*Elk and Deer Study,
Material Disposal Area G,
Technical Area 54: Source Document*

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by

J.K Ferenbaugh, P.R. Fresquez, M.H. Ebinger, G.J. Gonzales, and P.A. Jordan

ABSTRACT

As nuclear research has become more prevalent, environmental contamination from the disposal of radioactive waste has become a prominent issue. At Los Alamos National Laboratory (LANL) in northern New Mexico, radioactive contamination from disposal operations has raised some very specific concerns. Material Disposal Area G (Area G) is the primary low-level radioactive waste disposal site at LANL and occupies an area adjacent to land belonging to the Native American community of the Pueblo of San Ildefonso. Analyses of soil and vegetation collected from the perimeter of Area G have shown concentrations of radionuclides greater than background concentrations established for northern New Mexico. As a result, Pueblo residents had become concerned that contaminants from Area G could enter tribal lands through various ecological pathways. The residents specifically questioned the safety of consuming meat from elk and deer that forage near Area G and then migrate onto tribal lands. Consequently, this study addresses the uptake of ^3H , ^{90}Sr , ^{10}U , ^{238}Pu , ^{239}Pu , ^{241}Am , and ^{137}Cs by elk (*Cervus elaphus*) and deer (*Odocoileus hemionus*) that forage around the perimeter of Area G and the associated doses to the animals and to humans who consume these animals. Radionuclide uptake by and internal dose to animals was estimated using equations modified from National Council on Radiological Protection Report 76. The Residual Radiation computer code was used to estimate the external dose to animals and the dose to humans consuming meat. Soil and water concentrations from the perimeter of Area G and from background regions in northern New Mexico were averaged over 4 years (1993-1996) and used as input data for the models. Concentration estimates generated by the model correspond to the concentration range measured in actual tissue samples from elk and deer collected at LANL. The highest dose estimates for both animals (0.028 mrad/d) and humans (0.072 mrem/y) were well below guidelines established to protect the environment (100 mrad/d) and the public (100 mrem/y) from radiological health risks.

INTRODUCTION

In 1945, the first atomic detonation flashed across the New Mexico desert as a nuclear bomb was tested for use in World War II. Since that time, the uses of nuclear energy have become numerous and varied. Fission reactors provide energy, nuclear weapons have proliferated, x-rays and particle accelerators have advanced the health sciences, and scientists continue to find new uses for nuclear energy. With the increased use of nuclear energy, however, comes a requisite increase in nuclear waste. Nuclear waste includes radioactive waste and waste that is a mixture of chemical and radioactive constituents.

The first nuclear waste disposal sites often consisted of deeply bored pits with a cap or cover to divert precipitation. This method of disposal allows lateral movement of waste through the surrounding rock and soil and into nearby groundwater, where it can disperse throughout the environment (LANL 1997). After 1970, disposal sites were encased or had other engineered controls to contain waste. Despite these advances in disposal techniques, conventional disposal sites continue to leak radioactive contaminants into the environment. Researchers are optimistic that the newest methods of disposal, such as those employed at the Waste Isolation Pilot Plant (WIPP) in southern New Mexico, will prevent contamination from reaching the environment. However, conventional disposal sites without improved techniques will continue to be problematic.

Federal legislation, such as the National Environmental Policy Act of 1969 (NEPA), and government agency regulations, including Department of Energy (DOE) Order 5400.1 and DOE Order 5400.5, put a spotlight on the environmental impacts of both chemical and radioactive contaminants, such as their transport and uptake within

ecosystems. Facilities that produce, store, and/or dispose of nuclear waste must monitor and regulate their activities to comply with federal, state, and local regulations and policies regarding radioactive and chemical materials.

NEPA requires that agencies assess the environmental impact of any actions that they propose and allow public input before those actions are carried out. A brief Environmental Assessment may be sufficient, or an in-depth Environmental Impact Statement may be needed to comply with NEPA. This impact statement may then require some form of mitigation for the proposed activity. Environmental impacts at nuclear waste storage and disposal sites are particularly important to assess the potential for contamination to spread into the environment.

DOE Orders 5400.1 and 5400.5 pertain to protecting the environment and the public from adverse effects of radiation. Order 5400.1 establishes guidelines for environmental surveillance procedures and gives measurements defining the allowable quantity and quality of radionuclide releases to the environment by a facility (U.S. DOE 1988). Order 5400.5 establishes radiation dose limits to the public from facility activities, as well as concentration guidelines for air, soil, and water samples (U.S. DOE 1990). Nuclear waste storage and disposal sites must meet the requirements set forth by NEPA and government orders to maintain operation.

The public has noticed the increased attention of government agencies toward proper waste disposal. Residents close to disposal sites have raised concerns about the health and safety of having these sites near their homes. The possibility of ingesting or inhaling radioactive contaminants through soil, food, water, and air causes anxiety and fosters distrust of the organizations responsible for the disposal sites.

In response to regulations and public pressure, facilities involved with nuclear waste storage and disposal have implemented environmental surveillance programs in the areas surrounding disposal sites. These programs include monitoring of soil, air, water, and various biota, as well as any other pathways involving humans (NRC 1991, U.S. EPA 1972, U.S. DOE 1990).

Special attention frequently is given to pathways that are not entirely under human control. For example, animals that are hunted and consumed by people are potentially an important pathway for contaminants to reach humans (Figure 1). Large ungulates, such as elk (*Cervus elaphus*) and deer (*Odocoileus hemionus*), that forage at or near nuclear reactor sites, power plants, or waste disposal sites may accumulate radioactive contamination.

Figure 1. Radionuclide Pathways in Elk and Deer Study

These animals may transport these contaminants offsite; potentially posing a health threat to humans that may consume them. As well as comprising potential human health hazards, elk and deer are good indicator species for ecological/ecosystem health.

Monitoring an ecosystem allows small and subtle impacts to be detected before they can accumulate and/or amplify. Early detection of negative trends in ecological health may help to avert ecological disasters and keep ecological events from impacting human environments and food chains.

Los Alamos National Laboratory (LANL) is a DOE facility in north-central New Mexico. LANL has been home to mule deer since its creation in 1942 and has seasonally been home to elk since their reintroduction to New Mexico in the 1960s. Herds of elk and mule deer forage around the perimeter of LANL's primary low-level radioactive waste disposal site, Material Disposal Area G (Area G), and then move off of Laboratory lands onto the adjoining Pueblo of San Ildefonso. Some of these animals are subsequently hunted and consumed by Pueblo residents (Fresquez et al. 1998).

The eastern boundary of Area G borders the Sacred Area of San Ildefonso Pueblo, and Pueblo residents have expressed concern that contaminants from Area G may enter tribal lands through various pathways. Residents are specifically concerned about the health risks associated with the consumption of the elk and deer that forage around Area G and then move onto the Pueblo of San Ildefonso lands.

The magnitude of the health risks to animals and humans is based on the acceptable dose limits for protecting the public established by the International Atomic Energy Agency (IAEA) and the International Commission on Radiological Protection (ICRP). These limits have been adopted by the DOE and are 100 mrad/d (IAEA 1992) and 100 mrem/yr (ICRP 1990), respectively.

This study was conducted to address local concerns about hunting and consumption of elk and deer that forage around the perimeter of Area G by evaluating the risks associated with these ungulates. This study has three specific objectives:

- 1) Estimate the concentrations of seven principle radionuclides (^3H , ^{90}Sr , $^{\text{total}}\text{U}$, ^{238}Pu , ^{239}Pu , ^{241}Am , and ^{137}Cs) in muscle tissue of both elk and deer foraging around a low-level radioactive waste disposal site.
- 2) Estimate the radiation dose to these elk and deer from any ingested or inhaled radionuclides and from external exposure.
- 3) Estimate the dose to a human who consumes meat from potentially contaminated elk and deer.

This study will address the objectives using two approaches. The first approach uses a computer code that follows radionuclides through the environment from a soil source term to a human receptor. The Residual Radiation (RESRAD) code was used to estimate doses to humans exposed to radionuclides via different ecological pathways (Yu et al. 1993). Internal exposure for the elk and deer was estimated using equations from the National Council on Radiation Protection and Measurements (NCRP 1984) coded into a Microsoft Excel spreadsheet where fodder, water, and soil were assumed to be contaminated with radionuclides from the disposal site (Ebinger and Hansen 1994, 1996a, 1996b).

Concentration estimates generated by the models are compared to values obtained from tissue samples of elk and deer collected on or near LANL property as part of the current environmental surveillance program (Fresquez et al. 1998). A small number of elk samples are from radio-collared animals whose locations were recorded using global positioning systems technology (Biggs et al. 1997). Hunters or LANL personnel harvested radio-collared elk to obtain tissue samples. Comparison of model predictions

and actual samples is important because of the small sample size of elk whose locations over the past year, or longer, are known. Modeling is an inexpensive way to predict risk when compared to a full-scale sampling program, and comparison of the model estimates against reality may help evaluate whether this model is an acceptable means of predicting risk.

LITERATURE REVIEW

RADIONUCLIDES

Radionuclides are unstable isotopes of an element. These isotopes decay to a stable structure by emitting energy in the form of particles or rays. X-rays are one type of radioactive emission that most people are familiar with. The three major types of emitted radiation are alpha (α), beta (β), and gamma (γ) radiation.

The radionuclides of interest in this study are anthropogenic, however, some of them also occur naturally (Table 1). All of the radionuclides listed in Table 1 are products or by-products of nuclear research. Because of their long half-lives, these isotopes must be stored and disposed of carefully to prevent them from becoming biologically available. Environmental surveillance has indicated that these radionuclides are all present in elevated levels in soils and vegetation around the perimeter of LANL's waste disposal sites, which means they are bioavailable (Conrad et al. 1995, Fresquez et al. 1996, Bennett et al. 1997).

Tritium

Tritium is an isotopically heavy form of the element hydrogen, and it tends to follow the same pathways. As with hydrogen, most tritium in the environment is found

Table 1. Some Radionuclides Sampled in Soils, Water, Vegetation, and Biota at Area G and Their Properties

Element	Symbol	Type of Radiation	Half-life (years)	Source	Exposure Pathways	Retention
Tritium	H^3	β	1.24E+01	Natural (cosmic), fission, activation	Ingestion, inhalation, absorption	days
Strontium	Sr^{90}	β	2.91E+01	Fission	Ingestion, absorption	years
Cesium	Cs^{137}	β, γ	3.00E+01	Fission	Ingestion, absorption	weeks-months
Plutonium	Pu^{238}	α, γ	8.77E+01	Activation, fission	Ingestion, inhalation, adsorption	years
	Pu^{239}	α, γ	2.41E+04	Activation, fission	Ingestion, inhalation, adsorption	years
Uranium	U^{234}	α, γ	2.45E+05	Natural	Ingestion, inhalation, external γ	months
	U^{235}	α, γ	7.04E+08	Natural	Ingestion, inhalation, external γ	months
	U^{238}	α, γ	4.47E+09	Natural, fission	Ingestion, inhalation, external γ	months
Americium	Am^{241}	α, γ	4.32E+02	Activation, fission		

in water, although carbon compounds that include tritium do occur. Because tritium does not adsorb to biotic surfaces and sediments it rarely concentrates in tissues. Tritium enters plants through their roots, leaves, and stems. Animals take up tritium via ingestion, inhalation, and direct absorption through the skin (Whicker and Schultz 1982).

Strontium

Strontium-90 received a great deal of attention and study during the 1950s and 1960s due to nuclear atmospheric testing. Strontium is produced during nuclear fission, and it is a calcium analog that deposits in bone and bone marrow. Strontium forms soluble compounds that make it mobile in biological systems. Although strontium readily enters food webs, it does not seem to bioaccumulate, possibly because animal tissues will preferentially incorporate calcium over strontium (Engstrom et al. 1957, Whicker and Schultz 1982).

Cesium

Cesium is one of the most well-studied fission products, partially because it can be a significant contributor to the genetic effect of a radiation dose. Cesium is an analog to potassium, which concentrates in muscle tissue, but it is retained in the body for a longer period. In soils with low clay content, such as those found in the Los Alamos area, cesium is relatively available for bioincorporation. Cesium enters plants via root uptake, aerial deposition, and surface adsorption. Animals take in cesium through inhalation, ingestion, surface adsorption, and absorption (Whicker and Schultz 1982).

Actinides

Plutonium, uranium, and americium are all actinides, and they share the general characteristics of actinides. All of them occur naturally, and with the exception of uranium, occur in minute quantities, and are created during nuclear processes. Actinides are not biologically mobile, as they tend to form insoluble compounds. These elements accumulate in soils and sediments, but they have no known biological function. Actinides are taken up by animals through inhalation, ingestion, and surface contact.

These elements accumulate almost entirely in the bone, although the kidney and liver are also possible destinations (Whicker and Schultz 1982).

Plutonium

Plutonium is fuel for nuclear reactors and a component in nuclear weapons. Ninety percent of plutonium in terrestrial ecosystems is found in the soil. Resuspension of contaminated soil particles, and subsequent deposition on plant surfaces, contribute heavily to plutonium uptake by animals. Plutonium is potentially toxic to animals, and it is retained tenaciously in an animal's body, creating a long biological half-life (Whicker and Schultz 1982).

Uranium

Naturally occurring uranium is primordial and, as such, is ubiquitous in the environment. Uranium can be chemically toxic when sufficient quantities are ingested by an organism. However, in low concentrations uranium may stimulate plant growth. This may explain why plants take up uranium even though it does not appear to have any biological function (Whicker and Schultz 1982).

Americium

Americium is one of the most prevalent transuranic contaminants arising from nuclear reactions. It tends to form fairly insoluble oxides and hydroxides that are not bioavailable, and it is a bone-seeker that also concentrates in the liver (Eisenbud and Gesell 1997).

RADIONUCLIDE UPTAKE BY UNGULATES

Most radionuclides are present in the environment as a result of fallout from nuclear reactors, waste disposal, weapons testing, and accidents such as that which

occurred at Chernobyl in 1986. These worldwide levels of radionuclides are referred to as background radiation, and the radionuclides are available in the environment for uptake by organisms within the ecosystem (Eisenbud and Gesell 1997).

Because of increased radionuclide concentrations in proximity to nuclear research facilities, radionuclide uptake in the surrounding environment is a concern. Many studies have been done to investigate how radionuclides move through the environment, using different species as endpoints for contamination. Large ungulates are popular indicator species in these studies, possibly due to their consumption by humans (Hanson et al. 1975, Johanson and Bergstrom 1994).

There have been numerous studies on the uptake of radiocesium by large ungulates, some on the uptake of radiostrontium, and a few on the uptake of uranium. Most of these studies were inspired by previous studies on reindeer/caribou (*Rangifer tarandus*) in the northern latitudes. Caribou and reindeer play a key role in native food chains. These animals consume large quantities of lichen as forage, and lichen is particularly susceptible to collecting radionuclides from stratospheric fallout (Hanson et al. 1975). This radionuclide uptake makes the caribou a pathway for radionuclides into the human food chain. Certain groups of people, such as Laplanders, subsist almost entirely on meat from these animals, so there is the possibility of adverse health risks from a high level of radionuclide intake via reindeer meat.

Reindeer studies led researchers to evaluate other large ungulates for the presence of radionuclides. Studies involving cesium have been done in the United States on several populations of white-tailed and mule deer (Plummer et al. 1967, Hakonson and Whicker 1969, Whicker et al. 1965, Alldredge et al. 1974). In Europe, roe deer

(*Capreolus capreolus*) and moose (*Alces alces*) have been studied to determine cesium uptake and transfer to humans (Johanson and Bergstrom 1994). Although the animals in these studies are hunted in a recreational manner, they are not considered a major meat source for human consumption (Plummer et al. 1967). The cesium studies look at accumulation and elimination of cesium by deer, cesium uptake in relation to vegetation types, and the transfer of radiocesium to humans from these ungulates.

Plummer et al. (1967) found that white-tailed deer living in different ecosystems in the southeastern U.S. accumulated significantly different amounts of cesium. The difference was attributed to variation in concentrations of radionuclides in the forage the animals consumed, regardless of the age class of the deer. While a study conducted by Whicker et al. (1965) in Colorado found the same results in mule deer, Hakonson and Whicker (1969) found that mule deer fawns under five months old eliminated cesium more rapidly than adult deer. In addition, both of the latter studies found that sex made no difference in cesium elimination, although body weight did. This finding would make it appear as if males accumulated larger amounts of cesium than females because of their larger average body weight. Hakonson and Whicker (1969) concluded that roughly 89% of the variation in the elimination rate of cesium could be accounted for by body weight and the quantity of food intake. In addition, their study found that the amount of potassium, the metabolic analog of cesium, in the deer's diet did not affect the uptake or elimination of cesium by the deer.

Whicker et al. (1965) found a correlation between altitude and cesium uptake by deer. Above 8500 feet, cesium concentrations in deer muscle were significantly greater than at lower altitudes. This study found that soil concentrations of cesium generally

increased with altitude, although there was a large variance within this increase.

Vegetation showed a similar trend, with plants from the high summer ranges containing more cesium than plants collected from the winter range, which is lower in elevation.

These trends help explain the increase in cesium in deer muscle tissue since Whicker et al. determined that ingestion was the main pathway for cesium uptake.

Johanson and Bergstrom (1994) looked at the transfer of radiocesium from roe deer and moose to humans in Sweden. These animals are an important meat source in hunters' diets, and many of the animals are from areas that were affected by the Chernobyl reactor accident. Moose collected from an area known as Harbo were so contaminated that they could transfer enough cesium to hunters to reach 56 mrem per year. These numbers reflect only the dose from cesium-137, and they are greater than half of the ICRP guideline for allowable annual dose to a human from all known sources (100 mrem/yr).

For roe deer, the annual dose from deer to a human in Sweden ranges from 0.8 to 2.0 mrem. The largest annual effective dose to a person from roe deer obtained in the study was 70 mrem per year, from cesium alone. Concentrations of cesium in roe deer vary more than moose and depend on the habitat in which the deer are living. Johanson and Bergstrom's (1994) study indicates that increased amounts of cesium in ungulate meat will translate into increased cesium uptake, and a larger effective dose, in human consumers.

In addition to the previously mentioned cesium studies, there has been considerable work on studies involving strontium uptake by mule deer. Because strontium is a metabolic analog to calcium, it collects in bone rather than muscle tissue.

Schreckhise and Whicker (1975) found that strontium uptake in male deer was affected by season. Strontium uptake is greatest during periods of antler growth when new bone is being formed and compact bone is being mobilized for transfer to the developing antlers. Schreckhise and Whicker (1975) conjecture that the increase in strontium uptake by bucks can be explained by the increased uptake and assimilation of calcium for the new bone mineral. They found that gestation in doe deer did not appear to have the same effect on strontium uptake, but stated that more observations would be needed to determine if lactation or other variables would affect strontium uptake in female deer.

