CALCULATING DOSE TO NON-HUMAN BIOTA

Purpose

This Meteorology and Air Quality Group (MAQ) procedure describes the process for calculating radiological dose to non-human biota in accordance with the requirements of DOE Order 5400.5 and DOE-STD-1153-2002 for inclusion in annual environmental surveillance reports (ESRs) and other ecological risk assessment documentation.

Scope

This procedure applies to the calculation of radiological dose to non-human biota from exposure to soils, sediment, and water containing radionuclides released by current or past Laboratory operations.

In this procedure

This procedure addresses the following major topics:

Signatures

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General information about this procedure

Attachments

This procedure has two attachments.

Attach. Number	Attachment Title	No. of pages
1	Biota Dose Assessment at LANL	49
2	Site-Representative ^{137}Cs BCG for Aquatic System	1

History of revision

This table lists the revision history and effective dates of this procedure.

Revision	Date	Description Of Changes
0	5/12/04	New document.
1	4/14/06	Describe the use of RESRAD-BIOTA and added attachments 1 and 2.

Who requires training to this procedure?

The following personnel require training before implementing this procedure:

- individuals responsible for calculating doses to biota reported in the ESR or other ecological risk assessment documentation.

Annual retraining is required and will be by self-study ("reading") training.

Training method

The training method for this procedure is "**self-study**" (reading) and is documented in accordance with the procedure for training (MAQ-024).

Prerequisites

In addition to training to this procedure, the following training is also required prior to performing this procedure:

- Advanced training in radiation protection, e.g., Certified Health Physicist certification with the American Board of Health Physics;
- Dose modeling using the code RESRAD-Biota developed for the DOE's Graded Approach to Evaluating Radiation Doses to Aquatic and Terrestrial Biota (DOE-STD-1153-2002); [training may be attained through reading the standard documentation, working with the spreadsheet, and/or working with someone familiar with the model;]
- Training to the Biota Dose Assessment Quality Assurance Project Plan: ENV-MAQ-BIOTA.

General information, continued

Definitions specific to this procedure

Aquatic biota: organisms that inhabit water systems.

Bioaccumulation factor: the ratio of the concentration of a nuclide in the biota (wet weight) to the concentration in the surrounding media.

Biota: plant or animal life inhabiting a specific region; in this context, the term biota refers to free-living, non-domesticated, non-human life.

Biota concentration guide (BCG): the limiting concentration of a radionuclide in soil, water, or sediment that would not lead to exceeding dose limits for the protection of biota in the environment.

Dose: a general term used to describe the energy received by and biological effect to a receptor of ionizing radiation particles or rays from radionuclides in the environment.

Environmental media: a discrete portion of the environment, animate or inanimate, that may be sampled or measured directly.

Environmental monitoring or surveillance: the collection of samples of water, sediment, soil, foodstuffs, biota, or other media to measure the presence external radiation or radiological constituents in order to evaluate effects on resident biota.

External or direct exposure: exposure to doses received from radiation (e.g., photon or neutron) sources external to an organism's body.

Internal exposure: exposure to doses received from radiation sources deposited within an organism's body through ingestion, inhalation, or other respiratory processes, or absorption through the body surface.

RESRAD-BIOTA: computer program available from http://web.ead.anl.gov/resrad/ .

Riparian biota: organisms that inhabit land surfaces adjacent to or within stream courses.

Terrestrial biota: organisms that inhabit the land surface.

Background

Introduction

This procedure describes the process for applying the DOE graded approach (including general screening and site-specific assessment) to evaluate compliance with DOE dose limits for the protection of aquatic and terrestrial biota from releases of radionuclides from Laboratory operations.

Dose limits

The DOE technical standard, DOE-STD-1153-2002, sets forth dose limits that are used to demonstrate whether populations of plants and animals are adequately protected from the effects of ionizing radiation released by Laboratory operations. These limits are:

- Aquatic animals: the absorbed dose to aquatic animals should not exceed 1 rad/day (10 mGy/day) from exposure to radiation or radionuclides released into the aquatic environment. This dose limit is specified in DOE Order 5400.5.
- Terrestrial Plants: the absorbed dose to terrestrial plants should not exceed 1 rad/day (10 mGy/day) from exposure to radiation or radionuclides released into the terrestrial environment.
- Terrestrial animals: the absorbed dose to terrestrial animals should not exceed 0.1 rad/day (1 mGy/day) from exposure to radiation or radionuclides released into the terrestrial environment.

Avoiding measurable impairment of reproductive capability is deemed to be the critical biological effect in establishing these dose limits.

General screening

Data sources

The DOE graded approach to biota dose evaluation was designed to minimize the need to collect additional data above and beyond data sets normally available through routine environmental monitoring and surveillance programs. Radionuclide data for soils are typically provided by the Soils, Foodstuffs, and Biota sampling program within the Meteorology and Air Quality Group (MAQ) for the annual ESR. Water and sediment data are typically provided by the Water Quality and Hydrology Group (WQH). Other sources of data may be used as appropriate from other sources such as the Environmental Characterization and Remediation Program (ECR).

Locations

Attachment 1 is a complete list of the present and former technical areas associated with LANL, together with a biota dose assessment of each area. As new data becomes available, choose one or more of these locations for an updated assessment.

A location for which the human-public dose is less than 15 mrem/year according to a residential scenario cannot credibly have a biota dose that exceeds the limit of 0.1 rad/day. Therefore, there is no need to consider locations other than those listed in the attachment.

Data

As new data become available, update the concentrations listed in attachment 1, as needed. There are less than ten rows in each table in Attachment 1, so if all ten concentrations are less than 10% of the generic BCG listed in DOE-STD-1153-2002, the location passes the general screening and no further assessment is required.

General screening

Use RESRAD-BIOTA to compare measured data on radionuclide concentrations in environmental media to generic biota concentration guides (BCGs) presented in DOE-STD-1153-2002. This is called a “general screening.”

General screening, continued

Steps for general screening

To perform a general screening, perform the following steps.

Step	Action
1	In RESRAD-BIOTA, select “level 1.”
2	Enter the maximum radionuclide concentrations for the location into RESRAD-BIOTA.
3	Click on “Run.”
4	The “Results” file displays a red background for the “Total” if the general screening fails. Details on specific nuclides, etc., are provided by RESRAD-BIOTA.
5	If the locations fails the general screening, proceed to the site-specific screening, "level 2”.

Site-specific assessments

Overview

Site-specific assessments allow the evaluator to apply knowledge of site-specific conditions to refine the general screening. Maximum concentrations are replaced by average concentrations and default bioaccumulation factors are replaced by site-representative factors.

Steps in site-specific analysis

To perform a site-specific assessment, perform the following steps:

Step	Action
1	In RESRAD-BIOTA, select “level 2.”
2	Enter the average concentrations for the location into RESRAD-BIOTA. As discussed in Attachment 1, the concentrations are averaged over 3 ha for the population dose assessment mandated by DOE-STD-1153-2002. Also, as discussed in Attachment 1, other areas may be chosen for individual assessments.
3	In RESRAD-BIOTA, change the default bioaccumulation factors for cesium-137 and/or strontium-90 to site-representative values, as discussed in Attachments 1 and 2.
4	Click on “Run.”
5	The “Results” file lists the specific doses and the summed dose. If the results approach or exceed a limit, alert management as appropriate. Report the results in the annual Environmental Surveillance Report.

