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Human Scenarios for the Screening Assessment

Columbia River Comprehensive Impact Assessment

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Prepared by the Pacific Northwest National Laboratory
In Consultation with

U.S. Department of Energy

U.S. Environmental Protection Agency

Washington State Department of Ecology

Bechtel Hanford, Inc.

Dames & Moore

Confederated Tribes of the Umatilla Indian Reservation

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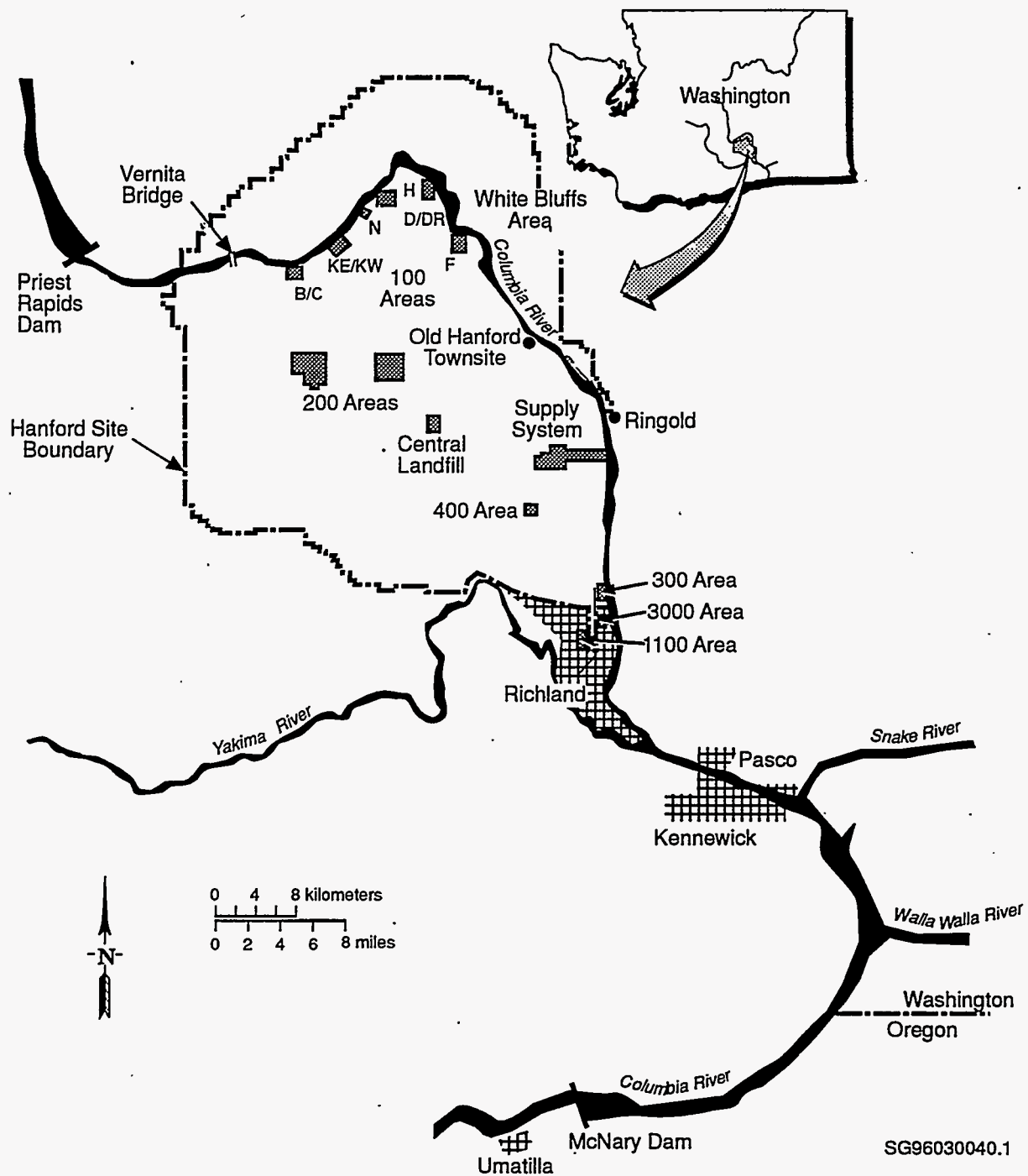Approved for Public Release

MASTER

Figure P.1. Map of the Hanford Site

Table P.1. Documents in Initial Phase of Columbia River Comprehensive Impact Assessment

Title	Document No.	Publication Date	Status
Data Compendium for the Columbia River Comprehensive Impact Assessment (Eslinger et al. 1994)	PNL-9785	April 1994	Final publication
List of Currently Classified Documents Relative to Hanford Operations and of Potential Use in the Columbia River Comprehensive Impact Assessment January 1, 1973 - June 20, 1994 (Miley and Huesties 1995)	PNL-10459	February 1995	Final publication
Identification of Contaminants of Concern (Napier et al. 1995)	PNL-10400	January 1995	Published as a draft - Issued first in January 1995 for review, then again in January 1996; comments from both review periods will be addressed and report will be a section in the *Screening Assessment and Requirements for a Comprehensive Assessment* report
Human Scenarios for the Screening Assessment (Napier et al. 1996)	DOE/RL-96-16-a Rev.0	March 1996	Published as a draft - Comments will be addressed and report will be a section in the *Screening Assessment and Requirements for a Comprehensive Assessment* report
Species for the Screening Assessment	DOE/RL-96-16-b Rev. 0	March 1996	To be published as a draft - Then comments will be addressed and report will be a section in the *Screening Assessment and Requirements for a Comprehensive Assessment* report
Data for the Screening Assessment	DOE/RL-96-16-c Rev.0	April 1996	To be published as a draft - Then comments will be addressed and report will be a section in the *Screening Assessment and Requirements for a Comprehensive Assessment* report
Screening Assessment and Requirements for a Comprehensive Assessment: Columbia River Comprehensive Impact Assessment	DOE/RL-96-16 Rev.0	July 1996	To be published as a draft - Will incorporate all previous draft publications (not those published as final) plus sections on site character-ization, screening assessment of risk, and CRCIA Team statement of work to be done after the initial phase
Screening Assessment and Requirements for a Comprehensive Assessment: Columbia River Comprehensive Impact Assessment	DOE/RL-96-16 Rev.1	October 1996	To be published final - Will incorporate responses to comments and minority opinions should any comments not be reconciled

Preface

· The protection of the Columbia River is of special interest to the public, government, and tribal governments as a source of drinking water, for crop irrigation, as ecological habitat, for recreation, and as a cultural resource. Because of past nuclear production operations along the Columbia River, there is intense public and tribal interest in assessing any residual Hanford Site related contamination along the river from the Hanford Reach to the Pacific Ocean. The Columbia River Comprehensive Impact Assessment was proposed to address these concerns.

Background

From 1944-1987, the U.S. Department of Energy (DOE) conducted nuclear production operations along the Hanford Reach of the Columbia River (see Figure P.1). The Hanford Reach extends 85 kilometers (51 miles) downstream from Priest Rapids Dam to the head of the McNary Pool near the city of Richland, Washington. These past nuclear operations resulted in the release of hazardous chemicals and radionuclides to the Columbia River. Whereas during the period of operation contaminant releases were direct to the river, most of today's problems are caused by past disposal of contaminated waste on land. Current conditions of the Columbia River reflect that contaminated waste is reaching the river via surface water, sediment, groundwater, external radiation, seeps and springs, and biota.

The area where the nuclear materials were produced is known as the Hanford Site. Four areas of the Hanford Site (the 100, 200, 300, and 1100 Areas) have been placed by the U.S. Environmental Protection Agency (EPA) on the national priorities list for cleanup. The national priorities list is a component of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) (42 USC 9601) enacted by the U.S. Congress.

The cleanup of the Hanford Site is a joint activity of three government agencies: DOE, EPA, and the Washington State Department of Ecology. These Tri-Party agencies have signed an agreement known officially as the *Hanford Federal Facility Agreement and Consent Order* and unofficially as the Tri-Party Agreement (Ecology et al. 1994). Milestones have been adopted for the Tri-Party Agreement that identify actions needed to ensure acceptable progress toward Hanford Site compliance with CERCLA, the *Resource Conservation and Recovery Act of 1976* (42 USC 6901), and the *Washington State Hazardous Waste Management Act* (RCW 1985).

During 1993, the Tri-Party agencies began work toward a comprehensive assessment of the impact of past nuclear operations on the current conditions of the Columbia River (DOE 1994). In January 1994, a revision to the Tri-Party Agreement (Change Order number M-13-93-06) adjusted the milestones designed to address cleanup strategies and achieve timely remedial decisions and actions concerning the Columbia River. This change order included a new Milestone, M-15-80 (formerly M-13-80b), that established the Columbia River Comprehensive Impact Assessment (CRCIA). In December 1995, a follow-on change order (M-15-95-09) modified the milestone, enhancing the review process and specifying target dates.

CRCIA Long-Term and Short-Term Objectives

Because the scope and priorities of CRCIA have been controversial, the Columbia River Comprehensive Impact Assessment Management Team (CRCIA Team) was formed in August 1995 to advise the Tri-Party agencies. The CRCIA Team meets weekly to share information and provide input to decisions made by the Tri-Party agencies concerning CRCIA. Representatives from the Confederated Tribes of the Umatilla Indian Reservation, Hanford Advisory Board, Nez Perce Tribe, Oregon State Department of Energy, and Yakama Indian Nation have been active participants on the team. The specific goals of the CRCIA Team are:

- provide recommendations on the CRCIA work being conducted by the Pacific Northwest National Laboratory

- provide recommendations on future work necessary for the assessment to be comprehensive

- represent public, tribal, and affected government interests

- act as an information resource for future decisions on remedial measures

The long-term objective of CRCIA (according to the CRCIA "Project Management Team Charter," dated October 1995) is to focus on the current impact of Hanford Site activities on the Columbia River and the resulting impact on human health and the environment. The comprehensive assessment will evaluate the extent of any resulting contamination and determine the current human and ecological risk from the Columbia River attributable to past and present activities at the Hanford Site. Human risk from exposure to radioactive and hazardous materials will be addressed for a range of river use options. Ecological resources in the study area will be evaluated to determine if current contaminant conditions pose significant hazards to biological communities. Information collected will be used in remedial action decisions for the Hanford Site.

The assessment of the Columbia River is being conducted in phases. The initial phase is a screening assessment of risk, which addresses current environmental conditions for a range of potential uses. Specifically, the short-term objectives of the work in this initial phase (according to an agreement signed by the CRCIA Team, dated October 1995) are:

1. Perform an assessment of contaminants derived from the Hanford Site (existing conditions including residual contaminants from past operations) in a screening assessment of risk to support the Interim Remedial Measures decisions

2. Compile and make available to the public the approximately 2000 documents identified in Appendix A of the data compendium (Eslinger et al. 1994); pertinent supporting Hanford Site data will be made available

3. Work with the declassification efforts of the Hanford Advisory Board to identify the Columbia River documents as a high priority for release

4. Define the essential work remaining to provide an acceptable comprehensive river impact assessment; this work will be documented in the same report as the screening assessment of risk

5. Provide data from numbers 2 and 3 above for reconciliation against the risk assessment

The Tri-Party agencies are conducting the CRCIA. The primary contractor for the initial phase of the CRCIA work is the Pacific Northwest National Laboratory. Bechtel Hanford, Inc. provides technical and public involvement coordination with environmental restoration activities. Technical peer reviewers are evaluating the work. Their review comments are compiled by the Directors of the Oregon Water Resources Research Institute and State of Washington Water Research Center and forwarded to DOE for resolution.

Scope of the Initial Phase of CRCIA

The scope of the initial phase of CRCIA is to provide a screening assessment of the current risk to humans and the environment resulting from Hanford-derived contaminants. For the initial phase of CRCIA, the segment of the Columbia River from Priest Rapids Dam (first impoundment upstream of the Hanford Site) to McNary Dam (first impoundment downstream of the Hanford Site) was selected as the study area. The parameters of the scope are:

Area:	Columbia River (Priest Rapids Dam to McNary Dam), groundwater (0.8 kilometer/0.5 mile in from the river), and adjacent riparian zone
Time:	January 1990 - February 1996 (date data were received for use in the screening assessment) with data gaps filled by earlier data where available
Contaminants:	Published in Napier et al. (1995)
Receptor Species:	Published in Becker et al. (1996)
Media:	Surface water, sediment, groundwater, external radiation, seeps and springs, biota

Work Integration and Documentation

The results of the initial phase of CRCIA are being reported in a series of documents (see Table P.1). These reports reflect the process involved in the screening assessment of risk. First the documents containing pertinent data were identified. That information was published in two reports (Eslinger et al. 1994 and Miley and Huesties 1995), which were issued as final documents.

These data documents helped to identify Hanford Site contaminants that affect the Columbia River. The winnowing process used to determine which of those contaminants should be evaluated in the screening assessment of risk was published in Napier et al. (1995) as a draft. The comments on the draft are being incorporated, and the contaminants information will appear as a section in the draft of the report on the screening assessment and requirements for a comprehensive assessment.

Next, potential groups of people with different exposures to the Columbia River were identified. With information from the Hanford Site Risk Assessment Methodology (DOE 1995) and with input from the CRCIA Team, scenarios were written defining the pathways and exposures for the various groups. Input from the scenarios will be used in the screening assessment of human risk. The scenarios are described in this report.

