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**METHODOLOGY USED TO COMPUTE MAXIMUM POTENTIAL
DOSES FROM INGESTION OF EDIBLE PLANTS AND
WILDLIFE FOUND ON THE HANFORD SITE**

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SUMMARY

This report describes methods used to estimate potential radiation doses from consumption of edible plants and wildlife, and includes example calculations.

Edible plants on the publicly accessible margins of the shoreline of the Hanford Site and wildlife that move offsite are potential sources of contaminated food for the general public. Calculations of potential radiation doses from consumption of agricultural plants and farm animal products are made routinely and reported annually for those produced offsite, using information about concentrations of radionuclides, consumption rates, and factors for converting radionuclide intake into dose. Dose calculations for onsite plants and wildlife are made intermittently when appropriate samples become available for analysis or when special studies are conducted. Consumption rates are inferred from the normal intake rates of similar food types raised offsite and from the edible weight of the onsite product that is actually available for harvest.

Example calculations were made of the dose from consumption of asparagus containing uranium and ^{137}Cs collected along the Columbia River near the southern project boundary in 1989 and an edible animal (duck) sampled from the Columbia River in 1989. The potential dose from consumption of 10 kg of such asparagus was calculated to be 0.05 mrem EDE. The potential dose from consumption of 0.5 kg of the river duck with the highest ^{137}Cs concentration measured during the period from 1977-1988 was calculated to be 1 mrem EDE. These doses are a small fraction of the DOE guidance of 100 mrem EDE per year established for protection of the public.

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INTRODUCTION

The purpose of this report is to summarize the assumptions, dose factors, consumption rates, and methodology used to evaluate potential radiation doses to persons who may eat contaminated wildlife or contaminated plants collected from the Hanford Site.

This report includes 1) a description of the number and variety of wildlife and edible plants on the Hanford Site, 2) methods for estimation of the quantities of these items consumed and conversion of intake of radionuclides to radiation doses, and 3) example calculations of radiation doses from consumption of plants and wildlife.

Several types of edible plants and wildlife occur on the U.S. Department of Energy's Hanford Site. Some edible plants are wild species while others are remnants of domestic plants and crops from pre-1943 farms. Wildlife is abundant on the Hanford Site, including species that are sought by local hunters. Although no hunting is allowed on the Site, mobile animals that normally reside onsite can move offsite, where they may be killed by hunters.

Potential doses from eating Columbia River fish (specifically panfish) are calculated routinely and are included in the total population doses reported annually in the Hanford environmental monitoring report (e.g., Jaquish and Bryce 1990). Columbia River fish are specifically addressed because of the large amount harvested (currently estimated at 15,000 kg/yr).

Samples of other wildlife are routinely collected as a part of the environmental surveillance program at the Site and edible plants are sampled when special needs arise. Typically, radioactive materials found in edible plants and wildlife are those expected from naturally occurring radionuclides and worldwide fallout from nuclear testing. Occasionally, concentrations of radionuclides detected in plant or animal samples collected near operating facilities or waste management sites are higher than in samples from offsite locations.

On those occasions when levels in wildlife or in edible plants are high enough to be of interest, a special calculation is performed to assess the potential radiation dose to a hypothetical consumer. Such special calcula-

calculations are based on measured concentrations of radionuclides in wildlife and edible plants and require additional data describing potential dietary and recreational activities, exposure times, and dosimetry.

The computer codes and associated data libraries currently used to calculate potential doses to members of the public from effluents released during routine operations have been published (Napier et al. 1988a,b,c). The specific parameters used for dose calculations in a given year are published in the Hanford Site Environmental Report for that year (e.g., Jaquish and Bryce 1990).

EDIBLE PLANTS AND WILDLIFE ON THE HANFORD SITE

A number of plant species grow on the Hanford Site that have the potential to be harvested and eaten by people. Table 1 lists examples of edible plants and their known distribution on the Hanford Site. The most avidly sought plant is wild asparagus, which grows along the Columbia River and elsewhere onsite. Some wild fruits are also abundant enough to be harvested, including mulberry, squawberry, and chokecherry. Cattails and watercress grow in areas where springs flow into the Columbia River and are also available to be harvested.

