based scenario is cultural activities. Cultural activities include such items as religious ceremonies or educational pursuits. A 30 day per year exposure frequency is assumed. This scenario is related to the subsistence scenario in that it can be assumed that these activities will occur if Native Americans are residing on the site full time. The factors associated with cultural activities are not included in the subsistence scenario factors, so must be considered separately.

4.2 Summary Intake Factor Results

Once all of the applicable exposure factors are known, an SIF can be calculated. The SIF is not dependent on any contaminant properties, only the exposure factors. The SIF's calculated for all the pathways corresponding to the previously described scenarios are given in the last column of the tables in Appendix B. They are also tabulated in Appendix C without their constituent factors for the purpose of comparison between the different scenarios for each pathway and contaminant type (non-carcinogenic, carcinogenic non-radioactive, radioactive). Each table represents a different media through which exposure may occur. For example, Table C-1 considers the soil-based pathways, while Table C-2 considers the air-based pathways. Not all pathways are present in every scenario. When a pathway is not present, a blank space appears in the table.

As stated, the SIF's provide a rough way to compare a scenario's effect on cleanup levels for each pathway. The shaded value in each table in Appendix C corresponds to the most restrictive value for that pathway. In Table C-1 it can be seen that the most restrictive value for the soil ingestion pathway results from the HSRAM residential scenario with an SIF of 1.3E-5 kg soil/(kg-d).

4.3 Preliminary Remediation Goal Results

The preliminary remediation goals for the new scenarios were calculated using the parameters developed which relate to the new exposure scenarios just described. The parameters are given in the tables in Appendix B, as well as the results for calculating the summary intake factors for each pathway which is applicable to the relevant scenario and contaminant type. The contaminants selected are those used in the *100 Area source Operable Unit Focused Feasibility Study*. They consist of 24 radionuclides, 8 metals, and 4 volatile organic compounds. For comparison to the baseline scenario used in the original FFS, only the soil related pathways were considered. These include soil ingestion, soil inhalation, and inhalation of volatile compounds present in the soil. The results for the PRG calculations using these pathways are given in Table 4.1a and Table 4.1b. The shaded areas in the tables show the most restrictive concentrations for each contaminant.

It can be seen that for the metals considered, the scenario based on a wildlife refuge archeologist results in the most restrictive concentrations for residual contamination. This is due to the higher than normal soil ingestion rate resulting from activities an archeologist might pursue. The lowest concentration allowed after remediation corresponds to mercury at 14.60 mg/kg. For radionuclides, the most restrictive scenario is the Native American subsistence scenario. Since this scenario assumes continuous residence on the site as well as ingestion of soil, the additional hazard from external exposure to radiation influences the calculation. The lowest

Table 4.1a: Preliminary Remediation Goals Calculated for New Exposure Scenarios
The numbers in each column represent the cleanup goals for soil contamination levels. The radionuclide levels are expressed in units of pCi/kg, and the remaining contaminants are expressed in units of mg/kg.

Contaminant	Wildlife Refuge Ranger	Wildlife Refuge Hunter	Wildlife Refuge Birdwatcher	Wildlife Refuge Archeologist	Wildlife Refuge Backpacker
Am-241	251.7	815.0	2315	904.1	1283
C-14	3.715E+6	1.592E+7	1.783E+8	2.229E+7	7.430E+7
Cs-134	1464	4705	13170	5270	7319
Cs-137	1.107	3.558	9.963	3.985	5.535
Co-60	4.327	13.91	38.94	15.58	21.63
Eu-152	1.273	4.093	11.46	4.584	6.367
Eu-154	2.303	7.404	20.73	8.293	11.52
Eu-155	781.4	2512	7033	2813	3907
H-3	2.659E+8	1.140E+9	1.267E+10	1.573E+9	5.280E+9
K-40	2.256	7.252	20.31	8.122	11.28
Na-22	172.4	554.0	1551	620.5	861.8
Ni-63	1.603E+7	6.869E+7	7.425E+8	8.968E+7	3.094E+8
Pu-238	8432	34330	1.953E+5	26830	90530
Pu-239	7151	29660	1.866E+5	22810	83810
Pu-240	6768	27630	1.598E+5	21730	73830
Ra-226	0.2054	0.6601	1.848	0.7393	1.027
Sr-90	1.724E+5	7.388E+5	8.205E+6	1.017E+6	3.419E+6
Tc-99	1.118E+6	4.047E+6	1.578E+7	4.808E+6	8.387E+6
Th-228	2682	8622	24140	9656	13410
Th-232	14940	57870	2.383E+5	36330	1.156E+5
U-233	12540	46960	1.780E+5	32660	89420
U-234	14620	55930	2.242E+5	36850	1.103E+5
U-235	5.075	16.31	45.68	18.27	25.38
U-238	33.74	108.5	304.3	121.2	169.0
Antimony	68.13	146.0	3270	20.44	681.3
Arsenic	3.298	14.09	157.7	19.63	65.69
Barium	2650	3650	71540	311.0	14900
Cadmium	170.3	365.0	8176	51.10	1703
Chromium VI	851.7	1825	40880	255.5	8517
Manganese	3238	4291	83380	356.1	17370
Mercury	50.26	106.5	18400	14.60	494.5
Zinc	51100	1.095E+5	2.453E+6	15330	5.110E+5
Aroclor 1260	0.7695	0.1099	36.71	4.573	15.30
Benzo(a)pyrene	0.8547	0.1161	38.80	4.827	16.17
Chrysene	812.2	116.0	38770	4826	16150
Pentachlorophenol	49.35	7.050	2353	293.3	980.5

Table 4.1b: Preliminary Remediation Goals Calculated for New Exposure Scenarios
The numbers in each column represent the cleanup goals for soil contamination levels. The radionuclide levels are expressed in units of pCi/kg, and the remaining contaminants are expressed in units of mg/kg.

Contaminant	Hanford Fish Hatchery Worker	Eastbank Fish Hatchery Worker	Native American Subsistence	Native American Hunting Gathering Fishing	Native American Cultural Non-subsistence
Am-241	298.6	57.68	7.658	9.189	136.4
C-14	1.154E+7	2.229E+6	4.423E+5	5.307E+5	2.654E+6
Cs-134	1705	329.4	43.57	52.28	784.2
Cs-137	1.289	0.2491	0.03295	0.03954	0.593
Co-60	5.039	0.9735	0.1288	0.1545	2.318
Eu-152	1.483	0.2865	0.03790	0.04548	0.1890
Eu-154	2.683	0.5183	0.06856	0.08227	1.234
Eu-155	910.1	175.8	23.26	27.91	418.6
H-3	8.258E+8	1.595E+8	3.165E+7	3.799E+7	1.906E+8
K-40	2.628	0.5076	0.06715	0.08058	1.209
Na-22	200.7	38.78	5.130	6.155	92.33
Ni-63	4.978E+7	9.617E+6	1.908E+6	2.290E+6	1.166E+7
Pu-238	20740	4008	681.8	818.1	7026
Pu-239	19040	3679	655.3	786.3	6157
Pu-240	16820	3250	556.1	667.4	56.38
Ra-226	0.2392	0.04620	6.112E-3	7.334E-3	0.1100
Sr-90	5.354E+5	1.034E+5	20520	24630	1.237E+5
Tc-99	1.810E+6	3.497E+5	50190	60220	6.785E+5
Th-228	3124	603.5	79.83	95.80	1437
Th-232	30300	5853	909.0	1091	13640
U-233	22630	4373	649.9	779.9	10060
U-234	28370	5482	836.7	1004	12500
U-235	5.911	1.142	0.1511	0.1813	2.719
U-238	39.37	7.606	1.006	1.208	18.11
Antimony	74.06	40.88	28.39	34.07	170.3
Arsenic	10.24	1.979	0.3927	0.4712	2.361
Barium	2880	1590	1104	1325	10840
Cadmium	185.1	102.2	70.97	85.17	425.8
Chromium VI	925.7	511.0	354.9	425.8	2129
Manganese	3520	1943	1349	1619	14260
Mercury	54.63	262.8	20.94	25.13	126.7
Zinc	55540	30660	21290	25550	1.278E+5
Aroclor 1260	2.390	0.4617	0.09161	0.1099	0.5513
Benzo(a)pyrene	2.523	0.4875	0.09673	0.1161	0.5818
Chrysene	2524	487.3	0.09669	116.0	581.7
Pentachlorophenol	153.5	29.66	0.05875	7.050	35.37

concentration allowed for a radionuclide corresponds to ^{226}Ra and is 6.112E-3 pCi/kg and the next lowest is ^{137}Cs at 0.03295 pCi/kg.

4.4 Monte Carlo Analysis

The PRG's calculated are based on single point values which usually represent an individual experiencing the maximum possible exposure. In reality, the exposure factors cannot be exactly known and are usually conservative assumptions or estimations. Since no individual is the same and does not have the same habits or lifestyle, a single value does not accurately describe the real-life situation. In order to more accurately model the exposure to a population a statistical distribution comprising data from more than one source should be the basis of a calculation. Software exists which will perform calculations using distributions as input rather than single values. Since the PRG's in this report were calculated using spreadsheets created in Excel, a software package called Crystal Ball (Decisioneering 1993) was used for the monte carlo analysis. Simulated distributions had to be used because the data to provide actual distributions for the input has not been collected. For this example, the soil ingestion pathway was used with ^{90}Sr as the contaminant. The equation to calculate the PRG is as follows: (see Chapter 3. Methodology)

$$SC_0 = \frac{TR}{[0.5^{\beta} \times \sum(SIF \times SF)_i]}$$

where:

SC_0 = soil concentration at time 0 (pCi/g)

TR	=	target risk (unitless)
β	=	calculated as $(time_t - time_0)/T_{0.5}$ ($T_{0.5}$ = radionuclide half-life)
SIF	=	summary intake factor (g)
SF	=	slope factor $(pCi)^{-1}$

and:

$$SIF = (IR \times ED)_{adult} \times EF \times CF$$

SIF	=	summary intake factor (g)
IR	=	ingestion rate (mg/d)
ED	=	exposure duration (yr)
EF	=	exposure frequency (d/yr)
CF	=	Conversion factor (1E-03 g/mg)

In this case, a lognormal distribution was used for the soil ingestion parameter and triangular distributions were used for the exposure frequency and the exposure duration

The following two pages show part of the report which can be created using Crystal Ball. Figure 4.1 gives the resulting distribution for the simulation in the form of a histogram. The statistics describing the resulting distribution are also given. These include items such as the mean, median, and standard deviation. Figure 4.2 gives the assumptions which went into the calculation. The lognormal distribution was selected to describe the soil ingestion in order to simulate the distribution in the American Industrial Health Council Exposure Factors Sourcebook (AIHC 1994) which showed a large peak followed by a sudden drop in the magnitude of ingestion values. The selection of triangular distributions for the duration and frequency was arbitrary.