Plummer et al. (1967) studied strontium uptake by white-tailed deer in Georgia. Their study found that plants in the Georgia area showed an average concentration of strontium that was higher than concentrations found in Colorado the previous year. The increased strontium in plants was attributed to the calcium-poor soils in their study area. Strontium concentrations in deer jaws were also higher for the white-tailed deer than for the Colorado mule deer, which indicates the increased levels moving through the food chain. However, the Georgia white-tails showed lower levels of strontium than the caribou studied in Alaska between 1963 and 1965 (Plummer et al. 1967). None of the strontium studies reviewed included uptake by humans or give human dose calculations.

The uptake of uranium is important for two reasons. In addition to being radioactive, uranium is chemically toxic if ingested or inhaled in large quantities. Studies have been done at Jefferson, Yuma, and Aberdeen Army proving grounds on the human health risk and ecorisk of depleted uranium (DU) fragments (Ebinger and Hanson 1994, Ebinger et al. 1996). These studies used computer models to estimate adverse effects from uranium on both deer and humans, and tissue samples were taken in some studies

(Ebinger et al. 1996). A steady-state model was used to estimate DU uptake by deer and humans, and a computer code designed for risk assessment, RESRAD, was used to estimate the human health risk. For each of the proving grounds, the model indicated that the uptake of uranium by deer is at concentrations that do not pose a health risk to the animals either radiologically or toxicologically (Ebinger and Hanson 1996a, 1996b, Ebinger et al. 1996). The model also indicated that the dose and risk to humans from consumption of deer that live on the proving grounds were insignificant (Ebinger and Hanson 1996a, 1996b, Ebinger et al. 1996).

The model estimates for the intake of uranium by deer at Aberdeen were compared to data from white-tails collected on the proving grounds and for deer offsite. The data from the harvested animals supported the conclusion that there was little uptake of uranium by deer (Ebinger et al. 1996), which also lends support to the model's estimate of minimal risk to humans consuming deer meat. This system of employing a model to estimate concentrations and doses and comparing the estimates to actual field data was used as the basis for the project at LANL.

ELK AND DEER OF THE PAJARITO PLATEAU

Elk and mule deer are the two most common large ungulates in northern New Mexico. Both species are native to the Pajarito Plateau region, although elk were extirpated prior to 1910 and reintroduced in 1948 and 1964-65 (White 1981).

Petroglyphs of elk found in canyons in the area suggest that elk lived here and were hunted by prehistoric Native Americans. However, excavations of local sites give no indication that elk were plentiful in the area (Allen 1996). A small elk population

remained until approximately 1906, when hunting pressure from Native Americans and Anglo-Americans combined to eliminate elk from northern New Mexico (Allen 1996).

In 1948, twenty-one cow/calf and seven bull elk from a herd in Jackson Hole, Wyoming were released into the Jemez Mountains. A second set of reintroductions occurred during 1964 and 1965, which released fifty-eight more Jackson Hole elk into the area (White 1981). Due to the prime habitat conditions, the elk population began to increase, and their range expanded to include Laboratory lands.

In June of 1977, a high-intensity crown fire burned across the lower Pajarito Plateau and transformed thousands of acres of coniferous forest into open grassland habitat (Foxy 1984). The La Mesa fire burned 15,720 acres of forested land, of which 3000 acres were located on LANL property. This burn created a large expanse of prime wintering habitat for the elk living on the Pajarito Plateau, and the elk population responded. Elk in the Jemez area are grazers that eat primarily grass and forbs, although woody browse is seasonally included in their diet (Wolters 1996).

The vegetative communities located on the eastern side of the Jemez Mountains, those closest to LANL, consist of six vegetation types: ponderosa pine, pinon-juniper, juniper-grassland, mixed conifer, spruce-fir, and subalpine grassland (White 1981). Pinon-juniper, ponderosa pine, grassland, and mixed conifer habitats were all used by radio-collared elk on LANL lands. Pinon-juniper forests are used more than anticipated, and grasslands are used the most disproportionately for their abundance (Biggs et al. 1997).

The creation of such a large expanse of grassy winter range by the La Mesa fire prompted an exponential increase in elk numbers during the following years, and studies

indicate that the elk population is still growing rapidly. White (1981) raised the concern of elk overpopulation after his biotelemetry study, and his prediction has proven correct. Recently, an interagency task group has been formed to find a way of dealing with the overabundance of elk in the Jemez/Los Alamos area.

The 1996 Dome Fire, which burned close to 17,000 acres of ponderosa pine woodland in Bandelier National Monument and the Santa Fe National Forest (Dahlby Barclay et al. 1998), created additional grassy winter range. This additional range will allow the elk population to remain high and possibly continue to increase.

The rapid increase in the Jemez elk population is facilitated by low mortality (Allen 1996). This population is largely immune to hunting pressures because of the nature of local land ownership. Hunting is allowed on Santa Fe National Forest and, by private invitation, on the Baca Land and Cattle Co. ranch in the Valle Grande. San Ildefonso Pueblo residents set their own hunting limits and schedules on pueblo lands. However, because of federal directives and missions, hunting cannot be allowed on LANL or Bandelier National Monument lands, and county ordinances also prohibit hunting on Los Alamos County lands. Thus, as elk have several refuges from hunting during the fall season, hunting does not constitute a significant check on the population.

In addition to low hunting mortality, elk have few natural predators in the area. The grey wolf (*Canis lupus*), which was the key predator of elk in this region, was extirpated from northern New Mexico by the mid 1900s (Brown 1988). The other likely elk predator, the mountain lion (*Felis concolor*), has long been persecuted in northern New Mexico. Although mountain lions are known to live on Bandelier and LANL lands, they do not appear to have any significant effect on elk numbers (Allen 1996). The

absence of predation and hunting mortality leave starvation and disease to control the elk numbers in the Jemez. As a result of the increased habitat created by fires, neither of these controls seem to be effective.

With hunting and traffic accidents causing the majority of deaths in the Jemez elk population, the mortality rate is very low. For the year-round LANL elk population the major source of mortality is traffic accidents, and the number of highway accidents appears to be increasing with the elk numbers (Gonzales et al. 1995). Elk have also become a backyard nuisance to the residents of Los Alamos, tearing up gardens and decimating fruit trees.

Elk have traditionally used some private and LANL lands as wintering habitat, migrating out of the Jemez Mountains during fall rut and returning to the higher regions in the spring (Fresquez et al. 1994). With the increased elk numbers and hunting pressure on U.S. Forest Service land, a small group of elk, 100 to 200 animals, now uses parts of the Laboratory year-round (Biggs, pers. comm. 1997). These elk can potentially forage in the vicinity of radioactively contaminated sites, leading to the uptake and transport of radionuclides off of LANL property.

The Laboratory is also home to mule deer. Eberhardt and White (1979) did the last extensive study of deer on Laboratory lands. At that time, mule deer were the most numerous large ungulate on LANL property. Their numbers were so great in the 1950s that limited hunting could not control their numbers and a trap-and-remove program was created in 1960 (Eberhardt and White 1979). The program lasted seven years and relocated 248 mule deer. Since that time, the deer population has decreased without

human intervention, possibly due to the increase in elk numbers and consequent resource competition (Allen 1996, Eberhardt and White 1979).

The current mule deer population size in the Jemez area, and on LANL property specifically, is unknown. Deer are regularly picked up as roadkill around the Laboratory, indicating that they are still present in the area, but aerial surveys done in Bandelier indicate that the deer population has decreased (Allen 1996). These surveys also indicate that the heavy elk use in the burned areas is excluding deer from this prime winter habitat (Allen 1996). This resource competition could potentially limit both deer survival and reproduction, and lead to the decline in deer populations seen in the area. Deer are considered to be browsers, with the majority of their diet being made up of forbs and shrubs. Elk are grazers, consuming mostly grass and only some forbs and shrubs (Holechek et al. 1995). In northern New Mexico, however, Stephenson et al. (1985) found that shrubs and forbs comprise more than 50% of an elk's diet which puts them into more direct competition with mule deer for forage. Despite low deer numbers, both elk and deer are hunted on lands adjacent to LANL, and they become part of the food chain that LANL is required to monitor.

STUDY SITE

LANL encompasses approximately 11,000 hectares (43 mi²) at the base of the Jemez Mountains in northern New Mexico (LASL 1981) (Figure 2). LANL is surrounded by U.S. Forest Service land to the north and west, Bandelier National Monument to the south, and the Pueblo of San Ildefonso to the east (Biggs et al. 1997). Because of the nature of operations at the Laboratory, all of the land associated with

Figure 2. Location of Area G

LANL is restricted access, creating a sanctuary for wildlife, including elk and mule deer. Herds of resident elk and deer live and forage around the perimeter of Area G at LANL, which is a fenced site occupying 26 hectares (0.1 mi²) adjacent to the Sacred Area of San Ildefonso Pueblo (LANL 1990a).

Area G is the primary low-level radioactive waste disposal site for the Laboratory, and it has been used for radioactive, transuranic (TRU), and mixed waste storage and disposal since 1957 (LANL 1997). Tritium, uranium, and activation and fission products make up the majority of radionuclides disposed at this site, and polychlorinated biphenyls (PCBs) and asbestos have regularly been buried at Area G (LANL 1990a).

Area G contains waste storage domes, a solid waste compactor, liquid waste disposal sites, TRU waste pads and trenches, and disposal pits and shafts. There are four TRU trenches; each trench is 200 ft long, 13 ft wide, and 6 ft deep. These trenches are all closed and have been covered with crushed tuff. Disposal pits are roughly 200 ft long, 60 ft wide, and 60 ft deep, with the exception of one circular pit. Only 3 out of 34 disposal pits at Area G remain in use, and the closed pits are capped with crushed tuff. Disposal shafts have diameters between 3 and 6 ft and are 60 ft deep. Disposal shafts are used primarily for tritium and PCB disposal. Older shafts with no casings or other controls have been closed and capped with concrete domes. Newer shafts have a metal and/or concrete casing running their entire depth in addition to the concrete cap. These are the shafts that are still in use (LANL 1997).

Climate plays a key role in the break down of disposal materials and the contamination of surrounding areas via leaching and erosion. Area G has a temperate, semiarid mountain climate. The daily temperature may vary up to 25 degrees Fahrenheit

with an average wind speed of 3.2 m/s (Usner 1996). Wind direction is primarily from the south-southwest across the mesa, although easterly winds may prevail at night (LANL 1997). Average precipitation ranges from 35–40 cm/year (LANL 1997, Nyhan et al. 1978), and most precipitation occurs in two seasons, July through August and November through March. The driest season tends to be September through October (LANL 1990a, Usner 1996).

Due to the location and function of Area G, it is a highly monitored site. Several studies have been done to determine if radioactive materials are migrating into the environment from the disposal operation at Area G. These studies include soil and surface water sampling (Conrad et al. 1995), vegetation sampling (Fresquez et al. 1996), and small mammal sampling (Bennett et al. 1997) by the Ecology group at LANL.

Analyses of soil samples collected from the perimeter of Area G show concentrations of radionuclides greater than the background concentrations established for northern New Mexico (Conrad et al. 1995, Fresquez et al. 1995). The soil at Area G is sandy loam derived from tuff, which was formed from a volcanic eruption in the Jemez Mountain range (Nyhan et al. 1978, Usner 1996). Because of environmental forces and anthropogenic disturbances the material sampled as surface soils is really a combination of soil and crushed tuff that has been brought to the surface (LANL 1997).

Vegetation at Area G also shows increased radionuclide levels (Fresquez et al. 1996). The vegetation is dominated by a pinon-juniper overstory, which consists largely of single-seed juniper and pinon pine. This pinon-juniper type of vegetation persists across the mesa top, including the perimeter around Area G (Usner 1996). Sagebrush, mountain mahogany, and various grass and cacti species dominate the understory (Banar

1993). The presence of invader species, such as chamisa, goosefoot, and sunflowers, throughout Area G is attributed to the constant disturbance caused by the excavation and burial associated with waste disposal. Some areas remain devoid of vegetation as a result of vehicle traffic and erosion (LANL 1997).

Small mammal surveys at Area G were recently done as a baseline for future studies and analysis (Bennett et al. 1997). Small mammals, such as rodents, can affect the distribution of radionuclides via burrowing, mound building, and direct soil/waste contact during these activities, in addition to ingestion and inhalation. These mammals become a potential pathway for transport of contamination outside of Area G and off of LANL property. This preliminary study has not shown any significant difference between contaminants associated with on-site rodents and rodents from a control site on LANL property, however, results were not compared to regional samples in this study (Bennett et al. 1997).

The study presented here is the first to address the concern over large ungulates that forage around the perimeter of Area G.

METHODS AND MATERIALS

MODEL SELECTION

This study was designed to implement a computer model that traces radionuclides from a source term, through the environment, to a human endpoint and to calculate doses to the human. Two transport models were considered for the project: Biotran II, created at LANL, and RESRAD, created at Argonne National Laboratory.

These two models were compared to see which would be more compatible with the study objectives. While both models were created to look at radionuclide transport, they use different input parameters, have different time frames, and follow different formats. In order to choose the best model for this project, implementation manuals were read, the creators of each model were contacted for additional information, and LANL personnel who were familiar with both models were consulted.

While both models had advantages and disadvantages, RESRAD was chosen for this study. It is a well-established Fortran code that has been used and accepted by several government agencies, including the DOE and the Department of Defense. The model is set up in a user-friendly way that is not hard to implement, and it has been used in studies similar to this one by LANL personnel (Ebinger and Hanson 1994, 1996a, 1996b, Ebinger et al. 1996). The input parameters for RESRAD were largely available from studies that have been done at Area G as part of the Laboratory's environmental monitoring.

The two largest drawbacks of the RESRAD code, with respect to this study, were shared by the Biotran II model. The first is that the code cannot accept a water concentration that is entirely independent of the soil concentration for a given radionuclide. This interdependence in the model does not reflect the situation at LANL, where the drinking water available to elk and deer is completely separate from the surface soil at Area G. The second drawback was that RESRAD was designed for concentration estimates and dose calculations for a human endpoint, but it is not set up to extract information about ecological receptors such as the animals themselves.

The second drawback in the RESRAD code created the need for a model that would address the ecological concerns of this study, namely the radionuclide concentrations in the elk and deer muscle and the dose to those animals. This problem was solved by adapting the spreadsheet model that Ebinger and Hanson (1994, 1996a, 1996b) used for their Army Proving Grounds studies to the Area G site. The spreadsheet model was designed to look at the concentrations of radionuclides in animals using contaminated sites. Adding a dose calculation for an animal to the model and using previously calculated concentrations and an added external exposure component were simple steps.

RESRAD PARAMETER ACQUISITION

To obtain the parameters necessary to run a site-specific cycle of the RESRAD model, several environmental studies done at the Area G site were reviewed, as well as regional studies for northern New Mexico. Appendix A lists the parameters used by the RESRAD computer model, their default values, and the values that were input for these model runs. This appendix also references each parameter when site-specific values are used. In instances where parameter values could not be obtained for Area G and varying the assigned value of the parameter significantly affected model output, the maximum value accepted by the model was used.

Preliminary model runs were completed, varying each parameter in turn while holding all other parameters at a fixed value, to determine which parameters had an impact on the final model output. This sensitivity analysis indicated which parameters had the greatest impact on the final model estimate. Those parameters were the amount of meat a person ingested, the amount of soil an animal ingested, and the mass loading of

soil in the air for foliar deposition. Values were obtained for the first ($23\text{kg}_{\text{meat}}/\text{y}$) and second ($0.12\text{ kg}_{\text{soil}}/\text{d}$) of these parameters specifically for the Area G scenario. The data for the third parameter could not be obtained for Area G, so the maximum value allowed by RESRAD ($1\text{g}/\text{m}^3$) was used. The use of this value was conservative to keep the model from underestimating the radionuclide concentrations and subsequent doses.

RESRAD MODEL RUNS

In order to look at different foraging and uptake scenarios within Area G and compare them to background scenarios for the region, eight sets of parameters were used in different model runs for both elk and deer. This created sixteen model runs overall, each with unique parameters. The scenarios created for both elk and deer are listed in Table 2.

Percent forage contamination refers to the proportion of food intake the animal obtained in the contaminated area, whether it is Area G or a background location. A value of 100% represents the maximum possible contaminant uptake by an animal via forage. The 50% value represents the average percent time spent by a group of radio-collared elk at LANL (Fresquez et al. 1998). In a study done on LANL property, a group of radio-collared elk spent an average of 50% of their time on Laboratory lands, which is the basis for the 50% model scenario. The 50% value for background must be used in order to account for 100% of forage consumed by animals that only obtain 50% of their food at Area G.

Percent water contamination does not change for any scenarios, with the exception of one background scenario, because of the geography of surface water on

Table 2. RESRAD and Steady-State Model Scenarios for Elk and Deer

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Percent forage contamination	100	100	50	50
Percent water contamination	100	100	100	100
Region	Area G	Area G	Area G	Area G
Percent time spent onsite	100	100	50	50
Soil concentrations	Mean	Mean + 2 St. Dev.	Mean	Mean + 2 St. Dev.
Water concentrations	Mean	Mean + 2 St. Dev.	Mean	Mean + 2 St. Dev.

	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Percent forage contamination	100	100	50	50
Percent water contamination	100	100	0	0
Region	Background	Background	Background	Background
Percent time spent onsite	100	100	50	50
Soil concentrations	Mean	Mean + 2 St. Dev.	Mean	Mean + 2 St. Dev.
Water concentrations	Mean	Mean + 2 St. Dev.	Mean	Mean + 2 St. Dev.

LANL property. There are only a few year-round watering holes on LANL property, and only one that is adjacent to Area G (Biggs et al. 1999). Therefore, it is assumed that all water ingested by LANL elk and deer is contaminated. This assumption leads to the zero percent background contamination for water in the last two scenarios.

The region designates whether the scenario simulates Area G or background regions in northern New Mexico. This was done so that comparisons could be made between these two regions in the model estimates, and so the effect of the waste disposal site could be examined.

Percent time onsite indicates how much time the animal spends in the contaminated zone, regardless of their activity during that time. Time spent onsite is used to calculate the external exposure to the animal when estimating doses.

Soil concentrations and water concentrations refer to which of two sets of values were used as source term values for the run. The first set of values, for both soil and water, is the mean concentration of the seven radionuclides included in this study, calculated over four years of environmental surveillance. The second set of values is the mean concentration plus two standard deviations. This set of source term values represents an upper limit, or a very conservative value, for the radionuclide concentrations present in the soil or water. The specific inputs used in this study are listed in Appendix B, along with the source term data used to calculate input values.

Once all the necessary scenario parameters had been gathered and entered into the model, ecological pathways had to be chosen. RESRAD allows the user to select from nine pathways to follow the radionuclides from the source term to the final endpoint. These pathways are external gamma, inhalation, plant ingestion, meat ingestion, milk

ingestion, aquatic food ingestion, drinking water, soil ingestion, and radon exposure. Anywhere from one to all nine of these pathways can be used for each model run, however, this study was only interested in the meat pathway for human consumption. The external exposure pathways for humans were not used because Area G is closed to the public, making direct exposure highly unlikely. The ingestion parameters, other than meat, were not used because they do not fall into the scope of this study. It is important to remember that RESRAD estimates only human uptake and dose, not those of the elk and deer. For the animal components the study used the spreadsheet model, as described below.