Simultaneously, a focusing process was used to identify the species and select those to be evaluated in the screening assessment of ecological risk. The focusing process and the results are provided in Becker et al. (1996).

The monitoring data available, the lists of contaminants and species to be evaluated, and the selection rules developed by the CRCIA Team determined which data were selected for use in the screening assessment of human and ecological risk.

As with the contaminants report, the scenarios, species, and data selection reports are being published first as drafts for review. The reports published first as drafts will be compiled into one document on the screening assessment and requirements for a comprehensive assessment. This document will provide the results of the screening assessment and a definition of the essential work remaining to provide an acceptable comprehensive river impact assessment.

Summary

Because of past nuclear production operations along the Columbia River, there is intense public and tribal interest in assessing any residual Hanford Site related contamination along the river from the Hanford Reach to the Pacific Ocean. The Columbia River Impact Assessment (CRCIA) was proposed to address these concerns. The assessment of the Columbia River is being conducted in phases. The initial phase is a screening assessment of risk, which addresses current environmental conditions for a range of potential uses.

One component of the screening assessment estimates the risk from contaminants in the Columbia River to humans. Because humans affected by the Columbia River are involved in a wide range of activities, various scenarios have been developed on which to base the risk assessments. The scenarios illustrate the range of activities possible by members of the public coming in contact with the Columbia River so that the impact of contaminants in the river on human health can be assessed. Each scenario illustrates particular activity patterns by a specific group. Risk will be assessed at the screening level for each scenario. This report defines the scenarios and the exposure factors that will be the basis for estimating the potential range of risk to human health from Hanford-derived radioactive as well as non-radioactive contaminants associated with the Columbia River. The potential range of risk will be assessed and published in a separate report on the screening assessment of risk.

In line with the scope of the screening assessment, the scenarios are Hanford Site specific. The U.S. Department of Energy (DOE) has developed generic scenarios for the Hanford Site (DOE 1995). At present, only two exposure scenarios in DOE's Hanford Site Risk Assessment Methodology (HSRAM) are available for current conditions at the Hanford Site: an industrial scenario and a recreational scenario. Because the goal of CRCIA, according to the CRCIA Management Team, is an assessment of current impact, scenarios (based on current conditions in the Columbia River) have been developed to reflect the possible uses of the Hanford Site in the near future. The human scenarios that will be used in the screening assessment of human risk are:

Industrial/Commercial Scenarios
- Industrial Worker (unmodified HSRAM definition)
- Fish Hatchery Worker

Wildlife Refuge/Wild and Scenic River Scenarios
- Ranger
- Hunter/Fisher
- Recreational Visitor (unmodified HSRAM with River-Focused Activities)

Native American Scenarios
- Subsistence Resident (an unrestricted use scenario)
- Hunter/Gatherer
- Cultural Activities Visitor
- Columbia River Island User (for application to Cobalt-60 particles)

General Population Scenarios
- Resident (modified HSRAM using Columbia River water instead of groundwater)
- Agricultural Resident (modified HSRAM using Columbia River water instead of groundwater)

In addition to the HSRAM industrial (unmodified), HSRAM recreational (unmodified), and HSRAM residential and agricultural resident (modified) scenarios, this report develops scenarios for the following activities: Fish Hatchery Worker; Ranger; Hunter/Fisher; and Native American subsistence, hunting/gathering, cultural/non-subsistence, and island user. The factors that define each scenario are listed and explained, and an initial range of variability is given to allow stochastic analyses.

Glossary

100 Areas
site of the Hanford production reactors, which include B, C, D, DR, F, H, KE, KW, and N Reactors

200 Areas
site of the Hanford chemical separations plants, which include the bismuth phosphate process plants (B and T Plants), plutonium uranium extraction plant (A Plant/PUREX), and reduction and oxidation plants (S Plant/REDOX)

300 Area
site of the research, development and fuel-fabrication operations

1100 Area
site of the warehouse, vehicle maintenance, and transportation operations center

beta particle
high energy electron emitted from a radioactive nucleus

bioaccumulation
tendency to occur in higher concentrations at higher food chain levels through dietary accumulation

bioconcentration factor
ratio between the radionuclide concentration in biota and the radionuclide concentration in the water in which the biota live and feed

biota
plants and animals

biotic
animate

carcinogenic (chemicals)
having the property of enhancing the possibility of contracting cancer

CERCLA
Comprehensive Environmental Response, Compensation, and Liability Act of 1980

Ci
abbreviation for curie

concentration
amount of a specified substance (e.g., a radioactive element) in a unit amount of another substance (e.g., river water, milk)

CRCIA
Columbia River Comprehensive Impact Assessment

CRCIA Team
Columbia River Comprehensive Impact Assessment Management Team

curie
unit of radioactivity corresponding to 3.7×10^{10} (37 billion) disintegrations per second (abbreviated Ci), 1 curie $= 3.7 \times 10^{10}$ Becquerel

deterministic value	natural random variation of a measured quantity around a central value; for example, in a room full of people, the height of the tallest individual might be selected as a conservative estimate of the deterministic value for the average height of all people in the room; see stochastic variability
DOE	U.S. Department of Energy
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
exposure	process of coming into contact with environmental materials
• internal exposure	contact with materials taken into the body through inhalation or ingestion
• external exposure	contact with materials on the outside of the body, as from submersion in water or immersion in air
half-life	time required for an initial number of radioactive atoms to be reduced to half that number by radiological transformations
Hanford Reach	stretch of the Columbia River that extends 85 kilometers (51 miles) downstream from Priest Rapids Dam to the head of the McNary Pool near the city of Richland, Washington
hazardous (chemicals)	having the property of being toxic at some level of exposure; generally used to differentiate from carcinogenic
HSRAM	Hanford Site Risk Assessment Methodology (DOE 1995)
irradiation	exposure of an object to ionizing radiation
median	middle value in a series of values arranged in order of size
model	conceptual representation of a physical/biological process; the representation may be graphical or a set of mathematical equations that simulate the process being modeled
pCi	picocurie, one-trillionth of a curie (10^{-12})
PNNL	Pacific Northwest National Laboratory

production operations	activities connected with the production reactors (B, C, D, DR, F, H, KE, KW, or N reactors) in which uranium or other fuel was irradiated with neutrons to produce radioactive materials; used primarily at Hanford to produce plutonium for weapons; used also for research
rad	radiation absorbed dose, unit of measurement used to describe absorbed dose
radioactivity	spontaneous emission of radiation (alpha, beta, gamma rays, and/or neutrons) by some isotopes as they transform into other isotopes
radionuclide	radioactive isotope of an element
RCRA	*Resource Conservation and Recovery Act of 1976*
reactor	see production operations
rem	roentgen equivalent man, unit of measurement used to describe radiation dose
risk assessment	estimation of the severity and likelihood of harm to human health or the environment occurring from exposure to a particular substance or activity
screening assessment of risk	risk assessment with limited scope; for example, the initial phase of CRCIA is a screening assessment of risk because it is restricted to 1) current conditions, 2) the area between Priest Rapids Dam and McNary Dam, 3) a limited number of contaminants, 4) a few selected receptor species, and 5) a limited amount of monitoring data; the objective of the screening assessment of risk is to identify areas where significant potential exists for adverse effects
sensitivity analysis	determination of the parameters and pathways that contribute most to the uncertainty in exposure calculations
seeps	locations where groundwater oozes to the surface
sensitivity	determination of the parameters and pathways that contribute most to uncertainty in dose results
slope factor	EPA's value which represents the lifetime excess cancer risk per unit of intake
springs	source of water issuing from the ground

stochastic variability   natural random variation of a measured quantity around a central value; for example, in a room full of people, there is an average height with some being taller and some shorter; the stochastic variability of that group is described by the differences between the individuals' heights and the average height; see deterministic value

surrogate (measurement)   estimated substitute measurement used when actual measurements not available

TPA   Tri-Party Agreement (officially, *Hanford Federal Facility Agreement and Consent Order*)

uncertainty   measure of variability in model parameters or dose estimates

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1.0 Introduction

One component of the initial phase of the Columbia River Comprehensive Impact Assessment (CRCIA) is a screening assessment of risk to humans. Because humans affected by the Columbia River are involved in a wide range of activities, various scenarios have been developed on which to base the risk assessments. The scenarios illustrate the range of activities possible by members of the public coming in contact with the Columbia River so that the impact of contaminants in the river on human health can be assessed. Each scenario illustrates particular activity patterns by a specific group. Risk will be assessed at the screening level for each scenario. This report defines the scenarios and the exposure factors that will be the basis for estimating the potential range of risk to human health from Hanford-derived radioactive as well as non-radioactive contaminants associated with the Columbia River. The potential range of risk will be assessed and published in a separate report on the screening assessment of risk.

1.1 Scope

In line with the scope of the work in the initial phase, the scenarios are Hanford Site specific. The U.S. Department of Energy (DOE) has developed generic scenarios for the Hanford Site (DOE 1995). At present, only two exposure scenarios in DOE's Hanford Site Risk Assessment Methodology (HSRAM) are available for current conditions at the Hanford Site: an industrial scenario and a recreational scenario. Numerous proposals are being considered for the future use of the Hanford Site and, in particular, the Hanford Reach, which is a stretch of river whose shoreline borders the Hanford Site. These proposals span a variety of land uses and human activity patterns, ranging from industrial use to conservation and Native American uses. Because the goal of CRCIA according to the Columbia River Comprehensive Impact Assessment Management Team (CRCIA Team) is an assessment of potential impact, scenarios (based on current conditions in the Columbia River) have been developed to reflect the possible uses of the Hanford Site in the near future. The human scenarios that will be used in the screening assessment of human risk are:

Industrial/Commercial Scenarios
- Industrial Worker (unmodified HSRAM definition)
- Fish Hatchery Worker

Wildlife Refuge/Wild and Scenic River Scenarios
- Ranger
- Hunter/Fisher
- Recreational Visitor (unmodified HSRAM with River-Focused Activities)

Native American Scenarios
- Subsistence Resident (an unrestricted use scenario included as a baseline for comparison)
- Hunter/Gatherer
- Cultural Activities Visitor
- Columbia River Island User (for application to Cobalt-60 particles)

General Population Scenarios
- Resident (modified HSRAM using Columbia River water instead of groundwater)
- Agricultural Resident (modified HSRAM using Columbia River water instead of groundwater)

These scenarios were selected with present and potential use of the Hanford Site in mind. For example, if portions of the Hanford Reach of the Columbia River were established as a wildlife refuge, the activities associated with that use might include ranger, hunter/fisher, or recreational visitor. Also, not all activities currently occurring on the site were evaluated. Tours of the B Reactor are being conducted, for instance. Exposure information for visitors on such tours might be desired in the future, but for the initial phase of the CRCIA work, no B Reactor Visitor Scenario was defined. The exposure scenarios selected are based on general agreement by the CRCIA Team and do not represent recommendations as to actual land use or cleanup levels.

1.2 Approach

The general intent of the screening assessment of human risk is to overestimate exposures to have some degree of certainty that the true exposure will be lower than the estimated exposure. Similarly, the intent is not to precisely estimate exposure but to ensure that all relevant and important aspects of a person's lifestyle have been incorporated into high-end exposure scenarios such that the same degree of conservativeness is applied to both suburban and subsistence/traditional scenarios.

The scenario definitions are based on activities rather than location. The potential of the Hanford Reach becoming a wildlife refuge illustrates why. The ranger, hunter/fisher, and recreational visitor would have different degrees of contact with the environmental media (surface water, spring water, soils, and sediments), and only the hunter/fisher would consume biota. Therefore, the exposures and risks to these three types of people could be quite different at the same location. Location will be taken into account when the scenarios are applied to particular areas of the Hanford Site, which will be published in a later report on the screening assessment of risk.

To define the scenarios as realistically as possible, the HSRAM industrial and recreational scenarios were used unmodified. The HSRAM residential and agricultural resident scenarios were modified to account for the use of Columbia River water instead of groundwater. Groundwater is the basis for the scenarios in HSRAM. For the Fish Hatchery Worker Scenario, information about actual time spent on the Hanford Site by fish hatchery workers was used. Information about actual hunting and fishing practices in the counties surrounding the Hanford Site was used to develop the Hunter/Fisher Scenario. The Ranger Scenario is a variant of the HSRAM industrial scenario. Limited tribal information was used to develop the Native American Scenarios. For applications other than the screening risk assessment, the Native American Scenarios will require review and modification by tribal technical staff.

The two main factors to be defined for each scenario are the contaminant pathways (media and exposure route of that media) and the exposure factors (intake/contact rate, exposure frequency, exposure duration, and special factors that apply to only certain media and exposure routes).

1.2.1 Pathways

Pathways consist of media which act as vehicles to carry contaminants along exposure routes. The media providing potential contamination to humans vary according to the particular scenario. The media considered are soil, air, seep/spring water, surface water, sediment, biota, and cultural. These media come in contact with humans via the exposure routes of ingestion, external radiation contact, dermal contact, and inhalation.