Records resulting from this procedure

Records

The following records generated as a result of this procedure are to be submitted upon completion of the dose assessment.

- Report the results in the annual Environmental Surveillance Report;
- Document changes in assumptions that were made if default values were not used in making comparisons to BCGs.

Click here to record “self-study” training to this procedure.

ATTACHMENT 1

Biota Dose Assessment at LANL

LA-UR-05-4699
Mike McNaughton, June 7, 2005

A. Purpose of biota dose assessment

The purpose of biota dose assessment is to determine if the doses to biota at LANL are below the limits in DOE orders. It also provides a measure of the significance of environmental radioactivity in the context of its importance to biota. In this respect, biota dose assessment provides a different perspective from human dose assessment because the largest biota dose is received at locations rarely visited by humans.

As defined by the DOE Standard, DOE-STD-1153-2002, biota are divided into plants and animals. Generally, plants receive the highest dose because they live their whole lives at one location. Animals range over a wider area, which usually dilutes their dose. Humans receive the lowest dose because they limit their time in areas with residual radioactivity and they do not eat the vegetation or drink the water in these areas.

Therefore, locations with no significant human dose become significant from the perspective of potential biota dose. Most of the locations discussed in the biota-dose sections have never been discussed in previous dose-assessments.

In the following sections, we discuss the approach, the calculations, and the results.

B. Approach

B1. Overview of radiological dose to biota

Whereas human dose has been calculated for decades by standard methods, biota dose assessment is comparatively new. The biota dose assessment methods used here are discussed in detail in the DOE Standard, DOE-STD-1153-2002, and in the Biota Dose Assessment Quality Assurance Project Plan, ENV-MAQ-BIOTA.

Human dose is measured in rem whereas biota dose is measured in rad. The word "rem" originated as an acronym for "roentgen equivalent for man". Today, it is more appropriate to think of it as "rad equivalent for mammals" for the following reasons. Roentgen should be replaced by rad, because the roentgen is an outdated unit, whereas the rad is directly related to the "Systeme International" (SI) unit, the gray (Gy): 100 rad = 1 Gy. Furthermore, man should be replaced by mammal because most of the measurements used mammals such as rats. The rem is derived from the rad by applying radiation-weighting factors and tissue-weighting factors derived from experiments on mammals.

Thus, the rem applies to mammals, but not to all types of biota. For example, there is a tissue-weighting factor for the mammary glands to give appropriate weight to the prevalence of breast cancer among humans, but only mammals have mammary glands.

Although tissue-weighting factors do not apply to all biota, a radiation-weighting factor is probably appropriate for biota. The scientific basis for the radiation-weighting factor is that some types of radiation are more harmful to DNA than others. All biota have DNA (and/or RNA) so presumably a radiation weighting factor applies to all biota. The DOE Standard explicitly applies the same alpha radiation-weighting factor to biota as to humans. This is a reasonable assumption, though there is little empirical data to confirm it. Applying the human radiation-weighting factors to all biota is generally considered conservative in that it probably overestimates the detriment to most biota.

In summary, as defined in the DOE Standard and used in this chapter, biota dose assessment uses the same radiation weighting as human dose assessment, but no tissue weighting. In this respect, it is similar to the human "dose equivalent" but not to "effective dose equivalent."

Dose assessment includes both internal and external dose, but because biota range in size from micrometers to meters, the biota dose assessment simultaneously assumes that biota are small enough that all external radiation penetrates the whole body and are large enough that all internal radiation is completely contained. This simplifies the calculation. For beta and gamma radiation, the dose is the total ionizing energy per unit mass deposited in an infinite medium: 1 Gy = 1 J/kg. For alpha particles, the dose is multiplied by the human radiation-weighting factor of 20.

B2. Dose limits

The DOE biota dose limits are based on the research summarized in 1996 by the United Nations Scientific Committee on the Effects of Atomic Radiation, UNSCEAR, and represent a consensus of national and international organizations, including the IAEA, ICRP, and NCRP.

The limits are applied to biota populations rather than to individual plants or animals as it is the goal of DOE to protect populations, especially with respect to preventing the impairment of reproductive capability within the population. However, the DOE does not define the size of a population. At LANL, we follow the standard LANL Ecorisk model (LA-UR-04-8246) and define the population area as 40 times the individual home-range area (Ryti 2004 and Bowman 2002). For example, for deer mice, the home range is approximately 0.075 ha (750 m^2) so the population area is 3 ha (30,000 m^2). Therefore, the population dose to mice is the average dose to all mice in an area of 3 ha. For convenience and simplicity, we adopt the same population area for plants (see Section 7 below.)

The DOE dose limits to biota populations are as follows.

Terrestrial animals: 100 mrad/day
Terrestrial plants: 1,000 mrad/day
Aquatic animals: 1,000 mrad/day

The aquatic limit is specified in DOE Order 5400.5, whereas the terrestrial limits are introduced in the DOE Standard, DOE-STD-1153-2002. The DOE Standard predicts the biota dose limits will be promulgated in the Code of Federal Regulations, 10 CFR 834, when guidance for demonstrating compliance has been developed.

There is no explicit limit for aquatic plants. Generally, plants are more resistant to radiation than animals, so the DOE Standard states that the limits on aquatic animals "should provide an indication that aquatic plants are also likely protected."

These dose limits consider effects such as death, impaired reproduction or growth, and genetic mutation, but not cancer. Thus, dose rates at the DOE dose limits "would not have any detrimental effect at the populations level" (UNSCEAR 1996).

B3. Scope

The scope of the biota dose assessment is described in the Biota Dose Assessment Quality Assurance Project Plan, ENV-MAQ-QAPP-BIOTA, and is summarized here.

To ensure that the assessment is comprehensive, it begins with an initial screening, mandated by the DOE Standard, that compares the maximum radionuclide concentrations in soil, sediment, and water with the DOE "Biota Concentration Guides", BCGs. These are screening-level concentrations that are unlikely to cause a limiting dose to the maximally exposed plant or animal, according to the most conservative assumptions. Apart from this initial screening, there is little significance to the BCGs. The DOE Standard states: "An important point is that exceeding the BCGs should not force a mandatory decision regarding remediation of the evaluation area, but rather is an indication that further investigation is likely necessary." These investigations and the resulting biota dose may be used as a measure of the environmental health.

The initial screening considers every location affected by past or present operations of the DOE or its predecessors at Los Alamos. The data pertaining to the location are obtained from the comprehensive database maintained by the environmental restoration (ER) group, ENV-ECR, from LA-UR-90-3400, and from the annual environmental surveillance reports.

The DOE Standard specifically excludes experimental facilities such as LANSCE, DARHT, and LACEF. Perhaps a mouse at LANSCE found a crack in the shielding and received a large dose in an exclusion area, but the effect on the mouse population is expected to be small because the area is small and few mice from the local population would be expected to enter this small area compared to their range. Thus, experimental facilities are outside the scope of this assessment.

More specifically, the DOE Standard discusses radioactive material, but does not discuss direct radiation such as is received in the exclusion areas (Very High Radiation Areas) of LANSCE, DAHRT, and LACEF. It would not be difficult to do a site-specific assessment for the residual 28 pCi/g of Sr-90 inside the fence of the SW Casa at TA-18 (PRS 18-003(c)) but it would be more challenging to invent a method of including the effects of intense point sources of radiation that are lethal at short distances. For example, how does one average the dose from the LANSCE beam (several mega-rad per second) with the dose from residual radioactive material (a few mill-rad per year)?