The quantities of edible plants collected each year from the Site are unknown. Collection of significant quantities of plants from the area downstream of the Vernita Bridge to the wooden powerline crossing at Ringold is unlikely since access to the shore on the Hanford Site is not permitted. Downstream of those towers access is permitted from the water up to the high water line. Some harvesting of plants, especially wild asparagus, is known to occur in these latter shoreline areas.

A number of mammals and game birds forage on the Hanford Site and then may wander offsite where they could be hunted. Edible mammals and game birds found on the Hanford Site are listed in Tables 2 and 3. Live body weights and estimated hunter kill data for the counties adjacent to the Hanford Site (Benton, Franklin, and Grant) are also given in Tables 2 and 3.

The largest and most desirable animal for hunting is the elk. Elk found onsite currently reside on the Arid Land Ecology (ALE) reserve, but animals occasionally leave the Site, where they may be legally hunted. During the 1989 hunting season, 12 elk were harvested offsite.

The next largest animal is the mule deer which ranges across the Hanford Site, including the islands located in the Columbia River. Research on the Hanford deer population has found that the animals can move offsite. One study found that 17 of 346 deer tagged onsite were shot offsite by hunters (Eberhardt et al. 1979). Most of the deer shot offsite were taken from islands in the Columbia River downstream from the Hanford Townsite.

TABLE 1. Examples of Edible Plants of the Hanford Site and Their General Distribution

<u>Common Name/Species</u>	<u>Edible Parts</u>	<u>Distribution</u>
Asparagus (exotic) <u>Asparagus officinalis</u>	Very young shoots	Found mostly on abandoned cultivated fields at the Hanford and White Bluffs townsites, near the 300 Area, and at scattered locations along the Columbia River shoreline
Apricot (exotic) <u>Prunus spp</u>	Fruit	Only a few trees at Hanford and White Bluffs townsites
Black walnut (exotic) <u>Juglans nigra</u>	Nuts	Only a few trees at Hanford and White Bluffs townsites
Mulberry (exotic) <u>Morus alba</u>	Fruit	Many trees scattered along the Columbia River shoreline
Chokecherry (native) <u>Prunus virginiana</u>	Fruit	A few bushes scattered along the Columbia River and near springs in the Rattlesnake Hills
Serviceberry (native) <u>Amelanchier alnifolia</u>	Fruit	A few bushes scattered near springs in the Rattlesnake Hills
Elderberry (native) <u>Sambucus cerulea</u>	Fruit	A few bushes scattered near springs in the Rattlesnake Hills
Squawberry (native) <u>Ribes aureum</u>	Fruit	A few bushes scattered along the Columbia River and near springs in the Rattlesnake Hills
Wild rose (native) <u>Rosa spp</u>	Fruit	A few bushes scattered along the Columbia River and near springs in the Rattlesnake Hills
Willow (native) <u>Salix spp</u>	Bark and foliage	Scattered along the shoreline of the Columbia River and near springs in the Rattlesnake Hills
Watercress (exotic) <u>Rotippa nasturtium-aquaticum</u>	Foliage	Semi-aquatic plant found near seeps along the shoreline of the Columbia River and near springs in the Rattlesnake Hills
Cattail (native) <u>Typha latifolia</u>	Foliage, pollen, and roots	Semi-aquatic plant found along the shoreline of the Columbia River and near springs in the Rattlesnake Hills
Chicory (exotic) <u>Cichorium intybus</u>	Foliage and roots	Scattered along the shoreline of the Columbia River and near springs in the Rattlesnake Hills
Dogbane (native) <u>Apocynum sibiricum</u>	Bark	Scattered along the shoreline of the Columbia River; also known as "Indian hemp."
Yarrow (native) <u>Achillea millefolium</u>	Foliage	Scattered over the Hanford Site and along the shoreline of the Columbia River
Salsify (exotic) <u>Tragopogon dubius</u>	Foliage and roots	Mostly in abandoned cultivated fields near the White Bluffs and Hanford townsites and in the Rattlesnake Hills
Dandelion (exotic) <u>Taraxacum officinale</u>	Foliage	Scarce along the shoreline of the Columbia River
Wild carrots (native) <u>Lotium spp.</u>	Roots	Scattered over the Hanford Site in terrestrial habitats
Bitterroot (native) <u>Lewisia rediviva</u>	Roots	Found only at high elevations in the Rattlesnake Hills
Wild onions (native) <u>Allium spp.</u>	Leaves and bulbs	Scattered over the Hanford Site and along the shoreline of the Columbia River
Dock (native) <u>Rumex salicifolius</u>	Leaves and stems	Scattered along the shoreline of the Columbia River

In 1989, a total of 98 deer were harvested from the three counties adjacent to the Hanford Site; some of those animals may have spent some time on the Site.