Figure 4.1: Forecast Output for Crystal Ball Monte Carlo Simulation

Forecast: Soil Ingestion PRG for Sr-90 **Cell: G88**

Summary:
Display Range is from 0.000E+0 to 5.500E+2 pCi/g
Entire Range is from 9.591E+0 to 2.487E+3 pCi/g
After 5,000 Trials, the Std. Error of the Mean is 2.264E+0

Statistics:	Value
Trials	5000
Mean	1.306E+02
Median (approx.)	7.938E+01
Mode (approx.)	4.675E+01
Standard Deviation	1.601E+02
Variance	2.563E+04
Skewness	4.27
Kurtosis	34.02
Coeff. of Variability	1.23
Range Minimum	9.591E+00
Range Maximum	2.487E+03
Range Width	2.477E+03
Mean Std. Error	2.264E+00

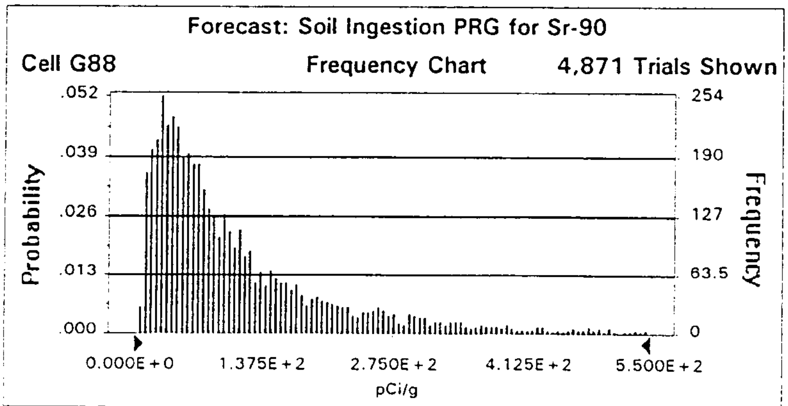


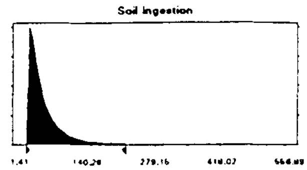
Figure 4.2: Assumptions for Crystal Ball Monte Carlo Simulation

Assumptions

Assumption: Soil Ingestion — Cell: C52

Lognormal distribution with parameters:

Mean	46.00
Standard Dev.	60.00

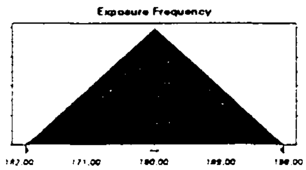


Selected range is from 0.00 to 216.00
Mean value in simulation was 40.16

Assumption: Exposure Frequency — Cell: G50

Triangular distribution with parameters:

Minimum	162.00
Likeliest	180.00
Maximum	198.00

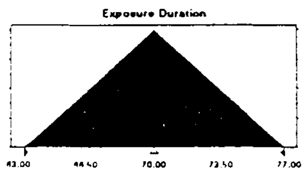


Selected range is from 162.00 to 198.00
Mean value in simulation was 179.97

Assumption: Exposure Duration — Cell: G60

Triangular distribution with parameters:

Minimum	63.00
Likeliest	70.00
Maximum	77.00



Selected range is from 63.00 to 77.00
Mean value in simulation was 69.99

End of Assumptions

CHAPTER 5. CONCLUSIONS

5.1 Summary

The PRG's calculated in this report were based on exposure scenarios developed in 1995 which are specific to the Hanford nuclear reservation in Washington State. The exposure scenarios were based on the assumption that access to the site will be restricted in some manner. In this case, the general categories of industrial, wildlife refuge, or Native American activities were used. Each of the scenarios developed in each category had a series of exposure factors describing the magnitude of the exposure to an individual. These factors were used in equations from the Hanford Site Risk Assessment Methodology to calculate the PRG's. It was found that the most restrictive scenario for the radionuclides and organic compounds analyzed was the Native American Subsistence scenario, while the Wildlife Refuge Archeologist Scenario was the most restrictive for the metals.

5.2 Future Research

This initial calculation of preliminary remediation goals leaves much possible future research to be completed. One of the areas which needs more work is the exposure scenario development. The scenarios outlined only cover part of the possible situations which may occur in the future. For example, the industrial type scenarios only cover fish hatchery workers, while in reality there will undoubtedly be other types of activities in this category. Also, the scenarios only apply to restricted access to the site, except in the case of Native American subsistence. It may be that access will be unrestricted, so new scenarios will have to be developed to describe the exposure.

A topic related to the exposure scenarios is the development of statistical distributions for the exposure factors used to calculate the PRG's. The monte carlo analysis in this report is presented only to describe the method. The distribution type as well as the factors describing the distribution will need to be determined in order to apply the results to Hanford. This will involve studies or surveys which will result in data which covers a range of possibilities. An indication of the accuracy of the deterministic result can then be estimated.

Finally, the calculation of the PRG's only considers a few of the possible pathways. In order to provide a complete evaluation of a land use scenario's effect on the remediation goals for specific contaminants, all of the pathways for each scenario should be evaluated. This will involve detailed evaluations of the contaminant concentrations in biota resulting from the soil contamination as well as partitioning to ground and surface water.

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APPENDICES

APPENDIX A

Summary Intake Factor Equations

A-1 INGESTION

A-1.1 Soil and Sediment

A-1.1.1 Noncarcinogenic

$$SIF = \frac{IR \times EF \times ED \times CF}{BW \times AT}$$

where:

SIF	=	summary intake factor (d^{-1})
IR	=	ingestion rate (mg/d)
EF	=	exposure frequency (d/yr)
ED	=	exposure duration (yr)
CF	=	conversion factor (1E-06 kg/mg)
BW	=	body weight (kg)
AT	=	averaging time (yr x 365 d/yr)

A-1.1.2 Carcinogenic - Nonradioactive

$$SIF = \frac{\left(\left(\frac{IR \times ED}{BW}\right)_{child} + \left(\frac{IR \times ED}{BW}\right)_{adult}\right) \times EF \times CF}{AT}$$

where:

SIF	=	summary intake factor (d^{-1})
IR	=	ingestion rate (mg/d)
ED	=	exposure duration (yr)
BW	=	body weight (kg)
EF	=	exposure frequency (d/yr)
CF	=	conversion factor (1e-06 kg/mg)
AT	=	averaging time (yr x 365 d/yr)

A-1.1.3 Carcinogenic - Radioactive

where:

$$SIF = \left(\left(IR \times ED\right)_{child} + \left(IR \times ED\right)_{adult}\right) \times EF \times CF$$

SIF	=	summary intake factor (g)
IR	=	ingestion rate (mg/d)
ED	=	exposure duration (yr)
EF	=	exposure frequency (d/yr)
CF	=	Conversion factor (1E-03 g/mg)

A-1.2 Surface and Groundwater

A-1.2.1 Noncarcinogenic

$$SIF = \frac{IR \times EF \times ED}{BW \times AT}$$

where:

SIF	=	summary intake factor (L/kg-d)
IR	=	ingestion rate (mg/d)
EF	=	exposure frequency (d/yr)
ED	=	exposure duration (yr)
BW	=	body weight (kg)
AT	=	averaging time (yr x 365 d/yr)

A-1.2.2 Carcinogenic - Nonradioactive

Same as for Noncarcinogenic

A-1.2.3 Carcinogenic - Radioactive

$$SIF = IR \times EF \times ED$$

where:

SIF	=	summary intake factor (L)
IR	=	ingestion rate (L/d)
EF	=	exposure frequency (d/yr)
ED	=	exposure duration (yr)

A-1.3 Biota

A-1.3.1 Noncarcinogenic

$$SIF = \frac{IR \times EF \times ED \times AF \times CF}{BW \times AT}$$

where:

SIF	=	summary intake factor (d^{-1})
IR	=	ingestion rate (mg/d)
EF	=	exposure frequency (d/yr)
ED	=	exposure duration (yr)
AF	=	intake adjustment factor (unitless), for game and fish only
CF	=	conversion factor (1E-03 kg/g)
BW	=	body weight (kg)
AT	=	averaging time (yr x 365 d/yr)

A-1.3.2 Carcinogenic - Nonradioactive

Same as for Noncarcinogenic

A-1.3.3 Carcinogenic - Radioactive

$$SIF = IR \times EF \times ED \times AF$$

where:

SIF	=	summary intake factor (L)
IR	=	ingestion rate (L/d)
EF	=	exposure frequency (d/yr)
ED	=	exposure duration (yr)
AF	=	intake adjustment factor (unitless), for game and fish only

A-2 INHALATION (Fugitive Dust)

A-2.1 Soil

A-2.1.1 Noncarcinogenic

$$SIF = \frac{IR \times EF \times ED}{BW \times AT \times PEF}$$

where:

SIF	=	summary intake factor (m^3/kg-d)
IR	=	inhalation rate (m^3/d)
EF	=	exposure frequency (d/yr)
ED	=	exposure duration (yr)
BW	=	body weight (kg)
AT	=	averaging time (yr x 365 d/yr)
PEF	=	particulate emission factor (m^3/kg)

A-2.1.2 Carcinogenic - Nonradioactive

Same as for Noncarcinogenic

A-2.1.3 Carcinogenic - Radioactive

$$SIF = \frac{IR \times EF \times ED \times CF}{PEF}$$

where:

SIF	=	summary intake factor (m^3/kg-d)
IR	=	inhalation rate (m^3/d)
EF	=	exposure frequency (d/yr)
ED	=	exposure duration (yr)
CF	=	conversion factor (1E-03 kg/g)
PEF	=	particulate emission factor (m^3/kg)

A-3 INHALATION (Volatile Compounds)

A-3.1 Soil

A-3.1.1 Noncarcinogenic

$$SIF = \frac{IR \times EF \times ED}{BW \times AT \times VF_s}$$

where:

SIF = summary intake factor (m^3/kg-d)
IR = inhalation rate (m^3/d)
EF = exposure frequency (d/yr)
ED = exposure duration (yr)
BW = body weight (kg)
AT = averaging time (yr x 365 d/yr)
VF_s = soil volatilization factor (m^3/kg)

A-3.1.2 Carcinogenic - Nonradioactive

Same as for Noncarcinogens

A-3.1.3 Carcinogenic - Radioactive

Not applicable.