It is not possible to assess the dose to every animal and every plant at LANL. Therefore, following the guidance of the DOE Standard (DOE-STD-1153-2002) and the ENV-ECR group (refer to LA-UR-04-8246), we calculate the dose to representative plants and animals. Trees of the pine family (pinaceae) are the best representatives for plants because they are the most radiosensitive and because their deep roots tap into buried contamination. (In future, chamisa may also be used.) Deer mice are the best representatives for animals because of their relatively small home range, which means the maximally exposed mouse spends a large fraction of its time in the most contaminated location.

For each location, we calculate the biota dose for four cases: the maximally exposed plant, the maximally exposed animal, the plant population, and the animal population.

The calculations are conveniently laid out in the computer program RESRAD-BIOTA. The initial screening mandated by the DOE Standard is level-1 of the RESRAD-BIOTA calculation. Locations that fail the level-1 screening are subjected to a level-2 assessment that includes consideration of the area and the bioaccumulations factors. These are discussed in detail in the following sections.

For humans, the dose from natural background is about 1 mrad/day. For biota, it ranges from 1 to 20 mrad/day, mostly from naturally-occurring radium and polonium. By comparison, doses less than 1 mrad/day from LANL have little significance. Therefore, results are reported in mrad/day, and biota dose rates less than 1 mrad/day are reported as "essentially zero".

The biota dose assessment includes the same pathways as the human dose assessment: external radiation, air, water, soil, and food. However, the DOE Standard states that the air pathway is negligible. This is because air moves rapidly. The air that is breathed by biota one minute is breathed by workers a minute later and by the public a few minutes after that, so the systems that safeguard the air pathway for workers and the public also protect the biota.

B4. Bioaccumulation factors

As used in the DOE Standard and in RESRAD-BIOTA, the bioaccumulation factor, B_{iv}, is the ratio of the concentration of the i^{th} radionuclide in biota to the concentration in the soil or water. This ratio is sometimes called the concentration ratio or the transfer factor.

These factors vary widely and depend on the soil or water chemistry, the type of organism, and the complexity of the ecology. Therefore, the DOE Standard provides a set of default factors and encourages the development of site-specific factors. As the first step in this process, consider how the factors are used.

The biota dose, D, is the sum of the internal and external doses, each of which is calculated by multiplying the concentration, C, by the dose-conversion factor, DCF: $D = C*DCF$. In the case of external dose, C_e is the concentration in the surrounding soil or water, whereas in the case of internal dose, C_i is the concentration in the plant or animal. This internal concentration may be measured directly, or it may be estimated from the external concentration and the bioaccumulation factor: $C_i = B_{iv}* C_e$. Combining these equations: $D = C_e*DCF_e + B_{iv}*C_e*DCF_i$.

Consider the important case of Cs-137 in soil. There are extensive measurements by Fresquez and others that show B_{iv} is between 0.01 and 0.1 throughout LANL and the surrounding areas (Fresquez 1997, LA-13304-MS; also Fresquez 2004, LA-14160-PR). (See also the discussion of TA-5, Mortandad Canyon, below.)

Since DCF_e is almost equal to DCF_i, the exact value of B_{iv} makes little difference provided it is smaller than 0.5. Therefore, based on Hakonson 1973, Miera 1978, and Fresquez 1997, we take the upper (most conservative) limit and use $B_{iv} = 0.1$ for Cs-137 in soil at LANL.

For Cs-137 in water, there are no measurements of B_{iv} at LANL, so we use $B_{iv} = 100$ for daphnia and water snails from the LANL Ecorisk database and from Baker and Soldat (1992).

For Sr-90 in soil, B_{iv} is between 0.1 and 1 (Fresquez 1997) so we take the upper limit and use $B_{iv} = 1$. In this case, the RESRAD-BIOTA calculation is very conservative. To see this, consider the equation: $D = C_e{*}DCF_e + B_{iv}{*}C_e{*}DCF_i$. To determine DCF_e, the DOE Standard assumes the organism is very small, and to determine DCF_i it assumes the organism is very large. The result is both DCF_e and DCF_i lead to the dose being delivered in an infinite medium, and when both are substituted into the equation for D, with $B_{iv} = 1$, the equation becomes $D = 2{*}C{*}DCF$, which is twice the true dose.

For radionuclides other than Cs-137 and Sr-90, the existing LANL data do not demonstrate values of B_{iv} that are substantially different from the default values in the DOE Standard, so we use the DOE default values for B_{iv}. The resulting doses are high, but not unreasonably so.

B5. Material Disposal Areas, MDAs

LANL has many material disposal areas, MDAs, that contain legacy waste. Some of these were established in the 1940s, without accurate records of their contents. Based on the best available information, the concentrations are greater than the DOE initial screening levels only at the following MDAs: A, B, C, G, H, T, W, and AB. Each of these MDAs is examined in the following sections.

For the MDAs, the soil concentrations may not be directly related to the biota concentrations. This is because the buried waste is unevenly distributed, it is packaged, and it is buried. It is unevenly distributed because the waste includes a few highly contaminated items mixed with many items that are only suspected of being contaminated. It is packaged, usually in a form that is relatively inaccessible to biota, in order to protect the health of the workers transporting the waste to the burial site. And most of the waste is buried below the depths usually accessed by biota. In some cases, the pits or shafts are protected by a biological barrier such as concrete.

When the soil data are inadequate, the biota dose can be calculated directly from external radiation measurements at the surface and from the concentrations in the biota, as recommended in the DOE Standard, Module 2 Section 5.1. If deep-rooted plants penetrate the pockets of radioactive waste, they bring radionuclides to the surface and make it available to animals, in which case the concentrations in the plants are the best indicators of biota dose. However, as discussed in the DOE Standard (Module 2 Section 6) a more complete picture is valuable, so we use the plant concentrations to deduce the effective soil concentrations sampled by the roots.

B6. Biota data

For more than 30 years, LANL has measured the radionuclide concentrations in biota (Fresquez 2004, etc.) Usually, the motivation was human dose assessment, so often the focus was on edible plants and animals. A related motivation was to investigate possible spread of contamination from foraging or burrowing animals and from deep-rooted plants, so there are data on bees, rodents, elk, deer, and a variety of plants (refer to Fresquez et al. in the annual environmental surveillance reports.) Fish have been studied off site, in the Rio Grande and nearby dams (Fresquez et al. in the ESR), but there are no studies of aquatic animals on site because the streams are mostly ephemeral and aquatic animals are not common.

The biota measurements demonstrate that LANL has small pockets of contamination surrounded by large areas that are relatively clean. As a rough approximation to put the contamination in perspective, I estimate the total area with contamination above the DOE initial screening levels is less than 0.1% of the total area of LANL. (The total area of LANL is about 10,000 ha and I estimate the total area above the screening levels is less than 10 ha.)

Therefore, animals with a large home range do not have above-background radioactivity. Significant radioactive material has not been detected in elk and deer because the large area over which they range effectively dilutes the contamination. In bees, only tritium has been detected above background (Fresquez 1997), and the resulting dose is less than a micro-rad per day. For this reason, it is more useful to consider animals that have a small home range, such as mice. The following section describes how the home range is factored into the calculation.

B7. Area

The DOE Standard mandates the use of the maximum measured concentrations for the initial screening. Then, for the site-specific assessment, it recommends averaging the data over an appropriate area, which might be the range of a population of animals, or the area of a particular type of habitat. In RESRAD-BIOTA, this averaging may be done with an "Area Factor", which is the ratio of the contaminated area to the area being assessed. Or it can be done by averaging the data over the area.