The general philosophy in defining the scenarios for the human risk assessment is to avoid screening out pathways, even if they only contribute limited exposure. Both direct and indirect exposure routes that contribute to the total multi-pathway exposure are assessed. Direct exposure routes are those listed above where ingestion pertains to water, crops, and soil on which pollutants have been directly deposited. Indirect exposure routes are those that result from assimilation of the pollutants into food sources. The indirect exposure routes may include ingestion of fish, meat (domestic and game), poultry (domestic and wild), eggs, dairy products, and cow's and mother's milk. Additional exposure routes may also be present, especially those which are specific to tribal cultures and migrant workers.

Each scenario is made up of components that are potentially exclusive; for example, inhalation of resuspended soil and inhalation of resuspended sediments. For the purpose of the screening risk assessment, the exclusive nature of these related pathways has been ignored, and both components have been included. Thus, for the example of inhalation of resuspended material, the total quantity of dirt inhaled is actually twice what might really be expected. Because human behavior is unpredictable and to capture the potential for risk from both the soil and sediments, no attempt has been made to apportion either pathway. The exposure from separate pathways will rarely be of the same magnitude, so the resulting effect is the highest exposure is automatically assigned to the most contaminated source. This philosophy is similar to that used for scenario development in HSRAM (DOE 1995).

1.2.2 Exposure Factors

Exposure factors are based on the scenario that is to be modeled. The exposure factors defined in the scenarios for use in the screening assessment of risk are the intake/contact rate, exposure frequency, exposure duration, and other factors that apply to only certain media and exposure routes. For instance, skin surface area is another factor that is accounted for when estimating the dermal contact.

HSRAM exposure scenarios include default values for the exposure factors. These default values can often be applied to the CRCIA screening assessment scenarios. Culture-specific activities, however, might require an increase in the default values. To determine such an increase for Native American activities, for instance, tribal staff need to indicate how much the default HSRAM residential scenario default values should be increased to account for a selected set of practices. Information about culture-specific practices is not required. Where possible, activities that are age and gender specific (those performed predominantly by women of childbearing age, elders, etc.) should also be identified.

1.3

The lifestyle of any given individual typically involves several scenarios. A fish hatchery worker might go on vacation and become a recreational visitor. However, the CRCIA screening assessment of risk to human health will follow the HSRAM practice of basing risk assessments on separate scenarios rather than on an individual's lifestyle which might incorporate a variety of the scenarios.

The particular location where culture-specific activities occur is problematic because exposure is closely tied to geographic points of maximum inhalation and deposition. If the location is not identified, then the most useful information to account for the location is the extent to which the default exposure factors should be increased or decreased.

1.3 Stochastic Variability

An objective of CRCIA is to provide information regarding the uncertainty of the risk information that is developed. This information will be developed using stochastic estimation of the risks, based primarily on the uncertainties inherent in the contaminant concentration in the sources and environmental media. However, there will also be variability in the exposure factors selected for the screening assessments, both inherent uncertainty about the selected factors and the inability to capture exactly the lifestyle of people simulated in the scenarios. For each scenario, the range for each intake/contact rate is given in terms of a minimum and maximum value and a corresponding deterministic value. The deterministic values are intended to be conservatively selected, such that exposures to contaminants should be overestimated. The majority of these minima and maxima have been selected using the professional judgement of the authors. Thus, they serve as opening suggestions in what is anticipated to be a continuing discussion. The resulting uncertainty and sensitivity analyses will be used to point out the areas where additional research is needed.

1.4 Key Points

The key points of the exposure scenarios are:

• These scenarios are intended to include the activities of most importance to particular socio-cultural user groups and to translate them into activity-based exposures.

• Each of the scenarios contains assumptions about frequency and duration of the activities, ranging from a few days per year to much more intense use over long time frames. The particular assumptions are specific to individual scenarios.

• These scenarios are amenable to sensitivity and uncertainty analyses, which together could demonstrate the relation between contaminant levels and activity-specific exposures.

• The Native American Scenarios will require review and modification by tribal technical staff before use in applications other than the screening assessment of risk.

2.0 Industrial/Commercial Scenarios

Industrial, commercial, and waste management activities are applicable both on and off the Hanford Site along the Columbia River. The worker scenario developed in HSRAM is a standard industrial/commercial scenario focused on worker exposures to residual environmental contamination. For the scenarios in this section, only the potential exposure from contact with environmental media (as opposed to substances encountered as part of the job) were considered.

A Fish Hatchery Worker Scenario was developed in this section because of the current hatchery activities in the K-Area and at Ringold. The new scenario is benchmarked against the HSRAM industrial scenario. Documentation was provided when possible by employees working under these conditions. However, written data supplied by the interviewed employees have not been validated.

2.1 Industrial Worker (Unmodified HSRAM Definition)

The HSRAM industrial scenario (DOE 1995) is included without modification. However, for use in the Columbia River screening assessment of risk, no groundwater pathways are activated. The specified factors are provided in Table 2.1.

2.2 Fish Hatchery Worker

Currently the Yakama Indian Nation is conducting a pilot experiment in commercial aquaculture by rearing domesticated coho salmon and steelhead-X-rainbow trout in partnership with Scientific Ecology Group, a Westinghouse subsidiary. This scenario is included because these projects are expected to continue. Present and proposed future operations include development of a fish hatchery at the 183-K East and West Filter Plant, Sedimentation and Flocculation Basins, Coagulation Basins, and the Purification Pools. This will be a hatchery similar in function and size of that currently administered by the State Hatchery Program.

The Fish Hatchery Worker description is based on duties described in the job classifications provided by the State Hatchery Program office for the Hanford pilot as well as information gathered from the Eastbank State Hatchery in Ringold. The Eastbank Hatchery is a mid-sized operation which should be comparable to the size of the Tribal Hatchery in the near future. A state hatchery employee may work on a full-time permanent, full-time temporary and/or seasonal basis. According to the job descriptions provided by the State Hatchery Program, the hatchery employee works an average of 250 days/year (estimate based on current employee records) and spends approximately 50-60% of working hours out-of-doors.

The greatest distinction from the standard worker scenario developed by HSRAM is the exposure frequency. In addition, the exposure duration is raised to 30 years for the screening assessment of risk. The rationale for exposure factor values summarized in Table 2.2 is as follows:

Table 2.1. Exposure Factors for the HSRAM Industrial Worker Scenario

Pathways		Exposure Factors[a]					
Media	Exposure Route	Intake/Contact Rate (per day)	Intake/Contact Rate Range Min - Max	Exposure Frequency (days/year)	Exposure Duration (years)	Other Factors	Other Factor Definitions
Soil	Ingestion	50 mg	10 - 150	146[b]	20	--	--
	External	8 hr	2 - 10	146	20	0.8	Shielding factor
	Dermal	0.2 mg/cm²	0.05 - 0.5	146	20	5,000 cm²	Skin surface area
	Inhalation	20 m³	15 - 30	146	20	50 µg/m³	Air mass loading
Air	Inhalation	20 m³	15 - 30	250	20	--	--
Surface Water	Ingestion	1 L	0 - 3	250	20	--	--
	External	8 hr	2 - 10	250	20	--	--
	Dermal	0.17 hr	0 - 1	250	20	20,000 cm²	Total skin surface

a. Selection of exposure factors is described in the text.
b. Derived from frequency of exposure of 0.4 of a year.

Table 2.2. Exposure Factors for the Fish Hatchery Worker Scenario

Pathways		Exposure Factors[a]					
Media	Exposure Route	Intake/Contact Rate (per day)	Intake/Contact Rate Range Min - Max	Exposure Frequency (days/year)	Exposure Duration (years)	Other Factors	Other Factor Definitions
Soil	Ingestion	100 mg	10 - 150	250	30	--	--
	External	8 hr	2 - 10	250	30	0.8	Shielding factor
	Dermal	1 mg/cm²	0.1 - 5	250	30	5,000 cm²	Skin surface area
	Inhalation	20 m³	15 - 30	250	30	50 µg/m³	Air mass loading
Air	Inhalation	20 m³	15 - 30	250	30	--	--
Surface Water	Ingestion	1 L	0 - 3	250	30	--	--
	External	8 hr	2 - 10	250	30	0.25	Geometry correction
	Dermal	1 hr	0 - 1	250	30	5,000 cm²	Skin surface area
a. Selection of exposure factors is described in the text.							

- **Soil Ingestion/External Radiation/Dermal/Inhalation** - The fish hatchery worker is assumed to ingest and/or inhale resuspended dust inadvertently during time spent on the Hanford Site. The daily ingestion intake (100 milligrams/day) is twice the HSRAM value to account for potentially wet and muddy conditions. The inhalation intake (20 m^3/day) is the same as the default value in HSRAM. External radiation exposure is based on an 8-hour working day with minimal shielding. Dermal contact with soil is increased to 1 mg/cm^2 per day over the HSRAM value of 0.2 mg/cm^2 per day.

- **Air Inhalation** - While on the Hanford Site the fish hatchery worker may inhale fugitive dust or gases from varying sources. The individual is assumed to inhale 20 m^3 per day, identical to HSRAM.

- **Surface Water Ingestion/External Radiation/Dermal** - Ingestion of surface water occurs advertently from using processed Columbia River water as drinking water on site and inadvertently from surface water spray while working around the open water. For the present purposes, however, the HSRAM default value of 1 liter/day for on-the-job ingestion was used. The individual is assumed to be exposed to external radiation from river water in the basins. Geometry factors account for some equivalent shielding. Frequent contact with the fish provides a route for dermal absorbtion. The value of 1 hour/day was selected, greater than the 0.17-hour default in HSRAM but with a reduced body surface area.

- **Groundwater** -.No contact with groundwater occurs at present for the tribal fish hatchery worker, although much of the water used in the Eastbank Hatchery comes from the uncontaminated Ringold Springs.

3.0 Wildlife Refuge/Wild and Scenic River Scenarios

The Hanford Site contains several areas of undisturbed ecologies. Various options have been proposed to preserve some or all of these areas, including use as a wildlife refuge or designation as a wild and scenic river.

If portions of the Hanford Site are designated as a wildlife refuge, no on-site continuous residence by humans is expected. Even the rangers would not live on site. The lands would be open to the public for a variety of uses, although no residential or agricultural uses would be permitted. The following recreational and scientific scenarios are possible under the wildlife refuge designation although not all of them were the basis of specific exposure scenario development:

- archeologist
- bird watcher
- deer hunter
- fisher
- intruder/vandal/trespasser
- other and general recreational users
- reactor tour guide
- refuge ranger
- scientific study, monitoring and surveillance workers

Recreational uses include many possible activities such as backpacking, bird watching, camping, picnicking, river boat touring, swimming, water skiing, and wildlife viewing. While there are no current plans for developing recreational facilities on the south shore of the Columbia River, possible development could include a boat-only overnight camping facility, self-guided auto tour routes, and hiking trails.

Public Law 100-605 directs the U.S. Department of Interior, in consultation with DOE, to make recommendations for preservation of the Hanford Reach of the Columbia River. One alternative considered is assignment of the Hanford Reach to the National Wild and Scenic Rivers System. If the Hanford Reach is designated a wild and scenic river, human exposure scenarios in addition to those provided in the HSRAM recreational scenario will be needed to assess risk. The first step in developing the new scenarios is to define wild and scenic river. The second is to understand what significant features would be protected under this classification. The last step is to determine what future land uses are possible given the definition and significant features.

The Wild and Scenic River Act (Public Law 90-542, as amended) uses the following definitions to designate wild or scenic areas. Wild river areas are those rivers or sections of rivers that are free of impoundments and generally inaccessible except by trail, with watersheds or shorelines essentially primitive, and waters unpolluted. These represent the vestiges of primitive America. Scenic river areas are those rivers or sections of rivers that are free of impoundments, with shorelines and watersheds still largely primitive, and shorelines largely undeveloped, but accessible in places by roads.

The location of significant features is important when assessing an actual exposure pathway. Significant features of the area were determined in the Hanford Reach Environmental Impact Statement (NPS 1994). Nationally significant features include:

- archaeologic artifacts of many indigenous cultures preserved along the river
- fall chinook salmon and their spawning and rearing habitat
- federally recognized threatened or endangered plant and animal species
- hydrology and geology suitable for siting of nuclear reactors and radioactive wastes
- intact ecosystem of the river and its adjacent land north to the ridgetop (Wahluke Slope)

Regionally significant features include:

- endangered plants and animals listed by the state
- flatwater recreation
- historic sites
- hunting
- Ringold agricultural area
- sport fishing
- White Bluffs along the north bank of the Hanford Reach

Uses allowed by the Wild and Scenic River Act would include:

- backpacking
- bird and wildlife viewing
- camping
- fishing
- horsepacking
- hunting
- motorized and non-motorized river craft
- mountain bike riding (non-motorized)
- picnicking
- swimming/skiing
- ranching, grazing, farming, and occupation of homes that exist on the date of the enactment

Several of these exposure pathways are covered under the HSRAM (DOE 1995) recreational scenario (see Section 3.3). Three scenarios have been selected for evaluation that should cover the range of potential exposures under the wildlife refuge and wild and scenic rivers possibilities. These are ranger, hunter/ fisher, and river-focused recreational visitor. The ranger represents an individual who visits most habitat types on the site on a regular basis. The hunter/fisher is an individual who visits the site frequently to fish and to hunt for deer, waterfowl, and upland game birds, and ingests game taken. The river-focused recreational visitor is similar to the hunter/fisher but spends more time directly on the river. The following sections describe the exposure pathways and factors for each of the three selected scenarios.