A-3.2 Surface and Groundwater

A-3.2.1 Noncarcinogenic

$$SIF = \frac{IR \times EF \times ED \times VF_{wvoc}}{BW \times AT}$$

where:

SIF = summary intake factor (m^3/kg-d)
IR = inhalation rate (mg/L)
EF = exposure frequency (d/yr)
ED = exposure duration (yr)
VF_{wvoc} = water volatilization factor for VOCs (L/m^3)
BW = body weight (kg)
AT = averaging time (yr x 365 d/yr)

A-3.2.2 Carcinogenic - Nonradioactive

Same as for Noncarcinogenic

A-3.2.3 Carcinogenic - Radioactive

$$SIF = IR \times EF \times ED \times VF_{wr}$$

where:

where: SIF = summary intake factor (L)
IR = inhalation rate (m^3/d)
EF = exposure frequency (d/yr)
ED = exposure duration (yr)
VF_{wr} = water volatilization factor for radon (L/m^3)

A-4 DERMAL EXPOSURE

A-4.1 Soil and Sediment

A-4.1.1 Noncarcinogenic

$$SIF = \frac{ABS \times AF \times CF \times \left(\left(\frac{SA \times EF \times ED}{BW} \right)_{child} + \left(\frac{SA \times EF \times ED}{BW} \right)_{adult} \right)}{AT}$$

where:

SIF = summary intake factor (d^{-1})
ABS = absorption factor (unitless)
AF = adherence factor (mg/cm^2-d)
CF = conversion factor (1E-06 kg/mg)
SA = surface area exposed (cm^2)
EF = exposure frequency (d/yr)
ED = exposure duration (yr)
BW = body weight (kg)
AT = averaging time (yr x 365 d/yr)

A-4.1.2 Carcinogenic - Nonradioactive

Same as for Noncarcinogenic

A-4.1.3 Carcinogenic - Radioactive

Not applicable

A-4.2 Surface and Groundwater

A-4.2.1 Noncarcinogenic

$$SIF = \frac{SA \times K_p \times ET \times EF \times ED \times CF}{BW \times AT}$$

SIF	=	summary intake factor (d^{-1})
SA	=	surface area exposed (cm^2)
K_p	=	permeability coefficient for a chemical in water through skin (cm/hr)
EF	=	exposure frequency (d/yr)
ED	=	exposure duration (yr)
CF	=	conversion factor (1E-06 kg/mg)
BW	=	body weight (kg)
AT	=	averaging time (yr x 365 d/yr)

A-4.2.2 Carcinogenic - Nonradioactive

Same as for Noncarcinogenic

A-4.2.3 Carcinogenic - Radioactive

Not applicable

A-5 EXTERNAL EXPOSURE TO RADIONUCLIDES

A-5.1 Soil

$$SIF = ET \times RF \times EF \times ED \times CF$$

where:

SIF	=	summary intake factor (yr)
ET	=	exposure time (hr/d)
RF	=	dose reduction factor (unitless)
EF	=	exposure frequency (d/yr)
ED	=	exposure duration (yr)
CF	=	conversion factor (1.14E-04 yr/hr)

APPENDIX B

Table B-1: Hanford Tribal Fish Hatchery Worker Scenario Exposure Factors - Non-Carcinogens

Pathway		Exposure Parameters[a]							Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors	
Soil[b]	Ingestion	100 mg/d	138	7	70	7 x 365	1E-6 kg/mg	--	5.4E-7 kg soil/(kg-d)
	Dermal	0.2 mg/cm^2-d	138	7	70	7 x 365	1E-6 kg/mg	5,000 cm^2, ABS[c]	ABS x 5.4E-6 kg soil/(kg-d)
	Inhalation	10 m^3/d	138	7	70	7 x 365	1E-9 kg/µg	50 µg/m^3	2.7E-9 kg soil/(kg-d)
Air[d]	Inhalation	10 m^3/d	138	7	70	7 x 365	--	--	5.4E-2 m^3/(kg-d)
Surface Water[e]	Ingestion	1 L/d	138	7	70	7 x 365	--	--	5.4E-3 L/(kg-d)
	Dermal	1 hr/d	138	7	70	7 x 365	1E-3 L/cm^3	5,000 cm^2, K_p[f]	K_p x 2.7E-2 L/(kg-d)

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are mg/kg dry soil.
c. ABS is the dermal absorption fraction for soil on the skin (USEPA 1992).
d. Units for air concentration are mg/m^3.
e. Units for surface water concentration are mg/L.
f. Chemical-specific permeability coefficient (cm/hr).

Table B-2: Hanford Tribal Fish Hatchery Worker Scenario Exposure Factors - Carcinogens (Non-radioactive)

Pathway		Exposure Parameters[a]							Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors	
Soil[b]	Ingestion	100 mg/d	138	7	70	70 x 365	1E-6 kg/mg	--	5.4E-8 kg soil/(kg-d)
	Dermal	0.2 mg/cm²-d	138	7	70	70 x 365	1E-6 kg/mg	5,000 cm², ABS[c]	ABS x 5.4E-7 kg soil/(kg-d)
	Inhalation	10 m³/d	138	7	70	70 x 365	1E-9 kg/µg	50 µg/m³	2.7E-10 kg soil/(kg-d)
Air[d]	Inhalation	10 m³/d	138	7	70	70 x 365	--	--	5.4E-3 m³/(kg-d)
Surface Water[e]	Ingestion	1 L/d	138	7	70	70 x 365	--	--	5.4E-4 L/(kg-d)
	Dermal	1 hr/d	138	7	70	70 x 365	1E-3 L/cm³	5,000 cm², K_p[f]	K_p x 2.7E-3 L/(kg-d)

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are mg/kg dry soil.
c. ABS is the dermal absorption fraction for soil on the skin (USEPA 1992).
d. Units for air concentration are mg/m³.
e. Units for surface water concentration are mg/L.
f. Chemical-specific permeability coefficient (cm/hr).

Table B-3: Hanford Tribal Fish Hatchery Worker Scenario Exposure Factors - Carcinogens (Radioactive)

Pathway		Exposure Parameters[a]					Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Conversion Factors	Other Factors	
Soil[b]	Ingestion	100 mg/d	138	7	1E-6 kg/mg	--	9.7E-2 kg soil
	External	8 hr/d	138	7	1.14E-4 yr/hr	0.8	7.0E-1 yr
	Dermal	0.2 mg/cm^2-d	138	7	1E-6 kg/mg	5,000 cm^2, ABS[c]	ABS x 9.7E-1 kg soil
	Inhalation	10 m^3/d	138	7	1E-9 kg/µg	50 µg/m^3	4.8E-4 kg soil
Air[d]	Inhalation	10 m^3/d	138	7	--	--	9.7E+3 m^3
Surface Water[e]	Ingestion	1 L/d	138	7	--	--	9.7E+2 L
	External	8 hr/d	138	7	1.14E-4 yr/hr	0.25	2.2E-1 yr
	Dermal	1 hr/d	138	7	1E-3 L/cm^3	5,000 cm^2, K_p[f]	K_p x 4.8E+3 L

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are pCi/kg dry soil.
c. ABS is the dermal absorption fraction for soil on the skin (USEPA 1992).
d. Units for air concentrationare pCi/m^3.
e. Units for surface water concentration are pCi/L.
f. Chemical-specific permeability coefficient (cm/hr).

Table B-4: Eastbank Commercial Fish Hatchery Worker Scenario Exposure Factors - Non-Carcinogens

Pathway		Exposure Parameters[a]							Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors	
Soil[b]	Ingestion	100 mg/d	250	20	70	20 x 365	1E-6 kg/mg	--	9.8E-7 kg soil/(kg-d)
	Dermal	0.2 mg/cm^2-d	250	20	70	20 x 365	1E-6 kg/mg	5,000 cm^2, ABS[c]	ABS x 9.8E-6 kg soil/(kg-d)
	Inhalation	10 m^3/d	250	20	70	20 x 365	1E-9 kg/µg	50 µg/m^3	4.9E-9 kg soil/(kg-d)
Air[d]	Inhalation	10 m^3/d	250	20	70	20 x 365	--	--	9.8E-2 m^3/(kg-d)
Surface Water[e]	Ingestion	1 L/d	250	20	70	20 x 365	--	--	9.8E-3 L/(kg-d)
	Dermal	1 hr/d	250	20	70	20 x 365	1E-3 L/cm^3	5,000 cm^2, K_p[f]	K_p x 4.9E-2 L/(kg-d)

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are mg/kg dry soil.
c. ABS is the dermal absorption fraction for soil on the skin (USEPA 1992).
d. Units for air concentration are mg/m^3.
e. Units for surface water concentration are mg/L.
f. Chemical-specific permeability coefficient (cm/hr).

Table B-5: Eastbank Commercial Fish Hatchery Worker Scenario Exposure Factors - Carcinogens (Non-radioactive)

Pathway		Exposure Parameters[a]							Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors	
Soil[b]	Ingestion	100 mg/d	250	20	70	70 x 365	1E-6 kg/mg	--	2.8E-7 kg soil/(kg-d)
	Dermal	0.2 mg/cm^2-d	250	20	70	70 x 365	1E-6 kg/mg	5,000 cm^2, ABS[c]	ABS x 2.8E-6 kg soil/(kg-d)
	Inhalation	10 m^3/d	250	20	70	70 x 365	1E-9 kg/µg	50 µg/m^3	1.4E-9 kg soil/(kg-d)
Air[d]	Inhalation	10 m^3/d	250	20	70	70 x 365	--	--	2.8E-2 m^3/(kg-d)
Surface Water[e]	Ingestion	1 L/d	250	20	70	70 x 365	--	--	2.8E-3 L/(kg-d)
	Dermal	1 hr/d	250	20	70	70 x 365	1E-3 L/cm^3	5,000 cm^2, K_p[f]	K_p x 1.4E-2 L/(kg-d)

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are mg/kg dry soil.
c. ABS is the dermal absorption fraction for soil on the skin (USEPA 1992).
d. Units for air concentration are mg/m^3.
e. Units for surface water concentration are mg/L.
f. Chemical-specific permeability coefficient (cm/hr).

Table B-6: Eastbank Commercial Fish Hatchery Worker Scenario Exposure Factors - Carcinogens (Radioactive)

Pathway		Exposure Parameters[a]					Summary Intake Factor
Soil[b]	Ingestion	100 mg/d	250	20	1E-6 kg/mg	--	5.0E-1 kg soil
	External	8 hr/d	250	20	1.14E-4 yr/hr	0.8	3.6E+0 yr
	Dermal	0.2 mg/cm^2-d	250	20	1E-6 kg/mg	5,000 cm^2, ABS[c]	ABS x 5.OE+0 kg soil
	Inhalation	10 m^3/d	250	20	1E-9 kg/µg	50 µg/m^3	2.5E-3 kg soil
Air[d]	Inhalation	10 m^3/d	250	20	--	--	5.0E+4 m^3
Surface Water[e]	Ingestion	1 L/d	250	20	--	--	5.0E+3 L
	External	8 hr/d	250	20	1.14E-4 yr/hr	0.25	1.1E+0 yr
	Dermal	1 hr/d	250	20	1E-3 L/cm^3	5,000 cm^2, K_p[f]	K_p x 2.5E+4 L

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are pCi/kg dry soil.
c. ABS is the dermal absorption fraction for soil on the skin (USEPA 1992).
d. Units for air concentrationare pCi/m^3.
e. Units for surface water concentration are pCi/L.
f. Chemical-specific permeability coefficient (cm/hr).