SPREADSHEET MODEL

This model is a simple, steady-state model based on a two-component approach designed by the National Council of Radiological Protection (NCRP) (NCRP 1984). The parameters used for the spreadsheet model can be found in Appendix C. For details on equations and calculations used in this model see Ebinger and Hanson (1994). The model traces radiocontaminants from soil and water sources through vegetation and into herbivorous animals. The important differences between this model and RESRAD are the lack of a time component in the spreadsheet model and the ability of the user to enter independent soil and water source concentrations into the spreadsheet.

The spreadsheet model was amended to include six radionuclides other than uranium. The same equations were used to calculate uptake and retention, but the specific coefficients and transfer factors for each radionuclide had to be added to the model. The soil-to-root uptake factors and muscle-retention-to-intake ratios were obtained from the RESRAD handbook (Yu et al. 1993). High and low values available

for the soil-to-root factors were obtained from the NCRP (NCRP 1984) and are listed in Table 3.

The spreadsheet model used by Ebinger and Hanson (1994) lacked an inhalation pathway and both internal and external exposure pathways for estimating dose to animals. The inhalation pathway was added for the Area G study, using a mass loading in air value and a breathing rate for the animal. The resulting internal radionuclide concentration changes were insignificant.

Internal doses to the animal were calculated using the ingested concentrations of all radionuclides rather than the concentrations retained by the animals. If the retained concentrations were used, the model would not include the dose from ingested radionuclides prior to their excretion from the animal. Even though these radionuclides are not incorporated into tissue, they can deliver a dose while they are in the animal's digestive tract.

Table 3. Soil-to-Root Uptake Factors

Radionuclide	Standard Value	Minimum Value	Maximum Value
¹⁰¹ U	2.5E-03	2.9E-04	9.0E-03
³ H	4.8E+00	--	--
⁹⁰ Sr	3.0E-01	1.7E-02	1.0E+00
¹³⁷ Cs	4.0E-02	6.4E-04	7.8E-02
²⁴¹ Am	1.0E-03	--	--
²³⁸ Pu	1.0E-03	1.0E-06	2.5E-04
²³⁹ Pu	1.0E-03	1.0E-06	2.5E-04

The equation used to calculate dose from the ingested concentration is

$$D = C_i * F_1 / BW, \quad (1)$$

where D is the effective dose to the animal from a given radionuclide (rad/d), C_i is the ingested concentration of each radionuclide (pCi/d), F_1 is a conversion factor (rad-g/d-pCi), and BW is the body mass of the animal (g).

The F_1 conversion factor is calculated as follows:

$$F_1 = 0.037 * E_d * F_d * 1.6E-6 * 0.01, \quad (2)$$

where 0.037 is an activity constant (dis/s-pCi), E_d is the energy of disintegration (MeV/dis), F_d is the fraction of disintegration (unitless), $1.6E-6$ is a conversion factor (erg/MeV), and 0.01 is another conversion factor (rad-g/erg).

Once the effective dose had been calculated for each radionuclide, the doses were summed to obtain a total effective dose to the elk or deer from internal exposure.

To account for the dose to animals from external exposure while on the contaminated site, a RESRAD estimate was obtained using only the external pathway to obtain a dose to a 70-kg human. This dose was then adjusted for body mass and added to the internal dose that had been calculated for the elk and deer. This is a rough estimate of external dose. The external dose to an animal exceeds the internal dose by a large enough margin that it was necessary to find a method of estimating the external component.

ASSUMPTIONS

Whenever a model is used to approximate the real world, assumptions have to be made. While a complete list of every assumption is beyond the scope of this paper, the more important assumptions should be mentioned and justified. These assumptions often

are used to create a uniform distribution, which is easier to model than a patchy framework or landscape. RESRAD requires numerous assumptions due to its complexity, however, the simple spreadsheet model shares the following assumptions with RESRAD.

The first set of assumptions pertains to the climate and conditions at Area G. A uniform climate was assumed for the entire disposal site and contaminated area, with no microclimate pockets due to vegetation, topography, or anthropogenic factors. Contamination was also assumed to be uniform in the soil at Area G. This assumption was necessary for RESRAD because the code uses a single value for each radionuclide as the soil source term input. In reality, concentrations of the various radionuclides differ with proximity to disposal sites for different waste types. Uniform contamination was assumed for the water source for similar reasons, although the contamination in the wetland comes from outfalls from other LANL technical sites rather than Area G.

Other assumptions deal with radionuclides and their mobility in the environment. Radionuclides are seldom 100% mobile through an ecosystem. They form insoluble compounds, bind to different substances within biota, and can be preferentially excluded from organisms, as mentioned in the literature review. For modeling purposes, however, it is assumed that all radionuclides are completely bioavailable and can move through the environment without obstruction. This mobility, combined with the previous assumption of uniform soil contamination, supports the assumption that all vegetation at Area G is contaminated.

As with vegetation, there are assumptions associated with the elk and deer at Area G. The first is that Pajarito wetland is the animals' only water source. This is supported

by the research of Biggs et al. (1999), who have mapped water locations at the Laboratory and used telemetry collars to track elk use of LANL property. For external exposure calculations, elk and deer are assumed to spend either half or all (see Table 2) of their time on the contaminated site, not just the time they spend foraging. While this is not necessarily the case, given that their water source is outside the contaminated area, it provides the maximum estimate of the external dose to these animals.

Two assumptions that deal specifically with the RESRAD model and its default parameters should be mentioned here as well. The default parameters used in the RESRAD handbook (Yu et al. 1993) are based on specific soil types and characteristics, such as sandy loam, texture, and pH. When these defaults are used in a model run, it is assumed that they accurately estimate conditions at that site. This study assumes these default values will accurately estimate conditions at Area G. When a parameter value that significantly affected the model outcome could not be measured for Area G, the maximum value allowed by the RESRAD code was used.

Using these assumptions and maximum values assures that the model will yield a conservative (maximum) estimate even with all of the uncertainties involved.

RESULTS AND DISCUSSION

CONCENTRATIONS IN ELK AND DEER MUSCLE

The radionuclide concentrations estimated in elk muscle for each of the model scenarios are listed in Table 4, and the results for deer muscle are listed in Table 5. The full results of each model run for concentrations are listed in Appendix D. The concentrations estimated by the computer model are small with the exception of tritium

Table 4. Estimated Radionuclide Concentrations (pCi/kg) in Elk Muscle

Model Scenario	^{tot} U	³ H	⁹⁰ Sr	¹³⁷ Cs	²⁴¹ Am	²³⁸ Pu	²³⁹ Pu
Area G 100% mean	1.1E-01	4.4E+02	3.8E+00	4.5E+00	1.4E-03	2.0E-02	1.2E-02
Area G 100% mean + 2 st. dev.	1.8E-01	5.7E+03	7.7E+02	1.4E+01	1.2E-02	1.9E-01	7.0E-02
Background 100% mean	6.5E-02	-3.5E+01	4.6E+00	3.3E+00	5.2E-05	2.3E-04	7.2E-04
Background 100% mean + 2 st. dev.	9.4E-02	1.1E+02	7.1E+00	7.6E+00	1.0E-04	5.6E-04	1.6E-03
Area G 50%/Background 50% mean	8.7E-02	2.1E+02	4.2E+00	3.8E+00	7.1E-04	1.0E-02	6.3E-03
Area G 50%/Background 50% mean + 2 st. dev.	1.4E-01	2.9E+03	3.9E+02	1.0E+01	5.9E-03	9.4E-02	3.5E-02

Table 5. Estimated Radionuclide Concentrations (pCi/kg) in Deer Muscle

Model Scenario	^{tot} U	³ H	⁹⁰ Sr	¹³⁷ Cs	²⁴¹ Am	²³⁸ Pu	²³⁹ Pu
Area G 100% mean	4.6E-02	2.0E+02	1.7E+00	2.0E+00	5.7E-04	8.5E-03	5.0E-03
Area G 100% mean + 2 st. dev.	7.5E-02	2.6E+03	3.5E+02	5.9E+00	4.9E-03	7.9E-02	2.9E-02
Background 100% mean	2.7E-02	-1.6E+01	2.1E+00	1.4E+00	2.0E-05	9.3E-05	2.8E-04
Background 100% mean + 2 st. dev.	3.9E-02	3.0E+01	3.2E+00	3.1E+00	3.6E-05	2.1E-04	5.7E-04
Area G 50%/Background 50% mean	3.6E-02	-7.8E+00	1.9E+00	1.7E+00	3.0E-04	4.3E-03	2.6E-03
Area G 50%/Background 50% mean + 2 st. dev.	5.7E-02	1.3E+03	1.8E+02	4.4E+00	2.5E-03	3.9E-02	1.5E-02

in animals that forage at Area G. When these results were compared with data collected from actual tissue samples taken around LANL property (Table 6, Fresquez et al. 1998), the majority of the model predictions fell within the range of the tissue sample values. This is true for Area G, background, and fifty-fifty Area G/background estimates. The model estimates for elk muscle fell outside of the range of sample values for tritium and americium. Deer muscle estimates did not correspond to the tissue sample range for tritium, uranium, and cesium. All model estimates were within the mean plus or minus two standard deviations range for collected tissue samples, however.

Table 6. Radionuclide Concentrations from Tissue Samples at LANL

Elk	^{tot} U (pCi/kg _{dry})	³ H (pCi/kg _{dry})	⁹⁰ Sr (pCi/kg _{dry})	¹³⁷ Cs (pCi/kg _{dry})	²⁴¹ Am (pCi/kg _{dry})	²³⁸ Pu (pCi/kg _{dry})	²³⁹ Pu (pCi/kg _{dry})
Minimum	-4.2E-01	-9.9E+01	-3.5E+01	-5.9E+00	9.0E-03	-4.9E-01	-6.3E-01
Maximum	3.1E+01	3.8E+03	1.4E+02	2.2E+02	1.1E-01	2.1E-01	2.5E-01
Mean	2.2E+00	4.7E+01	2.5E+01	3.5E+01	5.0E-02	-1.6E-02	-3.6E-03
St. Dev.	6.7E+00	1.1E+02	4.7E+01	5.2E+01	3.7E-02	1.3E-01	1.6E-01

Deer	^{tot} U (pCi/kg _{dry})	³ H (pCi/kg _{dry})	⁹⁰ Sr (pCi/kg _{dry})	¹³⁷ Cs (pCi/kg _{dry})	²⁴¹ Am (pCi/kg _{dry})	²³⁸ Pu (pCi/kg _{dry})	²³⁹ Pu (pCi/kg _{dry})
Minimum	1.3E-01	0.0E+00	-2.4E+01	-1.8E+00	-1.2E-02	-2.3E-02	-9.0E-03
Maximum	9.5E-01	2.7E+02	3.1E+02	0.0E+00	7.2E-02	4.8E-01	3.6E-01
Mean	4.5E-01	1.3E+01	4.9E+01	6.8E+01	2.9E-02	6.3E-02	6.9E-02
St. Dev.	2.7E-01	1.2E+01	1.1E+02	1.4E+02	2.3E-02	1.4E-01	1.2E-01

Estimated tritium values for the elk at Area G and fifty-percent time spent at Area G scenarios, using the mean plus two standard deviations as the source term, were higher

than the maximum values found in tissue samples. The high estimates are likely due to localized differences in soil and plant concentrations of tritium. Because Area G is a disposal site for tritium, there is a high concentration of this radionuclide known to be present. The tissue samples were taken largely from roadkills whose exact past foraging locations are not known. Most sites in the vicinity of LANL where these animals were likely to forage have lower concentrations of tritium than those found at Area G. This would support the model's estimate of higher tritium levels for the Area G scenarios.

Model estimates for americium in elk muscle were lower than tissue sample values for both background scenarios and for the fifty-fifty scenario when the average radionuclide concentrations were used as the source term. Because the roadkill animals were found on or near LANL lands, the tissue samples are expected to show increased levels of americium as compared to background estimates. The Area G model estimates for americium in elk meat correspond well to the range of observed tissue sample values.

As in elk, tritium estimates produced by the model for deer meat did not correspond to the range of values found in tissue samples. Both Area G scenarios had tritium estimates that exceeded the values from actual tissue samples. The explanation for this is likely the same as for elk, the increased tritium due to disposal shafts at Area G. Most deer collected as roadkill on or near LANL property were not located near to Area G, which would help to explain lower tritium levels in the tissue.

Uranium estimates obtained from model scenarios were all less than the minimum concentration (1.26×10^{-1} pCi/kg) measured in deer tissues. This may be partially due to the small sample size for deer tissue ($n = 11$). Model underestimation of uranium in the

tissue could also be due to parameters that were chosen specifically for Area G or due to naturally occurring uranium in Jemez region soils.

The computer model also overestimated cesium in deer tissue, although the overestimates were by less than one order of magnitude. This overestimation is attributed to model assumptions and conservative parameters because there is no evident ecological cause. The model was set up to overestimate tissue concentrations, so the high cesium estimates are not surprising (See Appendix C for model parameters).

Even when model predictions for concentrations were outside the range of observed values, they fell within the boundaries of the mean observed value plus or minus two standard deviations. So, model estimates generated by the spreadsheet appear to be fairly accurate in terms of the concentrations of radionuclides in elk and deer muscle in the LANL area.

DOSE TO ELK AND DEER

The dose to animals foraging at Area G consists of two main components. The internal dose from radionuclides that have been ingested or inhaled and the external dose from gamma radiation emitted from contaminated soil and vegetation. Table 7 contains the model estimates for dose to an elk, and Table 8 contains the estimates for dose to deer. The largest component of the total dose is typically from external exposure to an animal, which overshadows the internal dose. However, for the Area G scenario where the source term is mean soil concentration plus two standard deviations, the internal dose to a deer becomes the greater of the two components. The same scenario does not yield a greater internal than external dose for elk, most likely due to the elk's greater mass and

Table 7. Computer Estimated Dose to Elk

Animal Location/ Percent Time	Soil/Water Concentration	External dose mrad/d	Internal dose mrad/d	Total dose to animal mrad/d
Area G/100%	mean	1.48E-02	4.90E-04	1.53E-02
Area G/100%	mean + 2 st. dev.	4.05E-02	6.19E-03	4.67E-02
Background/100%	mean	9.70E-03	2.02E-04	9.90E-03
Background/100%	mean + 2 st. dev.	1.81E-02	3.15E-04	1.84E-02
Area G 50%/Bkgd 50%	mean	1.22E-02	3.45E-04	1.25E-02
Area G 50%/Bkgd 50%	mean + 2 st. dev.	2.93E-02	3.26E-03	3.26E-02

Table 8. Computer Estimated Dose to Deer

Animal Location/ Percent Time	Soil/Water Concentration	External dose mrad/d	Internal dose mrad/d	Total dose to animal mrad/d
Area G/100%	mean	3.51E-03	8.79E-04	4.39E-03
Area G/100%	mean + 2 st. dev.	9.56E-03	1.17E-02	2.13E-02
Background/100%	mean	2.29E-03	3.56E-04	2.65E-03
Background/100%	mean + 2 st. dev.	4.30E-03	5.48E-04	4.85E-03
Area G 50%/Bkgd 50%	mean	2.90E-03	6.16E-04	3.52E-03
Area G 50%/Bkgd 50%	mean + 2 st. dev.	6.93E-03	6.11E-03	1.30E-02

surface area. This increases the external dose received by the animal. In all other cases for elk and deer, the model estimates are greater for external dose than for internal.

Not surprisingly, the largest doses to elk and deer are the total doses when the animals spend 100% of the time at Area G. These doses to either elk (0.047 mrad/d) or deer (0.021 mrad/d) are still far below the IAEA guideline limit used by the DOE (100 mrad/d).

When background doses are subtracted from the scenarios involving Area G, the net effect of the Laboratory, in terms of dose, can be seen (Figure 3). The greatest net dose to an animal (0.028 mrad/d to an elk) is still several orders of magnitude less than the guideline value. Model estimates indicate that LANL waste disposal at Area G is not causing a significant risk to large ungulates foraging around that site.

Figure 3. Net dose to elk and deer at Area G

DOSE TO HUMANS

The dose to humans was calculated using a high level of meat consumption and assuming that all of the meat was contaminated (Appendix A). The doses to humans, listed in Tables 9 and 10, do not include an external dose because Area G is closed to the public, so there is no reason to look at external exposure. The dose to a human consuming elk or deer is broken down into water dependent and water independent components because RESRAD would not allow independent soil and water

Table 9. Estimated Dose to a Person Consuming 23kg of Elk Meat per Year

Animal Location/ Percent Time	Soil/Water Concentration	Water _{independent} Dose mrem/y	Water _{dependent} Dose mrem/y	Total Dose from Meat mrem/y
Area G/100%	mean	1.94E-02	1.70E-03	2.11E-02
Area G/100%	mean + 2 st. dev.	6.37E-02	7.98E-03	7.17E-02
Background/100%	mean	1.37E-02	1.96E-03	1.57E-02
Background/100%	mean + 2 st. dev.	2.25E-02	9.14E-03	3.16E-02
Area G 50%/Bkgd 50%	mean	1.66E-02	1.70E-03	1.83E-02
Area G 50%/Bkgd 50%	mean + 2 st. dev.	4.31E-02	7.98E-03	5.11E-02

Table 10. Estimated Dose to a Person Consuming 23kg of Deer Meat per Year

Animal Location/ Percent Time	Soil/Water Concentration	Water _{independent} Dose mrem/y	Water _{dependent} Dose mrem/y	Total Dose from Meat mrem/y
Area G/100%	mean	8.77E-03	4.65E-04	9.23E-03
Area G/100%	mean + 2 st. dev.	2.94E-02	2.19E-03	3.16E-02
Background/100%	mean	6.14E-03	5.37E-04	6.68E-03
Background/100%	mean + 2 st. dev.	1.01E-02	2.51E-03	1.26E-02
Area G 50%/Bkgd 50%	mean	7.45E-03	4.65E-04	7.92E-03
Area G 50%/Bkgd 50%	mean + 2 st. dev.	1.97E-02	2.19E-03	2.19E-02

concentrations in a single model run. For modeling purposes all radionuclides are being ingested by humans via meat; people are not drinking contaminated water.

The water independent component of the dose to humans is the larger component. It is approximately an order of magnitude larger than the water dependent component for every model scenario, indicating the larger contamination source for the animal muscle is forage as opposed to water. The water independent pathway is the forage from Area G, while the water dependant pathway is the water ingested from Pajarito Canyon. This result correlates with the radionuclide concentrations at Area G and in the Pajarito wetland in that Area G is a significantly more contaminated area.

The ICRP guideline for exposure to humans is 100 mrem/y from all sources (ICRP 1990). The largest dose to a person consuming deer meat from this study is 0.032 mrem/y, and the largest dose from elk meat is 0.072 mrem/y. These values are from model scenarios using the most conservative assumptions, and they are still four orders of magnitude below the recommended guideline. The dose to humans that use these elk and deer as a food source does not appear to be a significant health risk.