3.1 Ranger

In this scenario the ranger works out of an off-site facility and spends about 3 days/week (150 days/year) on the site. The ranger is assumed to be stationed off site because administration of Hanford as a wildlife refuge would be handled out of the Othello office of the U.S. Fish and Wildlife Service. A field facility on Hanford is unlikely to be established. While on site, the ranger spends a third of the time in each type of habitat: 1) upland range land, 2) along the shoreline, and 3) in a boat on the Columbia River.

The ranger does not drink water from the site. The Ranger Scenario is very similar to the HSRAM industrial scenario except that less time is spent on site. The ranger is assumed to work in the area for 30 years. The rationale for the exposure factor values summarized in Table 3.1 is as follows:

- **Soil Ingestion** - The ranger is assumed to ingest soil inadvertently during time spent on site and in the field. The entire daily intake is assumed to be related to the site.

- **Soil External Radiation Exposure** - The ranger is assumed to be on site 9 hours/day with a third of the time spent in each of three location types: shoreline, boating, and upland. The daily exposure period is set to 3 hours representing the time distribution for the ranger. A shielding reduction factor of 0.8 is applied per HSRAM for soils.

- **Soil Dermal Contact** - Dermal contact is assumed to occur associated with the inadvertent soil ingestion pathway. Soil adheres to the skin at a rate of 0.2 mg/cm^2 per day (one contact event per day). Contact occurs over a total skin surface area of 5,000 cm^2.

- **Resuspended Soil Inhalation** - Resuspension of soil with subsequent inhalation is assumed to occur at all times while the ranger is on site. The amount of resuspension is determined by use of the mass loading approach based on an ambient air mass loading value of 50 μg/m^3. The pollutant concentration in the particulate matter in air is assumed to be the same as the pollutant concentration in soil. The ranger is assumed to inhale a total of 10 m^3 of air during the 9 hours while on site. This provides an average daily intake rate of 10 m^3/day for the exposure analysis.

- **Air Inhalation** - While on site, the ranger is potentially exposed to airborne contamination via inhalation. The ranger is assumed to inhale a total of 10 m^3 of air during the 9 hours while on site. This provides an average daily intake rate of 10 m^3 per day for the exposure analysis. The inhalation exposure occurs for all on-site activities and is included for the entire 9 hours/day.

- **Surface Water Boating External Radiation Exposure** - While the ranger is involved in boating activities, s/he is exposed to radiation emitted from contamination in the water. The exposure frequency is 150 days/year and one-third of the 9-hour work day (3 hours/day). A shielding geometry factor of 0.5 (Napier et al. 1988) is applied because the dose rate is evaluated using factors for total immersion in water (swimming), but while boating the source is effectively one-half that of total immersion.

3.3

Table 3.1. Exposure Factors for the Ranger Scenario

Pathways		Exposure Factors[a]					
Media	Exposure Route	Intake/Contact Rate (per day)	Intake/Contact Rate Range . Min - Max	Exposure Frequency (days/year)	Exposure Duration (years)	Other Factors	Other Factor Definitions
Soil	Ingestion	100 mg	10 - 150	150	30	--	--
	External	3 hr	0 - 4	150	30	0.8	Shielding factor
	Dermal	0.2 mg/cm^2	0.05 - 0.5	150	30	5000 cm^2	Skin surface area
	Inhalation	10 m^3	7 - 15	150	30	50 µg/m^3	Air mass loading
Air	Inhalation	10 m^3	7 - 15	150	30	--	--
Surface Water	Boating External	3 hr	0 - 4	150	30	0.5	Shielding correction
Sediment	Ingestion	100 mg	10 - 150	150	30	--	--
	External	3 hr	0 - 4	150	30	0.2	Geometry correction
	Dermal	0.2 mg^2	0.05 - 0.5	150	30	5000 cm^2	Skin surface area
a. Selection of exposure factors is described in the text.							

- **Sediment Ingestion** - Contact is assumed to occur with shoreline sediment while the ranger is involved in activities along the Columbia River. The contact rate is assumed to be the same as for general soil contact. An intake of 100 milligrams/day is assumed for the time spent along the shore, which is the total daily intake.

- **Sediment Dermal Contact** - Dermal contact occurs along with sediment ingestion and is evaluated in the same manner as soil ingestion. Soil adheres to the skin at a rate of 0.2 mg/cm^2 per day (one contact event per day). Contact occurs over a total skin surface area of 5,000 cm^2.

- **Sediment External Radiation Exposure** - The ranger is exposed to radiation emitted from the sediment while standing on the sediment. The rate of exposure is evaluated in a manner similar to that for standing on contaminated ground, except that a geometry/shielding factor of 0.2 is applied to account for the finite width of the shoreline. The exposure frequency is 150 days/year and one-third of the 9-hour work day. The daily exposure period is set to 3 hours representing the time distribution for the ranger.

3.2 Hunter/Fisher

The Hunter/Fisher Scenario involves an individual who fishes and hunts for game birds and animals on the site. The individual is exposed to soil and air while hunting in upland regions, to shoreline sediment while fishing or hunting, and to river water while fishing and from ingestion of fish, birds, and deer. Upland hunting is considered in this analysis for the Columbia River because game could be potentially contaminated from forays into the riparian zone to browse or drink water.

Exposure to contaminated soil occurs during hunting trips to the site. The hunter success rate is assumed to be typical, but the total catch is 10 times the regional average; in other words, for waterfowl 100 ducks per season (2 ducks per day) and for upland game birds 25 pheasants per season (0.5 pheasants per day) (Washington Department of Fish and Wildlife 1992, 1993, 1994, 1995a). That implies the hunter makes 50 trips hunting for each type of bird: 50 to shoreline environments and 50 to upland areas. Each hunting trip involves 4 hours of on-site exposure with soil or sediment contact at the daily average value.

The maximum number of days that could be spent hunting deer in a season is the length of the various deer hunting seasons (bow, muzzleloader, and firearm). In state game management regions around Hanford (272, 278, 281, 284, 371, and 372) this is 48 days (Washington Department of Fish and Wildlife 1995b). However, it is unlikely that an individual hunter would spend the entire 48 days hunting. A maximum number of 20 days is used in the analysis. The total time spent in upland areas (deer hunting plus upland game bird hunting) is 70 days/year. The remaining 50 days is spent on the river shoreline or boating in the river. The rationale for the exposure factor values summarized in Table 3.2 is as follows:

- **Soil Ingestion** - The hunter is assumed to ingest soil inadvertently during time spent on-site and in the field. The entire daily intake of 100 milligrams/day is assumed to be related to the site.

3.5

Table 3.2. Exposure Factors for the Hunter/Fisher Scenario

Pathways		Exposure Factors[a]					
Media	Exposure Route	Intake/Contact Rate (per day)	Intake/Contact Rate Range Min - Max	Exposure Frequency (days/year)	Exposure Duration (years)	Other Factors	Other Factor Definitions
Soil	Ingestion	100 mg	10 - 150	70 .	30	--	--
	External	4 hr	0 - 8	70	30	0.8	Shielding factor
	Dermal	0.2 mg/cm^2	0.05 - 0.5	70	30	5000 cm^2	Skin surface area
	Inhalation	10 m^3	7 - 15	70	30	50 μg/m^3	Air mass loading
Air	Inhalation	10 m^3	7 - 15	120	30	--	--
Surface Water	External	4 hr	0 - 8	50	30	0.5	Geometry correction
Biota	Fish	54 g	0 - 100	365	30	0.5	WAC 1991 (173-340-730)
	Deer	15 g	0 - 30	365	30	0.19	Hunting success rate
	Upland Birds	9 g	0 - 20	365	30	--	--
	Waterfowl	35 g	0 - 50	365	30	--	--
Sediment	Ingestion	100 mg	10 - 150	50	30	--	--
	External	4 hr	0 - 8	50	30	0.2	Geometry correction
	Dermal	0.2 mg/cm^2	0.05 - 0.5	50	30	5000 cm^2	Skin surface area

a. Selection of exposure factors is described in the text.

- **Soil External Radiation Exposure** - The hunter is assumed to be on site 4 hours/day in upland areas with exposure to soil occurring during that period. A shielding reduction factor of 0.8 is applied per HSRAM.

- **Soil Dermal Contact** - Dermal contact is assumed to occur associated with the inadvertent soil ingestion pathway. Soil adheres to the skin at a rate of 0.2 mg/cm^2 per day (one contact event per day). Contact occurs over a total skin surface area of 5,000 cm^2.

- **Resuspended Soil Inhalation** - Resuspension of soil with subsequent inhalation is assumed to occur at all times while the hunter is on site. The amount of resuspension is determined by use of the mass loading approach as described for the Ranger Scenario. The hunter is assumed to inhale a total of 10 m^3 of air during the 4 hours while on site.

- **Air Inhalation** - While on site, the hunter is potentially exposed to airborne contamination via inhalation. The individual is assumed to inhale a total of 10 m^3 of air during the 4 hours while on site. The inhalation exposure occurs for all on-site activities and is included for the entire 4 hours/day.

- **Surface Water Boating External Radiation Exposure** - While the individual is involved in boating activities, s/he is exposed to radiation emitted from contamination in the water. The exposure frequency is 50 days/year and 4 hours/day. A shielding geometry factor of 0.5 (Napier et al. 1988) is applied because the dose rate is evaluated using factors for total immersion in water (swimming), but while boating the source is effectively one-half that of total immersion.

- **Deer Ingestion** - One deer per season is assumed to be shot and eaten by the hunter and his family. (Elk are not included in this analysis because Hanford elk remain on the Fitzner-Eberhardt Arid Land Ecology reserve almost exclusively and rarely travel across Highway 240 to the Columbia River.) The deer is assumed to have a total weight of 45 kilograms of which a 50-percent yield of deer meat is assumed for a total edible meat weight of 22.5 kilograms/deer (Paustenbach 1989). For an individual in the hunter family of four, the intake rate per individual for one 45-kilogram deer is 15 grams/day. Because the hunting is assumed to continue over a period of 30 years, the hunter success rate of 19 percent is retained from HSRAM.

- **Upland Game Bird Ingestion** - The upland game birds are assumed to be consumed by the hunter and family of four. The weight of meat from each bird is taken to be 0.5 kilogram (50 percent of a 1-kilogram bird). The total weight of upland game birds (25 birds per season) is 12.5 kilograms with consumption by a member of the hunter family of 9 grams/day.

- **Waterfowl Ingestion** - The waterfowl are assumed to be consumed by the hunter and family of four. The weight of meat from each bird is taken to be 0.5 kilogram (50 percent of a 1-kilogram bird). The total weight of water fowl meat (100 waterfowl per season) is 50 kilograms with consumption by each member of the hunter family of 35 grams/day.

- **Fish Ingestion** - The fish are assumed to be consumed by the individual and family. The HSRAM recreational rate of 54 grams/day is retained.

- **Sediment Ingestion** - Contact is assumed to occur with shoreline sediment while the hunter is involved in waterfowl and deer hunting along the Columbia River. The contact rate is assumed to be the same as for general soil contact. An intake of 100 milligrams/day is assumed, which is the total daily intake.

- **Sediment Dermal Contact** - Dermal contact occurs along with sediment ingestion and is evaluated in the same manner as soil ingestion. Soil adheres to the skin at a rate of 0.2 mg/cm^2 per day (one contact event per day). Contact occurs over a total skin surface area of 5,000 cm^2.

- **Sediment External Radiation Exposure** - The hunter is exposed to radiation emitted from the sediment while standing on the sediment. The rate of exposure is evaluated in a manner similar to that for standing on contaminated ground, except that a geometry/shielding factor of 0.2 is applied to account for the finite width.of the shoreline. The exposure frequency is 50 days/year and 4 hours/day.

3.3 Recreational Visitor (Unmodified HSRAM with River-Focused Activities)

This individual is included because many people currently use the Hanford Reach and adjacent wildlife refuge areas. Although there are a variety of year-round recreational activities, one of the most popular is sport fishing. The average angler catches salmon, steelhead, sturgeon and smallmouth bass. This individual may fish along the shoreline or from a motorized or non-motorized boat (DOA 1993). Fishing seasons in Washington are regulated by the Washington Department of Fish and Wildlife, and special rules and seasons are provided for trout, salmon, and sturgeon (Washington Department of Fish and Wildlife 1995c).

Jet and propeller-driven boats are used along the entire Hanford Reach, while non-motorized boats generally stay in the vicinity of the three primitive river access areas: Vernita Bridge, White Bluffs Ferry Landing (east side only), and Ringold Hatchery. Public access to shorelines and islands is restricted, and no overnight camping is allowed within the Hanford Site. Recreational boating is only a day use activity. Data as to daily fishing and boating stay times per individual have not been determined. However, current factors as reported in HSRAM indicate that this individual may be potentially exposed 7 days/year averaged over a 70-year lifetime.

For the purposes of this study, the standard HSRAM recreational scenario is used as a baseline. If the Hanford Reach is designated wild and scenic, the access to and use of the Reach would likely increase somewhat, and the 7 days/year exposure frequency for visitors might need to be increased. For this report, the HSRAM recreational scenario is included without modification. HSRAM-specified factors for this scenario are provided in Table 3.3.