Table B-7: Wildlife Refuge Ranger Scenario Exposure Factors - Non-carcinogens

Pathway		Exposure Parameters[a]							Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors	
Soil[b]	Ingestion	100 mg/d	150	20	70	20 x 365	1E-6 kg/mg	--	5.9E-7 kg soil/(kg-d)
	Dermal	0.2 mg/cm^2-d	150	20	70	20 x 365	1E-6 kg/mg	5,000 cm^2, ABS[c]	ABS x 5.9E-6 kg soil/(kg-d)
	Inhalation	10 m^3/d	150	20	70	20 x 365	1E-9 kg/µg	50 µg/m^3	2.9E-9 kg soil/(kg-d)
Air[d]	Inhalation	10 m^3/d	150	20	70	20 x 365	--	--	5.9E-2 m^3/(kg-d)
Sediment[e]	Ingestion	100 mg/d	150	20	70	20 x 365	1E-6 kg/mg	--	5.9E-7 kg sed./(kg-d)
	Dermal	0.2 mg/cm^2-d	150	20	70	20 x 365	1E-6 kg/mg	5,000 cm^2 ABS	ABS x 5.9E-6 kg sed./(kg-d)

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are mg/kg dry soil.
c. ABS is the dermal absorption fraction for soil on skin (USEPA 1992).
d. Units for air are mg/m^3.
e. Units for sediment ar mg/kg sediment.

Table B-8: Wildlife Refuge Ranger Scenario Exposure Factors - Carcinogens (Non-Radioactive)

Pathway		Exposure Parameters[a]							Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors	
Soil[b]	Ingestion	100 mg/d	150	20	70	70 x 365	1E-6 kg/mg	--	1.7E-7 kg soil/(kg-d)
	Dermal	0.2 mg/cm^2-d	150	20	70	70 x 365	1E-6 kg/mg	5,000 cm^2 ABS[c]	ABS x 1.7E-6 kg soil/(kg-d)
	Inhalation	10 m^3/d	150	20	70	70 x 365	1E-9 kg/µg	50 µg/m^3	8.4E-10 kg soil/(kg-d)
Air[d]	Inhalation	10 m^3/d	150	20	70	70 x 365	--	--	1.7E-2 m^3/(kg-d)
Sediment[e]	Ingestion	100 mg/d	150	20	70	70 x 365	1E-6 kg/mg	--	1.7E-7 kg sed./(kg-d)
	Dermal	0.2 mg/cm^2-d	150	20	70	70 x 365	1E-6 kg/mg	5,000 cm^2 ABS	ABS x 1.7E-6 kg sed./(kg-d)

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are mg/kg dry soil.
c. ABS is the dermal absorption fraction for soil on skin (USEPA 1992).
d. Units for air are mg/m^3.
e. Units for sediment ar mg/kg sediment.

Table B-9: Wildlife Refuge Ranger Scenario Exposure Factors - Carcinogens (Radioactive).

Pathway		Exposure Parameters[a]					Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Conversion Factors	Other Factors	
Soil[b]	Ingestion	100 mg/d	150	20	1E-06 kg/mg	--	3.0E-1 kg soil
	External	3 hr/d	150	20	1.14E-04 yr/hr	0.8	8.2E-1 yr
	Dermal	0.2 mg/cm^2-d	150	20	1E-6 kg/mg	5000 cm^2 ABS[c]	3.0E+0 ABS kg soil
	Inhalation	10 m^3/d	150	20	1E-9 µg/kg	50 $\mu g/m^3$	1.5E-3 kg soil
Air[d]	Inhalation	10 m^3/d	150	20	--	--	3.0E+4 m^3 air
Surface Water[e]	Boating External	3 hr/d	150	20	1.14E-4 yr/hr	0.5	5.1E-1 yr
Sediment[f]	Ingestion	100 mg/d	150	20	1E-6 kg/mg	--	3.0E-1 kg sediment
	Dermal	0.2 mg/cm^2-d	150	20	1E-6 kg/mg	5000 cm^2	3.0E-0 kg sediment
	External	3 hr/d	150	20	1.14E-4 yr/hr	0.2	2.1E-1 yr

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are pCi/kg dry soil.
c. ABS is the dermal absorption fraction for soil on skin (USEPA 1992).
d. Units for air are pCi/m^3.
e. Units for surface water concentration are pCi/L.
f. Units for sediment ar pCi/kg sediment.

Table B-10: Wildlife Refuge Hunter Scenario Exposure Factors - Non-carcinogens

Pathway		Exposure Parameters[a]							Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors	
Soil[b]	Ingestion	100 mg/d	70	10	70	10 x 365	1E-6 kg/mg	--	2.8E-7 kg soil/(kg-d)
	Dermal	0.2 mg/cm^2-d	70	10	70	10 x 365	1E-6 kg/mg	5,000 cm^2 ABS[c]	ABS x 2.8E-6 kg soil/(kg-d)
	Inhalation	10 m^3/d	70	10	70	10 x 365	1E-9 kg/µg	50 µg/m^3	2.4E-9 kg soil/(kg-d)
Air[d]	Inhalation	10 m^3/d	120	10	70	10 x 365	--	--	4.7E-2 m^3/(kg-d)
Biota[e]	Deer	15 g/d	365	10	70	10 x 365	1E-3 kg/g	0.13	2.8E-5 kg deer/(kg-d)
	Upland Bird	9 g/d	365	10	70	10 x 365	1E-3 kg/g	--	1.3E-4 kg bird/(kg-d)
	Waterfowl	35 g/d	365	10	70	10 x 365	1E-3 kg/g	--	5.0E-4 kg bird/(kg-d)
Sediment[f]	Ingestion	100 mg/d	50	10	70	10 x 365	1E-6 kg/mg	--	2.0E-7 kg sed./(kg-d)
	Dermal	0.2 mg/cm^2-d	50	10	70	10 x 365	1E-6 kg/mg	5,000 cm^2 ABS	ABS x 2.0E-6 kg sed./(kg-d)

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are mg/kg dry soil.
c. ABS is the dermal absorption fraction for soil on skin (USEPA 1992).
d. Units for air concentration are mg/m^3.
e. Units for biota concentration are mg/kg wet weight.
f. Units for sediment ar mg/kg sediment.

Table B-11: Wildlife Refuge Hunter Scenario Exposure Factors - Carcinogens (Non-Radioactive)

Pathway		Exposure Parameters[a]							Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors	
Soil[b]	Ingestion	100 mg/d	70	10	70	70 x 365	1E-6 kg/mg	--	4.0E-8 kg soil/(kg-d)
	Dermal	0.2 mg/cm^2-d	70	10	70	70 x 365	1E-6 kg/mg	5,000 cm^2, ABS[c]	ABS x 4.0E-7 kg soil/(kg-d)
	Inhalation	10 m^3/d	70	10	70	70 x 365	1E-9 kg/μg	50 μg/m^3	3.4E-10 kg soil/(kg-d)
Air[d]	Inhalation	10 m^3/d	120	10	70	70 x 365	--	--	6.8E-3 m^3/(kg-d)
Biota[e]	Deer	15 g/d	365	10	70	70 x 365	1E-3 kg/g	0.13[f]	4.0E-6 kg deer/(kg-d)
	Upland Bird	9 g/d	365	10	70	70 x 365	1E-3 kg/g	--	1.8E-5 kg bird/(kg-d)
	Waterfowl	35 g/d	365	10	70	70 x 365	1E-3 kg/g	--	7.1E-5 kg bird/(kg-d)
Sediment[g]	Ingestion	100 mg/d	50	10	70	70 x 365	1E-6 kg/mg	--	2.8E-8 kg sed./(kg-d)
	Dermal	0.2 mg/cm^2-d	50	10	70	70 x 365	1E-6 kg/mg	5,000 cm^2 ABS	ABS x 2.8E-7 kg sed./(kg-d)

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are mg/kg dry soil.
c. ABS is the dermal absorption fraction for soil on skin (USEPA 1992).
d. Units for air concentration are mg/m^3.
e. Units for biota concentration are mg/kg wet weight.
f. Hunter success rate of 13% applied for SE Washington.
g. Units for sediment ar mg/kg sediment.

Table B-12: Wildlife Refuge Hunter Scenario Exposure Factors - Carcinogens (Radioactive)

Pathway		Exposure Parameters[a]					Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Conversion Factors	Other Factors	
Soil[b]	Ingestion	100 mg/d	70	10	1E-06 kg/mg	--	7.1E-2 kg soil
	External	4 hr/d	70	10	1.14E-04 yr/hr	0.8	2.6E-1 yr
	Dermal	0.2 mg/cm^2-d	70	10	1E-6 kg/mg	5000 cm^2 ABS[c]	ABS x 7.1E-1 kg soil
	Inhalation	10 m^3/d	70	10	1E-9 kg/μg	50 $\mu g/m^3$	6.1E-4 kg soil
Air[d]	Inhalation	10 m^3/d	120	10	--	--	1.2E+4 m^3 air
Biota[e]	Deer	15 g/d	365	10	1E-3 kg/g	0.13[e]	7.1E+0 kg deer/(kg-d)
	Upland Birds	9 g/d	365	10	1E-3 kg/g	--	3.3E+1 kg bird/(kg-d)
	Water fowl	35 g/d	365	10	1E-3 kg/g	--	1.3E+2 kg bird/(kg-d)
Sediment[f]	Ingestion	100 mg/d	50	10	1E-06 kg/mg	--	7.1E-2 kg sediment
	Dermal	0.2 mg/cm^2-d	50	10	1E-06 kg/mg	5000 cm^2 ABS	ABS x 5.0E-1 kg sediment
	External	4 hr/d	50	10	1.14E-4 yr/hr	0.2	4.6E-2 yr

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are pCi/kg dry soil.
c. ABS is the dermal absorption fraction for soil on skin (USEPA 1992).
d. Units for air concentration are pCi/m^3.
e. Units for biota concentration are pCi/kg wet weight.
f. Units for sediment ar pCi/kg sediment.

Table B-13: Wildlife Refuge Bird Watcher Scenario Exposure Factors - Non-carcinogens

Pathway		Exposure Parameters[a]							Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors	
Soil[b]	Ingestion	25 mg/d	50	5	70	20 x 365	1E-6 kg/mg	--	1.2E-8 kg soil/(kg-d)
	Dermal	0.2 mg/cm^2-d	50	5	70	20 x 365	1E-6 kg/mg	5,000 cm^2 ABS[c]	ABS x 4.9E-7 kg soil/(kg-d)
	Inhalation	5 m^3/d	50	5	70	20 x 365	1E-9 kg/μg	50 μg/m^3	1.2E-10 kg soil/(kg-d)
Air[d]	Inhalation	5 m^3/d	50	5	70	20 x 365	--	--	2.4E-3 m^3/(kg-d)
Sediment[e]	Ingestion	25 mg/d	50	5	70	20 x 365	1E-6 kg/mg	--	1.2E-8 kg sed./(kg-d)
	Dermal	0.2 mg/cm^2-d	50	5	70	20 x 365	1E-6 kg/mg	5,000 cm^2 ABS	ABS x 4.9E-7 kg sed./(kg-d)

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are mg/kg dry soil.
c. ABS is the dermal absorption fraction for soil on skin (USEPA 1992).
d. Units for air concentration are mg/m^3.
e. Units for sediment are mg/kg sediment.