As with the dose to the elk and deer themselves, the background dose to a human can be subtracted from the onsite dose to obtain a net dose from LANL activities at Area G. Figure 4 shows the net doses to a human consuming elk or deer meat from Area G activities. The largest of these doses (0.04 mrem/y) comes from consuming meat from an elk that spends 100% of its time at Area G, using the mean radionuclide concentrations plus two standard deviations as the source term. This net dose is four orders of magnitude below the ICRP guideline and just over half of the overall dose from meat

consumption. The model estimates indicate that consuming elk and deer from Area G as a primary meat source should have no significant health risks for humans.

Figure 4. Dose to humans from meat ingestion

CONCLUSIONS

All model estimates of the concentrations of radionuclides in animal muscle, using site-specific parameters, fell within two standard deviations of the mean found in animal tissue samples collected around LANL. For most radionuclides the model estimates were within the range of observed values from tissue samples. These findings support that the models used in this study are acceptable estimators of radionuclide uptake and transport through the environment to an animal receptor.

The risks to elk and deer foraging at Area G are not significant given the low dose estimates obtained from the computer models. The significance of risk is based on

radiological exposure guidelines for animals that were recommended by the IAEA in 1992.

Dose estimates for humans consuming meat from elk or deer that have been foraging at Area G indicate that there is no significant health risk to these individuals from radionuclides. This finding is based upon current radiological exposure limits for the general public as set by the ICRP (ICRP 1990).

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-Appendix A-

RESRAD Site-Specific Parameter Summary

Menu	Parameter	Input	Default
R011 ³	Area of contaminated zone (m**2)	2.550E+05	1.000E+04
R011 ³	Thickness of contaminated zone (m)	3.048E-01	2.000E+00
R011 ³	Length parallel to aquifer flow (m)	1.000E-04	1.000E+02
R011 ³	Basic radiation dose limit (mrem/yr)	1.000E+02	3.000E+01
R011 ³	Time since placement of material (yr)	0.000E+00	0.000E+00
R013 ³	Cover depth (m)	0.000E+00	0.000E+00
R013 ³	Density of contaminated zone (g/cm**3)	1.500E+00	1.500E+00
R013 ³	Contaminated zone erosion rate (m/yr)	4.000E-03	1.000E-03
R013 ³	Contaminated zone total porosity	4.000E-01	4.000E-01
R013 ³	Contaminated zone effective porosity	3.200E-01	2.000E-01
R013 ³	Contaminated zone hydraulic conductivity (m/yr)	1.090E+03	1.000E+01
R013 ³	Contaminated zone b parameter	4.900E+00	5.300E+00
R013 ³	Average annual wind speed (m/sec)	3.200E+00	2.000E+00
R013 ³	Humidity in air (g/m**3)	8.000E+00	8.000E+00
R013 ³	Evapotranspiration coefficient	5.000E-01	5.000E-01
R013 ³	Precipitation (m/yr)	3.500E-01	1.000E+00
R013 ³	Irrigation (m/yr)	2.000E-01	2.000E-01
R013 ³	Runoff coefficient	2.000E-01	2.000E-01
R013 ³	Watershed area for nearby stream or pond (m**2)	1.000E+06	1.000E+06
R013 ³	Accuracy for water/soil computations	1.000E-01	1.000E-03
R014 ³	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND
R015 ³	Number of unsaturated zone strata	2	1
R015 ³	Unsat. zone 1, thickness (m)	2.743E+02	4.000E+00
R015 ³	Unsat. zone 1, soil density (g/cm**3)	1.500E+00	1.500E+00
R015 ³	Unsat. zone 1, total porosity	4.000E-01	4.000E-01
R015 ³	Unsat. zone 1, effective porosity	2.100E-01	2.000E-01
R015 ³	Unsat. zone 1, soil-specific b parameter	5.300E+00	5.300E+00
R015 ³	Unsat. zone 1, hydraulic conductivity (m/yr)	1.000E+01	1.000E+01
R015 ³	Unsat. zone 2, thickness (m)	4.000E+00	0.000E+00
R015 ³	Unsat. zone 2, soil density (g/cm**3)	1.500E+00	1.500E+00
R015 ³	Unsat. zone 2, total porosity	4.000E-01	4.000E-01
R015 ³	Unsat. zone 2, effective porosity	2.000E-01	2.000E-01
R015 ³	Unsat. zone 2, soil-specific b parameter	5.300E+00	5.300E+00
R015 ³	Unsat. zone 2, hydraulic conductivity (m/yr)	1.000E+01	1.000E+01
R016 ³	Distribution coefficients for Am-241		
R016 ³	Contaminated zone (cm**3/g)	2.000E+01	2.000E+01
R016 ³	Unsat. zone 1 (cm**3/g)	2.000E+01	2.000E+01
R016 ³	Unsat. zone 2 (cm**3/g)	2.000E+01	2.000E+01
R016 ³	Saturated zone (cm**3/g)	2.000E+01	2.000E+01
R016 ³	Leach rate (/yr)	0.000E+00	0.000E+00
R016 ³	Solubility constant	0.000E+00	0.000E+00

Menu	Parameter	Input	Default
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R016 ³	Distribution coefficients for Cs-137		
R016 ³	Contaminated zone (cm**3/g)	1.000E+02	1.000E+03
R016 ³	Unsaturated zone 1 (cm**3/g)	1.000E+03	1.000E+03
R016 ³	Unsaturated zone 2 (cm**3/g)	1.000E+03	1.000E+03
R016 ³	Saturated zone (cm**3/g)	1.000E+03	1.000E+03
R016 ³	Leach rate (/yr)	0.000E+00	0.000E+00
R016 ³	Solubility constant	0.000E+00	0.000E+00
R016 ³	Distribution coefficients for H-3		
R016 ³	Contaminated zone (cm**3/g)	1.000E+00	0.000E+00
R016 ³	Unsaturated zone 1 (cm**3/g)	1.000E+00	0.000E+00
R016 ³	Unsaturated zone 2 (cm**3/g)	0.000E+00	0.000E+00
R016 ³	Saturated zone (cm**3/g)	1.000E+00	0.000E+00
R016 ³	Leach rate (/yr)	0.000E+00	0.000E+00
R016 ³	Solubility constant	0.000E+00	0.000E+00
R016 ³	Distribution coefficients for Pu-238		
R016 ³	Contaminated zone (cm**3/g)	2.000E+02	2.000E+03
R016 ³	Unsaturated zone 1 (cm**3/g)	2.000E+03	2.000E+03
R016 ³	Unsaturated zone 2 (cm**3/g)	2.000E+03	2.000E+03
R016 ³	Saturated zone (cm**3/g)	2.000E+03	2.000E+03
R016 ³	Leach rate (/yr)	0.000E+00	0.000E+00
R016 ³	Solubility constant	0.000E+00	0.000E+00
R016 ³	Distribution coefficients for Pu-239		
R016 ³	Contaminated zone (cm**3/g)	2.000E+02	2.000E+03
R016 ³	Unsaturated zone 1 (cm**3/g)	2.000E+03	2.000E+03
R016 ³	Unsaturated zone 2 (cm**3/g)	2.000E+03	2.000E+03
R016 ³	Saturated zone (cm**3/g)	2.000E+03	2.000E+03
R016 ³	Leach rate (/yr)	0.000E+00	0.000E+00
R016 ³	Solubility constant	0.000E+00	0.000E+00
R016 ³	Distribution coefficients for Sr-90		
R016 ³	Contaminated zone (cm**3/g)	3.000E+00	3.000E+01
R016 ³	Unsaturated zone 1 (cm**3/g)	4.000E+02	3.000E+01
R016 ³	Unsaturated zone 2 (cm**3/g)	3.000E+01	3.000E+01
R016 ³	Saturated zone (cm**3/g)	3.000E+01	3.000E+01
R016 ³	Leach rate (/yr)	0.000E+00	0.000E+00
R016 ³	Solubility constant	0.000E+00	0.000E+00
R016 ³	Distribution coefficients for U-234		
R016 ³	Contaminated zone (cm**3/g)	5.000E+00	5.000E+01
R016 ³	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01
R016 ³	Unsaturated zone 2 (cm**3/g)	5.000E+01	5.000E+01
R016 ³	Saturated zone (cm**3/g)	5.000E+01	5.000E+01
R016 ³	Leach rate (/yr)	0.000E+00	1.022E-01
R016 ³	Solubility constant	0.000E+00	0.000E+00

Menu	Parameter	Input	Default
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R016 ³	Distribution coefficients for U-235		
R016 ³	Contaminated zone (cm**3/g)	5.000E+00	5.000E+01
R016 ³	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01
R016 ³	Unsaturated zone 2 (cm**3/g)	5.000E+01	5.000E+01
R016 ³	Saturated zone (cm**3/g)	5.000E+01	5.000E+01
R016 ³	Leach rate (/yr)	0.000E+00	0.000E+00
R016 ³	Solubility constant	0.000E+00	0.000E+00
R016 ³	Distribution coefficients for U-238		
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R016 ³	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01
R016 ³	Unsaturated zone 2 (cm**3/g)	5.000E+01	5.000E+01
R016 ³	Saturated zone (cm**3/g)	5.000E+01	5.000E+01
R016 ³	Leach rate (/yr)	0.000E+00	1.022E-01
R016 ³	Solubility constant	0.000E+00	0.000E+00
R016 ³	Distribution coefficients for daughter Ac-227		
R016 ³	Contaminated zone (cm**3/g)	2.000E+01	2.000E+01
R016 ³	Unsaturated zone 1 (cm**3/g)	2.000E+01	2.000E+01
R016 ³	Unsaturated zone 2 (cm**3/g)	2.000E+01	2.000E+01
R016 ³	Saturated zone (cm**3/g)	2.000E+01	2.000E+01
R016 ³	Leach rate (/yr)	0.000E+00	0.000E+00
R016 ³	Solubility constant	0.000E+00	0.000E+00
R016 ³	Distribution coefficients for daughter Np-237		
R016 ³	Contaminated zone (cm**3/g)	1.000E+00	1.000E+00
R016 ³	Unsaturated zone 1 (cm**3/g)	1.000E+00	1.000E+00
R016 ³	Unsaturated zone 2 (cm**3/g)	1.000E+00	1.000E+00
R016 ³	Saturated zone (cm**3/g)	1.000E+00	1.000E+00
R016 ³	Leach rate (/yr)	0.000E+00	0.000E+00
R016 ³	Solubility constant	0.000E+00	000E+00
R016 ³	Distribution coefficients for daughter Pa-231		
R016 ³	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01
R016 ³	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01
R016 ³	Unsaturated zone 2 (cm**3/g)	5.000E+01	5.000E+01
R016 ³	Saturated zone (cm**3/g)	5.000E+01	5.000E+01
R016 ³	Leach rate (/yr)	0.000E+00	0.000E+00
R016 ³	Solubility constant	0.000E+00	0.000E+00
R016 ³	Distribution coefficients for daughter Pb-210		
R016 ³	Contaminated zone (cm**3/g)	1.000E+02	1.000E+02
R016 ³	Unsaturated zone 1 (cm**3/g)	1.000E+02	1.000E+02
R016 ³	Unsaturated zone 2 (cm**3/g)	1.000E+02	1.000E+02
R016 ³	Saturated zone (cm**3/g)	1.000E+02	1.000E+02
R016 ³	Leach rate (/yr)	0.000E+00	0.000E+00
R016 ³	Solubility constant	0.000E+00	0.000E+00

Menu	Parameter	Input	Default
<hr/>			
R016 ³	Distribution coefficients for daughter Ra-226		
R016 ³	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01
R016 ³	Unsaturated zone 1 (cm**3/g)	7.000E+01	7.000E+01
R016 ³	Unsaturated zone 2 (cm**3/g)	7.000E+01	7.000E+01
R016 ³	Saturated zone (cm**3/g)	7.000E+01	7.000E+01
R016 ³	Leach rate (/yr)	0.000E+00	0.000E+00
R016 ³	Solubility constant	0.000E+00	0.000E+00
R016 ³	Distribution coefficients for daughter Th-229		
R016 ³	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04
R016 ³	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04
R016 ³	Unsaturated zone 2 (cm**3/g)	6.000E+04	6.000E+04
R016 ³	Saturated zone (cm**3/g)	6.000E+04	6.000E+04
R016 ³	Leach rate (/yr)	0.000E+00	0.000E+00
R016 ³	Solubility constant	0.000E+00	0.000E+00
R016 ³	Distribution coefficients for daughter Th-230		
R016 ³	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04
R016 ³	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04
R016 ³	Unsaturated zone 2 (cm**3/g)	6.000E+04	6.000E+04
R016 ³	Saturated zone (cm**3/g)	6.000E+04	6.000E+04
R016 ³	Leach rate (/yr)	0.000E+00	0.000E+00
R016 ³	Solubility constant	0.000E+00	0.000E+00
R016 ³	Distribution coefficients for daughter U-233		
R016 ³	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01
R016 ³	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01
R016 ³	Unsaturated zone 2 (cm**3/g)	5.000E+01	5.000E+01
R016 ³	Saturated zone (cm**3/g)	5.000E+01	5.000E+01
R016 ³	Leach rate (/yr)	0.000E+00	0.000E+00
R016 ³	Solubility constant	0.000E+00	0.000E+00
R017 ³	Inhalation rate (m**3/yr)	not used	8.400E+03
R017 ³	Mass loading for inhalation (g/m**3)	not used	1.000E-04
R017 ³	Shielding factor, external gamma	not used	7.000E-01
R017 ³	Fraction of time spent indoors	0.000E+00	5.000E-01
R017 ³	Fraction of time spent outdoors (on site)	0.000E+00	2.500E-01
R017 ³	Fractions of annular areas within AREA:		
R017 ³	Ring 1	not used	1.000E+00
R017 ³	Ring 2	not used	2.732E-01
R017 ³	Ring 3	not used	0.000E+00
R017 ³	Ring 4	not used	0.000E+00
R017 ³	Ring 5	not used	0.000E+00
R017 ³	Ring 6	not used	0.000E+00
R017 ³	Ring 7	not used	0.000E+00
R017 ³	Ring 8	not used	0.000E+00
R017 ³	Ring 9	not used	0.000E+00
R017 ³	Ring 10	not used	0.000E+00
R017 ³	Ring 11	not used	0.000E+00
R017 ³	Ring 12	not used	0.000E+00

Menu	Parameter	Input	Default
R018 ³	Fruits, vegetables and grain consumption (kg/yr)	0.000E+00	1.600E+02
R018 ³	Leafy vegetable consumption (kg/yr)	0.000E+00	1.400E+01
R018 ³	Milk consumption (L/yr)	not used	9.200E+01
R018 ³	Meat and poultry consumption (kg/yr)	2.300E+01	6.300E+01
R018 ³	Fish consumption (kg/yr)	not used	5.400E+00
R018 ³	Other seafood consumption (kg/yr)	not used	9.000E-01
R018 ³	Soil ingestion rate (g/yr)	0.000E+00	3.650E+01
R018 ³	Drinking water intake (L/yr)	0.000E+00	5.100E+02
R018 ³	Contamination fraction of drinking water	0.000E+00	1.000E+00
R018 ³	Contamination fraction of household water	not used	1.000E+00
R018 ³	Contamination fraction of livestock water	0.000E+00	1.000E+00
R018 ³	Contamination fraction of irrigation water	1.000E+00	1.000E+00
R018 ³	Contamination fraction of aquatic food	not used	5.000E-01
R018 ³	Contamination fraction of plant food	1.000E+00	-1
R018 ³	Contamination fraction of meat	1.000E+00	-1
R018 ³	Contamination fraction of milk	not used	-1
R019 ³	Livestock fodder intake for meat (kg/day)	5.900E+00	6.800E+01
R019 ³	Livestock fodder intake for milk (kg/day)	not used	5.500E+01
R019 ³	Livestock water intake for meat (L/day)	1.353E+01	5.000E+01
R019 ³	Livestock water intake for milk (L/day)	not used	1.600E+02
R019 ³	Livestock soil intake (kg/day)	1.200E-01	5.000E-01
R019 ³	Mass loading for foliar deposition (g/m**3)	1.000E+00	1.000E-04
R019 ³	Depth of soil mixing layer (m)	1.500E-01	1.500E-01
R019 ³	Depth of roots (m)	2.000E+00	9.000E-01
R019 ³	Drinking water fraction from ground water	0.000E+00	1.000E+00
R019 ³	Household water fraction from ground water	1.000E+00	1.000E+00
R019 ³	Livestock water fraction from ground water	not used	1.000E+00
R019 ³	Irrigation fraction from ground water	0.000E+00	1.000E+00
R19B ³	Wet weight crop yield for Non-Leafy (kg/m**2)	7.000E-01	7.000E-01
R19B ³	Wet weight crop yield for Leafy (kg/m**2)	1.500E+00	1.500E+00
R19B ³	Wet weight crop yield for Fodder (kg/m**2)	1.100E+00	1.100E+00
R19B ³	Growing Season for Non-Leafy (years)	1.700E-01	1.700E-01
R19B ³	Growing Season for Leafy (years)	2.500E-01	2.500E-01
R19B ³	Growing Season for Fodder (years)	4.200E-01	8.000E-02
R19B ³	Translocation Factor for Non-Leafy	1.000E-01	1.000E-01
R19B ³	Translocation Factor for Leafy	1.000E+00	1.000E+00
R19B ³	Translocation Factor for Fodder	1.000E+00	1.000E+00
R19B ³	Dry Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01
R19B ³	Dry Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01
R19B ³	Dry Foliar Interception Fraction for Fodder	2.500E-01	2.500E-01
R19B ³	Wet Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01
R19B ³	Wet Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01
R19B ³	Wet Foliar Interception Fraction for Fodder	2.500E-01	2.500E-01
R19B ³	Weathering Removal Constant for Vegetation	2.000E+01	2.000E+01
C14 ³	C-12 concentration in water (g/cm**3)	not used	2.000E-05
C14 ³	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02
C14 ³	Fraction of vegetation carbon from soil	not used	2.000E-02
C14 ³	Fraction of vegetation carbon from air	not used	9.800E-01