The habitats at LANL are large: pinon-juniper covers 5,000 ha; ponderosa pine covers 3,000 ha; grassland covers 1,000 ha; etc. Rather than average over such large areas, we choose three standard areas: 0.01 ha for a tree; 0.075 ha for a mouse; and 3 ha for a population of plants or animals. The first area, 0.01 ha, is the area chosen for LANL's soil monitoring program (Fresquez 1996). The second area, 0.075 ha, is approximately the home range of a deer mouse (Ecorisk 2004, LA-UR-04-8246). And the third area, 3 ha, is 40 times the home range of a deer mouse, which is the population area described by Ryti et al. and Bowman et al. (Ryti 2004 and Bowman 2002).

B8. Bees

Many studies have focused on animals with a large home range (Ferenbaugh LA-13596-MS, Soholt LA-13999). These studies have not detected significant amounts of radioactive material above background. This is because the areas of contamination are small compared with the home range of the animal so the animal's food consists of a small amount of contaminated material mixed with a large amount of uncontaminated material.

Bees have a home range intermediate between deer mice and elks or predators. The home range of a bee is on the order of 1,000 ha, which is much larger than the home range of a deer mouse (0.075 ha) but smaller than the area of LANL (10,000 ha). Nevertheless, the only radionuclide detected in bees has been tritium. In 1972, Tom Hakonson et al. measured 9,600 pCi/mL in Mortandad Canyon bees (LA-5184, LA-5586, and LA-5282-MS) and in 1985 (LA-10721-ENV Table G35, page 178) 99,000 pCi/mL was measured at TA-33. The environmental surveillance reports (ESR) show lower concentrations, declining from 3,300 pCi/mL at TA-53 and 1,800 pCi/mL at Area G in 1990, to less than 1,000 pCi/mL in 1997. There is also information in the following ESRs (for the LA numbers, see the references at the end of Section B): 1983 ESR pages 43-47; 1984 ESR page 176; 1989 ESR page 225; 1990 ESR page G-60-2, 1992 ESR page IV-71, and the 1997 ESR page 229.

The bee data are summarized in LA-13202-MS ("Tritium Concentrations in Bees and Honey at LANL: 1979-96" by PR Fresquez, DR Armstrong, and LH Pratt) and J. Environ Sci Health, A32(5), 1309-1323 (1997) ("radionuclides in bees and honey within and around LANL," PR Fresquez, DR Armstrong, and LH Pratt).

B9. Calculations

Most locations have a dominant radionuclide (Cs-137 at TA-5, Sr-90 at TA-10, U-238 at TA-15, Pu-239 at TA-21, etc.) Therefore, the discussion in each section focuses on the dominant case and introduces the other radionuclides at the end. An exception is TA-54, for which there are two discussions, one for Pu-239 and another for H-3.

In each section, the discussion begins by addressing the big issues: concentration, bioaccumulation factor, and area. Issues surrounding a particular radionuclide are addressed in detail the first time a radionuclide is discussed. Later sections refer back to the same conclusions and references.

Most locations have one medium, usually soil. Most locations have only ephemeral water, so water is only discussed in the aquatic section of TA-50.

The calculations use level-2 of RESRAD-BIOTA, which can be downloaded from: http://web.ead.anl.gov/resrad/ (or Google "resrad").

For each location, we report four doses: the maximum dose to a plant, the maximum dose to an animal, the dose to a plant population, and the dose to an animal population. The maximum dose to a plant corresponds to the most contaminated 0.01 ha. The maximum to an animal is averaged over 0.075 ha. And the population doses for both plants and animals are averaged over 3 ha.

B10. References for Section B

Baker 1992: DA Baker and JK Soldat, "Methods for estimating doses to organisms from radioactive materials released into the aquatic environment", PNL-8150, UC-602 (1992).

Bowman 2002: JA Bowman et al., "Dispersal distance of mammals is proportional to home range size", Ecology volume 83, pages 2049-2055 (2002).

DOE-STD-1153-2002: "A graded approach for evaluating radiation doses to aquatic and terrestrial biota" (2002).

Ferenbaugh 1999: JK Ferenbaugh, PR Fresquez, MH Ebinger, GJ Gonazles, PA Jordan, "Elk and deer study", LA-13596-MS (1999).

Fresquez 1996: PR Fresquez et al., "Radionuclides and radioactivity in soils within and around Los Alamos National Laboratory, 1974 through 1994, trends and dose comparisons." LA-13149-MS (1996).

Fresquez 1997a: PR Fresquez et al., "Radionuclide concentrations in pinto beans, sweet corn, and zucchini squash grown in Los Alamos Canyon at LANL", LA-13304-MS (1997).

Fresquez 1997b: PR Fresquez, DR Armstrong, and LH Pratt, "Radionuclides in bees and honey within and around LANL" J. Environ, Sci. Health, A32(5), 1309-1323 (1997).

Fresquez 1997c: PR Fresquez, DR Armstrong, and LH Pratt, "Tritium concentrations in bees and honey at LANL, 1979-1996", LA-13202-MS (1997).

Fresquez 1998: Fresquez, P.R., D.A. Armstrong, M.A. Mullen, and L. Naranjo, Jr. (The uptake of radionuclides by beans, squash, and corn growing in contaminated alluvial soils at Los Alamos National Laboratory" Journal of Environmental Science and Health B33 (1) 99-115 (1998).

Fresquez 2000a: Fresquez, P.R., J.D. Huchton, M.A. Mullen, and L. Naranjo, Jr,. "Pinon pine tree study, Los Alamos National Laboratory: source document," Los Alamos National Laboratory report LA-13693-MS. Los Alamos, NM (2000).

Fresquez 2000b: Fresquez, P.R., J. Huchton, M.A. Mullen, and L. Naranjo, Jr,. "Radionuclides in pinon pine (Pinus edulis) tree shoots and nuts from Los Alamos National Laboratory lands," Health Physics 78 (6): S83 (2000).

Fresquez 2000c: Fresquez, P.R., J. Huchton, M.A. Mullen, and L. Naranjo, Jr,. "Radionuclides in pinon pine (Pinus edulis) nuts collected from Los Alamos National Laboratory lands and the dose from consumption," Journal of Environmental Science and Health 35 (5): 611–622 (2000).

Fresquez 2004: Fresquez, P.R. and G.J. Gonzales. "Radionuclide Concentrations in Vegetation at the Los Alamos National Laboratory in 2002/2003," Los Alamos National Laboratory report LA-14160-PR. Los Alamos, NM (2004).

Hakonson 1973: TE Hakonson, LW Nyhan, LJ Johnson, KV Bostick, "Ecological investigation of radioactive materials in waste discharge areas at Los Alamos", LA-5282-MS (1973).

Hakonson 1976: TE Hakonson and KV Bostick, "The availability of environmental radioactivity to honeybee colonies at Los Alamos", J. of Environmental Quality volume 5, pp 307 to 310, (1976) and LA-UR-74-1816.

LA-UR-04-8246: "Screening level ecological risk assessment methods" (2004).

LA-UR-01-990: "Derivation and use of radionuclide screening action levels" (2002).

Ryti 2004: Randall T. Ryti, James Markwiese, Richard Mirenda, Lars Soholt, "Preliminary Remediation Goals for Terrestrial Wildlife", Human and Ecological Risk Assessment, 10: 437-450, 2004.