Table B-14: Wildlife Refuge Bird Watcher Scenario Exposure Factors - Carcinogens (Non-Radioactive)

Pathway		Exposure Parameters[a]							Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors	
Soil[b]	Ingestion	25 mg/d	50	5	70	70 x 365	1E-6 kg/mg	--	3.5E-9 kg soil/(kg-d)
	Dermal	0.2 mg/cm^2-d	50	5	70	70 x 365	1E-6 kg/mg	5,000 cm^2 ABS[c]	ABS x 1.4E-7 kg soil/(kg-d)
	Inhalation	5 m^3/d	50	5	70	70 x 365	1E-9 kg/μg	50 μg/m^3	3.5E-11 kg soil/(kg-d)
Air[d]	Inhalation	5 m^3/d	50	5	70	70 x 365	--	--	7.0E-4 m^3/(kg-d)
Sediment[e]	Ingestion	25 mg/d	50	5	70	70 x 365	1E-6 kg/mg	--	3.5E-9 kg sed./(kg-d)
	Dermal	0.2 mg/cm^2-d	50	5	70	70 x 365	1E-6 kg/mg	5,000 cm^2 0.5 ABS	ABS x 1.4E-7 kg sed./(kg-d)

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are mg/kg dry soil.
c. ABS is the dermal absorption fraction for soil on skin (USEPA 1992).
d. Units for air concentration are mg/m^3.
e. Units for sediment are mg/kg sediment.

Table B-15: Wildlife Refuge Bird Watcher Scenario Exposure Factors - Carcinogens (Radioactive).

Pathway		Exposure Parameters[a]					Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Conversion Factors	Other Factors	
Soil[b]	Ingestion	25 mg/d	50	5	1E-06 g/mg	--	6.3E-3 kg soil
	External	4 hr/d	50	5	1.14E-04 yr/hr	0.8	9.1E-2 yr
	Dermal	0.2 mg/cm^2-d	50	5	1E-6 g/mg	5000 cm^2 ABS[c]	ABS 2.5E-1 kg soil
	Inhalation	5 m^3/d	50	5	1E-9 kg/µg	50 $\mu g/m^3$	6.3E-5 kg soil
Air[d]	Inhalation	5 m^3/d	50	5	--	--	1.3E+3 m^3 air
Surface Water[e]	Boating External	4 hr/d	50	5	1.14E-4 yr/hr	0.5	5.7E-2 yr
Sediment[f]	Ingestion	25 mg/d	50	5	1E-06 kg/mg	--	6.3E-3 kg sediment
	Dermal	0.2 mg/cm^2-d	50	5	1E-6 kg/mg	5000 cm^2 ABS	ABS 2.5E-1 kg sediment
	External	4 hr/d	50	5	1.14E-4 yr/hr	0.2	2.3E-2 yr

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are pCi/kg dry soil.
c. ABS is the dermal absorption fraction for soil on skin (USEPA 1992).
d. Units for air concentration are pCi/m^3.
e. Units for surface water concentration are pCi/L.
f. Units for sediment are pCi/kg sediment.

Table B-16: Wildlife Refuge Archeologist Scenario Exposure Factors - Non-carcinogens

Pathway		Exposure Parameters[a]							Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors	
Soil[b]	Ingestion	200 mg/d[c]	250	1	70	1 x 365	1E-6 kg/mg	--	2.0E-6 kg soil/(kg-d)
	Dermal	0.5 mg/cm^2-d[d]	250	1	70	1 x 365	1E-6 kg/mg	5,000 cm^2 ABS[e]	ABS x 2.4E-5 kg soil/(kg-d)
	Inhalation	15 m^3/d[f]	250	1	70	1 x 365	1E-9 kg/µg	200 µg/m^3[g]	2.9E-8 kg soil/(kg-d)
Air[h]	Inhalation	15 m^3/d[f]	250	1	70	1 x 365	--	--	1.5E-1 m^3/(kg-d)

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are mg/kg dry soil.
c. Soil ingestion rate set to twice average daily soil intake rate
d. Dermal adherence factor set to 0.5 representing higher than average soil contact.
e. ABS is the dermal absorption fraction for soil on skin (USEPA 1992).
f. Inhalation rates based on 8 hours of heavy work, taken to be 50% greater than the 8 hour intake from "light activity" (ICRP 1975).
g. Air mass loading for suspension is set to 200 µg/m^3 representing 4 times the average value.
h. Units for air concentration are mg/m^3.

Table B-17: Wildlife Refuge Archeologist Scenario Exposure Factors - Carcinogens (Non-Radioactive)

Pathway		Exposure Parameters[a]							Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors	
Soil[b]	Ingestion	200 mg/d[c]	250	1	70	70 x 365	1E-6 kg/mg	--	2.8E-8 kg soil/(kg-d)
	Dermal	0.5 mg/cm^2-d[d]	250	1	70	70 x 365	1E-6 kg/mg	5,000 cm^2 ABS[e]	ABS x 3.5E-7 kg soil/(kg-d)
	Inhalation	15 m^3/d[f]	250	1	70	70 x 365	1E-9 kg/μg	200 μg/m^3[g]	4.2E-10 kg soil/(kg-d)
Air[h]	Inhalation	15 m^3/d[f]	250	1	70	70 x 365	--	--	2.1E-3 m^3/(kg-d)

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are mg/kg dry soil.
c. Soil ingestion rate set to twice average daily soil intake rate
d. Dermal adherence factor set to 0.5 representing higher than average soil contact.
e. ABS is the dermal absorption fraction for soil on skin (USEPA 1992).
f. Inhalation rates based on 8 hours of heavy work, taken to be 50% greater than the 8 hour intake from "light activity" (ICRP 1975).
g. Air mass loading for suspension is set to 200 μg/m^3 representing 4 times the average value.
h. Units for air concentration are mg/m^3.

Table B-18: Wildlife Refuge Archeologist Scenario Exposure Factors - Carcinogens (Radioactive)

Pathway		Exposure Parameters[a]					Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Conversion Factors	Other Factors	
Soil[b]	Ingestion	200 mg/d[c]	250	1	1E-6 kg/mg	--	5.0E-2 g soil
	External	8 hr/d	250	1	1.14E-4 yr/hr	1.0	2.3E-1 yr
	Dermal	0.5 mg/cm^2-d[d]	250	1	1E-6 kg/mg	5000 cm^2 ABS[e]	ABS 6.3E-1 g soil
	Inhalation	15 m^3/d[f]	250	1	1E-9 kg/µg	200 µg/m^3[g]	7.5E-4 g soil
Air[h]	Inhalation	15 m^3/d[f]	250	1	--	--	3.8E+3 m^3 air

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are pCi/kg dry soil.
c. Soil ingestion rate set to twice average daily soil intake rate
d. Dermal adherence factor set to 0.5 representing higher than average soil contact.
e. ABS is the dermal absorption fraction for soil on skin (USEPA 1992).
f. Inhalation rates based on 8 hours of heavy work, taken to be 50% greater than the 8 hour intake from "light activity" (ICRP 1975).
g. Air mass loading for suspension is set to 200 µg/m^3 representing 4 times the average value.
h. Units for air concentration are pCi/m^3.

Table B-19: Wildlife Refuge Backpacker Scenario Exposure Factors - Non-carcinogens

Pathway		Exposure Parameters[a]							Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors	
Soil[b]	Ingestion	100 mg/d	15	10	70	10 x 365	1E-6 kg/mg	--	5.9E-8 kg soil/(kg-d)
	Dermal	0.2 mg/cm^2-d	15	10	70	10 x 365	1E-6 kg/mg	5,000 cm^2 ABS[c]	ABS x 5.9E-7 kg soil/(kg-d)
	Inhalation	20 m^3/d	15	10	70	10 x 365	1E-9 kg/µg	50 µg/m^3	5.9E-10 kg soil/(kg-d)
Groundwater[d]	Ingestion	2 L/d	15	10	70	10 x 365	--	--	1.2E-3 L/(kg-d)
Air[e]	Inhalation	20 m^3/d	15	10	70	10 x 365	--	--	1.2E-2 m^3/(kg-d)
Biota[f]	Fish	250 g/d	15	10	70	10 x 365	1E-3 kg/g	--	1.5E-4 kg fish/(kg-d)
Sediment[f]	Ingestion	100 mg/d	15	10	70	10 x 365	1E-6 kg/mg	--	5.9E-8 kg sed./(kg-d)
	Dermal	0.2 mg/cm^2-d	15	10	70	10 x 365	1E-6 kg/mg	5,000 cm^2 ABS	ABS x 5.9E-7 kg sed./(kg-d)

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are mg/kg dry soil.
c. ABS is the dermal absorption fraction for soil on skin (USEPA 1992).
d. Units for groundwater concentration are mg/L.
e. Units for air concentration are mg/m^3.
f. Units for biota concentration are mg/kg wet weight.
g. Units for sediment ar mg/kg sediment.

Table B-20: Wildlife Refuge Backpacker Scenario Exposure Factors - Carcinogens (Non-Radioactive)

Pathway		Exposure Parameters[a]							Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors	
Soil[b]	Ingestion	100 mg/d	15	10	70	70 x 365	1E-6 kg/mg	--	8.4E-9 kg soil/(kg-d)
	Dermal	0.2 mg/cm^2-d	15	10	70	70 x 365	1E-6 kg/mg	5,000 cm^2 ABS[c]	ABS x 8.4E-8 kg soil/(kg-d)
	Inhalation	20 m^3/d	15	10	70	70 x 365	1E-9 kg/µg	50 µg/m^3	8.4E-11 kg soil/(kg-d)
Groundwater[d]	Ingestion	2 L/d	15	10	70	70 x 365	--	--	1.7E-4 L/(kg-d)
Biota[e]	Fish	250 g/d	15	10	70	70 x 365	1E-3 kg/g	--	2.1E-5 kg fish/(kg-d)
Air[f]	Inhalation	20 m^3/d	15	10	70	70 x 365	--	--	1.7E-3 m^3/(kg-d)
Sediment[g]	Ingestion	100 mg/d	15	10	70	70 x 365	1E-3 g/mg	--	8.4E-9 kg sed./(kg-d)
	Dermal	0.2 mg/cm^2-d	15	10	70	70 x 365	1E-3 g/mg	5,000 cm^2 ABS	ABS x 8.5E-8 kg sed./(kg-d)

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are mg/kg dry soil.
c. ABS is the dermal absorption fraction for soil on skin (USEPA 1992).
d. Units for groundwater concentration are mg/L.
e. Units for biota concentration are mg/kg wet weight.
f. Units for air concentration are mg/m^3
g. Units for sediment ar mg/kg sediment.

Table B-21: Wildlife Refuge Backpacker Scenario Exposure Factors - Carcinogens (Radioactive).