Menu	Parameter	Input	Default
C14	³ C-14 evasion layer thickness in soil (m)	not used	3.000E-01
C14	³ C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07
C14	³ C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10
C14	³ Fraction of grain in beef cattle feed	not used	8.000E-01
C14	³ Fraction of grain in milk cow feed	not used	2.000E-01
STOR	³ Storage times of contaminated foodstuffs (days):		
STOR	³ Fruits, non-leafy vegetables, and grain	0.000E+00	1.400E+01
STOR	³ Leafy vegetables	0.000E+00	1.000E+00
STOR	³ Milk	1.000E+00	1.000E+00
STOR	³ Meat and poultry	0.000E+00	2.000E+01
STOR	³ Fish	7.000E+00	7.000E+00
STOR	³ Crustacea and mollusks	7.000E+00	7.000E+00
STOR	³ Well water	1.000E+00	1.000E+00
STOR	³ Surface water	1.000E+00	1.000E+00
STOR	³ Livestock fodder	0.000E+00	4.500E+01
R021	³ Thickness of building foundation (m)	not used	1.500E-01
R021	³ Bulk density of building foundation (g/cm**3)	not used	2.400E+00
R021	³ Total porosity of the cover material	not used	4.000E-01
R021	³ Total porosity of the building foundation	not used	1.000E-01
R021	³ Volumetric water content of the cover material	not used	5.000E-02
R021	³ Volumetric water content of the foundation	not used	3.000E-02
R021	³ Diffusion coefficient for radon gas (m/sec):		
R021	³ in cover material	not used	2.000E-06
R021	³ in foundation material	not used	3.000E-07
R021	³ in contaminated zone soil	not used	2.000E-06
R021	³ Radon vertical dimension of mixing (m)	not used	2.000E+00
R021	³ Average building air exchange rate (1/hr)	not used	5.000E-01
R021	³ Height of the building (room) (m)	not used	2.500E+00
R021	³ Building interior area factor	not used	0.000E+00
R021	³ Building depth below ground surface (m)	not used	-1.000E+00
R021	³ Emanating power of Rn-222 gas	not used	2.500E-01
R021	³ Emanating power of Rn-220 gas	not used	1.500E-01

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	³ suppressed
2 -- inhalation (w/o radon)	³ suppressed
3 -- plant ingestion	³ active
4 -- meat ingestion	³ active
5 -- milk ingestion	³ suppressed
6 -- aquatic foods	³ suppressed
7 -- drinking water	³ active
8 -- soil ingestion	³ active
9 -- radon	³ suppressed

RESRAD Parameter Sources

Parameters	Values	Source
Area of contaminated zone (sq. m)	255000	Environmental Surveillance of Low-level Radioactive Waste Management Areas at Los Alamos during 1987. p. 4 (LANL 1990)
Thickness of contaminated zone (m)	0.3048	RFI Status Report for Tritium in Surface Soils at MDA-G, TA-54. p. 8 (LANL 1997)
Basic radiation dose limit (mrem/yr)	100	Limits of Intakes of Radionuclides by Workers (ICRP 1978)
Contaminated zone erosion rate (m/yr)	0.004	RFI Status Report for Tritium in Surface Soils at MDA-G, TA-54. p. 7 (LANL 1997)
Contaminated zone effective porosity	0.32	Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5. p. 210 (Yu et al. 1993)
Contaminated zone hydraulic conductivity (m/yr)	1090	Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5. p. 200 (Yu et al. 1993)
Contaminated zone b parameter	4.9	Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5. p. 200 (Yu et al. 1993)
Average annual wind speed (m/sec)	3.2	Environmental Surveillance of Low-level Radioactive Waste Management Areas at Los Alamos during 1987. p. 7 (LANL 1990)
Precipitation (m/yr)	0.35	RFI Status Report for Tritium in Surface Soils at MDA-G, TA-54. p. 11 (LANL 1997)
Accuracy for water/soil computations	0.01	Based on significant figures from base measurements used.
Unsaturated zone, thickness (m)	274.3	RFI Status Report for Tritium in Surface Soils at MDA-G, TA-54. p. 12 (LANL 1997)
Unsaturated zone, effective porosity	0.21	Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5. p. 210 (Yu et al. 1993)
Distribution coefficient, contaminated zone, Cs-137	100	Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5. pp. 202, 203 (Yu et al. 1993)
Distribution coefficient, contaminated zone, H-3	1	Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5. p. 202 (Yu et al. 1993)
Distribution coefficient, contaminated zone, Pu-239	200	Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5. pp. 202, 205 (Yu et al. 1993)
Distribution coefficient, contaminated zone, Sr-90	3	Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5. p. 203 (Yu et al. 1993)
Distribution coefficient, contaminated zone, U-234	5	Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5. pp. 202, 204 (Yu et al. 1993)
Distribution coefficient, contaminated zone, U-235	5	Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5. pp. 202, 204 (Yu et al. 1993)
Distribution coefficient, contaminated zone, U-238	5	Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5. pp. 202, 204 (Yu et al. 1993)
Fraction of time spent indoors, onsite	0	No onsite human activity
Fraction of time spent outdoors, onsite	0	No onsite human activity
Fruits, vegetables, and grain consumption (kg/yr)	0	Only meat consumption considered in this study

RESRAD Parameter Sources (cont.)

Parameters	Values	Source
Leafy vegetable consumption (kg/yr)	0	Only meat consumption considered in this study
Meat and poultry consumption (kg/yr)	23	Personal communication, Denny Armstrong, 1997
Soil ingestion rate (g/yr)	0	Only meat consumption considered in this study
Drinking water intake (L/yr)	0	Only meat consumption considered in this study
Livestock fodder intake (kg/d)	5.9, 2.69	Robbins 1983, Elk of North America: Ecology and Management. p. 325 (for elk and deer, respectively)
Livestock water intake (L/day)	13.53, 3.70	Lautier et al. 1988, Sample et al. 1997. p. 21 (for elk and deer, respectively)
Livestock soil intake (kg/d)	0.12, 0.05	Arthur and Alldredge 1979, Beyer et al. 1994 (for elk and deer, respectively)
Mass loading for foliar deposition (g/cubic m)	1	Maximum limit possible in RESRAD code
Depth of roots (m)	2	RFI Status Report for Tritium in Surface Soils at MDA-G, TA-54. p. 7 (LANL 1997)
Drinking water fraction from ground water	0	Only meat consumption considered in this study
Growing season for fodder (years)	0.42	Soil Survey of Los Alamos County, New Mexico. p. 9 (Nyhan et al. 1978)
Storage time of contaminated meat (days)	0	Maximum dose occurs when meat is not stored, but consumed immediately.

-Appendix B-

Perimeter soil sample data from Area G, 1993-1996

Sample Location	Sample Date	H-3 pCi/g	Am-241 pCi/g	Cs-137 pCi/g	U-238 pCi/g	U-235 pCi/g	U-234 pCi/g	Pu-238 pCi/g	Pu-239 pCi/g	Sr-90 ^a pCi/g
G-9-01	7/6/93	0.01	-0.016	0.332	1.16	0.05	1.24	0.002	0.020	
G-10-01	7/6/93	0.02	0.102	0.800	1.06	0.05	1.14	0.012	0.030	
G-11-01	7/6/93	0.02	0.141	0.474	0.76	0.04	0.82	0.009	0.016	
G-12-01	7/6/93	0.02	-0.015	0.151	0.76	0.04	0.82	0.018	0.010	
G-12-03	7/6/93	0.02	0.005	1.430	1.03	0.05	1.10	0.012	0.070	
G-13-01	7/6/93	0.01	0.001	-0.019	0.73	0.03	0.78	0.003	0.008	
G-13-09	7/6/93	0.01	-0.016	0.383	1.03	0.05	1.10	0.002	0.021	
G-14-01	7/6/93	0.02	0.009	0.389	0.76	0.04	0.82	0.006	0.009	
G-15-01	7/6/93	0.03	-0.012	0.309	1.00	0.05	1.07	0.014	0.020	
G-15-02	7/6/93	0.00	-0.024	1.000	1.76	0.08	1.89	0.007	0.047	
G-16-01	7/6/93	0.05	0.022	1.100	1.06	0.05	1.14	0.012	0.052	
G-17-01	7/6/93	0.00	0.019	0.105	0.73	0.03	0.78	0.004	0.013	
G-17-02	7/6/93	0.09	0.000	1.830	1.26	0.06	1.35	0.011	0.077	
G-17-03	7/6/93	0.02	0.014	0.313	1.10	0.05	1.17	0.008	0.021	
G-18-01	7/6/93	0.04	0.037	0.404	1.03	0.05	1.10	0.005	0.015	
G-19-01	7/6/93	0.03	0.083	0.032	0.86	0.04	0.92	0.002	0.003	
G-20-01	7/6/93	0.05	-0.024	1.250	0.80	0.04	0.85	0.015	0.044	
G-20-02	7/6/93	0.11	-0.018	0.037	0.76	0.04	0.82	0.009	0.014	
G-21-01	7/6/93	0.00	-0.003	0.090	0.53	0.02	0.57	0.008	0.006	
G-21-02	7/6/93	0.03	0.004	0.285	0.93	0.04	1.00	0.012	0.009	
G-22-01	7/6/93	0.06	0.005	0.020	1.03	0.05	1.10	0.005	0.001	
G-23-01	7/8/93	0.00	0.016	0.214	0.76	0.04	0.82	0.007	0.007	
G-23-02	7/8/93	0.00	-0.009	0.371	0.73	0.03	0.78	0.032	0.027	
G-24-01	7/8/93	0.00	0.095	0.567	0.70	0.03	0.75	0.038	0.030	
G-24-02	7/8/93	0.10	0.055	1.110	0.67	0.03	0.71	0.007	0.045	
G-25-01	7/8/93	0.00	0.116	1.750	1.50	0.07	1.60	0.007	0.058	
G-26-01	7/8/93	0.00	0.151	1.700	1.43	0.07	1.53	0.009	0.080	
G-27-01	7/8/93	0.00	0.076	0.898	1.16	0.05	1.24	0.005	0.033	
G-28-01	7/8/93	0.10	0.107	0.232	0.83	0.04	0.89	0.003	0.006	
G-28-02	7/8/93	0.10	0.230	0.740	0.70	0.03	0.75	0.011	0.027	
G-28-03	7/8/93	0.10	0.092	0.376	0.83	0.04	0.89	0.063	0.054	
G-29-01	7/8/93	1.00	0.132	0.395	0.63	0.03	0.68	0.059	0.025	
G-29-02	7/8/93	2.20	0.123	0.741	0.80	0.04	0.85	0.007	0.025	
G-29-03	7/8/93	117.02	0.191	0.443	0.96	0.05	1.03	0.013	0.012	
G-30-01	7/8/93	2.00	0.218	0.390	1.06	0.05	1.14	0.041	0.043	
G-31-01	7/8/93	11.40	0.109	0.982	1.20	0.06	1.28	0.023	0.065	
G-31-02	7/8/93	1.00	0.094	0.376	0.80	0.04	0.85	0.004	0.010	
G-31-03	7/8/93	0.50	0.124	0.231	0.67	0.03	0.71	0.004	0.009	
G-32-01	7/8/93	1.87	0.060	0.787	0.73	0.03	0.78	0.007	0.028	
G-32-02	7/8/93	0.80	0.196	0.495	0.93	0.04	1.00	0.007	0.024	
G-32-03	7/8/93	0.50	0.096	0.438	0.93	0.04	1.00	0.012	0.027	
G-33-01	7/8/93	0.30	0.057	1.170	1.13	0.05	1.21	0.009	0.107	
G-34-01	7/8/93	0.00	0.064	0.159	0.67	0.03	0.71	0.007	0.018	
G-34-02	7/8/93	0.10	0.207	0.405	0.93	0.04	1.00	0.002	0.201	
G-34-03	7/8/93	0.10	0.019	0.144	1.03	0.05	1.10	0.001	0.018	
G-34-04	7/8/93	0.10	-0.024	0.200	0.90	0.04	0.96	0.023	0.036	
G-35-01	7/12/93	0.16	0.670	0.210	0.70	0.03	0.75	0.013	0.100	
G-35-02	7/12/93	0.16	0.510	0.970	0.73	0.03	0.78	0.004	0.042	
G-36-01	7/12/93	0.13	1.080	0.690	0.73	0.03	0.78	0.030	0.216	
G-36-02	7/12/93	0.10	0.640	0.100	0.63	0.03	0.68	0.002	0.014	

Sample Location	Sample Date	H-3 pCi/g	Am-241 pCi/g	Cs-137 pCi/g	U-238 pCi/g	U-235 pCi/g	U-234 pCi/g	Pu-238 pCi/g	Pu-239 pCi/g	Sr-90 pCi/g
G-38-01	7/12/93	0.09	0.430	0.070	0.63	0.03	0.68	0.041	1.944	
G-38-02	7/12/93	3.59	0.530	0.025	0.57	0.03	0.60	0.065	0.691	
G-39-01	7/12/93	0.10	0.560	0.030	0.63	0.03	0.68	0.844	0.350	
G-39-02	7/12/93	0.14	0.440	0.025	0.37	0.02	0.39	0.052	0.131	
G-40-01	7/12/93	0.11	0.210	0.300	0.76	0.04	0.82	3.298	0.320	
G-40-02	7/12/93	0.11	0.170	0.220	0.67	0.03	0.71	2.045	0.189	
G-41-02	7/12/93	0.10	0.260	0.450	0.93	0.04	1.00	1.485	0.062	
G-42-01	7/12/93	0.18	0.250	0.230	0.73	0.03	0.78	2.110	0.727	
G-43-01	7/12/93	0.58	0.440	0.030	0.83	0.04	0.89	0.516	0.440	
G-43-02	7/12/93	0.34	0.300	0.360	0.70	0.03	0.75	0.286	0.164	
G-44-01	7/12/93	4.30	0.510	0.045	0.90	0.04	0.96	1.134	0.433	
G-45-01	7/12/93	3.92	0.430	0.040	0.80	0.04	0.85	4.987	0.368	
G-46-01	7/12/93	1.79	0.330	1.370	0.80	0.04	0.85	2.152	0.609	
G-46-02	7/12/93	0.55	0.250	0.240	0.83	0.04	0.89	2.314	0.430	
G-47-01	7/12/93	0.20	0.540	0.450	0.80	0.04	0.85	0.126	3.400	
G-48-01	7/13/93	0.18	0.160	0.740	0.70	0.03	0.75	0.099	0.237	
G-48-02	7/13/93	0.14	0.520	0.420	0.68	0.03	0.73	0.149	0.923	
G-48-03	7/13/93	0.36	0.469	0.090	0.62	0.03	0.67	0.185	1.614	
G-49-01	7/13/93	0.16	0.677	0.310	0.86	0.04	0.92	0.106	2.000	
G-50-01	7/13/93	0.59	1.020	0.060	0.75	0.03	0.80	0.083	0.315	
G-50-02	7/13/93	0.20	0.400	0.015	0.81	0.04	0.87	0.090	0.178	
G-51-01	7/13/93	1.56	0.257	0.150	0.99	0.05	1.06	0.035	0.034	
G-52-01	7/13/93	0.00	0.008	0.070	0.57	0.03	0.61	0.007	0.012	
G-52-02	7/13/93	0.26	0.183	0.500	0.93	0.04	1.00	0.016	0.024	
G-52-03	7/13/93	0.08	0.100	0.390	0.79	0.04	0.85	0.040	0.051	
G-53-01	7/13/93	0.03	0.204	0.410	0.97	0.05	1.04	0.012	0.030	
G-54-01	7/13/93	0.05	0.151	0.290	0.53	0.02	0.57	0.015	0.031	
G-54-02	7/13/93	0.02	-0.103	0.180	0.59	0.03	0.63	0.011	0.030	
G-55-01	7/13/93	0.03	0.167	0.140	0.82	0.04	0.88	0.009	0.014	
G-57-01	7/13/93	0.02	0.183	1.090	1.41	0.07	1.50	0.009	0.069	
G-58-01	7/13/93	0.05	0.112	0.015	0.88	0.04	0.94	0.038	0.019	
G-10-02	7/21/93	0.09		2.380	1.29	0.06	1.38	0.022	0.092	
G-5-01	7/14/94	0.04	0.075	0.520	2.33	0.11	2.49	0.030	0.094	
G-5-02	7/14/94	0.02	0.014	0.280	1.80	0.08	1.92	0.000	0.024	
G-6-01	7/14/94	0.01	0.005	0.230	1.23	0.06	1.32	0.004	0.006	
G-7-01	7/14/94	0.03	0.003	0.330	1.36	0.06	1.46	0.005	0.007	
G-8-01	7/14/94	0.01	0.006	0.320	1.26	0.06	1.35	0.001	0.007	
G-8-02	7/14/94	0.01	0.030	0.360	1.46	0.07	1.57	0.001	0.010	
G-9-01	7/14/94	0.08	0.030	0.560	1.86	0.09	1.99	0.007	0.100	
G-10-01	7/14/94	0.02	0.006	0.380	1.53	0.07	1.64	0.004	0.009	
G-10-02	7/14/94	0.06	0.026	0.390	1.70	0.08	1.81	0.007	0.067	
G-11-01	7/14/94	0.01	0.007	0.300	1.40	0.07	1.49	0.007	0.013	
G-12-01	7/14/94	0.01	0.013	0.210	1.33	0.06	1.42	0.003	0.012	
G-12-03	7/14/94	0.03	0.030	0.470	1.50	0.07	1.60	0.007	0.090	
G-13-01	7/14/94	0.04	0.007	0.340	1.26	0.06	1.35	0.007	0.020	
G-13-09	7/14/94	0.02	0.011	0.300	1.70	0.08	1.81	0.005	0.028	
G-14-01	7/14/94	0.01	0.013	0.160	0.86	0.04	0.92	0.007	0.008	
G-15-01	7/14/94	0.01	0.014	0.310	1.66	0.08	1.78	0.016	0.043	
G-15-02	7/14/94	0.02	0.018	0.300	1.36	0.06	1.46	0.015	0.060	
G-15-02R	7/14/94	0.01	0.01 J	0.340	1.36	0.06	1.46	0.020	0.031	
G-16-01	7/14/94	0.06	0.011	0.320	1.13	0.05	1.21	0.004	0.019	
G-17-01	7/14/94	0.03	0.008	0.360	1.43	0.07	1.53	0.004	0.006	