Table 3.3. Exposure Factors for the HSRAM Recreational Visitor Scenario

Pathways		Exposure Factors					
Media	Exposure Route	Intake/Contact Rate [a] (per day)	Intake/Contact Rate Range Min - Max	Exposure Frequency (days/year)	Exposure Duration[a] (years)	Other Factors	Other Factor Definitions
Soil	Ingestion	200 mg (C) 100 mg (A)	20 - 500 10 - 150	7	6 (C) 24 (A)	--	--
	External	8 hr	2 - 12	7	30	0.8	Shielding correction
	Dermal	0.2 mg/cm²	0.05 - 0.5	7	30	5000 cm²	Skin surface area
Air	Inhalation	20 m³	15 - 30	7	30	--	--
Seep/Spring Water	Ingestion	2 L	0 - 3	7	30	--	--
	Dermal	0.17 hr	0 - 1	7	30	20,000 cm²	Skin surface area
Surface Water	Ingestion	2 L	0 - 3	7	30	--	--
	Dermal	2.6 hr	1 - 8	7	30	20,000 cm²	Skin surface area
Sediment	Ingestion	200 mg (C) 100 mg (A)	20 - 500 10 - 150	7	6 (C) 24 (A)	--	--
	Dermal	0.2 mg/cm²	0.05 - 0.5	7	30	5000 cm²	Skin surface area
Biota	Waterfowl	--	--	--		--	--
	Game	15 g[b]	0 - 9	365	30	0.19	See footnote c
	Fish	54 g[d]	0 - 100	365	30	0.5	Diet fraction
	Plants	--	--	--	--	--	--

a. Factors recommended in EPA (1991) except as noted.
b. Venison consumption rate based on a 45-kilogram deer per family per year (Paustenbach 1989)
c. Intake adjusted for upperbound mean deer hunter success rate of 19 percent for game management unit 370
d. WAC (1991) (173-340-730).

C = Child
A = Adult

3.9

4.0 Native American Scenarios

The range of potential Native American activities on the Hanford Site is very broad. They include activities specifically delineated in the Treaties and also include a range of unlisted but reserved rights related to traditional lifestyles and to preservation activities related to heritage (natural and cultural) resources. Specific activities (or activity categories) include hunting, gathering, collecting, fishing and processing of the catch along the shoreline, pasturing of livestock, working in the fish hatchery, as well as ceremonial, educational, seasonal, social, and trade activities, including a variety of unique activities, some of which have no standard suburban surrogate activity in HSRAM. Fish hatchery work (except for actual time spent on/in the river) is considered in the Industrial/Commercial Scenarios. The other activities are intended to be included here.

Four semi-quantitative but not necessarily all-inclusive scenarios were constructed to span the range of potential treaty-reserved activities:

- Subsistence Resident (an unrestricted use scenario included as a baseline for comparison)

- Hunter/Gatherer (hunting/gathering/fishing/collecting/pasturing activities without groundwater ingestion)

- Cultural Activities Visitor (without groundwater ingestion)

- Columbia River Island User (for application to Cobalt-60 particles)

The Subsistence Resident Scenario is intended to represent a reasonable set of activities that reflect a traditional lifestyle with activities occurring for life on what is now the Hanford Site. This particular scenario is based on limited tribal information. Therefore, this scenario may not adequately represent any complete set of tribal activities. However, this set of activities is to be used in the screening analysis. The activities assume access to both the shoreline and to seeps/springs. Seep/spring water could be used for ingestion and biotic uptake directly from in situ groundwater, but it is assumed that irrigation would not occur (an unresolved issue).

The Hunter/Gatherer and Cultural Activities Visitor Scenarios basically split the Subsistence Resident Scenario into two sets of lesser activity: 150 days/year spent hunting, gathering, fishing and 30 days/year spent on non-food and medicine activities. These two scenarios assume that there is no groundwater access except via biotic uptake. Seep/spring water ingestion is included in the river water ingestion. The hunter/gatherer who visits the site to gather food and medicine is assumed to spend 100 days/year fishing, 25 days hunting, and 25 days gathering. While some of these activities are, in fact, gender-specific and age-specific, they are combined into a single activity set at present. A listing of specific activities conducted under food-related and non-food-related headings is not required for screening-level precision. Only an indication of the frequency of site visits and similar information related to the degree of contact with environmental media is needed. Further, specific information about particular plant species and other

sensitive information is not useful because the fate and transport models of contaminant movement through the biosphere may not at present provide a way to discriminate among species. Fate and transport models must be examined for their ability to handle information about species-specific uptake and distribution among plant parts or animal tissues before justification exists for requesting sensitive information from tribal members.

Issues especially relevant to Native American scenarios are:

1. The extent of on-site groundwater/seep/spring use is unresolved at present. For the Subsistence Resident Scenario, full seep/spring access is assumed for ingestion but not irrigation. Water ingestion rates are divided between surface water and seep/spring water, as deemed appropriate by tribal technical staff. For the other three scenarios, no seep/spring use is assumed except via biotic uptake.

2. Different tribes have historically used the Hanford Reach to different degrees. The issue is how to protect those tribes and individual members who are most exposed and how to determine to what degree full exercise of treaty-reserved rights imposes uneven exposure burdens on particular individuals or groups. In addition, the sensitive segments of the subsistence population (children, elders, women of child-bearing age) are not addressed in these scenarios.

3. Ethics and equity issues will likely fall disproportionately on tribal communities as they are asked to accept decisions that have ramifications on their ability to exercise treaty-reserved rights. There are many issues that will need to be identified and discussed in open forums.

4. The subsistence scenario is based on limited input from tribal staff. Additional development of this and the subsidiary scenarios should occur before these scenarios are used for routine regulatory analyses.

4.1 Subsistence Resident

In this scenario, a person fully exercises treaty-reserved rights and spends full time (365 days, 24 hours/day) on the site for a lifetime of 70 years. Activities include hunting, gathering, collecting, fishing, and limited pasturing of livestock. Pasturing of livestock for consumption is included here because human exposure could result, but pasturing of horses would be considered part of an ecological assessment because the horse is the ultimate receptor. Exposures related to these activities can occur both from ingestion as well as during gathering, preparation, and non-ingestion uses (Harris 1993, 1995). Additionally, exposures not related to nutrition could occur during other types of Hanford Site visits, such as religious and educational. Access to seep/spring water for all uses except irrigation and surface water are assumed, as is access to the shoreline. Preliminary assumptions and selection of exposure factors are described below and for the most part do not consider stratification of activities among age groups or by gender, although this clearly occurs. As with all of these scenarios, this section will require review and modification by tribal technical staff before this scenario is used in applications other than the screening assessment of risk. The rational for the exposure factor values is as follows:

- **Soil Ingestion** - A person is assumed to continue a child's soil ingestion rate (200 milligrams/day) throughout life. A child's ingestion could be considered separately, because a child ingests more per body weight than an adult. However, in this example the 6 (conventional) childhood years are not separated from the adult years.

- **Soil External Radiation Exposure** - The person is assumed to be on site 24 hours/day, and, for this example, the time is not divided among location types (shoreline, boating and upland). A shielding reduction factor of 0.8 is applied per HSRAM, which assumes that the person is standing on contaminated soil during the entire exposure period. This factor may need to be modified as appropriate for activities such as gathering of root crops.

- **Soil Dermal Contact** - Dermal contact is assumed to occur associated with the inadvertent soil ingestion pathway. Soil is assumed to adhere to the skin at a rate of 1 mg/cm^2 per day (compared to the 0.2 mg/cm^2 default value). Contact would occur over a skin surface area of 5,000 cm^2 (this is the default value and represents 25 percent of the total skin surface area). The skin absorption fraction (ABS) is pollutant-specific. The increased soil adherence rate needs to be reviewed for suitability for not only initial contact, for instance, during gathering of root crops but also during cleaning and preparation.

- **Resuspended Soil Inhalation** - Resuspension of soil with subsequent inhalation is assumed to occur at all times while the person is on site. The amount of resuspension is determined by use of the mass loading approach based on an ambient air mass loading value of 100 μg/m^3 (twice the EPA recommended value for suburban areas). The pollutant concentration in the particulate matter is assumed to be the same as the pollutant concentration in the soil. The person is assumed to inhale 30 m^3 of air during the 24 hours s/he is on-site. This is 150 percent of the default value to account for a more active outdoor lifestyle.

- **Air Inhalation** - The person is assumed to inhale 150 percent of the default volume of air per day (30 m^3/day) to account for a lifestyle more active than that assumed for suburban dwellers.

- **Seep/Spring Water Ingestion** - For this scenario, the person is assumed to get two-thirds (2 liters/day) of his daily water intake from seep/spring water. The total of seep/spring water plus surface water ingestion equals 150 percent of the default value of 2 liters/day to account for an active, outdoor lifestyle. This ratio could be altered if appropriate. No decay of radionuclides between withdrawal of seep/spring water and ingestion is assumed and no filtration of particulate matter (in other words, the concentration of contaminant in unfiltered seep/spring water is the appropriate comparison value unless determined to be otherwise appropriate).

- **Seep/Spring Water Inhalation** - The inhalation rate of 15 m^3/day represents volatilization of pollutants from seep/spring water into a relatively small space or short distance. It typically includes indoor activities such as showering and cooking. Because these activities or analogues of these activities could be expected to occur during subsistence living, the default factor is included here. The quantity of water in indoor air is based on the absolute humidity (Andelman 1990).

4.3

- **Seep/Spring Water Dermal Contact** - On the average, 1 hour/day is assumed to be spent in activities associated with seeps or springs, such as digging for roots, collecting medicines, or drawing water. This is assumed to contaminate a portion of the skin (5000 cm^2), rather than the entire body.

- **Surface Water Ingestion** - For this scenario, the person is assumed to get one-third (1 liter/day) of his daily water intake from surface water and the rest from seep/spring water. While a person is expected to inadvertently ingest water during swimming (at a rate of 0.01 liter/hour x 2.6 hours/swim), this is not expected to add significantly to his total daily water intake. Swimming-specific exposures can be pulled out of the surface water exposures and evaluated separately if desired.

- **Surface Water External Radiation Exposure** - Swimming and boating are assumed to occur for 2.6 hours/day for 70 days/year, and shoreline use is assumed to occur for 12 hours/day for 270 days/year. During boating, the boat is assumed to shield the person from half of the radiation coming from the surface water.

- **Surface Water Inhalation** - The person is assumed to inhale near-surface volatiles while swimming 2.6 hours each of 70 days during the year. The volume of air (15 m^3/day) has been split among seep/spring water and surface water inhalation routes.

- **Surface Water (Swimming) Dermal Contact** - The dermal contact during swimming assumed 2.6 hours of swimming for 70 days, with a total skin surface contact area of 20,000 cm^2. The absorption coefficient is pollutant specific.

- **Food Ingestion Rates** - A fish consumption rate of 270 grams/day (10-fold higher than HSRAM) is a rough estimate of a high-end consumption rate (CRITFC 1994) but is likely to be well below traditional subsistence levels (DOI 1942, Hunn 1990, CRCIA Team meeting minutes February 6, 1996). Tribal input indicates that this may be a composite of 50 percent fresh weight and 50 percent dried weight, so conversion with a wet-to-dry ratio of 3 yields the value used of 540 grams/day equivalent fresh weight.

Food ingestion factors were adjusted upward from HSRAM by assuming that 100 percent of plant material ingested is of local origin and 100 percent of fish ingested is of local origin. HSRAM includes all types of plants within general fruit and vegetable categories rather than subdividing plant types into root, vine, leafy, fruit and grass/pasture. Strenge and Chamberlain (1994) further indicate that current Hanford models use a single set of contaminant-specific uptake factors that do not distinguish among plant species or classes, plant types, or plant parts, so that there is, in effect, a single overall vegetable-matter ingestion rate in HSRAM. On the basis of tribal input, this is increased here to 660 grams/day based on 330 grams/day intake, of which 50 percent is fresh and 50 percent is dried. Conversion to fresh weight, assuming a wet-to-dry ratio of 3, gives the equivalent fresh weight used. It will not be useful to investigate specific ingestion rates of roots, fruits, etc. unless uptake factors to specific plant parts (roots versus leaves) or specific plant species are available. Medicinal and other uses of plant material, however, may provide reason for a slight increase in this ingestion

4.4

rate. Methods of preparation and use might need to be specified for particular situations. Each risk assessment application should be reviewed for the ability of the fate and transport models to provide the level of detail needed for the assessment context.

The HSRAM value for meat and game intake is superceded with a single animal protein consumption rate based on tribal input of 75 grams/day of animal protein (which may include flesh, fat, marrow, etc.), of which 50 percent is fresh and 50 percent is dried. Conversion to fresh weight, assuming a wet-to-dry ratio of 3, gives the equivalent fresh weight of 150 grams/day. The waterfowl and upland game bird consumption rates are assumed to be the same for subsistence as they are for the Hunter/Fisher Scenario. This needs to be reviewed for seasonal take, length of season, and special hunting privileges. Again, since contaminant concentration among animal/fowl species is currently modeled solely on the basis of proportional animal body weight, it will not be useful to determine consumption rates of specific species or animal organs/tissues unless information about contaminant uptake and tissue distribution is available.

For the screening-level risk assessment, ingestion pathways for milk from locally grazing cattle and for eggs collected from local nests, have not been included. However, these pathways are indicated in Table 4.1 as placeholders to indicate to future readers the possible necessity of including these pathways. An additional pathway that should also be considered is mothers' breast milk.

- **Shoreline Sediment Ingestion** - Contact is assumed to occur daily since most of the on-site activity is directed toward river-based resources and activities. The sediment ingestion rate is the same as that for soil and is in addition to it.