Soholt, L., G.J. Gonzales, P.R. Fresquez, K. Bennett and E. Lopez. 2003. Estimating Radiological Doses to Predators Foraging on a Low-Level Waste Management Area. Los Alamos National Laboratory report LA-13999. Los Alamos, NM.

UNSCEAR 1996: United Nations Scientific Committee on the Effects of Atomic Radiation (1996).

B11. Annual Environmental Surveillance Reports (ESR) LA Report Numbers

Year	LA report number
1959	LAMS-2397
1960	LAMS-2499
1961	LAMS-2702
1962	LAMS-2870
1963	LAMS-3071
1964	LA-3245-MS
1965	LA-3516
1966	LA-3663
1967	LA-3887
1968	LA-4133
1969	LA-4388
1970	LA-4661 and LA-4672-MS
1971	LA-4871-MS and LA-4970
1972	LA-5097-MS and LA-5184
1973	LA-5586
1974	LA-5977-PR
1975	LA-6321-MS
1976	LA-6801-MS
1977	LA-7263-MS
1978	LA-7800-ENV
1979	LA-8200-ENV

1980 LA-8810-ENV
1981 LA-9349-ENV
1982 LA-9762-ENV
1983 LA-10100-ENV
1984 LA-10421-ENV
1985 LA-10721-ENV
1986 LA-10992-ENV
1987 LA-11306-ENV
1988 LA-11628-ENV
1989 LA-12000-ENV
1990 LA-12271-MS
1991 LA-12572-ENV
1992 LA-12764-ENV
1993 LA-12973-ENV
1994 LA-13047-ENV
1995 LA-13210-ENV
1996 LA-13343-ENV
1997 LA-13487-ENV
1998 LA-13633-ENV
1999 LA-13775-ENV
2000 LA-13861-ENV
2001 LA-13979-ENV
2002 LA-14085-ENV
2003 LA-14162-ENV
2004 LA-14239-ENV

C. Biota dose calculations and results

The following sections discuss each technical area (TA) at LANL.

A useful general reference is the “Solid Waste Management Units Report”, LA-UR-90-3400. Annual data are in the annual environmental surveillance reports; to help find them in the library catalog, the LA report numbers are listed at the end of Section B, above. Useful references for individual TAs are listed at the end of the specific section.

TA-0 (Off Site)

The designation “TA-0” means off site. Current radiological operations are not performed off site, but there are legacy sites that are sometimes listed as off site, though all of these are associated with a historical TA. For example, Acid Canyon and Pueblo Canyon are associated with TA-45.

In this document, some SWMUs listed under TA-0 are discussed under other TAs, as follows.

SWMU 0-001 is the location of the sediment traps in Mortandad Canyon. This is discussed in the TA-5 section.

SWMU 0-005 is Tom Hakonson's fenced "garden plot" near the Mortandad Canyon sediment traps (White, Hakonson, and Alquist, J. Environ. Qual. vol 10, p 294, 1981). This is discussed in the TA-5 section.

The other SWMUs listed under TA-0 have been remediated to human-residential standards and have no significant environmental radioactive contamination or biota dose.

TA-1

TA-1 was the original technical area in the vicinity of Ashley Pond in downtown Los Alamos. It has been remediated to human residential standards, except for the hillside south of the fence. (Acid Canyon is discussed under TA-45.)

The hillside of Los Alamos Canyon south of the Los Alamos Inn was contaminated in the early 1940s by several outfalls from the original TA-1. The primary radionuclide is Pu-239. The highest levels are on Hillside 138, downhill from and 20 to 50 m southwest of 2101 Trinity Drive Suite U. The hillside is within TA-41, is fenced, and access is restricted by locked gates.

These hillsides are described in the ER report: “RFI Work Plan for Operable Unit 1078”, LA-UR-92-838 and in LA-UR-95-2680. This 1992 report refers to sampling data collected in 1977 by Ahlquist et al., reported in LA-6887. However, a remedial action (voluntary corrective action) in 1996 was reported in the ER report “Remedial Action Status Report for Potential Release Site 1-001(d) Hillside 138” dated January 1997.

The 1992 report (LA-UR-92-838, Table 4.5-1, page 4-30) documents 36 pCi/g of Pu-239 at Hillside 137, 68 pCi/g of U-235 at Hillside 140, and 797 pCi/g of Pu-239 at Hillside 138. These concentrations were converted to dose based on a human residential scenario and reported in LA-UR-92-838 Table 4.4-1.

The 1996 remedial action was based on measurements with a FIDLER instrument. According to the memo from Paul Black to Valerie Rhodes, dated 20 July 1996, subject “FIDLER cleanup level based on new 1996 data”, the goals of the remedial action correspond to a Pu-239 concentration of about 300 pCi/g. According to the “Remedial Action Status Report” dated January 1997, the contamination was reduced by 60%, which also indicates the final average concentration was about 300 pCi/g. This is similar to the concentration in Acid Canyon; (for a discussion of Acid Canyon, see the TA-45 Section).

According to RESRAD-BIOTA, 300 pCi/g causes 24 mrad/day to the most exposed plant. The contaminated area is on the order of 0.01 ha, so averaging over 0.075 ha, the dose to the most exposed mouse is about 1 mrad/day. Averaging over 3 ha, the population doses are essentially zero.

In summary, near TA-1 the dose to the human public and to biota are both small.

References for TA-1

A. John Ahlquist et al., "Radiological Survey and Decontamination of the Main Technical Area TA-1," LA-6887 (1977).

LA-UR-92-838, "RFI Work Plan for Operable Unit 1078" (1992).

LA-UR-95-2680, "RFI report for TA-1 aggregate F" (1995).

TA-2 (Omega West)

TA-2 was the site of several research reactors, beginning with the "Water Boiler" in the 1940s and ending with the Omega-West reactor, which is now decommissioned and decontaminated.

Radiation was detected from TA-2 during the Aerial Radiological Survey in 1994 (DOE/NV/11718-107, UC-702, 1998). At this time, the reactor fuel rods were being removed from TA-2. During 2002, the facility was dismantled and decontaminated.

LA Canyon was examined in the LA and Pueblo Canyons Investigation Report, LA-UR-04-2714 (by Danny Katzman and Steve Reneau). According to this report, the residual contamination is far below the BCGs for all radionuclides except Cs-137 and Sr-90. With B_{iv} = 1 for Sr-90 and BIV = 0.01 for Cs-137, the biota doses from LANL are less than 1 mrad/day.

References for TA-2

DOE 1998: "An aerial survey of the Los Alamos National Laboratory and surrounding area, DOE/NV/11718-107, UC-702, (1998).

LA-UR-04-2714, "LA and Pueblo Canyons Investigation Report," (2004).

TA-3 (South Mesa Core Area)

TA-3 was a firing site before 1945. In 1945, it was cleaned to human-health standards and in 1950 many facilities were moved from TA-1 to TA-3. TA-3 then became the main technical area. There is no significant environmental radioactive contamination and therefore no significant biota dose at TA-3.

TA-4 (Alpha Site)

TA-4 has been incorporated into the present TA-52 and TA-63. TA-4 operated as a firing site for small conventional explosives from 1944 to 1946. It underwent decontamination and decommissioning in the 1950s, except for TA-4-1 which was demolished in 1985. No radioactivity was detected during the surveys in 1953 and 1985. In conclusion, there is no significant biota dose.