Sample Location	Sample Date	H-3 pCi/g	Am-241 pCi/g	Cs-137 pCi/g	U-238 pCi/g	U-235 pCi/g	U-234 pCi/g	Pu-238 pCi/g	Pu-239 pCi/g	Sr-90 ^a pCi/g
G-17-02	7/14/94	0.10	0.021	0.360	1.70	0.08	1.81	0.009	0.079	
G-17-03	7/14/94	0.04	0.013	0.260	1.46	0.07	1.57	0.004	0.029	
G-18-01	7/14/94	0.03	0.010	0.380	1.73	0.08	1.85	0.004	0.024	
G-19-01	7/14/94	0.01	0.134	0.370	1.66	0.08	1.78	0.011	0.037	
G-19-02	7/14/94	0.04	0.008	0.310	1.16	0.05	1.24	0.003	0.010	
G-20-01	7/14/94	0.12	0.017	1.050	1.50	0.07	1.60	0.009	0.038	
G-20-02	7/14/94	0.12	0.006	0.260	1.40	0.07	1.49	0.003	0.009	
G-21-01	7/14/94	0.02	0.013	0.840	1.33	0.06	1.42	0.014	0.013	
G-21-01R	7/14/94	0.03	0.016	0.340	1.33	0.06	1.42	0.020	0.028	
G-22-01	7/14/94	0.07	0.003	0.330	1.20	0.06	1.28	0.005	0.002	
G-23-01	7/14/94	0.05	0.003	0.360	1.36	0.06	1.46	0.002	0.007	
G-23-02	7/14/94	0.10	0.015	0.300	1.33	0.06	1.42	0.007	0.042	
G-24-01	7/14/94	0.03	0.007	0.330	1.26	0.06	1.35	0.005	0.012	
G-24-02	7/14/94	0.16	0.010	0.360	1.43	0.07	1.53	0.006	0.027	
G-25-01	7/14/94	0.06	0.021	1.680	1.63	0.08	1.74	0.007	0.057	
G-26-01	7/14/94	0.12	0.018	1.750	1.60	0.07	1.71	0.006	0.065	
G-27-01	7/14/94	0.38	0.017	1.400	1.40	0.07	1.49	0.004	0.033	
G-28-01	7/14/94	0.30	0.010	0.330	1.16	0.05	1.24	0.004	0.023	
G-28-02	7/14/94	0.28	0.015	0.370	1.36	0.06	1.46	0.009	0.029	
G-29-01	7/14/94	1.79	0.009	0.220	0.93	0.04	1.00	0.023	0.011	
G-29-02	7/14/94	15.58	0.018	0.400	1.46	0.07	1.57	0.026	0.045	
G-29-03	7/14/94	22.60	0.006	0.390	1.46	0.07	1.57	0.005	0.015	
G-30-01	7/14/94	1.24	0.007	0.310	1.10	0.05	1.17	0.009	0.025	
G-31-01	7/14/94	13.36	0.032	1.890	1.80	0.08	1.92	0.024	0.117	
G-31-01R	7/14/94	12.04	0.027	0.810	1.60	0.07	1.71	0.019	0.096	
G-31-02	7/14/94	1.63	0.006	0.310	1.43	0.07	1.53	0.009	0.010	
G-31-03	7/14/94	0.58	0.006	0.260	1.00	0.05	1.07	0.007	0.010	
G-32-01	7/14/94	1.10	0.076	0.390	1.80	0.08	1.92	0.022	0.392	
G-32-02	7/14/94	0.82	0.010	0.320	1.36	0.06	1.46	0.007	0.027	
G-32-03	7/14/94	0.51	0.025	0.310	1.50	0.07	1.60	0.010	0.058	
G-33-01	7/14/94	0.26	0.020	0.380	1.46	0.07	1.57	0.016	0.122	
G-34-01	7/14/94	0.06	0.008	0.390	1.33	0.06	1.42	0.006	0.012	
G-34-02	7/14/94	0.07	0.016	0.330	1.46	0.07	1.57	0.005	0.046	
G-34-03	7/14/94	0.06	0.008	0.280	1.60	0.07	1.71	0.004	0.040	
G-34-04	7/14/94	0.05	0.016	0.280	1.46	0.07	1.57	0.020	0.050	
G-34-05	7/21/94	0.09	0.017	0.390	1.10	0.05	1.17	0.050	0.049	
G-34-06	7/21/94	0.21	0.015	0.520	1.56	0.07	1.67	0.017	0.088	
G-34-07	7/21/94	0.16	0.007	0.400	1.26	0.06	1.35	0.009	0.023	
G-34-08	7/21/94	0.08	0.033	0.460	1.60	0.07	1.71	0.008	1.048	
G-34-09	7/21/94	0.31	0.012	0.360	1.56	0.07	1.67	0.008	0.065	
G-34-10	7/21/94	0.24	0.412	0.700	1.56	0.07	1.67	0.106	2.773	
G-34-11	7/21/94	0.30	0.090	0.540	1.63	0.08	1.74	0.052	0.542	
G-34-12	7/21/94	0.18	0.006	0.390	1.33	0.06	1.42	0.006	0.007	
G-34-13	7/21/94	0.58	0.012	0.440	1.36	0.06	1.46	0.259	0.028	
G-34-14	7/21/94	0.27	0.006	0.430	1.06	0.05	1.14	0.098	0.022	

Sample Location	Sample Date	H-3 pCi/g	Am-241 pCi/g	Cs-137 pCi/g	U-238 pCi/g	U-235 pCi/g	U-234 pCi/g	Pu-238 pCi/g	Pu-239 pCi/g	Sr-90 ^a pCi/g
G-34-15	7/21/94	0.25	0.011	0.480	1.23	0.06	1.32	0.157	0.028	
G-35-01	7/14/94	0.09	0.084	1.260	1.40	0.07	1.49	0.010	0.125	
G-35-02	7/14/94	0.13	0.053	0.310	1.36	0.06	1.46	0.016	0.643	
G-36-01	7/14/94	0.06	0.053	0.540	1.70	0.08	1.81	0.009	0.122	
G-36-01R	7/14/94	0.08	0.047	0.650	1.50	0.07	1.60	0.014	0.115	
G-36-02	7/14/94	0.05	0.015	0.350	1.36	0.06	1.46	0.005	0.034	
G-38-01	7/21/94	0.15	0.014	0.480	1.33	0.06	1.42	0.005	0.031	
G-38-02	7/21/94	1.62	0.181	0.390	1.50	0.07	1.60	0.211	0.982	
G-39-01	7/21/94	0.10	0.042	0.390	1.23	0.06	1.32	0.681	0.203	
G-39-02	7/21/94	0.13	0.021	0.430	1.03	0.05	1.10	0.042	0.068	
G-40-01	7/21/94	0.09	0.068	0.550	1.70	0.08	1.81	2.489	0.281	
G-40-02	7/21/94	0.10	0.059	0.390	1.53	0.07	1.64	3.434	0.295	
G-41-02	7/21/94	0.16	0.051	0.460	1.46	0.07	1.57	1.163	0.156	
G-42-01	7/21/94	0.06	0.082	0.420	1.50	0.07	1.60	0.385	1.031	
G-43-01	7/21/94	0.51	0.249	0.460	1.40	0.07	1.49	0.574	1.814	
G-43-01R	7/21/94	0.55	0.106	0.470	1.43	0.07	1.53	0.687	0.481	
G-43-02	7/21/94	0.34	0.119	0.480	1.30	0.06	1.39	0.508	0.711	
G-44-01	7/21/94	3.40	0.242	0.440	1.43	0.07	1.53	15.778	0.588	
G-45-01	7/21/94	13.97	0.270	0.460	1.46	0.07	1.57	1.266	0.639	
G-46-01	7/21/94	2.06	0.336	0.430	1.73	0.08	1.85	16.683	1.173	
G-46-02	7/21/94	0.98	0.249	0.530	1.50	0.07	1.60	1.863	1.093	
G-47-01	7/21/94	0.18	0.242	0.460	1.23	0.06	1.32	0.078	1.782	
G-48-01	7/21/94	0.24	0.050	0.680	1.43	0.07	1.53	0.131	0.297	
G-48-02	7/21/94	0.19	0.103	0.690	1.60	0.07	1.71	0.081	0.579	
G-48-03	7/21/94	0.19	0.126	0.450	1.43	0.07	1.53	0.085	1.157	
G-49-01	7/21/94	0.11	0.055	0.420	0.90	0.04	0.96	0.028	0.216	
G-50-01	7/18/94	0.28	1.546	0.120	1.26	0.06	1.35	0.142	1.063	
G-50-02	7/18/94	0.21	0.102	0.120	1.30	0.06	1.39	0.033	0.075	
G-51-01	7/18/94	0.15	0.015	0.140	1.50	0.07	1.60	0.017	0.031	
G-52-01	7/18/94	0.08	0.008	0.140	1.43	0.07	1.53	0.006	0.011	
G-52-02	7/18/94	0.11	0.007	0.140	1.06	0.05	1.14	0.009	0.009	
G-52-03	7/18/94	0.10	0.020	0.140	1.30	0.06	1.39	0.031	0.050	
G-53-01	7/18/94	0.06	0.014	0.890	1.50	0.07	1.60	0.015	0.043	
G-54-01	7/18/94	0.06	0.007	0.290	1.40	0.07	1.49	0.019	0.016	
G-54-02	7/18/94	0.06	0.012	0.160	1.36	0.06	1.46	0.008	0.033	
G-55-01	7/18/94	0.05	0.014	0.230	1.23	0.06	1.32	0.007	0.044	
G-55-01R	7/18/94	0.05	0.020	0.130	1.30	0.06	1.39	0.006	0.098	
G-57-01	7/18/94	0.03	0.012	1.140	1.46	0.07	1.57	0.008	0.037	
G-58-01	7/18/94	0.03	0.008	0.300	1.40	0.07	1.49	0.052	0.025	
G-59-01	7/18/94	0.02	0.010	1.170	1.80	0.08	1.92	0.005	0.029	
G-60-01	7/18/94	0.01	0.009	0.580	1.46	0.07	1.57	0.003	0.022	
G-62-01	7/18/94	0.01	0.003	0.180	1.53	0.07	1.64	0.002	0.013	
G-64-01	7/18/94	0.01	0.012	0.220	1.73	0.08	1.85	0.005	0.029	
G-65-02	7/18/94	0.01	0.006	0.170	1.50	0.07	1.60	0.003	0.008	
G-65-01	7/18/94	0.02	0.013	1.280	1.36	0.06	1.46	0.006	0.057	

Sample Location	Sample Date	H-3	Am-241	Cs-137	U-238	U-235	U-234	Pu-238	Pu-239	Sr-90 ^a
		pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
G-5-01	7/25/95	0.00	-0.12	1.760	1.62	0.08	1.73	0.004	0.085	
G-5-02	7/25/95	0.01	0.09	0.880	1.29	0.06	1.38	0.056	0.060	
G-6-01	7/25/95	0.00	-0.03	0.050	0.84	0.04	0.90	0.000	0.003	
G-7-01	7/25/95	0.01	0.02	0.250	0.94	0.04	1.01	0.001	0.009	
G-8-01	7/25/95	0.00	0.01	0.150	0.71	0.03	0.76	-0.001	0.007	
G-8-02	7/25/95	0.01	0.15	0.450	0.77	0.04	0.83	0.004	0.021	
G-29-01	7/25/95	0.83	-0.15	0.070	0.99	0.05	1.06	0.059	0.022	
G-29-02	7/25/95	0.75	0.00	0.280	0.85	0.04	0.91	0.053	0.028	
G-29-03	7/25/95	0.91	0.01	0.230	0.85	0.04	0.91	0.012	0.014	
G-30-01	7/25/95	0.79	0.07	0.030	0.53	0.02	0.57	0.007	0.005	
G-31-01	7/25/95	2.10	-0.02	0.880	1.10	0.05	1.18	0.035	0.079	
G-31-02	7/25/95	1.33	0.00	0.020	0.69	0.03	0.73	0.013	0.020	
G-31-03	7/25/95	1.06	-0.05	0.100	0.66	0.03	0.71	0.003	0.004	
G-32-01	7/25/95	0.45	0.11	0.020	0.55	0.03	0.59	0.006	0.009	
G-32-02	7/25/95	0.56	0.05	0.030	1.08	0.05	1.15	0.011	0.067	
G-32-03	7/25/95	0.31	0.03	0.190	0.89	0.04	0.95	0.034	0.021	
G-34-04	7/25/95	0.11	0.00	0.150	1.00	0.05	1.07	0.029	0.034	
G-34-05	7/25/95	0.10	0.23	0.050	0.87	0.04	0.94	0.008	0.007	
G-34-07	7/25/95	0.08	0.19	0.030	0.74	0.03	0.79	0.006	0.003	
G-34-09	7/25/95	0.10	0.07	0.320	1.03	0.05	1.10	0.017	0.071	
G-34-10	7/25/95	0.11	0.12	0.140	0.74	0.03	0.79	0.028	0.199	
G-34-13	7/25/95	0.08	0.01	0.090	0.73	0.03	0.78	0.212	0.023	
G-38-02	7/25/95	1.02	0.14	0.250	0.91	0.04	0.98	0.078	1.132	
G-39-01	7/25/95	0.07	0.03	0.110	0.54	0.03	0.58	0.445	0.231	
G-39-02	7/25/95	0.02	0.08	0.020	0.73	0.03	0.78	0.085	0.114	
G-40-01	7/25/95	0.03	0.09	0.160	0.70	0.03	0.75	1.309	0.169	
G-40-02	7/25/95	0.05	0.22	0.340	0.88	0.04	0.95	1.731	0.267	
G-41-02	7/25/95	0.02	0.14	0.220	0.81	0.04	0.87	2.182	0.206	
G-42-01	7/25/95	0.02	0.08	0.270	1.00	0.05	1.07	1.420	0.736	
G-42-06	7/25/95	0.11	0.08	0.030	0.95	0.04	1.02	0.120	6.290	
G-43-01	7/25/95	0.16	0.40	0.460	0.98	0.05	1.05	0.277	0.558	0.400
G-44-07	7/25/95	0.18	0.97	0.210	0.96	0.04	1.02	0.626	0.942	
G-45-04	7/25/95	0.50	0.74	0.350	0.82	0.04	0.88	0.964	1.301	
G-45-05	7/25/95	0.16	0.69	0.330	0.75	0.04	0.80	0.303	0.378	
G-45-06	7/25/95	0.35	0.12	0.080	0.80	0.04	0.86	0.231	0.151	
G-45-07	7/25/95	2.03	0.63	0.680	1.03	0.05	1.10	10.700	1.200	
G-46-01	7/25/95	0.45	0.34	1.100	1.02	0.05	1.09	7.760	1.060	
G-46-02	7/25/95	0.10	0.92	0.330	0.85	0.04	0.91	1.971	0.825	
G-47-01	7/25/95	0.04	0.89	0.470	0.79	0.04	0.85	0.111	2.477	
G-49-01	7/25/95	0.09	0.61	0.140	0.70	0.03	0.75	0.044	0.342	
G-49-04	7/25/95	0.07	0.42	0.130	0.87	0.04	0.93	0.022	0.092	
G-50-01	7/25/95	0.09	0.30	0.190	0.97	0.05	1.04	0.062	0.211	
G-50-02	7/25/95	0.06	0.67	0.030	0.84	0.04	0.90	0.038	0.048	
G-52-01	7/25/95	0.02	0.90	0.350	0.97	0.05	1.04	0.014	0.025	
G-52-02	7/25/95	0.02	0.32	0.160	0.66	0.03	0.70	0.005	0.012	

Sample Location	Sample Date	H-3 pCi/g	Am-241 pCi/g	Cs-137 pCi/g	U-238 pCi/g	U-235 pCi/g	U-234 pCi/g	Pu-238 pCi/g	Pu-239 pCi/g	Sr-90 ^a pCi/g
G-52-03	7/25/95	0.03	0.51	0.370	0.83	0.04	0.89	0.028	0.035	
G-53-01	7/25/95	0.02	0.01	0.500	0.79	0.04	0.85	0.010	0.020	
G-53-02	7/25/95	0.23	0.49	0.420	0.92	0.04	0.99	0.019	0.023	
G-54-01	7/25/95	0.02	-0.01	0.440	0.90	0.04	0.96	0.016	0.025	
G-54-02	7/25/95	0.03	0.04	0.350	0.98	0.05	1.05	0.009	0.035	
G-55-01	7/25/95	0.02	-0.03	0.110	0.83	0.04	0.89	0.004	0.015	0.300
G-57-01	7/25/95	0.01	0.02	1.630	1.39	0.07	1.49	0.011	0.093	
G-58-01	7/25/95	0.09	0.01	0.180	0.78	0.04	0.84	0.025	0.033	
G-59-01	7/25/95	0.01	0.02	0.020	1.17	0.05	1.25	0.004	0.002	
G-60-01	7/25/95	0.01	-0.06	0.160	0.97	0.05	1.04	0.004	0.009	
G-62-01	7/25/95	0.00	0.06	0.660	1.00	0.05	1.07	0.008	0.025	
G-64-01	7/25/95	0.01	-0.02	0.400	0.95	0.04	1.01	0.005	0.011	
G-65-02	7/25/95	0.00	0.00	0.170	0.97	0.05	1.04	0.004	0.010	
G-44-07	7/26/96	0.00	-0.08	0.050				0.005	0.009	
G-45-06	7/26/96	1.00	0.090	0.030				0.059	0.042	
G-45-07	7/26/96	1.12	0.020	0.180				0.246	0.119	
G-47-01	7/26/96	0.31	0.090	0.410				0.134	0.443	
G-49-04	7/26/96	0.07	0.030	0.080				0.018	0.079	
G-50-01	7/26/96	0.15	0.090	0.100				0.027	0.067	
G-50-02	7/26/96	0.22	0.540	0.100				0.068	0.072	
G-52-01	7/26/96	0.05	0.140	0.530				0.021	0.036	
G-52-02	7/26/96	0.05	0.010	0.740				0.028	0.053	
G-52-03	7/26/96	0.71	0.090	0.330				0.042	0.042	
G-58-01	7/26/96	0.02	0.090	0.230				0.032	0.016	
G-29-01	7/25/96	3.38	0.080	0.200				0.022	0.019	
G-29-02	7/25/96	18.63	0.140	0.540				0.022	0.029	0.200
G-29-03	7/25/96	34.68	0.190	0.430				0.002	0.013	
G-30-01	7/25/96	0.80	0.610	0.180				0.011	0.009	0.100
G-31-01	7/25/96	2.20	0.200	0.730				0.014	0.048	
G-31-02	7/25/96	1.76	0.000	0.210				0.012	0.015	
G-31-03	7/25/96	1.14	1.070	0.200				0.006	0.009	
G-32-01	7/25/96	1.24	0.020	1.100				0.007	0.054	
G-32-02	7/25/96	0.35	0.130	0.370				0.007	0.054	
G-32-03	7/25/93	0.18	0.160	0.230				0.007	0.027	
G-34-04	7/25/96	0.06	1.100	0.240				0.025	0.053	
G-38-02	7/25/96	0.46	0.320	0.180				0.051	0.452	
G-39-01	7/25/96	0.06	13.100	0.110				0.590	0.168	
G-39-02	7/25/96	0.00	0.110	0.100				0.031	0.052	
G-42-01	7/25/96	0.04	0.270	0.340				0.654	0.661	
G-46-02	7/26/96	0.32	0.880	0.280				2.462	0.450	
G-40-02	8/5/96	0.07	0.150	0.090				0.511	0.074	
G-42-06	8/5/96	0.30		0.130				0.113	0.130	
G-44-07	8/5/96	1.04	0.210	0.460				0.208	0.178	
G-45-04	8/5/96	0.77	0.370	0.440				0.571	0.320	
G-45-05	8/5/96	1.02	0.500	0.340				0.243	0.428	
G-46-01	8/5/96	1.50	1.090	0.490				2.866	0.314	
G-49-01	8/5/96	0.03	0.190	0.080				0.005	0.043	