- **Shoreline Sediment Dermal Contact** - This pathway is similar to the surface soil dermal pathway, and it may be appropriate to split exposure time between them.

- **Shoreline Sediment External Radiation Exposure** - The person is exposed to radiation emitted from the sediment while standing on the shoreline. A shore width geometry correction factor of 0.2 is applied to account for the non-infinite nature of the shoreline contamination.

- **Cultural Pathways** - Particular activities, such as sweat bathing and smudging, need to be included. These can be factored into the equations provided in Section 6. Activities can be disaggregated into their component pathways. Details regarding culturally sensitive practices may be then reaggregated into lumped exposure factors. This approach may be expanded to include direct exposure to cultural materials and/or dermal absorption from contact from cultural materials. For the screening level risk assessment, sweat bathing is explicitly added. Based on tribal descriptions, a nominal time of 1 hour/ day is assumed to be spent inside a sweat lodge kept at 80 degrees Centigrade (180 degrees Fahrenheit). Air inside the sweat lodge is assumed to be saturated with water (equivalent to 0.3 kilograms of water per m^3 of air), which adds to the potential for inhalation and dermal exposures.

Table 4.1. Exposure Factors for the Native American Subsistence Resident Scenario

Pathways		Exposure Factors					
Media	Exposure Route	Intake/Contact Rate (per day)	Intake/Contact Rate Range Min - Max	Exposure Frequency (days/year)	Exposure Duration (years)	Other Factors	Other Factor Definitions
Soil	Ingestion[a]	200 mg	20 - 500	270	70	--	--
	External	24 hr	12 - 24	270	70	0.8	Shielding factor
	Dermal	1 mg/cm²	0.5 - 5	270	70	5000 cm²	Skin surface area
	Inhalation	30 m³	20 - 35	270	70	100 μg/m³	Air mass loading
Air	Inhalation	30 m³	20 - 35	365	70	--	--
Seep/Spring Water	Ingestion[b]	2 L	0 - 3	365	70	--	--
	Dermal[c]	1 hr	0 - 2	365	70	20,000 cm²	Skin surface area
	Inhalation[d]	15 m³	10 - 20	365	70	0.1 L/m³	See footnote e
Surface Water	Ingestion[b]	1 L	0 - 3	365	70	--	--
	External	2.6 hr	0.5 - 4	70	70	0.5	Geometry correction
	Dermal[f]	2.6 hr	1 - 4	70	70	20,000 cm²	Skin surface area
	Inhalation[g]	15 m³	10 - 20	70	70	0.1 L/m³	See footnote e
Sediment	Ingestion	200 mg	20 - 500	270	70	--	--
	External	12 hr	4 - 24	270	70	0.2	Geometry correction
	Dermal	1 mg/cm²	0.5 - 5	270	70	5000 cm²	Skin surface area
Biota[h]	Fish[i]	540 g	100 - 600	365	70	--	--
	Fruit and vegetation	660 g	200 - 800	365	70	--	--
	Animal protein[j]	150 g	75 - 200	365	70	--	--
	Milk[k]	0.6 L	0 - 1	365	70	--	--
	Upland Birds	9 g	0 - 20	365	70	--	--
	Waterfowl	35 g	0 - 50	365	70	--	--
	Wild bird eggs[k]	45 g	0 - 135	365	70	--	--
Cultural[l]	Inhalation	1 hr	0.25 - 1.5	365	70	0.3 L/m³	Saturated air at 80° C (180°F)
	Dermal	1 hr	0.25 - 1.5	365	70	20,000 cm²	Skin surface area

Table 4.1. (contd)

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. Ingestion of seep/spring water + surface water equals 3 liters/day.

c. The dermal factor for seep/spring water in HSRAM reflects bathing. For this scenario, it is assumed that seep/spring water is encountered regularly while gathering roots.

d. In HSRAM, seep/spring water use is a household scenario where inhalation comes from volatilization during showering and other household use. To the extent that analogous activities occur, this factor is retained.

e. 0.0001 x 1000 liters/m^3 (Andleman 1990).

f. For surface water, only swimming (2.6 hours/day) is included.

g. As for seep/spring water, exposures may still occur that are the equivalent of suburban household exposures.

h. Foodchain pathways include deposition, soil uptake and seep/spring water uptake, 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), etc.

i. Fish consumption includes multiple species and parts eaten, prepared both fresh and dried. Equivalent fresh weight is given here.

j. The animal protein consumption rate includes meat, fat, and marrow, prepared fresh or dried. The equivalent fresh weight is given here.

k. These pathways are not considered in the screening risk assessment but are included here for future reference.

l. The unique pathway related to volatilization of contaminants from water during sweat bathing is included here. The absolute humidity is based on saturated conditions at a temperature of 80 degrees Centigrade (180 degrees Farenheit).

4.7

4.2 Hunter/Gatherer

This scenario is a subset of the Subsistence Resident Scenario, a subset that contains only the pathways related to foods and medicines. The hunter/gatherer is assumed to be on site for 150 days/year of which 100 are spent fishing, 25 hunting and 25 gathering/collecting. Shoreline access is assumed, and these activities remain at the 24 hours/day duration for 30 years. These frequencies are intended to represent a reasonable but less-than-subsistence usage level. The most significant difference is that no direct seep/ spring water access is assumed, and, therefore, seep/spring contamination can only reach the person through the food chain. Table 4.2 summarizes the exposure values used for the Hunter/Gatherer Scenario.

4.3 Cultural Activities Visitor

This scenario is the other subset of the Subsistence Resident Scenario. It includes on-site access for 30 days/year for cultural activities and not for gathering and ingesting foods and medicines. The types of activities intended to be addressed in the Cultural Activities Visitor Scenario include ceremonial, educational, religious, and similar activities. Presently, no surface water or biota are included. To the extent that some of the cultural activities may require the special collection and/or ingestion of water, plant or animal material, these media may need to be included in this scenario. No confidential information has been used. These semi-quantitative applications estimate what fraction of a person's time might be spent in a general area. Table 4.3 summarizes the exposure values used for the Cultural Activities Visitor Scenario.

4.4 Columbia River Island User

Discrete radioactive particles, primarily cobalt-60, have been found on islands and along the shores of the Columbia River (Sula 1980). These were identified as of concern to dose (Napier et al. 1995). The scenario is based on Native American traditional uses of the island involving extended occupation and as a base for fishing or other traditional uses.

Within the basic scenario, several pathways are evaluated. These include inhaling a particle, ingesting a particle (during incidental ingestion of small amounts of sediments), direct external radiation exposure without contact, and lodging of a particle on the skin.

The time spent on the island is important in calculating the likelihood that a person will interact with a particle. For the initial phase of the CRCIA analyses, a distribution of times is used. The distribution used assumes an individual spends a minimum of 4 hours and a maximum of 40 days on the island every year. The most likely value is 2 days.

Standard values are provided by HSRAM for uptake of soil onto skin (DOE 1995). A skin loading of 0.2 mg/cm^2 is used. However, a distribution of the retention time of the soil on the skin is used. Soil is assumed to remain on the skin from 0 to 48 hours in a triangular distribution with a most likely value of 2 hours. Exposed skin area is assumed to be at least 5000 cm^2 and ranges uniformly up to the total skin area of 15,000 cm^2.

Table 4.2. Exposure Factors for the Native American Hunter/Gatherer Scenario

Pathways		Exposure Factors					
Media	Exposure Route	Intake/Contact Rate (per day)	Intake/Contact Rate Range Min - Max	Exposure Frequency (days/year)	Exposure Duration (year)	Other Factors	Other Factor Definitions
Soil	Ingestion[a]	200 mg	20 - 500	150	30	--	--
	External	24 hr	12 - 24	150	30	0.8	Shielding factor
	Dermal	1 mg/cm²	0.5 - 5	150	30	5000 cm²	Skin surface area
	Inhalation	20 m³	15 - 30	150	30	100 μg/m³	Air mass loading
Air	Inhalation	20 m³	15 - 30	150	30	--	--
Surface Water	Ingestion	2 L	0 - 3	100	30	--	--
	External	2.6 hr	0.5 - 4	50	30	0.5	Geometry correction
	Dermal[b]	2.6 hr	0.5 - 4	50	30	20,000 cm²	Skin surface area
Sediment	Ingestion	200 mg	20 - 500	100	30	--	--
	External	12 hr	4 - 24	100	30	0.2	Geometry correction
	Dermal	1 mg/cm²	0.5 - 5	100	30	5000 cm²	Skin surface area
Biota[c]	Fish[d]	540 g	100 - 600	365	30	--	--
	Fruit and vegetation	660 g	200 - 800	365	30	--	--
	Game	150 g	75 - 250	365	30	--	--
	Upland Birds	9 g	0 - 20	365	30	--	--
	Waterfowl	35 g	0 - 50	365	30	--	--
	Wild bird eggs[e]	45 g	0 - 135	365	30	--	--

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. For surface water, only swimming (2.6 hours/day) is included.
c. Foodchain pathways include deposition, soil uptake and seep/spring water uptake, 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), etc.
d. Fish consumption includes multiple species and parts eaten, prepared both fresh and dried. Equivalent fresh weight is given here.
e. This pathway is not considered in the scoping level risk assessment but is included here for future reference.

Table 4.3. Exposure Factors for the Native American Cultural Activities Visitor Scenario

Pathways		Exposure Parameters					
Media	Exposure Route	Intake/Contact Rate (per day)	Intake/Contact Rate Range Min - Max	Exposure Frequency (days/year)	Exposure Duration (years)	Other Factors	Other Factor Definitions
Soil/Sediment	Ingestion[a]	200 mg	20 - 500	30	30	--	--
	External	24 hr	12-24	30	30	0.8	Shielding Factor
	Dermal	1 mg/cm²	0.5 - 5	30	6(C) 24(A)	2500 cm²(C) 5000 cm²(A)	Skin surface area
	Inhalation	10 m³	7 - 15	30	30	100 μg/m³	Air mass loading
Air	Inhalation	20 m³	15 - 30	30	30	--	--
Cultural[b]	Dermal	1 hr	0.25 - 1.5	30	30	20,000 cm²	Skin surface area
	Inhalation	1 hr	0.25 - 1.5	30	30	0.3 kg/m³	Saturated air at 80°C (180°F)

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. The unique pathway related to volatilization of contaminants from water during sweat bathing is included here. The absolute humidity is based on saturated conditions at a temperature of 80 degrees centigrade (180 degrees Farenheit)

C = Child
A = Adult

Other exposure factors used are per HSRAM (see Table 4.4). The particle activity is described as a log normal distribution with a median of 2.3 μCi and a geometric standard deviation of 2.8. In some instances, the value of the average particle activity is needed. It is taken to be 2.3 with a normal distribution and standard deviation of 10 percent. The particle density in the rocky areas is assumed to lie uniformly between $5x10^{-8}$ particles per m^3 and $1x10^{-6}$ particles per m^3. In the sandy areas, it is assumed to range from the same low, $5x10^{-8}$, to as high as $4x10^{-6}$. No credit is assumed for shielding from direct irradiation other than that afforded by the distributed nature of the particles in soil.

Table 4.4 Exposure Factors for the Columbia River Island User Scenario

Constant	Value
Sediment ingestion rate	200 mg/day
Ingestion dose factor	3.77 rem/pCi
Ingestion slope factor	0.00000673 pCi^{-1}
Cobalt-60 half-life	5.27 years
Lifetime	70 years
Dust loading	0.1 mg/m^3
Breathing rate	20 m^3/day
Soil density	500 mg/cm^3

A series of equations were established to describe the individual exposure pathways for the Columbia River island user. These equations differ from the more general ones presented in Section 6.

For the likelihood of being subjected to a skin lesion/beta particle burn, the equation is

(Probability of picking up a particle on the skin/day) * (Number of days on the island/year)
* (Particle activity) * (Time on the skin)

For external irradiation without direct contact, the equation is

(Time spent on island) * (Particle density) * (Slope factor) * (Decay integral)

The decay integral is required in this calculation because the slope factor is defined for constant exposure over a lifetime. Thus, the scenario assumes that the individual is exposed every year of her/his life. Because cobalt-60 has a 5.27-year half-life, the exposures decrease rapidly. This must be accounted for in the exposure estimate.

For the possibility of ingestion of a particle, the equation is

(Ingestion rate) * (Concentration) * (Time on island) * (Ingestion slope factor) * (Decay integral)

The scenario is established for a lifetime of exposure, so the annual exposures are multiplied by the integral of the activity over a 70 year lifetime.

For inhalation, the equation is based on lodging of a discrete particle in the nose, as

(Inhalation rate) * (Time on island) * (Particle density) * (Particle activity) * (Retention time in nose)

The possibility of inhaling a discrete radioactive particle was addressed by Durham and Soldat in the appendix of Cooper and Woodruff (1993). They found the physical size of the particles was such that it was not possible to inhale one into the lungs. At worst, the particles would lodge in the anterior portion of the nose. Durham used the specific activity of hot particles commonly found in the commercial nuclear industry in his calculation (60,000 Ci/cm^3). This specific activity relates to relatively young particles. Those found in the Columbia River from plutonium production activities are at least 25 years old and so older than those studied by Durham. Thus, for the same particle activity, the particles would physically be much larger than assumed by Durham. He based his calculations on a 10-micron particle. The typical size found by Sula is 0.1 mm (100 microns). Therefore, the nasal retention used by Durham (1 to 2 days) is considerably longer than what would occur with this size particle. Nevertheless, a retention of up to 2 days has been used in this analysis.