TA-5 (Beta Site and Mortandad Canyon)

The original TA-5, known as Beta Site, was a firing site on the mesa east of TA-52. It operated from 1944 to 1947 and underwent D&D in 1985. TA-5 now includes Mortandad Canyon.

Mortandad Canyon has received radioactive liquid waste from several technical areas, beginning in the 1950s with waste from TA-35, and continuing today with waste from TA-50. (refer to Emelity LA-UR-96-1283, and to the “Work Plan for Mortandad Canyon”, LA-UR-97-3291). The part of the canyon with measurable biota dose extends about 3 km, from the TA-50 outfall to Mortandad Observation Well MCO-8.2 in TA-5.

Mortandad Canyon tributaries include Pratt Canyon and Effluent Canyon. We consider Pratt Canyon in the TA-35 section and Effluent Canyon in the TA-50 section.

Mortandad Canyon is monitored annually and the results are published in the annual reports “Environmental Surveillance at Los Alamos”. It has also been the focus of several specific investigations. (See the references by Hakonson, White, Fresquez, Nyhan, and Reneau, listed at the end of this section).

The canyon has above-background concentrations of plutonium, americium, uranium, tritium, strontium-90, and cesium-137. Tritium has the highest curie content, but the tritium dose is low because the beta emitted from tritium has very-low energy. Cs-137 causes the highest dose, followed by Sr-90 and the transuranics. The Sr-90 and transuranic concentrations are generally about 10% of the Cs-137 concentration and together they contribute less than half the dose. Uranium is slightly above background and contributes the least dose.

It is not possible to calculate a definitive average concentration for the radionuclides because different authors measured different radionuclides in different locations. Many of the measurements are in the stream channel, which has been scoured by decades of intermittent flow. Generally, the largest concentrations are in the banks of the narrow reach (M2) that extends for 2 km below the TA-50 outfall, and in the broad floodplain 2 to 3 km below the outfall (reaches M2 and M3).

For the present preliminary assessment, we first focus on Cs-137, which is the dominant contributor to biota dose. Consider the worst case reported in 1972 by Hakonson et al. (LA-5282-MS) and by Nyhan et al. (LA-7298-MS) and compare this with the worst case reported in 2003 by Reneau et al. (LA-UR-03-5997). Hakonson's worst case of 3361 pCi/g is larger than Reneau's worst case of 870 pCi/g, presumably because of 33 years of decay and erosion. Averaging Hakonson's data and correcting for decay, the average in the first 500 m below the TA-50 outfall is 500 pCi/g in alluvial soil or sediment. Thus, we conclude that the Cs-137 concentration in this reach (M-2W) is less than 1,000 pCi/g, and the Sr-90 concentration is less than 100 pCi/g.

Reach M2-W is narrow, with steep banks. According to Nyhan 1982 the Cs-137 concentration decreases with distance from the stream channel and is generally less than 100 pCi/g at 0.38 m from the stream channel. This is much narrower than the home range of a mouse, so an area factor (see Section B7) of approximately 0.1 has been used in the biota dose calculations.

Further downstream, in reaches M3 and M4 about 2 to 3 km below the outfall, the canyon is wider and the concentrations are generally lower (Bennett, Biggs, and Fresquez, LA-13104-MS, and Reneau LA-UR-03-5997). In 1981, White, Hakonson, and Alquist reported a maximum Cs-137 concentration of 217 pCi/g and an average of 116 pCi/g in the soil at the "garden plot" (PRS 00-005). Correcting for decay from 1977 to the present, the average concentration near this location is now about 100 pCi/g. According to FIMAD plot ID 107934, it decreases to much less than the default BCG (20 pCi/g) downstream of Mortandad Canyon Observation Well MCO-8.2.

Summarizing, we assume the Cs-137 concentration is about 1,000 pCi/g in reach M2-W, about 100 pCi/g near the sediment traps (PRS 00-001) 2.5 km from the outfall, and less than 10 pCi/g beyond about 3 km from the TA-50 outfall. The Sr-90, Am-241, and Pu-239 concentrations are about 10% of the Cs-137 concentration.

In order to complete this preliminary dose assessment, we need site-specific bioaccumulation factors. White, Hakonson, and Ahlquist report dry-weight plant-to-soil concentration ratios for Cs-137 in Mortandad Canyon. Combining these with the moisture conversion ratios published by Fresquez et al. (LA-UR-04-4122) we conclude that the worst case wet-plant-to-soil bioaccumulation factor is 0.03 for Cs-137.

There are no definitive bioaccumulation factors for animals in this location so we estimate the product of the bioaccumulation factor and the area factor, using the data of Hakonson et al. (LA-5282-MS) and Bennett et al. (LA-UR-13104-MS). The Cs-137 concentration measured by Hakonson in mice was 1 pCi/g. There was no significant difference between the mouse concentrations in the narrow reach with high soil concentrations (M2W) and the wider reaches with lower soil concentrations (M3 and M4). Apparently, the narrow strip with high concentration is only a small fraction of the home range of a mouse, whereas the wider strip with lower concentration is a larger fraction of its home range. Therefore, the product of the area factor and the bioaccumulation factor is the same in the various reaches.

The contaminated area near the sediment traps is larger than the home range of a mouse so the area factor in this location is 1. The soil concentration is 100 pCi/g and the mouse concentration is 1 pCi/g, so the bioaccumulation factor is about 0.01. In the narrow reach, M2-W, if we assume the bioaccumulation factor is also 0.01 and the area factor is 0.1, then the product is 0.001, which is consistent with the data: 1,000 pCi/g in soil and 1 pCi/g in mice.

Bennett, Biggs, and Fresquez also measured Cs-137 in mice. After correcting for the ratio of ash to wet weight, the wet-weight concentration was 0.1 pCi/g in the carcasses compared with 18 pCi/g in the sediment, which also indicates the bioaccumulation factor is about 0.01.

These small values of the bioaccumulation factor (B_{iv}) all show that the internal dose is small and that the Cs-137 dose is mostly external. In this case, as discussed in Section B, the exact value of B_{iv} makes no difference. To be conservative and for consistency we set $B_{iv} = 0.1$.

For a Cs-137 concentration of 100 pCi/g in the soil over an area of 3 ha, the individual and population doses are 5 mrad/day to animals and plants alike. In the narrow part of the canyon where the concentration is 1,000 pCi/g, an area factor of 0.1 applies to individual animals and to a population of trees. This results in the same dose, 5 mrad/day, because 1,000 pCi/g with an area factor of 0.1 is equivalent to 100 pCi/g with an area factor of 1.

For Sr-90, the plant concentration measured by Bennett et al., 1 pCi/g wet weight, results in an internal dose of 0.06 mrad/day in the plants. The transuranic concentrations, 0.002 pCi/g wet, result in doses of 0.01 mrad/day. Thus, the data for plants and animals show the internal doses from all radionuclides are much smaller than the external dose from Cs-137.

To summarize, measurements over 35 years demonstrate that the biota dose is mostly external dose from Cs-137. Preliminary estimates indicate a total dose of 5 to 10 mrad/day to individual animals and to a population of plants. The dose to individual plants in the most contaminated reach (M2W) may be as high as 50 to 100 mrad/day.