Unlike deer and elk, smaller game mammals are not expected to travel offsite. However, a few cottontail rabbits could be shot along the shoreline of the Columbia River where hunting is allowed on land between the high water line and the current water line. Beaver, raccoon, and muskrat are edible and could be hunted for food, but it is more likely they would be trapped for their fur. Table 2 shows the numbers of beavers, raccoons, and muskrats taken in the three counties adjacent to the Hanford Site during the 1989-1990 hunting season.

Table 3 lists important game birds found on the Hanford Site, their average body weights, estimated hunter kill for 1989, and distribution on the Site. The most abundant game bird that breeds onsite is the mourning dove. The dove is a migrating species and most individuals leave the Site in early fall after the hunting season.

Another abundant game bird is the chukar. The largest onsite concentration of chukars occurs in the Rattlesnake Hills where the gray partridge can also be found. These birds generally do not migrate or move about extensively. However, there may be some movement offsite and a few could be harvested by hunters on land adjacent to the Site.

Ring-necked pheasants and california quail are found along the shoreline and on islands in the Columbia River and along spring streams in the Rattlesnake Hills. The numbers of pheasants and quail shot by hunters in these areas is unknown, but hunting activity along the Hanford Site has recently increased, as hunting on islands in the Hanford Reach has increased in popularity. Estimated hunter kill in adjacent counties during the 1989 hunting season is shown in Table 3.

Several species of waterfowl use areas of open water located within the Hanford Site. The B-3 ditch (within the 200 East Area) and B pond (east of the 200 East Area) are disposal sites for industrial waste (cooling) water. The disposal trench north of the 300 Area also receives cooling water, but it has recently been covered with wire mesh to exclude wildlife.

TABLE 2. Mammals of the Hanford Site, Body Weights, Estimated Hunter Kill on Adjacent Land, and Onsite Distribution

<u>Common Name/Species</u>	<u>Body Weight, kg(b)</u>	<u>Estimated Hunter Kill(a)</u>		<u>Distribution</u>	
		<u>From Adjacent Counties</u>	<u>Number/ Hunter/Yr</u>		<u>From Hanford Site</u>
Elk <u>Cervus elaphus</u>	320 to 450 (male)	0	0.11	12	ALE Reserve
Mule deer <u>Odocoileus hemionus</u>	55 to 180 (male)	98	0.28	?	Sitewide
Black-Tailed Hare (Jackrabbit) <u>Lepus californicus</u>	1.4 to 3	1480	0.47	?	Sitewide
Cottontail <u>Sylvilagus nuttallii</u>	0.7 to 1.4	3090	3.8	?	Sitewide
Raccoon <u>Procyon lotor</u>	8 to 24	40	0.17	?	Columbia River Shoreline
Beaver <u>Castor canadensis</u>	14 to 27	332	?	?	Columbia River Shoreline
Muskrat <u>Ondatra zibethicus</u>	1 to 1.8	1610	?	?	Columbia River Shoreline

- (a) WDW (1990a, b, and c).
 (b) Burt and Grossenheider (1976).

West Lake is a natural pond located near the center of the Site that is used occasionally by waterfowl. A study conducted in the 1970s showed that waterfowl preferred the larger open bodies of water to the smaller ponds and trenches (Price and Fitzner 1979). Dabbling ducks were the most prevalent ducks, accounting for 97% of the total number. Mallards and other dabbling ducks are sought by hunters. For example, in 1988 the mallard, northern pintail, green-winged teal, american widgeon and northern shoveler collectively comprised over 92% of the total waterfowl harvest in Washington State (Bartonek 1989). Only a few of the edible waterfowl species breed on the Hanford Site; the islands in the Columbia River are preferred nesting sites for a resident population of Canada geese. Most of the waterfowl shot along the shoreline and on the islands of the Columbia River are probably migrants on their way south for the winter and have spent little time foraging on the Hanford Site.