5.0 General Population Scenarios

In the CRCIA screening assessment, two general population scenarios will be assessed for risk: a Resident Scenario and an Agricultural Resident Scenario. Except for the differences denoted below, the factors used for both of these scenarios are from HSRAM (DOE 1995).

To accommodate potential irrigation with river water for the Resident Scenario, irrigation of fruits and vegetables is included at a rate of 45 inches/year. No groundwater pathways are included in applications off the Hanford Site. HSRAM-specified factors for this scenario are provided in Table 5.1.

To accommodate potential irrigation with river water for the Agricultural Resident Scenario, irrigation of fruits and vegetables is included at a rate of 45 inches/year. No groundwater pathways are included in applications off the Hanford Site. HSRAM-specified factors for this scenario are provided in Table 5.2.

Table 5.1. Exposure Factors for the HSRAM Resident Scenario

Pathway		Exposure Parameters					
Media	Exposure Route	Intake/Contact Rate [a] (per day)	Intake/Contact Rate Range Min - Max	Exposure Frequency[b] (days/year)	Exposure Duration[a] (year)	Other Factors	Other Factor Definitions
Soil	Ingestion	200 mg (C) 100 mg (A)	20 - 500 10 - 150	365	6 (C) 24 (A)	--	--
	External	24 hr[c]	8 - 24	365	30	0.8	Shielding factor
	Dermal	0.2 mg/cm^2	0.05 - 0.5	180	30	5000 cm^2	Skin surface area
Air	Inhalation	20 m^3	15 - 30	365	30	--	--
Seep/Spring Water	Ingestion	2 L[b]	0 - 3	365	30	--	--
	Dermal	0.17 hr	0 - 1	365	30	20,000 cm^2	Skin surface area
	Inhalation	15 m^3[d]	10 - 20	365	30	0.1 L/m^3	See footnote e
Surface Water	Ingestion	2 L[b]	0 - 3	365	30	--	--
	Dermal/showering	0.17 hr	0.1 - 1	365	30	20,000 cm^2	Skin surface area
	Dermal/swimming	2.6 hr	0 - 8	7	30	20,000 cm^2	Skin surface area
	Inhalation	15 m^3[e]	10 - 20	365	30	0.1 L/m^3	See footnote e
Sediment[k]	Ingestion	200 mg (C) 100 mg (A)	20 - 500 10 - 150	7	6 (C) 24 (A)	--	--
	Dermal	0.2 mg/cm^2	0.05 - 0.5	7	30	5000 cm^2	Skin surface area
Biota[l]	Fish	54 g[f]	0 - 100	365	30	0.5	See footnote f
	Fruit	42 g[g]	0 - 100	365	30	--	--
	Vegetable	80 g[g]	0 - 200	365	30	--	--

a. Factors recommended in EPA (1991) except as noted.
b. Factors recommended in WAC (1991) (173-340-720, 740, 750, Method B) except as noted.
c. Site-specific factor; see text for additional information.
d. Indoor inhalation rate (EPA 1991).
e. 0.0001 x 1,000 liters/m^3 (Andelman 1990).
f. WAC (1991) (173-340-730).
g. Based on wet weight (EPA 1991).

C = Child
A = Adult

Table 5.2. Exposure Factors for the HSRAM Agricultural Resident Scenario

Pathways		Exposure Parameters					
Media	Exposure Route	Intake/Contact Rate [a] (per day)	Intake/Contact Rate Range Min - Max	Exposure Frequency[b] (days/year)	Exposure Duration[a] (years)	Other Factors	Other Factor Definitions
Soil	Ingestion	200 mg (C) 100 mg (A)	20 - 500 10 - 150	365	6 (C) 24 (A)	--	--
	External	24 hr[c]	8 - 24	365	30	0.8	Shielding factor
	Dermal	0.2 mg/cm²	0.05 - 0.5	365	30	5000 cm²	Skin surface area
Air	Inhalation	20 m³	15 - 30	365	30	--	--
Groundwater	Ingestion	2 L[b]	0 - 3	365	30	--	--
	Dermal	0.17 hr	0 - 1	365	30	20,000 cm²	Skin surface area
	Inhalation	15 m³ᵈ	10 - 20	365	30	0.1 L/m³	See footnote e
Surface Water	Ingestion	2 L[b]	0 - 3	365	30	--	--
	Dermal/showering	0.17 hr	0.1 - 1	365	30	20,000 cm²	Skin surface area
	Dermal/swimming	2.6 hr	0 - 8	7	30	20,000 cm²	Skin surface area
	Inhalation	15 m³ᵈ	10 - 20	365	30	0.1 L/m³	See footnote e
Sediment	Ingestion	200 mg (C) 100 mg (A)	20 - 500 10 - 150	7ᶜ	6 (C) 24 (A)	--	--
	Dermal	0.2 mg/cm²	0.05 - 0.5	7	30	5,000 cm²	Skin surface area
Biota	Fish	54 gᶠ	0 - 100	365	30	0.5	See footnote f
	Fruit	42 gᵍ	0 - 200	365	30	--	--
	Vegetable	80 gᵍ	0 - 300	365	30	--	--
	Game	15 gʰ	0 - 100	365	30	0.19	See footnote i
	Beef	75 g	0 - 150	365	30	--	--
	Dairy	300 g	100 - 1000	365	30	--	--

a. Factors recommended in EPA (1991) except as noted.
b. Factors recommended in WAC (1991) (173-340-720, 740, 750, Method B) except as noted.
c. Site-specific factor; see text for additional information.
d. Indoor inhalation rate (EPA 1991).
e 0.0001 x 1,000 liters/m³ (Andelman 1990).
f. WAC (1991) (173-340-730.)
g. Based on wet weight (EPA 1991).
h. Venison consumption rate based on 45-kilogram deer per family per year (Paustenbach 1989).
i. Intake adjusted for upperbound hunter success rate of 19 percent for game management unit 370.

C = Child
A = Adult

6.0 Exposure Equations

The exposure equations described in this section will be used to assess human risk at a screening level. The results of that work will be published in a future report on the screening assessment of risk. The values defined in the various scenarios will be the values used in these equations. The equations are based on the exposure routes: external radiation, dermal, inhalation, and ingestion. These exposure equations are adapted and expanded from those in Appendix D of the Hanford Site Risk Assessment Methodology (DOE 1995). The same notation and terminology is used for consistency with HSRAM. Additions (described in the previous sections) have been made to the equations to make them more directly applicable to the CRCIA screening assessment scenarios.

6.1 External Radiation Exposure

$$
\begin{aligned}
\text{Dose}_{ext} = {} & [(C_{soil} \times ET_{soil} \times RF_{soil} \times EF_{soil} + C_{sed} \times ET_{sed} \times EF_{sed}) \times DF1 + \\
& C_{river} \times ET_{swim} \times EF_{swim} \times DF2 + C_{river} \times ET_{boat} \times EF_{boat} \times DF3 + \\
& \Sigma\, (C_{items} \times ET_{items} \times EF_{items} \times DF4)] \times ED
\end{aligned}
$$

where.

C_{soil}	=	Radionuclide concentration in soil (pCi/g)
C_{sed}	=	Radionuclide concentration in sediment (pCi/g)
C_{river}	=	Radionuclide concentration in river water (pCi/L)
C_{items}	=	Radionuclide concentrations in cultural items (pCi/g) - an example might be woven mats made of contaminated reeds
DF1	=	Dose conversion factor for soils and sediments (rem/hr per pCi/g)
DF2	=	Dose conversion factor for swimming (rem/hr per pCi/L)
DF3	=	Dose conversion factor for boating (rem/hr per pCi/L)
DF4	=	Dose conversion factor for contact with small items (rem/hr per pCi/g)
Dose_{ext}	=	External dose from radionuclide (rem)
ED	=	Exposure duration (yr)
EF_{soil}	=	Exposure frequency for soils (day/yr)
EF_{sed}	=	Exposure frequency for sediments (day/yr)
EF_{swim}	=	Exposure frequency for swimming (day/yr)
EF_{boat}	=	Exposure frequency for boating (day/yr)
EF_{items}	=	Exposure frequency for each cultural item (day/yr)
ET_{soil}	=	Exposure time for soils (hr/day)
ET_{sed}	=	Exposure time for sediments (hr/day)
ET_{swim}	=	Exposure time for swiming (hr/day)
ET_{boat}	=	Exposure time for boating (hr/day)
Et_{items}	=	Exposure frequency for each cultural item (hr/day)
RF_{soil}	=	Soil shielding factor (dimensionless)

If the exposures of children are significantly different from adults, it may be desirable to apply this equation twice, once for the 0-6 year age group and once for the adult age group. Separate estimates of the exposure times and exposure frequencies would be required.

6.2 Dermal Exposure (Carcinogenic, Non-Carcinogenic, Non-Radioactive)

$$DAD = [C_{soil} \times AF_{soil} \times ABS \times SA_{soil} \times EF_{soil} \times CF1 +$$

$$C_{sed} \times AF_{sed} \times ABS \times SA_{sed} \times EF_{sed} \times CF1 +$$

$$\Sigma (C_{other} \times AF_{other} \times ABS \times SA_{other} \times ET_{other} \times EF_{other} \times CF2) +$$

$$C_{seep} \times K_p \times SA_{seep} \times ET_{seep} \times EF_{seep} \times CF3 +$$

$$C_{river} \times K_p \times SA_{river} \times ET_{river} \times EF_{river} \times CF3] \times ED/(BW \times AT)$$

where

ABS	=	Material-specific absorption factor (unitless)
AF_{soil}	=	Adherence factor for soil (mg/cm^2 per day)
AF_{sed}	=	Adherence factor for sediment (mg/cm^2 per day)
Af_{other}	=	Adherence factor for cultural materials (mg/cm^2 per day)
AT	=	Averaging time (yr x 365 day/yr)
BW	=	Body weight (kg)
C_{soil}	=	Contaminant concentration in soil (mg/kg)
C_{sed}	=	Contaminant concentration in sediment (mg/kg)
C_{other}	=	Contaminant concentration in cultural materials (mg/kg) - examples might include ashes or pigments
C_{seep}	=	Contaminant concentration in seep/spring water (mg/L)
C_{river}	=	Contaminant concentration in river water (mg/L)
CF1	=	Unit conversion factor (1E-6 kg/mg)
CF2	=	Unit conversion factor (1E-6 kg/mg / 24 hr/day)
CF3	=	Unit conversion factor (1E-3 L/cm^3)
DAD	=	Dermally absorbed dose (mg/kg per day)
ED	=	Exposure duration (yr)
EF_{soil}	=	Exposure frequency to soils (day/yr)
EF_{sed}	=	Exposure frequency to sediments (day/yr)
EF_{other}	=	Exposure frequency to cultural materials (day/yr)
EF_{seep}	=	Exposure frequency to seep/spring water (day/yr)
EF_{river}	=	Exposure frequency to river water (day/yr)
ET_{seep}	=	Exposure time to seep/spring water (hr/day)
ET_{river}	=	Exposure time to river water (hr/day)
ET_{other}	=	Exposure time to cultural materials (hr/day)

6.2

$$K_p \quad = \quad \text{permeability coefficient for a chemical in water through skin (cm/hr)}$$

K_p = permeability coefficient for a chemical in water through skin (cm/hr)

SA_{soil} = Body surface area exposed to soils (cm²)

SA_{sed} = Body surface area exposed to sediments (cm²)

Sa_{other} = Body surface area exposed to cultural materials (cm²)

SA_{seep} = Body surface area exposed to seep/spring water (cm²)

SA_{river} = Body surface area exposed to river water (cm²)

This equation will be applied twice, once for children age 0-6 and once for adults, and the results summed.

6.3 Inhalation Exposure (Non-Radioactive)

$$INH = (C_{soil} \times ML \times ET_{soil} \times EF_{soil} + C_{seep} \times VF \times ET_{seep} \times EF_{seep} +$$

$$C_{river} \times VF \times ET_{river} \times EF_{river} + C_{other} \times CF_{other} \times ET_{other} \times EF_{other}) \times$$

$$ED \times IR / (BW \times AT \times CF4)$$

where

AT = Averaging time (yr x 365 day/yr)

BW = Body weight (kg)

C_{soil} = Contaminant concentration in soil (mg/kg)

C_{seep} = Contaminant concentration in seep/spring water (mg/L)

C_{river} = Contaminant concentration in river water (mg/L)

C_{other} = Contaminant concentration in other airborne material (mg/kg) - examples might include wood smoke from fires or smoke from ceremonial burning

CF4 = Unit conversion factor (24 hr/day)

CF_{other} = Factor relating cultural materials to air concentration, probably dependent on material type (for example, soil product, vegetation product) (kg/m³)

ED = Exposure duration (yr)

EF_{soil} = Exposure frequency to resuspended dusts (day/yr)

EF_{seep} = Exposure frequency to volatilized seep/spring water dusts (day/yr)

EF_{river} = Exposure frequency to volatilized river water (day/yr)

Ef_{other} = Exposure frequency to materials resuspended from cultural activities (day/yr)

ET_{soil} = Exposure time for breathing resuspended dusts (hr/day)

ET_{seep} = Exposure time for breathing volatilized seep/spring water (hr/day)

ET_{river} = Exposure time for breathing volatilized river water (hr/day)

ET_{other} = Exposure time for breathing materials suspended from cultural activities (hr/day)

INH = Chronic daily inhalation intake (mg/kg per day)

IR = Inhalation rate (m³/day)

ML = Mass loading of soil in air (kg/m³)

VF = Volatilization factor (L/m³)

6.3

If there are significant age-related differences, this equation may need to be applied to children and adults separately and the results summed.