The following table summarizes the preliminary assessment, pending detailed investigations planned for 2005. The uncertainty is at least a factor of 2 so all numbers in the table have been rounded. The concentrations are approximately those in reach M4, near the sediment traps and the garden plot. With B_{iv} set to 0.01 for Cs-137 and 1 for Sr-90, these concentrations were entered into RESRAD-BIOTA to calculate the population doses and the maximum animal dose. The maximally-exposed plant is in reach M2W where the maximum concentration is ten times greater, so the maximum dose to plants is ten times the population dose to plants (with rounding.)

All of the doses are less than 10% of the DOE limits.

radionuclide	Soil conc. (pCi/g)	maximum dose (mrad/day)		population dose (mrad/day)	
		Plant	Animal	Plant	Animal
Am-241	10	5	0	1	0
Pu-239	10	5	0	1	0
U-238	3	1	0	0	0
H-3	1000	5	1	1	1
Cs-137	100	50	5	5	5
Sr-90	10	10	1	1	1

References for TA-5

K. Bennett, J. Biggs, P. Fresquez, "Radionuclide Contaminant Analysis of Small Mammals, Plants, and Sediments within Mortandad Canyon, 1994" LA-13104-MS (1996).

L.A. Emelity, "A History of Radioactive Liquid Waste Management at Los Alamos" LA-UR-96-1283 (1996).

Fresquez, P.R., D.A. Armstrong, M.A. Mullen, and L. Naranjo, Jr., "The uptake of radionuclides by beans, squash, and corn growing in contaminated alluvial soils at Los Alamos National Laboratory," Journal of Environmental Science and Health B33 (1) 99-115 (1998).

Fresquez, P.R., J.D. Huchton, M.A. Mullen, and L. Naranjo, Jr,. “Pinon pine tree study, Los Alamos National Laboratory: source document,” Los Alamos National Laboratory report LA-13693-MS. Los Alamos, NM (2000).

Fresquez, P.R., J. Huchton, M.A. Mullen, and L. Naranjo, Jr,. “Radionuclides in pinon pine (Pinus edulis) tree shoots and nuts from Los Alamos National Laboratory lands,” Health Physics 78 (6): S83 (2000).

Fresquez, P.R., J. Huchton, M.A. Mullen, and L. Naranjo, Jr,. “Radionuclides in pinon pine (Pinus edulis) nuts collected from Los Alamos National Laboratory lands and the dose from consumption,” Journal of Environmental Science and Health 35 (5): 611–622 (2000).

PR Fresquez, JK Ferenbaugh, L Naranjo, Jr., "Moisture conversion ratios for the foodstuffs and nonfoodstuffs biota environmental surveillance programs at LANL" LA-UR-04-4122 (2004).

TE Hakonson, KV Bostick, "The availability of environmental radioactivity to honeybee colonies at Los Alamos", LA-UR-74-1816 and Journal of Environmental Quality 5, pp 307-310 (1976).

T.E. Hakonson, J.W. Nyhan, L.J. Johnson, K.V. Bostick "Ecological Investigation of Radioactive Materials in Waste Discharge Areas at Los Alamos", LA-5282-MS, (1973).

T.E. Hakonson and K.V. Bostick, "Cesium-137 and plutonium in liquid waste discharge areas at Los Alamos" in Radioecology and Energy Resources, Proceedings of the Fourth National Symposium on Radioecology, 1975, edited by Colbert E. Cushing, Jr., and published by Dowden, Hutchingon, and Ross. (1975).

LA-UR-97-3291, “Work Plan for Mortandad Canyon,” (1997).

JW Nyhan, TE Hakonson, FR Miera, KV Bostick, "Temporal Changes in the Distribution of 137Cs in Alluvial Soils at Los Alamos" LA-7298-MS, ER ID 5726, (1978).

JW Nyhan, GC White, G Trujillo, "Soil plutonium and cesium in stream channels and banks of Los Alamos effluent-receiving areas" Health Physics volume 43 pp 531-541 (1982).

Steven Reneau, Randy Ryti, Paul Drakos, Terre Mercier, "Status of Mortandad Canyon sediment investigations" LA-UR-03-5997 (2003).

GC White, TE Hakonson, AJ Ahlquist, "Factors affecting radionuclide availability to vegetables grown at Los Alamos" Journal of Environmental Quality volume 10 pp 294-299 (1981).

TA-6 (Two-mile mesa)

TA-6 included several firing sites with low levels of uranium contamination. The amounts are too small for Pa-234m to show up on the aerial surveys, and the concentrations are much smaller than at EF Site, so the biota doses are much smaller than at EF Site. EF Site is discussed in the TA-15 section, below.

TA-6 includes Material Disposal Area MDA F, which is discussed in LA-UR-90-3283, LA-6848-MS, LA-UR-80-3110, and LA-UR-98-2550. According to LA-UR-98-2550, most of the materials were buried in 1946 and 1947 to protect classification, with the expectation that they would be declassified soon thereafter. For many years, MDA F was monitored with TLDs (see the ESR) and it was confirmed that external radiation is indistinguishable from background. Samples at a location designated as SWMU 6-007 show radioactivity about 0.3 pCi/g. All these observations show the radioactivity is very small and the biota dose from LANL is less than 1 mrad/day.

Conclusion: there is no significant environmental radioactive contamination and no significant biota dose at TA-6.

References for TA-6

WR Hansen, DL Mayfield, LJ Walker, "Interim environmental surveillance plan for LASL radioactive waste areas" LA-UR-80-3110

LA-UR-98-2550, “Work Plan for Pajarito Canyon”, (1998).

MA Rogers, "History and environmental setting of LASL near surface land disposal facilities for radioactive wastes (areas A, B, C, D, E, F, G, and T)" LA-6848-MS (page A-9) (1977).

LF Soholt et al., "Environmental Surveillance of low-level radioactive-waste-management areas at Los Alamos during 1987", LA-UR-90-3283 (1990).

TA-7 (Gomez Ranch site)

This former firing site was abandoned in 1947 and incorporated into TA-6. There is no significant environmental radioactive contamination and no significant biota dose.

TA-8 (Anchor West)

The Radiographic Testing Facility, TA-8-23, is a category-2 nuclear facility. TA-8-24 is the Isotope Building. These are active facilities.

MDA Q (SWMU 8-006) is in TA-8. In 1946, remnants of 1945 tests were buried here. It probably contains small amounts of natural and depleted uranium. However, the concentrations and the biota dose are much smaller than at EF Site, discussed in the TA-15 section.

In summary, there is no significant biota dose.

TA-9 (Anchor Site East)

TA-9 is east of and further from the boundary than TA-8. It includes MDA M (SWMU 9-013), which was remediated in an “expedited cleanup” in 1995 (ER ID 47257) but may still contain small amounts of uranium.

There is no significant biota dose.

TA-10, Bayo Canyon

Bayo Canyon was the site of the original TA-10, which was contaminated during the radioactive lanthanum (RaLa) project during the 1940s and 1950s. TA-10 was decommissioned in 1963 and transferred to Los Alamos County in 1967.

Bayo Canyon is described in the ER report “Work Plan for the North Canyons”, LA-UR-01-1316. Most areas have been remediated to the standards for human health. The exception is the combined area of PRS 10-003 and 10-007 (a.k.a. decision set 10-002(a)-99). The only significant contamination is in an area of about 0.1 ha that is fenced and posted as a Soil Contamination Area. The most important radionuclide is Sr-90, which is the focus of the following discussion. Other radionuclide concentrations are listed in LA-UR-01-1316 and summarized in the table below.