Sample Location	Sample Date	H-3 pCi/g	Am-241 pCi/g	Cs-137 pCi/g	U-238 pCi/g	U-235 pCi/g	U-234 pCi/g	Pu-238 pCi/g	Pu-239 pCi/g	Sr-90 ^a pCi/g
G-40-01	8/7/96	0.07	0.550	0.610				2.650	0.763	
G-41-02	8/7/96	0.05	0.760	0.290				1.810	0.180	
G-34-05	8/8/96	0.08	0.130	0.080				0.022	0.061	
G-34-07	8/8/96	0.04	0.160	0.100				0.001	0.017	
G-34-09	8/8/96	0.06	1.080	0.140				0.004	0.011	
G-34-10	8/8/96	0.06	1.080	1.750				0.079	1.620	
G-34-13	8/8/96	0.03	0.900	0.120				0.112	0.015	

^a Strontium data taken from Fresquez et al. 1995

N	291	287	291	250	250	250	291	291	4
Mean	1.22	0.211	0.42	1.12	0.05	1.19	0.398	0.235	0.25
St. Dev.	7.51	0.808	0.39	0.35	0.02	0.37	1.645	0.570	0.13
Mean + 2 St. Dev.	16.24	1.827	1.19	1.82	0.09	1.94	3.688	1.375	0.51

Background soil data, 1993-1996^b

	H-3 (pCi/g)	Am-241 (pCi/g)	Cs-137 (pCi/g)	U-238 (pCi/g)	U-235 (pCi/g)	U-234 (pCi/g)	Pu-238 (pCi/g)	Pu-239 (pCi/g)	Sr-90 (pCi/g)
Mean	-0.10	0.006	0.28	0.63	0.03	0.68	0.004	0.011	0.30
St. Dev.	0.01	0.001	0.13	0.13	0.01	0.14	0.002	0.004	0.07
Mean + 2 St. Dev.	-0.08	0.008	0.54	0.90	0.05	0.96	0.008	0.019	0.44

^b Data from LANL Environmental Surveillance Reports, 1993-1996

-Appendix C-

Spreadsheet Model Parameters

Input Parameters

CONSTANTS:	Deer	Elk
Fodder consumed (Q_f), kg/d	2.7	5.9
Soil consumed (Q_{soil}), kg/d	0.05	0.12
Water consumed (Q_w), L/d	3.7	13.5
Air inhaled (Q_{inh}), m ³ /d	13.6	43.2
Body weight (BW), kg	55.8	236
Inhalation rate, m ³ /kg _{bw} d	0.24	0.18

SOURCE TERM INPUT VALUES:
See Appendix B

Intermediate parameters

CONSTANTS:

Soil to Root Factors

See Table 3

Radionuclide	Muscle concentration to intake ratio(d/kg)
U	3.40E-04
³ H	1.20E-02
⁹⁰ Sr	8.00E-03
¹³⁷ Cs	3.00E-02
²⁴¹ Am	5.00E-05
²³⁸ Pu	4.00E-04
²³⁹ Pu	4.00E-04

CALCULATION VALUES:

$$FSR = FA * FAR * ASR$$

FSR = 2.47E-04, Forage to soil ratio for foliar deposition
 FA = 1, Area factor for dilution of resuspended, contaminated soil
 FAR = 2.47, Forage to air ratio
 ASR = 1.00E-04, Air to soil ratio

$$FAR = 3.16E04 * (V * f * T (1 - \exp(-\lambda t_e))) / (Y * \lambda)$$

V = 1.00E-03m/s, Settling velocity
 f = 1, Fraction of dust on leaf
 T = 1, Translocation to edible part of plant
 $\lambda = 18.0675\text{yr}^{-1}$, Weathering rate constant
 $t_e = 0.25\text{yr}$, Exposure time
 Y = 0.7kg/m², Fodder biomass

Concentration Calculation Parameters

CONSTANTS:	100%	50%
Fraction of soil contaminated (f_s)	1	0.5
Fraction of forage contaminated (f_f)	1	0.5
Fraction of water contaminated (f_w)	1	1, 0 (see p. 27)

CALCULATION VALUES

$$C_{\text{meat}} = C_I * \text{MIR}$$

C_{meat} = Concentration of the given radionuclide in animal muscle

C_I = Internalized concentration

MIR = Muscle to intake ratio for the given radionuclide (See above)

$$C_I = C_{\text{ing}} + C_{\text{inh}}$$

C_{ing} = Concentration of the given radionuclide ingested

C_{inh} = Concentration of the given radionuclide inhaled

$$C_{\text{inh}} = Q_{\text{inh}} * C_{\text{air}}$$

C_{air} = Concentration of contaminated dust in air

$$C_{\text{ing}} = (C_{\text{air}} + C_{\text{root}}) * Q_f * f_f + C_{\text{soil}} * Q_{\text{soil}} * f_s + C_w * Q_w * f_w$$

C_{root} = Concentration of the given radionuclide taken into the root from the soil

C_{soil} = Concentration of the given radionuclide in the soil

C_w = Concentration of the given radionuclide in the water

$$C_{\text{air}} = C_{\text{soil}} * \text{FSR}$$

$$C_{\text{root}} = C_{\text{soil}} * \text{SRF}$$

SRF = Soil to root uptake factor for the given radionuclide (Table 3)

C_{soil} and C_w are the source term values input by the model user (See Appendix B)

Dose Calculation Parameters

CONSTANTS:

Radionuclide	Energy of Disintegration (MeV)	Fraction of Disintegration
U	4.19	0.77
	4.147	0.23
^3H	0.00569	1
^{90}Sr	0.1958	1
^{137}Cs	0.1568	1
^{241}Am	5.486	0.85
	5.44	0.13
^{238}Pu	5.499	0.72
	5.456	0.28
^{239}Pu	5.15	0.73
	5.143	0.15
	5.104	0.12

Radionuclide	F ₁ (rad g/d pCi)
U	2.14E-04
³ H	2.91E-07
⁹⁰ Sr	1.00E-05
¹³⁷ Cs	8.02E-06
²⁴¹ Am	2.75E-04
²³⁸ Pu	2.81E-04
²³⁹ Pu	2.63E-04

Steady-state Model
Background mean scenario

For Deer																
Compartment:	C _{air}	C _{root}	C _{soil}	C _{water}	Q _{fodder}	Q _{soil}	Q _{water}	Q _{inh}	f _t	f _w	Radionuclide	C _{ing}	C _{inh}	C _i	Muscle/intake ratio	C _{meat}
units:	pCi/g	pCi/g	pCi/g	pCi/L	g/d	g/d	L/d	g/d	(unitless)	(unitless)	(unitless)	pCi/d	pCi/d	pCi/d	(pCi/kgmeat)/(pCi/d)	pCi/kg
	3.31E-04	3.35E-03	1.34	0.62	2700	50	3.7	13.6	1	1	U	7.9E+01	4.5E-03	7.9E+01	3.4E-04	2.7E-02
	-2.47E-05	-4.80E-01	-0.1	-6.75	2700	50	3.7	13.6	1	1	³ H	-1.3E+03	-3.4E-04	-1.3E+03	1.2E-02	-1.6E+01
	7.41E-05	9.00E-02	0.3	0.9	2700	50	3.7	13.6	1	1	Sr	2.6E+02	1.0E-03	2.6E+02	8.0E-03	2.1E+00
	6.92E-05	1.12E-02	0.28	0.75	2700	50	3.7	13.6	1	1	Cs	4.7E+01	9.4E-04	4.7E+01	3.0E-02	1.4E+00
	1.48E-06	6.00E-06	0.006	0.021	2700	50	3.7	13.6	1	1	Am	4.0E-01	2.0E-05	4.0E-01	5.0E-05	2.0E-05
	9.89E-07	4.00E-06	0.004	0.005	2700	50	3.7	13.6	1	1	²³⁸ Pu	2.3E-01	1.3E-05	2.3E-01	4.0E-04	9.3E-05
	2.72E-06	1.10E-05	0.011	0.03	2700	50	3.7	13.6	1	1	²³⁹ Pu	7.0E-01	3.7E-05	7.0E-01	4.0E-04	2.8E-04
For Elk																
Compartment:	C _{air}	C _{root}	C _{soil}	C _{water}	Q _{fodder}	Q _{soil}	Q _{water}	Q _{inh}	f _t	f _w	Radionuclide	C _{ing}	C _{inh}	C _i	Muscle/intake ratio	C _{meat}
units:	pCi/g	pCi/g	pCi/g	pCi/L	g/d	g/d	L/d	g/d	(unitless)	(unitless)	(unitless)	pCi/d	pCi/d	pCi/d	(pCi/kgmeat)/(pCi/d)	pCi/kg
	3.31E-04	3.35E-03	1.34	0.62	5900	120	13.5	43.2	1	1	U	1.9E+02	1.4E-02	1.9E+02	3.4E-04	6.5E-02
	-2.47E-05	-4.80E-01	-0.1	-6.75	5900	120	13.5	43.2	1	1	³ H	-2.9E+03	-1.1E-03	-2.9E+03	1.2E-02	-3.5E+01
	7.41E-05	9.00E-02	0.3	0.9	5900	120	13.5	43.2	1	1	Sr	5.8E+02	3.2E-03	5.8E+02	8.0E-03	4.6E+00
	6.92E-05	1.12E-02	0.28	0.75	5900	120	13.5	43.2	1	1	Cs	1.1E+02	3.0E-03	1.1E+02	3.0E-02	3.3E+00
	1.48E-06	6.00E-06	0.006	0.021	5900	120	13.5	43.2	1	1	Am	1.0E+00	6.4E-05	1.0E+00	5.0E-05	5.2E-05
	9.89E-07	4.00E-06	0.004	0.005	5900	120	13.5	43.2	1	1	²³⁸ Pu	5.8E-01	4.3E-05	5.8E-01	4.0E-04	2.3E-04
	2.72E-06	1.10E-05	0.011	0.03	5900	120	13.5	43.2	1	1	²³⁹ Pu	1.8E+00	1.2E-04	1.8E+00	4.0E-04	7.2E-04

Steady-state Model

Background mean + 2 st. dev. Scenario

For Deer

Compartment:	C _{air}	C _{root}	C _{soil}	C _{water}	Q _{fodder}	Q _{soil}	Q _{water}	Q _{inh}	f _s	f _w	Radionuclide	C _{ing}	C _{inh}	C _i	Muscle/intake ratio	C _{meat}
units:	pCi/g	pCi/g	pCi/g	pCi/L	g/d	g/d	L/d	g/d	(unitless)	(unitless)	(unitless)	pCi/d	pCi/d	pCi/d	(pCi/kgmeat)/(pCi/d)	pCi/kg
	4.70E-04	4.75E-03	1.9	1.22	2700	50	3.7	13.6	1	1	U	1.1E+02	6.4E-03	1.1E+02	3.4E-04	3.9E-02
	4.94E-06	9.60E-02	0.02	607	2700	50	3.7	13.6	1	1	³ H	2.5E+03	6.7E-05	2.5E+03	1.2E-02	3.0E+01
	1.09E-04	1.32E-01	0.44	4.07	2700	50	3.7	13.6	1	1	Sr	3.9E+02	1.5E-03	3.9E+02	8.0E-03	3.2E+00
	1.33E-04	2.16E-02	0.54	4.58	2700	50	3.7	13.6	1	1	Cs	1.0E+02	1.8E-03	1.0E+02	3.0E-02	3.1E+00
	1.98E-06	8.00E-06	0.008	0.077	2700	50	3.7	13.6	1	1	Am	7.1E-01	2.7E-05	7.1E-01	5.0E-05	3.6E-05
	1.98E-06	8.00E-06	0.008	0.029	2700	50	3.7	13.6	1	1	²³⁸ Pu	5.3E-01	2.7E-05	5.3E-01	4.0E-04	2.1E-04
	4.70E-06	1.90E-05	0.019	0.114	2700	50	3.7	13.6	1	1	²³⁹ Pu	1.4E+00	6.4E-05	1.4E+00	4.0E-04	5.7E-04

For Elk

Compartment:	C _{air}	C _{root}	C _{soil}	C _{water}	Q _{fodder}	Q _{soil}	Q _{water}	Q _{inh}	f _s	f _w	Radionuclide	C _{ing}	C _{inh}	C _i	Muscle/intake ratio	C _{meat}
units:	pCi/g	pCi/g	pCi/g	pCi/L	g/d	g/d	L/d	g/d	(unitless)	(unitless)	(unitless)	pCi/d	pCi/d	pCi/d	(pCi/kgmeat)/(pCi/d)	pCi/kg
	4.70E-04	4.75E-03	1.9	1.22	5900	120	13.5	43.2	1	1	U	2.8E+02	2.0E-02	2.8E+02	3.4E-04	9.4E-02
	4.94E-06	9.60E-02	0.02	607	5900	120	13.5	43.2	1	1	³ H	8.8E+03	2.1E-04	8.8E+03	1.2E-02	1.1E+02
	1.09E-04	1.32E-01	0.44	4.07	5900	120	13.5	43.2	1	1	Sr	8.9E+02	4.7E-03	8.9E+02	8.0E-03	7.1E+00
	1.33E-04	2.16E-02	0.54	4.58	5900	120	13.5	43.2	1	1	Cs	2.5E+02	5.8E-03	2.5E+02	3.0E-02	7.6E+00
	1.98E-06	8.00E-06	0.008	0.077	5900	120	13.5	43.2	1	1	Am	2.1E+00	8.5E-05	2.1E+00	5.0E-05	1.0E-04
	1.98E-06	8.00E-06	0.008	0.029	5900	120	13.5	43.2	1	1	²³⁸ Pu	1.4E+00	8.5E-05	1.4E+00	4.0E-04	5.6E-04
	4.70E-06	1.90E-05	0.019	0.114	5900	120	13.5	43.2	1	1	²³⁹ Pu	4.0E+00	2.0E-04	4.0E+00	4.0E-04	1.6E-03

Steady-state Model

Background mean 50% scenario

For Deer

Compartment:	C _{air}	C _{root}	C _{soil}	C _{water}	Q _{fodder}	Q _{soil}	Q _{water}	Q _{inh}	f _g	f _r	f _w	Radionuclide	C _{ing}	C _{inh}	C _i	Muscle/intake ratio	C _{meat}
units:	pCi/g	pCi/g	pCi/g	pCi/L	g/d	g/d	L/d	g/d	(unitless)	(unitless)	(unitless)	(unitless)	pCi/d	pCi/d	pCi/d	(pCi/kgmeat)/(pCi/d)	pCi/kg
	3.31E-04	3.35E-03	1.34	0.62	2700	50	3.7	13.6	0.5	0.5	0	U	3.8E+01	4.5E-03	3.8E+01	3.4E-04	1.3E-02
	-2.47E-05	-4.80E-01	-0.1	-6.75	2700	50	3.7	13.6	0.5	0.5	0	³ H	-6.5E+02	-3.4E-04	-6.5E+02	1.2E-02	-7.8E+00
	7.41E-05	9.00E-02	0.3	0.9	2700	50	3.7	13.6	0.5	0.5	0	Sr	1.3E+02	1.0E-03	1.3E+02	8.0E-03	1.0E+00
	6.92E-05	1.12E-02	0.28	0.75	2700	50	3.7	13.6	0.5	0.5	0	Cs	2.2E+01	9.4E-04	2.2E+01	3.0E-02	6.7E-01
	1.48E-06	6.00E-06	0.006	0.021	2700	50	3.7	13.6	0.5	0.5	0	Am	1.6E-01	2.0E-05	1.6E-01	5.0E-05	8.0E-06
	9.89E-07	4.00E-06	0.004	0.005	2700	50	3.7	13.6	0.5	0.5	0	²³⁸ Pu	1.1E-01	1.3E-05	1.1E-01	4.0E-04	4.3E-05
	2.72E-06	1.10E-05	0.011	0.03	2700	50	3.7	13.6	0.5	0.5	0	²³⁹ Pu	2.9E-01	3.7E-05	2.9E-01	4.0E-04	1.2E-04

For Elk

Compartment:	C _{air}	C _{root}	C _{soil}	C _{water}	Q _{fodder}	Q _{soil}	Q _{water}	Q _{inh}	f _g	f _r	f _w	Radionuclide	C _{ing}	C _{inh}	C _i	Muscle/intake ratio	C _{meat}
units:	pCi/g	pCi/g	pCi/g	pCi/L	g/d	g/d	L/d	g/d	(unitless)	(unitless)	(unitless)	(unitless)	pCi/d	pCi/d	pCi/d	(pCi/kgmeat)/(pCi/d)	pCi/kg
	3.31E-04	3.35E-03	1.34	0.62	5900	120	13.5	43.2	0.5	0.5	0	U	9.1E+01	1.4E-02	9.1E+01	3.4E-04	3.1E-02
	-2.47E-05	-4.80E-01	-0.1	-6.75	5900	120	13.5	43.2	0.5	0.5	0	³ H	-1.4E+03	-1.1E-03	-1.4E+03	1.2E-02	-1.7E+01
	7.41E-05	9.00E-02	0.3	0.9	5900	120	13.5	43.2	0.5	0.5	0	Sr	2.8E+02	3.2E-03	2.8E+02	8.0E-03	2.3E+00
	6.92E-05	1.12E-02	0.28	0.75	5900	120	13.5	43.2	0.5	0.5	0	Cs	5.0E+01	3.0E-03	5.0E+01	3.0E-02	1.5E+00
	1.48E-06	6.00E-06	0.006	0.021	5900	120	13.5	43.2	0.5	0.5	0	Am	3.8E-01	6.4E-05	3.8E-01	5.0E-05	1.9E-05
	9.89E-07	4.00E-06	0.004	0.005	5900	120	13.5	43.2	0.5	0.5	0	²³⁸ Pu	2.5E-01	4.3E-05	2.5E-01	4.0E-04	1.0E-04
	2.72E-06	1.10E-05	0.011	0.03	5900	120	13.5	43.2	0.5	0.5	0	²³⁹ Pu	7.0E-01	1.2E-04	7.0E-01	4.0E-04	2.8E-04

Steady-state Model

Background mean + 2 st. dev. 50% scenario

For Deer

Compartment:	C _{air}	C _{root}	C _{soil}	C _{water}	Q _{fodder}	Q _{soil}	Q _{water}	Q _{inh}	f _z	f _r	f _w	Radionuclide	C _{ing}	C _{inh}	C _i	Muscle/intake ratio	C _{meat}
units:	pCi/g	pCi/g	pCi/g	pCi/L	g/d	g/d	L/d	g/d	(unitless)	(unitless)	(unitless)	(unitless)	pCi/d	pCi/d	pCi/d	(pCi/kgmeat)/(pCi/d)	pCi/kg
	4.70E-04	4.75E-03	1.9	1.22	2700	50	3.7	13.6	0.5	0.5	0	U	5.5E+01	6.4E-03	5.5E+01	3.4E-04	1.9E-02
	4.94E-06	9.60E-02	0.02	607	2700	50	3.7	13.6	0.5	0.5	0	³ H	1.3E+02	6.7E-05	1.3E+02	1.2E-02	1.6E+00
	1.09E-04	1.32E-01	0.44	4.07	2700	50	3.7	13.6	0.5	0.5	0	Sr	1.9E+02	1.5E-03	1.9E+02	8.0E-03	1.5E+00
	1.33E-04	2.16E-02	0.54	4.58	2700	50	3.7	13.6	0.5	0.5	0	Cs	4.3E+01	1.8E-03	4.3E+01	3.0E-02	1.3E+00
	1.98E-06	8.00E-06	0.008	0.077	2700	50	3.7	13.6	0.5	0.5	0	Am	2.1E-01	2.7E-05	2.1E-01	5.0E-05	1.1E-05
	1.98E-06	8.00E-06	0.008	0.029	2700	50	3.7	13.6	0.5	0.5	0	²³⁸ Pu	2.1E-01	2.7E-05	2.1E-01	4.0E-04	8.5E-05
	4.70E-06	1.90E-05	0.019	0.114	2700	50	3.7	13.6	0.5	0.5	0	²³⁹ Pu	5.1E-01	6.4E-05	5.1E-01	4.0E-04	2.0E-04