TABLE 3. Game Birds of the Hanford Site, Body Weights, Estimated Hunter Kill on Adjacent Land, and Onsite Distribution

Common Name/Species	Body Weight (kg)	Estimated Hunter Kill in Adjacent Counties(a)		Distribution on Hanford Site
		1989 Total	Birds/Man/Yr	
Chukar (exotic) <u>Alectoris chukar</u>	0.5 to 1	5,310	3.1	Terrestrial habitats in the Rattlesnake Hills and Gable Mountain
Gray partridge (exotic) <u>Perdix</u>	0.5	1,480	1.0	Terrestrial habitats in the Rattlesnake Rattlesnake Hills and Gable Mountain
Mourning dove (native) <u>Zenaidura macroura</u>	<0.5	30,800	10.8	Site-wide
Ring-necked pheasant (exotic) <u>Phasianus colchicus</u>	1 to 1.4	51,100	3.4	Shoreline of the Columbia River and near Rattlesnake Springs
California quail (exotic) <u>Callipepla californicus</u>	<0.5	17,800	3.8	Shoreline of the Columbia River and near Rattlesnake Springs
Mallard (native) <u>Anas platyrhynchos</u>	1 to 1.4	64,100	3.7	Columbia River, West Lake, B Pond, and 300 Area Trench
Other edible dabbling ducks(b)	0.5 to 1.4	36,600	0.3	Columbia River, West Lake, B Pond, and 300 Area Trench
Canada goose (native) <u>Branta canadensis</u>	2.3 to 5.4	15,600	1	Columbia River and rarely onsite ponds and trenches

(a) Bartonek (1989); Bartonek (1990); WDW (1990b).

(b) Edible dabbling ducks include the Green-winged teal (Anas crecca), american wigeon (Anas americana), northern pintail (Anas acuta), and northern shoveler (Anas clypeata).

RADIATION DOSE CALCULATIONS

Potential radiation doses from consumption of wildlife and edible plants from the Hanford Site can be estimated from measured concentrations of radionuclides in the foods, quantities consumed, and standard dose conversion factors.

CONCENTRATIONS IN EDIBLE SPECIES

Concentrations of radionuclides in game animals, game birds and fish from the Hanford Site have been measured routinely for over three decades. Results obtained from samples collected during the period from 1971 through 1988 have been summarized (Eberhardt et al. 1989). Radionuclides identified in these samples included those expected from fallout of nuclear weapons testing debris (^{90}Sr , ^{131}I and ^{137}Cs), natural occurring radionuclides (^{40}K and uranium with decay products) and those of Hanford origin (^{32}P , ^{60}Co , ^{65}Zn , ^{131}I , and ^{137}Cs). Eberhardt et al. (1989) stated that, "Differentiating between radionuclide contamination from worldwide fallout and that resulting from Hanford activities was difficult, especially for wildlife samples, which were obtained almost entirely onsite. However, waterfowl were an exception to this observation, in that most birds collected from ponds and trenches onsite frequently had markedly higher concentrations of ^{137}Cs in muscle tissue than birds obtained from the nearby Columbia River."

When calculating radiation doses, no credit is taken for reduction of radionuclide concentrations in foods during preparation or cooking. Although such losses have been measured for a few specific radionuclides in specific foods, the available data are incomplete and the reductions measured ranged from 10% to 50% (Soldat and Harr 1971). Reductions of concentrations might be made for radioactive decay of the shorter-lived radionuclides ^{32}P and ^{131}I , when there is evidence of delayed consumption, such as preservation of Columbia River whitefish by smoking.

CONSUMPTION RATES

The consumption of edible plants harvested from the Hanford Site is limited by the amount available for harvest in areas accessible to the

general public. Plant growth will vary from year to year depending on weather conditions; the actual amount harvested per person is difficult to estimate. Therefore, dose calculations often are based on conservative estimates of the maximum amount potentially consumed by an individual in the course of a growing season. An example is the assumption that someone could harvest enough asparagus from the Hanford Site to provide all of the asparagus that a maximum consumer would eat in one year.

Consumption of meat is estimated by considering the weight of the edible fraction of the harvested animals and the frequency of consumption by a maximum consumer (Jaquish and Bryce 1990). The typical "usable" weight from the hunter's bag is commonly estimated to be two-thirds of the body weight (see Tables 2 and 3 for body weights). Edible meat would be the usable weight minus skin, fat, and bone. Some game birds, such as chukar, partridge, dove, or quail are small and provide only a single meal, or part of a meal, for one person. Although the edible meat may be shared with other family members, the conservative assumption is that each game bird is consumed by one person. Larger game animals, even when shared by several family members and friends, could provide more than one meal per person.