Pathway		Exposure Parameters[a]					Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Conversion Factors	Other Factors	
Soil[b]	Ingestion	100 mg/d	15	10	1E-6 kg/mg	--	1.5E-2 kg soil
	External	12 hr/d	15	10	1.14E-04 yr/hr	0.8	1.6E-1 yr
	Dermal	0.2 mg/cm^2-d	15	10	1E-6 kg/mg	5000 cm^2 ABS[c]	ABS x 1.5E-1 kg soil
	Inhalation	20 m^3/d	15	10	1E-9 kg/µg	50 µg/m^3	1.5E-4 kg soil
Air[d]	Inhalation	20 m^3/d	15	10	--	--	3.0E+3 m^3 air
Groundwater[e]	Ingestion	2 L/d	15	10	--	--	3.0E+2 L
Biota[f]	Fish	250 g/d	15	10	1E-3 kg/g	--	3.8E+1 kg fish
Sediment[g]	Ingestion	100 mg/d	15	10	1E-06 kg/mg	--	1.5E-2 kg sediment
	Dermal	0.2 mg/cm^2-d	15	10	1E-6 kg/mg	5000 cm^2	1.5E-1 kg sediment
	External	12 hr/d	15	10	1.14E-4 yr/hr	0.2	4.1E-2 yr

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are pCi/kg dry soil.
c. ABS is the dermal absorption fraction for soil on skin (USEPA 1992).
d. Units for air concentration are pCi/m^3.
e. Units for groundwater concentration are pCi/L.
f. Units for biota concentration are pCi/kg wet weight.
g. Units for sediment ar pCi/kg sediment.

Table B-22: Native American Subsistence Scenario Exposure Factors - Non-carcinogens

Pathway		Exposure Parameters							Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors	
Soil	Ingestion[a]	200 mg/d	180	70	70	70 x 365	1E-6 kg/mg	--	1.4E-6 kg soil/(kg-d)
	Dermal	1 mg/cm^2-d	180	6 (C) 64 (A)	16 (C) 70 (A)	70 x 365	1E-6 kg/mg	2,500 cm^2 (C) 5,000 cm^2 (A) ABS	ABS x 3.9E-5 kg soil/(kg-d)
	Inhalation[b]	20 m^3/d	180	70	70	70 x 365	1E-9 kg/µg	50 µg/m^3	7.0E-9 kg soil/(kg-d)
Groundwater	Ingestion[c]	1 L/d	180	70	70	70 x 365	--	--	7.0E-3 L/(kg-d)
	Inhalation[d]	15 m^3/d	180	70	70	70 x 365	--	0.5 L/m^3	5.3E-2 L/(kg-d)
	Dermal[e]	0.17 hr/d	180	70	70	70 x 365	1E-3 L/cm^3	20,000 cm^2 k_p	2.4E-2 K_p L/(kg-d) (shower)
Air	Inhalation	20 m^3/d	180	70	70	70 x 365	--	--	1.4E-1 m^3/(kg-d)
Surface Water	Ingestion[f]	1 L/d	180	70	70	70 x 365	--	--	2.7E-3 L/(kg-d)
	Inhalation	15 m^3/d	180	70	70	70 x 365	--	0.5 L/m^3	5.3E-2 L/(kg-d)
	Dermal[g]	2.6 hr/d (swimming)	70	70	70	70 x 365	1E-3 L/cm^3	20,000 cm^2 K_p	1.4E-1 K_p L/(kg-d) (swimming)
Biota[h] Ingestion: - Food - Medicine - Herbs - Other	Fish[i]	270 g/d	365	70	70	70 x 365	1E-3 kg/g	--	3.9E-3 kg food/(kg-d)
	Fruit and vegetation	250 g/d	365	70	70	70 x 365	1E-3 kg/g	--	3.6E-3 kg food/(kg-d)
	Game[j]	75 g/d	365	70	70	70 x 365	1E-3 kg/g	--	1.1E-3 kg food/(kg-d)
	Upland Birds	9 g/d	365	70	70	70 x 365	1E-3 kg/g	--	1.3E-4 kg food/(kg-d)
	Waterfowl	35	365	70	70	70 x 365	1E-3 kg/g	--	5.0E-4 kg food/(kg-d)
Sediment	Ingestion	200 mg/d	180	70	70	70 x 365	1E-6 kg/mg	--	1.4E-6 kg sed./(kg-d)
	Dermal	1.0 mg/cm^2-d	180	6 (C) 64 (A)	16 (C) 70 (A)	70 x 365	1E-6 kg/mg	2,500 cm^2 (C) 5,000 cm^2 (A) ABS	3.9E-5 kg sed./(kg-d)
Other Unique pathways[k]									

Table B-22: Native American Subsistence Scenario Exposure Factors - Non-carcinogens

a. Soil ingestion is typically separated into child (200 mg/d) and adult (100 mg/d) factors, but considering the activities included in these scenarios, it seems reasonable to assume that the higher rate would persist throughout a lifetime.
b. Soil inhalation is the same as dust resuspension and inhalation.
c. Ingestion of groundwater + surface water should equal 2 L/d, distributed among them as appropriate; in this example they are distributed equally.
d. In HSRAM, groundwater use is a household scenario, which may not be appropriate for subsistence scenarios. Groundwater inhalation comes from volatilization during showering and other household use. To the extent that outdoor volatilization and/or sweat bathing occurs, this factor should be retained, possibly reducing the exposure frequency (days/year or hours/day).
e. The dermal factor for groundwater pathways reflects bathing, which may not be appropriate. For this example, it was assumed that groundwater is used for bathing 180 days/yr and surface water for swimming 70 d/yr.
f. As for groundwater, exposures may still occur that are equivalent of suburban household exposures.
g. For surface water, only swimming (2.6 hr/d) is included.
h. Foodchain pathways include deposition, soil uptake and groundwater usptake, as well as aquatic pathways. There are also additional factors relevant to human ingestion, such as additional plant parts used or eaten (and multiple parts per plant that rotate through the seasons), medicinal uses (infusions, teas, poultices, etc.), other potential contact with people or their foods (food storage basketry, sleeping mats, extensive contact during basketmaking, use of bones, feathers and sinews, and many other things.
i. Note that fish consumption includes multiple species and parts eaten.
j. The suburban meat consumption rate is 74 g/d plus 1 g/d of game; for subsistence, 74 g/d is assumed
to be game, with no domestic meat consumption.
k. Other unique pathways (e.g. volatilization of contaminants from water during sweat bathing, inhalation of cooking fire smoke) need to be included if they contribute to total exposure.

Table B-23: Native American Subsistence Scenario Exposure Factors - Carcinogens (Non-Radioactive)

Pathway		Exposure Parameters							Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors	
Soil	Ingestion	200 mg/d	180	70	70	70 x 365	1E-6 kg/mg	--	1.4E-6 kg soil/(kg-d)
	Dermal	1 mg/cm^2-d	180	6 (C) 64 (A)	16 (C) 70 (A)	70 x 365	1E-6 kg/mg	2,500 cm^2 (C) 5,000 cm^2 (A) ABS	ABS x 3.9E-5 kg soil/(kg-d)
	Inhalation	20 m^3/d	180	70	70	70 x 365	1E-9 kg/µg	50 µg/m^3	7.0E-9 kg soil/(kg-d)
Groundwater	Ingestion	1 L/d	180	70	70	70 x 365	--	--	7.0E-3 L/(kg-d)
	Inhalation	15 m^3/d	180	70	70	70 x 365	--	0.5 L/m^3	5.3E-2L/(kg-d)
	Dermal	0.17 hr/d	180	70	70	70 x 365	1E-3 L/cm^3	20 ,000 cm^2 K_p	2.4E-2 L/(kg-d)
Air	Inhalation	20 m^3/d	180	70	70	70 x 365	--	--	1.4E-1 m^3/(kg-d)
Surface Water	Ingestion	1 L/d	180	70	70	70 x 365	--	--	7.0E-3 L/(kg-d)
	Inhalation	15 m^3/d	180	70	70	70 x 365	--	0.5 L/m^3	5.3E-2 L/(kg-d)
	Dermal	2.6 hr/d (swimming)	70	70	70	70 x 365	1E-3 L/cm^3	20,000 cm^2 K_p	1.4E-1 K_p L/(kg-d) (swimming)
Biota Ingestion: - Food - Medicine - Herbs - Other	Fish	270 g/d	365	70	70	70 x 365	1E-3 kg/g	--	3.9E-3 kg food/(kg-d)
	Fruit and vegetation	250 g/d	365	70	70	70 x 365	1E-3 kg/g	--	3.6E-3 kg food/(kg-d)
	Game[j]	75 g/d	365	70	70	70 x 365	1E-3 kg/g	--	1.1E-3 kg food/(kg-d)
	Upland Birds	9 g/d	365	70	70	70 x 365	1E-3 kg/g		1.3E-4 kg food/(kg-d)
	Waterfowl	35	365	70	70	70 x 365	1E-3 kg/d	--	5.0E-4 kg food/(kg-d)
Sediment	Ingestion	200 mg/d	180	70	70	70 x 365	1E-6 kg/mg	--	1.3E-6 kg sed./(kg-d)
	Dermal	1.0 mg/cm^2-d	180	6 (C) 64 (A)	16 (C) 70 (A)	70 x 365	1E-6 kg/mg	2,500 cm^2 (C) 5,000 cm^2 (A) ABS	ABS X 3.9E-5 kg sed./(kg-d)
Other unique pathways									
notes: see Table B-22									

Table B-24: Native American Subsistence Scenario Exposure Factors - Carcinogens (Radioactive)

Pathway		Exposure Parameters					Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Conversion Factors	Other Factors	
Soil	Ingestion	200 mg/d	180	70	1E-6 kg/mg	--	2.5E+0 kg soil
	External	24 hr/d	180	70	1.14E-04 yr/hr	0.8	2.8E+1 yr
	Dermal	1 mg/cm^2-d	180	70	1E-6 kg/mg	5000 cm^2 ABS	ABS x 6.3E+1 kg soil
	Inhalation	20 m^3/d	180	70	1E-9 kg/µg	50 µg/m^3	1.3E-2 kg soil
Air	Inhalation	20 m^3/d	180	70	--	--	2.5E+5 m^3 air
Groundwater	Ingestion	1 L/d	180	70	--	--	1.3E+4 L
	Inhalation	15 m^3/d	180	70	--	0.1 L/m^3	1.9E+4 L
	Dermal	0.17 hr/d	180	70	1E-3 L/cm^3	20,000 cm^2 K_p	4.3E+4 K_p L
Surface Water	Ingestion	1 L/d	180	70	--	--	1.3E+4 L
	Inhalation	15 m^3/d	180	70	--	0.1 L/m^3	1.9E+4 L
	Dermal	2.6 hr/d (swimming)	70	70	1E-3 L/cm^3	20,000 cm^2 K_p	2.5E+5 K_p L
Biota	Fish	270 g/d	365	70	1E-3 kg/d	--	6.9E+6 kg food/(kg-d)
	Fruit and vegetation	250 g/d	365	70	1E-3 kg/d	--	6.4E+6 kg food/(kg-d)
	Game	75 g/d	365	70	1E-3 kg/d	--	1.9E+6 kg food/(kg-d)
	Upland Birds	9 g/d	365	70	1E-3 kg/g		2.3E+5 kg food/(kg-d)
	Waterfowl	35 g/d	365	70	1E-3 kg/d	--	8.9E+5 kg food/(kg-d)
Sediment	Ingestion	200 mg/d	180	70	1E-06 kg/mg	--	2.5E+0 kg sediment
	Dermal	1 mg/cm^2-d	180	70	1E-6 kg/mg	5000 cm^2 ABS	ABS x 6.3E+1 kg sediment
	External	12 hr/d	180	70	1.14E-4 yr/hr	0.2	6.9E+0 yr
Other unique pathways							
notes: see Table B-22							