6.4 Inhalation Exposure (Radioactive)

$$\text{Dose}_{inh} = (C_{soil} \times ML \times ET_{soil} \times EF_{soil} \times CF5 + C_{seep} \times VF \times ET_{seep} \times EF_{seep} +$$

$$C_{river} \times VF \times ET_{river} \times EF_{river} + C_{other} \times CF_{other} \times ET_{other} \times EF_{other} \times CF5) \times$$

$$ED \times IR \times DF5 / CF4$$

where

C_{soil}	=	Radionuclide concentration in soil (pCi/g)
C_{seep}	=	Radionuclide concentration in seep/spring water (pCi/L)
C_{river}	=	Radionuclide concentration in river water (pCi/L)
C_{other}	=	Radionuclide concentration in other airborne material (pCi/g) - examples might include wood smoke from fires or smoke from ceremonial burning
CF4	=	Unit conversion factor (24 hr/day)
CF5	=	Unit conversion factor (1000g/kg)
CF_{other}	=	Factor relating cultural materials to air concentration, probably dependent on material type (soil product, vegetation product)(kg/m^3)
DF5	=	Inhalation dose factor (rem/pCi)
Dose_{inh}	=	Inhalation dose from radionuclide (rem)
ED	=	Exposure duration (yr)
EF_{soil}	=	Exposure frequency to resuspended dusts (day/yr)
EF_{seep}	=	Exposure frequency to volatilized seep/spring water dusts (day/yr)
EF_{river}	=	Exposure frequency to volatilized river water (day/yr)
Ef_{other}	=	Exposure frequency to materials resuspended from cultural activities (day/yr)
ET_{soil}	=	Exposure time for breathing resuspended dusts (hr/day)
ET_{seep}	=	Exposure time for breathing volatilized seep/spring water (hr/day)
ET_{river}	=	Exposure time for breathing volatilized river water (hr/day)
Et_{other}	=	Exposure time for breathing materials suspended from cultural activities (hr/day)
IR	=	Inhalation rate (m^3/d)
ML	=	Mass loading of soil in air (kg/m^3)
VF	=	Volatilization factor (L/m^3)

If there are significant age-related differences, this equation may need to be applied to children and adults separately and the results summed.

6.5 Ingestion Exposure (Non-Radioactive)

$$ING = \quad (C_{soil} \times IR_{soil} + C_{sed} \times IR_{sed} + C_{river} \times IR_{river} + C_{seep} \times IR_{seep} +$$

$$C_{fish} \times IR_{fish} + C_{leafy} \times IR_{leafy} + C_{root} \times IR_{root} + C_{meat} \times IR_{meat} +$$

$$C_{milk} \times IR_{milk} + C_{bird} \times IR_{bird}) \times EF \times ED/(AT \times BW)$$

where

AT	=	Averaging time (yr x 365 day/yr)
BW	=	Body weight (kg)
C_{soil}	=	Contaminant concentration in soil (mg/kg)
C_{sed}	=	Contaminant concentration in sediment (mg/kg)
C_{river}	=	Contaminant concentration in river water (mg/kg)
C_{seep}	=	Contaminant concentration in seep/spring water (mg/kg)
C_{fish}	=	Contaminant concentration in fish (mg/kg)
C_{leafy}	=	Contaminant concentration in above-ground vegetation (mg/kg)
C_{root}	=	Contaminant concentration in root vegetables (mg/kg)
C_{meat}	=	Contaminant concentration in meat (mg/kg)
C_{milk}	=	Contaminant concentration in milk (mg/kg)
C_{bird}	=	Contaminant concentration in domestic and wild birds (mg/kg)
ED	=	Exposure duration (yr)
EF	=	Exposure frequency (day/yr)
ING	=	Chronic daily ingestion rate (mg/kg per day)
IR_{soil}	=	Ingestion rate of soil (kg/day)
IR_{sed}	=	Ingestion rate of sediment (kg/day)
IR_{river}	=	Ingestion rate of river water (kg/day)
IR_{seep}	=	Ingestion rate of seep/spring water (kg/day)
IR_{fish}	=	Ingestion rate of fish (kg/day)
IR_{leafy}	=	Ingestion rate of above-ground vegetation (kg/day)
IR_{root}	=	Ingestion rate of root vegetables (kg/day)
IR_{meat}	=	Ingestion rate of meat (kg/day)
IR_{milk}	=	Ingestion rate of milk (kg/day)
IR_{bird}	=	Ingestion rate of domestic and wild birds (kg/day)

This equation will be applied twice, once for children age 0-6 and once for adults, and the results summed. Each of the concentration values may need to be estimated from a basic environmental measurement using concentration ratios, bioaccumulation factors, or other related techniques.

6.6 Ingestion Exposure (Radioactive)

$$Dose_{ing} = (C_{soil} \times IR_{soil} + C_{sed} \times IR_{sed} + C_{river} \times IR_{river} + C_{seep} \times IR_{seep} +$$

$$C_{fish} \times IR_{fish} + C_{leafy} \times IR_{leafy} + C_{root} \times IR_{root} + C_{meat} \times IR_{meat} +$$

$$C_{milk} \times IR_{milk} + C_{bird} \times IR_{bird}) \times EF \times ED \times CF5 \times DF6$$

where

C_{soil}	=	Radionuclide concentration in soil (pCi/g)
C_{sed}	=	Radionuclide concentration in sediment (pCi/g)
C_{river}	=	Radionuclide concentration in river water (pCi/g)
C_{seep}	=	Radionuclide concentration in seep/spring water (pCi/g)
C_{fish}	=	Radionuclide concentration in fish (pCi/g)
C_{leafy}	=	Radionuclide concentration in above-ground vegetation (pCi/g)
C_{root}	=	Radionuclide concentration in root vegetables (pCi/g)
C_{meat}	=	Radionuclide concentration in meat (pCi/g)
C_{milk}	=	Radionuclide concentration in milk (pCi/g)
C_{bird}	=	Radionuclide concentration in domestic and wild birds (pCi/g)
CF5	=	Unit conversion factor (1000 g/kg)
DF6	=	Ingestion dose factor (rem/pCi)
$Dose_{ing}$	=	Ingestion dose (rem)
ED	=	Exposure duration (yr)
EF	=	Exposure frequency (day/yr)
IR_{soil}	=	Ingestion rate of soil (kg/day)
IR_{sed}	=	Ingestion rate of sediment (kg/day)
IR_{river}	=	Ingestion rate of river water (kg/day)
IR_{seep}	=	Ingestion rate of seep/spring water (kg/day)
IR_{fish}	=	Ingestion rate of fish (kg/day)
IR_{leafy}	=	Ingestion rate of above-ground vegetation (kg/day)
IR_{root}	=	Ingestion rate of root vegetables (kg/day)
IR_{meat}	=	Ingestion rate of meat (kg/day)
IR_{milk}	=	Ingestion rate of milk (kg/day)
IR_{bird}	=	Ingestion rate of domestic and wild birds (kg/day)

This equation should be applied twice, once for children age 0-6 and once for adults, and the results summed. Each of the concentration values may need to be estimated from a basic environmental measurement using concentration ratios, bioaccumulation factors, or other related techniques.

7.0 References

42 USC 6901 et seq. October 21, 1976. *Resource Conservation and Recovery Act of 1976*. Public Law 94-580.

42 USC 9601 et seq (as amended). December 11, 1980. *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*. Public Law 96-510

Andelman, J.B. 1990. "Total Exposure to Volatile Organic Chemicals in Potable Water" in *Significance and Treatment of Volatile Organic Compounds in Water Supplies*. N.M Ram, R.F. Christman, K.G. Cantor (eds.). Lewis Publishers.

Becker, J.M., C.A. Brandt, D.D. Dauble, A.D. Maughan, and T.K. O'Neil. 1996. *Receptor Species for the Screening Assessment of Impact to the Columbia River*. DOE/RL-96-16-b, U.S. Department of Energy, Richland, Washington.

CRITFC - Columbia River Inter-Tribal Fish Commission. 1994. *A Fish Consumption Survey of the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin*. CRITFC 94-3, Portland, Oregon.

Cooper, A.T., and R.K. Woodruff. 1993. *Investigation of Exposure Rates and Radionuclide and Trace Metal Distributions Along the Hanford Reach of the Columbia River*. PNL-8789, Pacific Northwest Laboratory, Richland, Washington.

DOA - U.S. Department of Agriculture. 1993. Draft Environmental Impact Statement: *Wild and Scenic Snake River Recreation Management Plan, Hells Canyon National Recreation Area*. Portland, Oregon.

DOE - U.S. Department of Energy. 1995. *Hanford Site Risk Assessment Methodology*. DOE/RL-91-45, Rev. 3, Richland, Washington.

DOE - U.S. Department of Energy. 1994. *Columbia River Impact Evaluation Plan*. DOE/RL-92-28, Rev. 1, Richland, Washington.

DOI - U.S. Department of the Interior. 1942. *Report on the Source, Nature and Extent of the Fishing, Hunting and Miscellaneous Related Rights of Certain Indian Tribes in Washington and Oregon Together with Affidavits Showing Locations of a Number of Usual and Accustomed Fishing Grounds and Stations*. Los Angeles, California.

Ecology - Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy. 1994. *Hanford Federal Facility Agreement and Consent Order*. Document No. 89-10, Rev. 3 (The Tri-Party Agreement), Ecology, Olympia, Washington.

EPA - U.S. Environmental Protection Agency. 1991. *Standard Default Exposure Factors*. OSWER Directive 9285.6-03, EPA, Washington, D.C.

Eslinger, P.W., L.R. Huesties, A.D. Maughan, T.B. Miley, and W.H. Walters. 1994. *Data Compendium for the Columbia River Comprehensive Impact Assessment*. PNL-9785, Pacific Northwest Laboratory, Richland, Washington.

Harris, S.G. 1993. "The Nez Perce ERWM's Recommendations for Refinement of Risk Assessment Proposed by DOE's Columbia River Impact Evaluation Plan." Nez Perce Department of Environmental Restoration and Waste Management, Lapwai, Idaho.

Harris, S.G. 1995. "A Limited Sample of Concerns of the Confederated Tribes of the Umatilla Indian Reservation Community on Using an Appropriately Designed Risk Assessment Model." *Scoping Report: Nuclear Risks in Tribal Communities*, Appendix B. Confederated Tribes of the Umatilla Indian Reservation, Pendleton, Oregon.

Hunn, E.S. 1990. *Nch'i-wana, "The Big River": Mid-Columbia Indians and Their Land.*. University of Washington Press, Seattle, Washington.

Miley, T.B., and L.R. Huesties. 1995. *List of Currently Classified Documents Relative to Hanford Operations and of Potential Use in the Columbia River Comprehensive Impact Assessment, January 1, 1973-June 20, 1994*. PNL-10459, Pacific Northwest Laboratory, Richland, Washington.

Napier, B.A., N.C. Batishko, D.A. Heise-Craff, M.F. Jarvis, and S.F. Synder. 1995. *Identification of Contaminants of Concern*. PNL-10400, Pacific Northwest Laboratory, Richland, Washington.

Napier, B.A., R. A. Peloquin, D. L. Strenge, and J. V. Ramsdell. 1988. *GENII - The Hanford Environmental Radiation Dosimetry Software System*. PNL-6584, Pacific Northwest Laboratory, Richland, Washington.

NPS - National Park Service. 1994. *Hanford Reach of the Columbia River*. Comprehensive River Conservation Study and Environmental Impact Statement: Final, Vol. 1. Seattle, Washington.

Paustenbach, D.J. 1989. *The Risk Assessment of Environmental and Human Health Hazards: A Textbook of Case Studies*. John Wiley & Sons, Inc., New York.

RCW - Revised Code of Washington. 1985. "Hazardous Waste Management Act." RCW 70.105, Olympia, Washington.

Strenge, D.L., and P.J. Chamberlain. 1994. *Evaluation of Unit Risk Factors in Support of the Hanford Remedial Action Environmental Impact Statement.* PNL-10190, Pacific Northwest Laboratory, Richland, Washington.

Sula, M.J. 1980. *Radiological Survey of Exposed Shorelines and Islands of the Columbia River Between Vernita and the Snake River Confluence.* PNL-3127, Pacific Northwest Laboratory, Richland, Washington.

WAC - Washington Administrative Code. 1991. "The Model Toxics Control Act Cleanup Regulations." WAC-173-340 as amended, Olympia, Washington.

Washington Department of Wildlife. 1992. "Game Harvest Report: 1991-92." Olympia, Washington.

Washington Department of Wildlife. 1993. "Game Harvest Report: 1992-93." Olympia, Washington .

Washington Department of Fish and Wildlife. 1994. "Game Harvest Report: 1993-94." Olympia, Washington.

Washington Department of Fish and Wildlife. 1995a. "Game Harvest Report: 1994." Olympia, Washington.

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