DOSE CONVERSION FACTORS

Factors for conversion of the quantity of a specific radionuclide ingested to radiation dose are those given in DOE EH-0071 (DOE 1988), which in turn were derived from the dosimetry data in the several parts of the International Commission on Radiological Protection Publication 30 (ICRP 1979-1982) and ICRP Publication 48 (ICRP 1986). These dose factors are based on the 50-year committed internal radiation dose received by the organs of the Reference Man (ICRP 1975) from a unit intake of a radionuclide. Dose factors are given for the 50-year committed dose equivalent to individual body organs, and for the 50-year committed effective dose equivalent (EDE). The latter is a risk-based value calculated as a weighted sum of the dose equivalents received by the individual organs.

EXAMPLE DOSE CALCULATIONS

The following example calculations illustrate the methodology used to calculate potential radiation doses from consumption of wild asparagus collected from the Hanford Site and consumption of meat from a duck obtained from the Columbia River.

EDIBLE PLANTS

A pertinent example of the calculation of the potential radiation dose from consumption of an edible plant harvested from the Hanford Site involves wild asparagus growing in the vicinity of the 300 Area near the southern boundary of the Site. The asparagus is in an area that is accessible to the public and there have been indications that some has been harvested (WHC 1990). Asparagus samples taken in 1989 were found to contain low levels ^{137}Cs and uranium. The ^{137}Cs was present at concentrations low enough (maximum 0.018 pCi/g dry weight) to be the result of fallout from past weapons tests. The concentrations of uranium found in the asparagus (maximum 0.026 $\mu\text{g/g}$ dry weight) were higher than the background concentrations of uranium (0.008 $\mu\text{g/g}$ dry weight) naturally occurring in southeastern Washington.

The highest calculated potential radiation dose was found for the samples of asparagus containing the second highest concentration of ^{137}Cs (0.011 pCi/g dry weight) and the highest concentration of uranium (0.026 $\mu\text{g/g}$ dry weight). The isotopic composition of the uranium was not available; but, the conservative assumption was made that the uranium composition matched that for uranium enriched to 3% in ^{235}U . Other isotopes present in such uranium are ^{234}U at 0.03% and ^{238}U at 97%.

The measured ratio of wet to dry weight for the samples varied from 3 to 3.5; a value of 3 is used in the dose calculations for conservatism. The dose factors used in the calculation are the 50-year committed EDE per unit intake of the radionuclide (DOE 1988). The dose calculations are illustrated in Table 4. The total potential EDE dose from consumption of 10 kg of asparagus grown in 1989 is 0.05 mrem.

TABLE 4. Example Calculation of Effective Dose Equivalent (EDE) from Consumption of 10 kg of Asparagus

<u>Radionuclide</u>	<u>Concentration, pCi/g Wet Weight</u>	<u>Dose Factor, mrem/pCi Intake</u>	<u>EDE, mrem</u>
137Cs	3.7 E-3	5.0 E-5	1.8 E-3
234U	1.6 E-2	2.6 E-4	4.2 E-2
235U	5.5 E-4	2.5 E-4	1.4 E-3
238U	<u>2.8 E-3</u>	2.3 E-4	<u>6.5 E-3</u>
Total	1.9 E-2		5.0 E-2

EDIBLE ANIMALS

The calculation chosen for this example is based on the consumption of 0.5 kg of edible meat from a duck collected from the Columbia River in 1981. The concentration of 137Cs was 44.5 pCi/g (Eberhardt et al. 1989). This was the highest concentration measured in any of the waterfowl samples collected from the Columbia River during the period 1977 through 1988. No other radionuclides were detected in the edible meat of this duck. The dose factor for 137Cs is 5.0 E-5 mrem per pCi ingested (DOE 1988).

The potential radiation dose from consumption of the duck is simply the product of the weight consumed, the concentration of 137Cs, and the dose factor:

$$\text{Dose} = (500 \text{ g}) \cdot (44.5 \text{ pCi/g}) \cdot (5.0 \text{ E-5 mrem/pCi}) = 1 \text{ mrem EDE}$$

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