Table B-25: Native American Hunting/Gathering Scenario Exposure Factors - Non-carcinogens

Pathway		Exposure Parameters							Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors	
Soil	Ingestion	200 mg/d	150	70	70	70 x 365	1E-6 kg/mg	--	1.2E-6 kg soil/(kg-d)
	Dermal	1 mg/cm^2-d	150	6 (C) 64 (A)	16 (C) 70 (A)	70 x 365	1E-6 kg/mg	2,500 cm^2 (C) 5,000 cm^2 (A) ABS	ABS x 3.2E-5 kg soil/(kg-d)
	Inhalation	20 m^3/d	150	70	70	70 x 365	1E-9 kg/μg	50 μg/m^3	5.9E-9 kg soil/(kg-d)
Groundwater	Ingestion	N/A	--	--	--	--	--	--	--
	Inhalation	N/A	--	--	--	--	--	--	--
	Dermal	N/A	--	--	--	--	--	--	--
Air	Inhalation	20 m^3/d	150	70	70	70 x 365	--	--	1.2E-1 m^3/(kg-d)
Surface Water	Ingestion	1 L/d	100	70	70	70 x 365	--	--	3.9E-3 L/(kg-d)
	Dermal	2.6 hr/d	50	70	70	70 x 365	1E-3 L/cm^3	20,000 cm^2 K_p	1.0E-1 K_p L/(kg-d)
Biota Ingestion: - Food - Medicine - Herbs - Other	Fish	270 g/d	365	70	70	70 x 365	1E-3 kg/g	--	3.9E-3 kg food/(kg-d)
	Fruit and vegetation	250 g/d	365	70	70	70 x 365	1E-3 kg/g	--	3.6E-3 kg food/(kg-d)
	Game	75 g/d	365	70	70	70 x 365	1E-3 kg/g	--	1.1E-3 kg food/(kg-d)
	Upland Birds	9 g/d	365	70	70	70 x 365	1E-3 kg/g	--	1.3E-4 kg food/(kg-d)
	Waterfowl	35 g/d	365	70	70	70 x 365	1E-3 kg/g	--	5.0E-4 kg food/(kg-d)
Sediment	Ingestion	200 mg/d	100	70	70	70 x 365	1E-6 kg/mg	--	7.8E-7 kg sed./(kg-d)
	Dermal	1.0 mg/cm^2-d	100	6 (C) 64 (A)	16 (C) 70 (A)	70 x 365	1E-6 kg/mg	2,500 cm^2 (C) 5,000 cm^2 (A) ABS	ABS X 2.2E-5 kg sed./(kg-d)
Other unique pathways									
notes: see Table B-22									

Table B-26: Native American Hunting/Gathering Scenario Exposure Factors - Carcinogens (Non-Radioactive)

Pathway		Exposure Parameters							Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors	
Soil	Ingestion	200 mg/d	150	70	70	70 x 365	1E-6 kg/mg	--	1.2E-6 kg soil/(kg-d)
	Dermal	1 mg/cm^2-d	150	6 (C) 64 (A)	16 (C) 70 (A)	70 x 365	1E-6 kg/mg	2,500 cm^2 (C) 5,000 cm^2 (A) ABS	ABS x 3.2E-5 kg soil/(kg-d)
	Inhalation	20 m^3/d	150	70	70	70 x 365	1E-9 kg/μg	50 μg/m^3	5.9E-9 kg soil/(kg-d)
Groundwater	Ingestion	N/A				--	--	--	--
	Inhalation	N/A				--	--	--	--
	Dermal	N/A				--	--	--	--
Air	Inhalation	20 m^3/d	150	70	70	70 x 365	--	--	1.2E-1 m^3/(kg-d)
Surface Water	Ingestion	1 L/d	100	70	70	70 x 365	--	--	3.9E-3 L/(kg-d)
	Dermal	2.6 hr/d	50	70	70	70 x 365	1E-3 L/cm^3	20,000 cm^2 K_p	1.0E-1 L/(kg-d)
Biota Ingestion: - Food - Medicine - Herbs - Other	Fish	270 g/d	365	70	70	70 x 365	1E-3 kg/g	--	3.9E-3 kg food/(kg-d)
	Fruit and vegetation	250 g/d	365	70	70	70 x 365	1E-3 kg/g	--	3.6E-3 kg food/(kg-d)
	Game	75 g/d	365	70	70	70 x 365	1E-3 kg/g	--	1.1E-3 kg food/(kg-d)
	Upland Birds	9 g/d	365	70	70	70 x 365	1E-3 kg/g	--	1.3E-4 kg food/(kg-d)
	Waterfowl	35 g/d	365	70	70	70 x 365	1E-3 kg/g	--	5.0E-4 kg food/(kg-d)
Sediment	Ingestion	200 mg/d	100	70	70 (A)	70 x 365	1E-6 kg/mg	--	7.8E-7 kg sed./(kg-d)
	Dermal	1.0 mg/cm^2-d	100	6 (C) 64 (A)	16 (C) 70 (A)	70 x 365	1E-6 kg/mg	2,500 cm^2 (C) 5,000 cm^2 (A) ABS	ABS X 2.2E-5 kg sed./(kg-d)
Other unique pathways									
notes: see Table B-22									

Table B-27: Native American Hunting/Gathering Scenario Exposure Factors - Carcinogens (Radioactive)

Pathway		Exposure Parameters					Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Conversion Factors	Other Factors	
Soil	Ingestion	200 mg/d	150	70	1E-6 kg/mg	--	2.1E+0 kg soil
	External	24 hr/d	150	70	1.14E-04 yr/hr	0.8	2.3E+1 yr
	Dermal	1 mg/cm^2-d	150	70	1E-6 kg/mg	5000 cm^2 ABS	5.3E+1 ABS x kg soil
	Inhalation	20 m^3/d	150	70	1E-9 kg/μg	50 $\mu g/m^3$	1.1E-2 kg soil
Air	Inhalation	20 m^3/d	150	70	--	--	2.1E+3 m^3 air
Groundwater	Ingestion	N/A	--	--	--	--	--
	Inhalation	N/A	--	--	--	--	--
	Dermal	N/A	--	--	--	--	--
Surface Water	Ingestion	1 L/d	100	70	--	--	7.0E+3 L
	Dermal	2.6 hr/d	50	70	1E-3 L/cm^3	20,000 cm^2 K_p	3.6E+5 L
Biota	Fish	270 g/d	365	70	1E-3 kg/g	--	6.9E+6 kg food/(kg-d)
	Fruit and vegetation	250 g/d	365	70	1E-3 kg/g	--	6.4E+6 kg food/(kg-d)
	Game	75 g/d	365	70	1E-3 kg/g	--	1.9E+6 kg food/(kg-d)
	Upland Birds	9 g/d	365	70	1E-3 kg/g	--	2.3E+5 kg food/(kg-d)
	Waterfowl	35 g/d	365	70	1E-3 kg/g	--	8.9E+5 kg food/(kg-d)
Sediment	Ingestion	200 mg/d	100	70	1E-06 kg/mg	--	1.4E+0 kg sediment
	Dermal	1 mg/cm^2-d	100	70	1E-6 kg/mg	5000 cm^2 ABS	ABS x 3.5E+1 kg sediment
	External	12 hr/d	100	70	1.14E-4 yr/hr	0.2	9.6E-1 yr
Other unique pathways							
notes: see Table B-22							

Table B-28: Native American Cultural Activities Scenario Exposure Factors - Non-carcinogens

Pathway		Exposure Parameters							Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors	
Soil	Ingestion	200 mg/d	30	70	70	70 x 365	1E-6 kg/mg	--	2.3E-7 kg soil/(kg-d)
	Dermal	1 mg/cm^2-d	30	6 (C) 64 (A)	16 (C) 70 (A)	70 x 365	1E-6 kg/mg	2,500 cm^2 (C) 5,000 cm^2 (A) ABS	ABS x 6.5E-6 kg soil/(kg-d)
	Inhalation	10 m^3/d	30	70	70	70 x 365	1E-9 kg/μg	50 $\mu g/m^3$	5.9E-10 kg soil/(kg-d)
Air	Inhalation	10 m^3/d	30	70	70	70 x 365	--	--	1.2E-2 m^3/(kg-d)
Other unique pathways									
notes: see Table B-22									

Table B-29: Native American Cultural Activities Scenario Exposure Factors - Carcinogens (Non-radioactive)

Pathway		Exposure Parameters							Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr	Conversion Factors	Other Factors	
Soil	Ingestion	200 mg/d	30	70	70(A)	70 x 365	1E-6 kg/mg	--	2.3E-7 kg soil/(kg-d)
	Dermal	1 mg/cm^2-d	30	6(C) 64(A)	16(C) 70(A)	70 x 365	1E-6 kg/mg	2500 cm^2(C) 5000 cm^2(A) ABS	ABS x 6.5E-6 kg soil/(kg-d)
	Inhalation	10 m^3/d	30	70	70	70 x 365	1E-9 kg/μg	50 μg/m^3	5.9E-10 kg soil/kg-d)
Air	Inhalation	20 m^3/d	30	70	70	70 x 365	--	--	2.3E-2 m^3 air/(kg-d)
Other unique pathways									
notes: see Table B-22									

Table B-30: Native American Cultural Activities Scenario Exposure Factors - Carcinogens (Radioactive)