For Elk

Compartment:	C _{air}	C _{root}	C _{soil}	C _{water}	Q _{fodder}	Q _{soil}	Q _{water}	Q _{inh}	f _z	f _r	f _w	Radionuclide	C _{ing}	C _{inh}	C _i	Muscle/intake ratio	C _{meat}
units:	pCi/g	pCi/g	pCi/g	pCi/L	g/d	g/d	L/d	g/d	(unitless)	(unitless)	(unitless)	(unitless)	pCi/d	pCi/d	pCi/d	(pCi/kgmeat)/(pCi/d)	pCi/kg
	4.70E-04	4.75E-03	1.9	1.22	5900	120	13.5	43.2	0.5	0.5	0	U	1.3E+02	2.0E-02	1.3E+02	3.4E-04	4.4E-02
	4.94E-06	9.60E-02	0.02	607	5900	120	13.5	43.2	0.5	0.5	0	³ H	2.8E+02	2.1E-04	2.8E+02	1.2E-02	3.4E+00
	1.09E-04	1.32E-01	0.44	4.07	5900	120	13.5	43.2	0.5	0.5	0	Sr	4.2E+02	4.7E-03	4.2E+02	8.0E-03	3.3E+00
	1.33E-04	2.16E-02	0.54	4.58	5900	120	13.5	43.2	0.5	0.5	0	Cs	9.7E+01	5.8E-03	9.7E+01	3.0E-02	2.9E+00
	1.98E-06	8.00E-06	0.008	0.077	5900	120	13.5	43.2	0.5	0.5	0	Am	5.1E-01	8.5E-05	5.1E-01	5.0E-05	2.5E-05
	1.98E-06	8.00E-06	0.008	0.029	5900	120	13.5	43.2	0.5	0.5	0	²³⁸ Pu	5.1E-01	8.5E-05	5.1E-01	4.0E-04	2.0E-04
	4.70E-06	1.90E-05	0.019	0.114	5900	120	13.5	43.2	0.5	0.5	0	²³⁹ Pu	1.2E+00	2.0E-04	1.2E+00	4.0E-04	4.8E-04

Steady-state Model

Area G mean scenario

For Deer

Compartment:	C _{air}	C _{root}	C _{soil}	C _{water}	Q _{fodder}	Q _{soil}	Q _{water}	Q _{inh}	f _z	f _w	Radionuclide	C _{ing}	C _{inh}	C _i	Muscle/intake ratio	C _{meat}
units:	pCi/g	pCi/g	pCi/g	pCi/L	g/d	g/d	L/d	g/d	(unitless)	(unitless)	(unitless)	pCi/d	pCi/d	pCi/d	(pCi/kgmeat)/(pCi/d)	pCi/kg
	5.83E-04	5.90E-03	2.36	0.32	2700	50	3.7	13.6	1	1	U	1.4E+02	7.9E-03	1.4E+02	3.4E-04	4.6E-02
	3.01E-04	5.86E+00	1.22	139.5	2700	50	3.7	13.6	1	1	³ H	1.6E+04	4.1E-03	1.6E+04	1.2E-02	2.0E+02
	6.18E-05	7.50E-02	0.25	0.5	2700	50	3.7	13.6	1	1	Sr	2.2E+02	8.4E-04	2.2E+02	8.0E-03	1.7E+00
	1.04E-04	1.68E-02	0.42	0.11	2700	50	3.7	13.6	1	1	Cs	6.7E+01	1.4E-03	6.7E+01	3.0E-02	2.0E+00
	5.21E-05	2.11E-04	0.211	0.023	2700	50	3.7	13.6	1	1	Am	1.1E+01	7.1E-04	1.1E+01	5.0E-05	5.7E-04
	9.84E-05	3.98E-04	0.398	0.005	2700	50	3.7	13.6	1	1	²³⁸ Pu	2.1E+01	1.3E-03	2.1E+01	4.0E-04	8.5E-03
	5.81E-05	2.35E-04	0.235	0.005	2700	50	3.7	13.6	1	1	²³⁹ Pu	1.3E+01	7.9E-04	1.3E+01	4.0E-04	5.0E-03

For Elk

Compartment:	C _{air}	C _{root}	C _{soil}	C _{water}	Q _{fodder}	Q _{soil}	Q _{water}	Q _{inh}	f _z	f _w	Radionuclide	C _{ing}	C _{inh}	C _i	Muscle/intake ratio	C _{meat}
units:	pCi/g	pCi/g	pCi/g	pCi/L	g/d	g/d	L/d	g/d	(unitless)	(unitless)	(unitless)	pCi/d	pCi/d	pCi/d	(pCi/kgmeat)/(pCi/d)	pCi/kg
	5.83E-04	5.90E-03	2.36	0.32	5900	120	13.5	43.2	1	1	U	3.3E+02	2.5E-02	3.3E+02	3.4E-04	1.1E-01
	3.01E-04	5.86E+00	1.22	139.5	5900	120	13.5	43.2	1	1	³ H	3.7E+04	1.3E-02	3.7E+04	1.2E-02	4.4E+02
	6.18E-05	7.50E-02	0.25	0.5	5900	120	13.5	43.2	1	1	Sr	4.8E+02	2.7E-03	4.8E+02	8.0E-03	3.8E+00
	1.04E-04	1.68E-02	0.42	0.11	5900	120	13.5	43.2	1	1	Cs	1.5E+02	4.5E-03	1.5E+02	3.0E-02	4.5E+00
	5.21E-05	2.11E-04	0.211	0.023	5900	120	13.5	43.2	1	1	Am	2.7E+01	2.3E-03	2.7E+01	5.0E-05	1.4E-03
	9.84E-05	3.98E-04	0.398	0.005	5900	120	13.5	43.2	1	1	²³⁸ Pu	5.1E+01	4.2E-03	5.1E+01	4.0E-04	2.0E-02
	5.81E-05	2.35E-04	0.235	0.005	5900	120	13.5	43.2	1	1	²³⁹ Pu	3.0E+01	2.5E-03	3.0E+01	4.0E-04	1.2E-02

Steady-state Model

Area G mean + 2 st. dev. scenario

For Deer

Compartment:	C _{air}	C _{root}	C _{soil}	C _{water}	Q _{fodder}	Q _{soil}	Q _{water}	Q _{inh}	f _s	f _w	Radionuclide	C _{ing}	C _{inh}	C _i	Muscle/intake ratio	C _{meat}
units:	pCi/g	pCi/g	pCi/g	pCi/L	g/d	g/d	L/d	g/d	(unitless)	(unitless)	(unitless)	pCi/d	pCi/d	pCi/d	(pCi/kgmeat)/(pCi/d)	pCi/kg
	9.39E-04	9.50E-03	3.8	0.98	2700	50	3.7	13.6	1	1	U	2.2E+02	1.3E-02	2.2E+02	3.4E-04	7.5E-02
	4.00E-03	7.78E+01	16.2	804	2700	50	3.7	13.6	1	1	³ H	2.1E+05	5.5E-02	2.1E+05	1.2E-02	2.6E+03
	1.26E-02	1.53E+01	51	1.61	2700	50	3.7	13.6	1	1	Sr	4.4E+04	1.7E-01	4.4E+04	8.0E-03	3.5E+02
	2.94E-04	4.76E-02	1.19	2	2700	50	3.7	13.6	1	1	Cs	2.0E+02	4.0E-03	2.0E+02	3.0E-02	5.9E+00
	4.52E-04	1.83E-03	1.83	0.05	2700	50	3.7	13.6	1	1	Am	9.8E+01	6.2E-03	9.8E+01	5.0E-05	4.9E-03
	9.12E-04	3.69E-03	3.69	0.01	2700	50	3.7	13.6	1	1	²³⁸ Pu	2.0E+02	1.2E-02	2.0E+02	4.0E-04	7.9E-02
	3.41E-04	1.38E-03	1.38	0.025	2700	50	3.7	13.6	1	1	²³⁹ Pu	7.4E+01	4.6E-03	7.4E+01	4.0E-04	2.9E-02

For Elk

Compartment:	C _{air}	C _{root}	C _{soil}	C _{water}	Q _{fodder}	Q _{soil}	Q _{water}	Q _{inh}	f _s	f _w	Radionuclide	C _{ing}	C _{inh}	C _i	Muscle/intake ratio	C _{meat}
units:	pCi/g	pCi/g	pCi/g	pCi/L	g/d	g/d	L/d	g/d	(unitless)	(unitless)	(unitless)	pCi/d	pCi/d	pCi/d	(pCi/kgmeat)/(pCi/d)	pCi/kg
	9.39E-04	9.50E-03	3.8	0.98	5900	120	13.5	43.2	1	1	U	5.3E+02	4.1E-02	5.3E+02	3.4E-04	1.8E-01
	4.00E-03	7.78E+01	16.2	804	5900	120	13.5	43.2	1	1	³ H	4.7E+05	1.7E-01	4.7E+05	1.2E-02	5.7E+03
	1.26E-02	1.53E+01	51	1.61	5900	120	13.5	43.2	1	1	Sr	9.6E+04	5.4E-01	9.6E+04	8.0E-03	7.7E+02
	2.94E-04	4.76E-02	1.19	2	5900	120	13.5	43.2	1	1	Cs	4.5E+02	1.3E-02	4.5E+02	3.0E-02	1.4E+01
	4.52E-04	1.83E-03	1.83	0.05	5900	120	13.5	43.2	1	1	Am	2.3E+02	2.0E-02	2.3E+02	5.0E-05	1.2E-02
	9.12E-04	3.69E-03	3.69	0.01	5900	120	13.5	43.2	1	1	²³⁸ Pu	4.7E+02	3.9E-02	4.7E+02	4.0E-04	1.9E-01
	3.41E-04	1.38E-03	1.38	0.025	5900	120	13.5	43.2	1	1	²³⁹ Pu	1.8E+02	1.5E-02	1.8E+02	4.0E-04	7.0E-02

Steady-state Model
Area G mean 50% scenario

For Deer																		
Compartment:	C _{air}	C _{root}	C _{soil}	C _{water}	Q _{fodder}	Q _{soil}	Q _{water}	Q _{inh}	f _s	f _f	f _w	Radionuclide	C _{ing}	C _{inh}	C _i	Muscle/intake ratio	C _{meat}	
units:	pCi/g	pCi/g	pCi/g	pCi/L	g/d	g/d	L/d	g/d	(unitless)	(unitless)	(unitless)	(unitless)	pCi/d	pCi/d	pCi/d	(pCi/kgmeat)/(pCi/d)	pCi/kg	
	5.83E-04	5.90E-03	2.36	0.32	2700	50	3.7	13.6	0.5	0.5	1	U	6.9E+01	7.9E-03	6.9E+01	3.4E-04	2.3E-02	
	3.01E-04	5.86E+00	1.22	139.5	2700	50	3.7	13.6	0.5	0.5	1	³ H	8.5E+03	4.1E-03	8.5E+03	1.2E-02	1.0E+02	
	6.18E-05	7.50E-02	0.25	0.5	2700	50	3.7	13.6	0.5	0.5	1	Sr	1.1E+02	8.4E-04	1.1E+02	8.0E-03	8.8E-01	
	1.04E-04	1.68E-02	0.42	0.11	2700	50	3.7	13.6	0.5	0.5	1	Cs	3.4E+01	1.4E-03	3.4E+01	3.0E-02	1.0E+00	
	5.21E-05	2.11E-04	0.211	0.023	2700	50	3.7	13.6	0.5	0.5	1	Am	5.7E+00	7.1E-04	5.7E+00	5.0E-05	2.9E-04	
	9.84E-05	3.98E-04	0.398	0.005	2700	50	3.7	13.6	0.5	0.5	1	²³⁸ Pu	1.1E+01	1.3E-03	1.1E+01	4.0E-04	4.3E-03	
	5.81E-05	2.35E-04	0.235	0.005	2700	50	3.7	13.6	0.5	0.5	1	²³⁹ Pu	6.3E+00	7.9E-04	6.3E+00	4.0E-04	2.5E-03	
For Elk																		
Compartment:	C _{air}	C _{root}	C _{soil}	C _{water}	Q _{fodder}	Q _{soil}	Q _{water}	Q _{inh}	f _s	f _f	f _w	Radionuclide	C _{ing}	C _{inh}	C _i	Muscle/intake ratio	C _{meat}	
units:	pCi/g	pCi/g	pCi/g	pCi/L	g/d	g/d	L/d	g/d	(unitless)	(unitless)	(unitless)	(unitless)	pCi/d	pCi/d	pCi/d	(pCi/kgmeat)/(pCi/d)	pCi/kg	
	5.83E-04	5.90E-03	2.36	0.32	5900	120	13.5	43.2	0.5	0.5	1	U	1.7E+02	2.5E-02	1.7E+02	3.4E-04	5.6E-02	
	3.01E-04	5.86E+00	1.22	139.5	5900	120	13.5	43.2	0.5	0.5	1	³ H	1.9E+04	1.3E-02	1.9E+04	1.2E-02	2.3E+02	
	6.18E-05	7.50E-02	0.25	0.5	5900	120	13.5	43.2	0.5	0.5	1	Sr	2.4E+02	2.7E-03	2.4E+02	8.0E-03	1.9E+00	
	1.04E-04	1.68E-02	0.42	0.11	5900	120	13.5	43.2	0.5	0.5	1	Cs	7.7E+01	4.5E-03	7.7E+01	3.0E-02	2.3E+00	
	5.21E-05	2.11E-04	0.211	0.023	5900	120	13.5	43.2	0.5	0.5	1	Am	1.4E+01	2.3E-03	1.4E+01	5.0E-05	6.9E-04	
	9.84E-05	3.98E-04	0.398	0.005	5900	120	13.5	43.2	0.5	0.5	1	²³⁸ Pu	2.5E+01	4.2E-03	2.5E+01	4.0E-04	1.0E-02	
	5.81E-05	2.35E-04	0.235	0.005	5900	120	13.5	43.2	0.5	0.5	1	²³⁹ Pu	1.5E+01	2.5E-03	1.5E+01	4.0E-04	6.0E-03	

Steady-state Model

Area G mean + 2 st. dev. Scenario

For Deer

Compartment:	C _{air}	C _{root}	C _{soil}	C _{water}	Q _{fodder}	Q _{soil}	Q _{water}	Q _{inh}	f _s	f _r	f _w	Radionuclide	C _{ing}	C _{inh}	C _i	Muscle/intake ratio	C _{meat}
units:	pCi/g	pCi/g	pCi/g	pCi/L	g/d	g/d	L/d	g/d	(unitless)	(unitless)	(unitless)	(unitless)	pCi/d	pCi/d	pCi/d	(pCi/kgmeat)/(pCi/d)	pCi/kg
	9.39E-04	9.50E-03	3.8	0.98	2700	50	3.7	13.6	0.5	0.5	1	U	1.1E+02	1.3E-02	1.1E+02	3.4E-04	3.8E-02
	4.00E-03	7.78E+01	16.2	804	2700	50	3.7	13.6	0.5	0.5	1	³ H	1.1E+05	5.5E-02	1.1E+05	1.2E-02	1.3E+03
	1.26E-02	1.53E+01	51	1.61	2700	50	3.7	13.6	0.5	0.5	1	Sr	2.2E+04	1.7E-01	2.2E+04	8.0E-03	1.8E+02
	2.94E-04	4.76E-02	1.19	2	2700	50	3.7	13.6	0.5	0.5	1	Cs	1.0E+02	4.0E-03	1.0E+02	3.0E-02	3.1E+00
	4.52E-04	1.83E-03	1.83	0.05	2700	50	3.7	13.6	0.5	0.5	1	Am	4.9E+01	6.2E-03	4.9E+01	5.0E-05	2.5E-03
	9.12E-04	3.69E-03	3.69	0.01	2700	50	3.7	13.6	0.5	0.5	1	²³⁸ Pu	9.8E+01	1.2E-02	9.9E+01	4.0E-04	3.9E-02
	3.41E-04	1.38E-03	1.38	0.025	2700	50	3.7	13.6	0.5	0.5	1	²³⁹ Pu	3.7E+01	4.6E-03	3.7E+01	4.0E-04	1.5E-02

For Elk

Compartment:	C _{air}	C _{root}	C _{soil}	C _{water}	Q _{fodder}	Q _{soil}	Q _{water}	Q _{inh}	f _s	f _r	f _w	Radionuclide	C _{ing}	C _{inh}	C _i	Muscle/intake ratio	C _{meat}
units:	pCi/g	pCi/g	pCi/g	pCi/L	g/d	g/d	L/d	g/d	(unitless)	(unitless)	(unitless)	(unitless)	pCi/d	pCi/d	pCi/d	(pCi/kgmeat)/(pCi/d)	pCi/kg
	9.39E-04	9.50E-03	3.8	0.98	5900	120	13.5	43.2	0.5	0.5	1	U	2.7E+02	4.1E-02	2.7E+02	3.4E-04	9.3E-02
	4.00E-03	7.78E+01	16.2	804	5900	120	13.5	43.2	0.5	0.5	1	³ H	2.4E+05	1.7E-01	2.4E+05	1.2E-02	2.9E+03
	1.26E-02	1.53E+01	51	1.61	5900	120	13.5	43.2	0.5	0.5	1	Sr	4.8E+04	5.4E-01	4.8E+04	8.0E-03	3.9E+02
	2.94E-04	4.76E-02	1.19	2	5900	120	13.5	43.2	0.5	0.5	1	Cs	2.4E+02	1.3E-02	2.4E+02	3.0E-02	7.2E+00
	4.52E-04	1.83E-03	1.83	0.05	5900	120	13.5	43.2	0.5	0.5	1	Am	1.2E+02	2.0E-02	1.2E+02	5.0E-05	5.9E-03
	9.12E-04	3.69E-03	3.69	0.01	5900	120	13.5	43.2	0.5	0.5	1	²³⁸ Pu	2.4E+02	3.9E-02	2.4E+02	4.0E-04	9.4E-02
	3.41E-04	1.38E-03	1.38	0.025	5900	120	13.5	43.2	0.5	0.5	1	²³⁹ Pu	8.8E+01	1.5E-02	8.8E+01	4.0E-04	3.5E-02