Pathway		Exposure Parameters					Summary Intake Factor
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Conversion Factors	Other Factors	
Soil	Ingestion	200 mg/d	30	70	1E-6 kg/mg	--	4.2E-1 kg soil
	External	8 hr/d		70	1.14E-04 yr/hr	0.8	1.3E+0 yr
	Dermal	1 mg/cm^2-d	30	70	1E-6 kg/mg	5000 cm^2 ABS	ABS x 1.1E+1 kg soil
	Inhalation	10 m^3/d	30	70	1E-9 kg/µg	50 µg/m^3	1.1E-3 kg soil
Air	Inhalation	10 m^3/d	30	70	--	--	2.1E+4 m^3 air
Other unique pathways							

notes: see Table B-22

APPENDIX C

Table C-1: Soil Based Pathways - Summary Intake Factors

Activity Type	Non-Carcinogens			Carcinogens (Non-radioactive)			Radioactive			
	Ingestion kg soil/(kg-d) (A-1.1.1)	Dermal kg soil/(kg-d) x ABS (A-4.1.1)	Inhalation kg soil/(kg-d) (A-2.1.1)	Ingestion kg soil/(kg-d) (A-1.1.2)	Dermal kg soil/(kg-d) x ABS (A-4.1.2)	Inhalation kg soil/(kg-d) (A-2.1.2)	Ingestion kg soil/(kg-d) (A-1.1.3)	Dermal kg soil/(kg-d) x ABS (A-4.1.3)	Inhalation kg soil/(kg-d) (A-2.1.3)	External yr (A-5.1)
Hanford Hatchery	5.4E-7	5.4E-6	2.7E-9	5.4E-8	5.4E-7	2.7E-10	9.7E-2	9.7E-1	4.8E-4	7.0E-1
Eastbank Hatchery	9.8E-7	9.8E-6	4.9E-9	2.8E-7	2.8E-6	1.4E-9	5.0E-1	5.0E+0	2.5E-3	3.6E+0
HSRAM Industrial	2.9E-7	5.7E-6	--	8.2E-8	1.6E-6	--	1.5E-1	--	--	2.1E+0
Ranger	5.9E-7	5.9E-6	2.9E-9	1.7E-7	1.7E-6	8.4E-10	3.0E-1	3.0E+0	1.5E-3	8.2E-1
Hunter	2.8E-7	2.8E-6	2.4E-9	4.0E-8	4.0E-7	3.4E-10	7.1E-2	7.1E-1	6.1E-4	2.6E-1
Birdwatcher	1.2E-8	4.9E-7	1.2E-10	3.5E-9	1.4E-7	3.5E-11	6.3E-3	2.5E-1	6.3E-5	9.1E-2
Backpacker	5.9E-8	5.9E-7	5.9E-10	8.4E-9	8.4E-8	8.4E-11	1.5E-2	1.5E-1	1.5E-4	1.6E-1
Archeologist	2.0E-6	2.4E-5	2.9E-8	2.8E-8	3.5E-7	4.2E-10	5.0E-2	6.3E-1	7.5E-4	2.3E-1
Subsistence	1.4E-6	3.9E-5	7.0E-9	1.8E-6	3.9E-5	7.0E-9	2.5E+0	6.3E+1	1.3E-2	2.8E+1
Hunter/Gatherer	1.2E-6	3.2E-5	5.9E-9	1.8E-6	3.9E-5	7.0E-9	2.5E+0	6.3E+1	1.3E-2	2.8E+1
Cultural Activities	2.3E-7	6.5E-6	5.9E-10	3.0E-7	6.5E-6	1.2E-9	4.2E-1	1.1E+1	2.1E-3	4.6E+0
HSRAM Recreational	2.4E-7	3.4E-7	--	3.0E-8	1.5E-7	--	2.5E-2	--	--	1.5E-1
HSRAM Residential	1.3E-5	8.7E-6	--	1.6E-6	3.7E-6	--	1.3E+0	--	--	2.4E+1

Table C-2: Air Based Pathways - Summary Intake Factors

Activity Type	Non-carcinogens Inhalation $m^3/(kg\text{-}d)$ (A-3.1.1)	Carcinognes (Non-radioactive Inhalation $m^3/(kg\text{-}d)$ (A-3.1.2)	Radioactive Inhalation m^3 (A-3.1.3)
Hanford Hatchery	5.4E-2	5.4E-3	9.7E+3
Eastbank Hatchery	9.8E-2	2.8E-2	5.0E+4
HSRAM Industrial	2.0E-1	5.6E-2	1.0E+5
Ranger	5.9E-2	1.7E-2	3.0E+4
Hunter	4.7E-2	6.8E-3	1.2E+4
Birdwatcher	2.4E-3	7.0E-4	1.3E+3
Backpacker	1.2E-2	1.7E-3	3.0E+3
Archeologist	1.5E-1	2.1E-3	3.8E+3
Subsistence	1.4E-1	1.4E-1	2.5E+5
Hunter/Gatherer	1.2E-1	1.2E-1	2.1E+3
Cultural Activities	1.2E-2	2.3E-2	2.3E-2
HSRAM Recreational	1.2E-2	2.3E-3	4.2E+3
HSRAM Residential	6.3E-1	1.2E-1	2.2E+5

Table C-3: Groundwater Based Pathways - Summary Intake Factors

Activity Type	Non-Carcinogens			Carcinogens (Non-radioactive)			Radioactive			
	Ingestion L/(kg-d) (A-1.2.1)	Dermal (L-hr)/(kg-cm-d) x K_p (A-4.2.1)	Inhalation L/(kg-d) (A-3.2.1)	Ingestion L/(kg-d) (A-1.2.2)	Dermal (L-hr)/(kg-cm-d) x K_p (A-4.2.2)	Inhalation L/(kg-d) (A-3.2.2)	Ingestion L (A-1.2.3)	Dermal (L-hr)/(kg-cm-d) x K_p (A-4.2.3)	Inhalation L (A-3.2.3)	External yr (NA)
Hanford Hatchery	--	--	--	--	--	--	--	--	--	--
Eastbank Hatchery	--	--	--	--	--	--	--	--	--	--
HSRAM Industrial	9.8E-3	3.3E-2	9.8E-2	2.8E-3	9.5E-3	2.8E-2	5.0E+3	--	1.0E+4	--
Ranger	--	--	--	--	--	--	--	--	--	--
Hunter	--	--	--	--	--	--	--	--	--	--
Birdwatcher	--	--	--	--	--	--	--	--	--	--
Backpacker	1.2E-3	--	--	1.7E-4	--	--	3.0E+2	--	--	--
Archeologist	--	--	--	--	--	--	--	--	--	--
Subsistence	7.0E-3	2.4E-2	5.3E-2	7.0E-3	2.4E-2	5.3E-2	1.3E+4	4.3E+4	1.9E+4	--
Hunter/Gatherer	--	--	--	--	--	--	--	--	--	--
Cultural Activities	--	--	--	--	--	--	--	--	--	--
HSRAM Recreational	1.2E-3	9.3E-4	--	2.3E-4	4.0E-4	--	4.2E+2	--	--	--
HSRAM Residential	6.3E-2	4.9E-2	1.1E-1	1.2E-2	2.1E-2	4.6E-2	2.2E+4	--	1.6E+4	--

Table C-4: Surface Water Based Pathways - Summary Intake Factors

Activity Type	Non-Carcinogens			Carcinogens (Non-radioactive)			Radioactive			
	Ingestion L/(kg-d) (A-1.2.1)	Dermal (L-hr)/(kg-cm-d) x K_p (A-4.2.1)	Inhalation L/(kg-d) (A-3.2.1)	Ingestion L/(kg-d) (A-1.2.2)	Dermal (L-hr)/(kg-cm-d) x K_p (A-4.2.2)	Inhalation L/(kg-d) (A-3.2.2)	Ingestion L (A-1.2.3)	Dermal (L-hr)/(kg-cm-d) x K_p (A-4.2.3)	Inhalation L (A-3.2.3)	External yr (NA)
Hanford Hatchery	5.4E-3	2.7E-2	--	5.4E-4	2.7E-3	--	9.7E+2	4.8E+3	--	2.2E-1
Eastbank Hatchery	9.8E-3	4.9E-2	--	2.8E-3	1.4E-2	--	5.0E+3	2.5E+4	--	1.1E+0
HSRAM Industrial	9.8E-3	3.3E-2	9.8E-2	2.8E-3	9.5E-3	2.8E-2	5.0E+3	--	1.0E+4	--
Ranger	--	--	--	--	--	--	--	--	--	5.1E-1
Hunter	--	--	--	--	--	--	--	--	--	--
Birdwatcher	--	--	--	--	--	--	--	--	--	5.7E-2
Backpacker	--	--	--	--	--	--	--	--	--	--
Archeologist	--	--	--	--	--	--	--	--	--	--
Subsistence	2.7E-3	1.4E-1	5.3E-2	7.0E-3	1.4E-1	5.3E-2	1.3E+4	2.5E+5	1.9E+4	--
Hunter/Gatherer	3.9E-3	1.0E-1	--	3.9E-3	1.0E-1	--	7.0E+3	3.6E+5	--	--
Cultural Activities	--	--	--	--	--	--	--	--	--	--
HSRAM Recreational	1.2E-3	6.1E-3	--	2.3E-4	6.1E-3	--	4.2E+2	--	--	--
HSRAM Residential	6.3E-2	4.9E-2 (bath) 1.4E-2 (Swim)	1.1E-1	1.2E-2	2.1E-2 (bath) 6.1E-3 (swim)	4.6E-2	2.2E+4	--	1.6E+4	--

Table C-5: Biota Ingestion Based Pathways - Summary Intake Factors

Activity Type	Non-Carcinogens					Carcinogens (Non-radioactive)					Radioactive				
	Fish (A-1.3.1)	Fruit and Veg. (A-1.3.1)	Game (A-1.3.1)	Upland Birds (A-1.3.1)	Waterfowl (A-1.3.1)	Fish (A-1.3.2)	Fruit and Veg. (A-1.3.2)	Game (A-1.3.2)	Upland Birds (A-1.3.2)	Waterfowl (A-1.3.2)	Fish (A-1.3.3)	Fruit and Veg. (A-1.3.3)	Game (A-1.3.3)	Upland birds (A-1.3.3)	Waterfowl (A-1.3.3)
Hanford Hatchery	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Eastbank Hatchery	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
HSRAM Industrial	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ranger	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hunter	--	--	2.8E-5	1.3E-4	5.0E-4	--	--	4.0E-6	1.8E-5	7.1E-5	--	--	1.0E+1	3.3E+1	1.3E+2
Birdwatcher	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Backpacker	1.5E-4	--	--	--	--	2.1E-5	--	--	--	--	3.8E+1	--	--	--	--
Archeologist	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Subsistence	3.9E-3	3.6E-3	1.1E-3	1.3E-4	5.0E-4	3.9E-3	3.6E-3	1.1E-3	1.3E-4	5.0E-4	6.9E+6	6.4E+6	1.9E+6	2.3E+5	8.9E+5
Hunter/Gatherer	3.9E-3	3.6E-3	1.1E-3	1.3E-4	5.0E-4	3.9E-3	3.6E-3	1.1E-3	1.3E-4	5.0E-4	6.9E+6	6.4E+6	1.9E+6	2.3E+5	8.9E+5
Cultural Activities	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
HSRAM Recreational	3.9E-4	--	2.7E-6	--	--	1.7E-4	--	1.2E-6	--	--	3.0E+5	--	2.1E+3	--	--
HSRAM Residential	3.9E-4	6.0E-4 (fruit) 1.1E-3 (veg.)	--	--	--	1.7E-4	2.6E-4 (fruit) 4.9E-4 (veg.)	--	--	--	3.0E+5	4.6E+5 (fruit) 8.8E+5 (veg.)	--	--	--