The highest soil concentration of Sr-90 is 42,000 pCi/g at a depth of 5.2 m. At a depth of 3.6 m, the maximum is 3,000 pCi/g. And at shallower depths, less than 3 m, the maximum Sr-90 concentration is 200 pCi/g. These data raise the question: are biota in contact with the contamination at 5.2 m, at 3.6 m, or only at shallower depths?

Plants are certainly bringing Sr-90 to the surface. Fresquez (LA-13050-MS, 1995) describes a measurement in Chamisa of 2,000 pCi/g wet weight in Bayo Canyon. And more recently, up to 199 pCi/g of Sr-90 in vegetation was measured during an interim remedial action in 1997 (page 3-51 of LA-UR-01-1316).

According to Foxx 1984 and Tierney 1987, the maximum root depth that has been measured, worldwide, for chamisa is 4.57 m, so it is reasonable to correlate the chamisa concentration of 2,000 pCi/g with the soil concentration of 3,000 pCi/g at a depth of 3.6 m. This suggests a site-specific Sr-90 bioaccumulation factor of 0.7, which is consistent with the range of 0.1 to 1 measured in LA Canyon (Fresquez 1997a). Therefore, we assume the plants are in contact with the Sr-90 at a depth of 3.6 m, but not at 5.2 m.

Assuming a worst-case Sr-90 concentration of 2,000 pCi/g in a plant and essentially the same concentration in soil (B_{iv} = 1), the maximum dose to an individual plant is approximately 100 mrad/day.

For the most-exposed mouse, we average over 0.075 ha. The average concentration in chamisa is about 100 pCi/g. Using either Table 2.3 or Table 2.4 of Module 3 of the DOE Standard, this causes a dose of 6 mrad/day. The population area is 40 times the individual home range, so the population dose for both plants and animals is 6/40 mrad/day, which is essentially zero. These doses are summarized in the following table.

radionuclide	**Soil conc. (pCi/g)**	**maximum dose (mrad/day)**		**population dose (mrad/day)**	
		Plant	**Animal**	**Plant**	**Animal**
Am-241	0	0	0	0	0
Pu-239	0	0	0	0	0
U-238	3	0	0	0	0
H-3	0	0	0	0	0
Cs-137	2	0	0	0	0
Sr-90	2,000	100	6	0	0

References for TA-10

RW Ferenbaugh, TE Buhl, AS Stoker, WR Hansen, "Environmental analysis of the Bayo Canyon (TA-10) site, Los Alamos, NM" LA-9252-MS (1982).

TS Foxx, GD Tierney and JM Williams, "Rooting depths of plants on Low-level waste disposal sites" LA-10253-MS (1984)

TS Foxx, GD Tierney and JM Williams, "Rooting depths of plants relative to biological and environmental factors" LA-10254-MS (1984)

Fresquez 1995: "Strontium concentrations in chamisa (chrysothamnus nauseosus) shrub plants growing in a former liquid waste disposal area in Bayo Canyon", LA-13050-MS by P.R. Fresquez, T.R. Foxx, and L. Naranjo (1995)

P.R. Fresquez et al., “Strontium Concentrations in Chamisa Shrub Plants Growing in a Former Liquid Waste Disposal Area in Bayon Canyon,” LA-13050-MS (1995)

P.R. Fresquez et al., "Radionuclide concentrations in pinto beans, sweet corn, and zucchini squash grown in Los Alamos Canyon at LANL", LA-13304-MS (1997)

Fresquez, P.R., D.A. Armstrong, M.A. Mullen, and L. Naranjo, Jr. “The uptake of radionuclides by beans, squash, and corn growing in contaminated alluvial soils at Los Alamos National Laboratory,” Journal of Environmental Science and Health B33 (1) 99-115 (1998).

Fresquez, P.R., J.D. Huchton, M.A. Mullen, and L. Naranjo, Jr,. “Pinon pine tree study, Los Alamos National Laboratory: source document,” Los Alamos National Laboratory report LA-13693-MS. Los Alamos, NM (2000).

Fresquez, P.R., J. Huchton, M.A. Mullen, and L. Naranjo, Jr,. “Radionuclides in pinon pine (Pinus edulis) tree shoots and nuts from Los Alamos National Laboratory lands,” Health Physics 78 (6): S83 (2000).

Fresquez, P.R., J. Huchton, M.A. Mullen, and L. Naranjo, Jr,. “Radionuclides in pinon pine (Pinus edulis) nuts collected from Los Alamos National Laboratory lands and the dose from consumption,” Journal of Environmental Science and Health 35 (5): 611–622 (2000).

LA-UR-01-1316: “Work Plan for the North Canyons”, (page 3-51) (1997).

GD Tierney and TS Foxx, "Root lengths of plants on Los Alamos National Lab. Lands" LA-10865-MS (1987).

GC White, TE Hakonson, AJ Ahlquist, "Factors affecting radionuclide availability to vegetables grown at Los Alamos" Journal of Environmental Quality volume 10 pp 294-299 (1981).

TA-11 (K Site)

TA-11 is next to TA-16. It includes MDA S (SWMU 11-009), which does not contain significant amounts of radioactive material. Phil Fresquez has a soil sampling site nearby. The soil sampling results are close to background.

There is no significant environmental radioactive contamination and no significant biota dose.

TA-12 (L Site)

L Site was a firing site north of TA-14, constructed in 1945 and abandoned in 1951. D&D was completed in 1960 and the area was incorporated into TA-14 in 1989. It may contain small amounts of residual uranium. The concentrations are much smaller than at EF Site, discussed in the TA-15 section below, so there is no significant biota dose.

TA-13 (P Site in S Site)

P Site was a firing site, constructed in 1944, decommissioned in 1950, and incorporated into TA-16. It may contain small amounts of residual uranium. There is no significant biota dose.

TA-14 (Q Site)

Q Site is an explosives complex east of TA-9. It was constructed in 1944 and is still in use. It may contain small amounts of residual uranium. There is no significant biota dose.

TA-15 (R Site)

TA-15 includes MDA N, MDA Z, that contain uranium. There are several firing sites, including the DARHT and PHERMEX facilities that are exempt from biota dose assessment (DOE-STD-1153-2002).

Uranium and depleted uranium are widespread at TA-15. The most significant is EF Site, which is discussed in the next section.

TA-15, EF Site

U-238 is widespread at LANL; it is present at most firing sites and buried in most disposal pits. By far the highest concentration is at EF site in TA-15, 15-004(f)-99 (Becker 1992). This conclusion is confirmed by aerial surveys that detect and quantify uranium from the gamma emissions of Pa-234m (EGG-10282-1095, 1989, and DOE/NV/11718-107, 1998). The total mass of U-238 near EF site is estimated to be about 35,000 to 63,000 kg (LANL 1998, LA-UR-98-2250). This is about half the total U-238 dispersed at LANL. Therefore, EF site represents the worst case for U-238.

Ecological studies at EF site were reported in a series of five papers: Hanson 1976, Hanson 1977, Hanson 1978, White 1979, and White 1980. They show the average U-238 soil concentration is about 1,500 pCi/g within a 10 m radius of the firing point, decreasing to 600 pCi/g at 20 m, and 200 pCi/g from 50 to 100 m.

Data in the ER database show the U-234 activity is about 30% of the U-238 concentration. Therefore, we assume the following concentrations:
within 10 m of the firing point:
U-238 1,500 pCi/g; U-234 500 pCi/g;
20 m from the firing point:
U-238 600 pCi/g; U-234 200 pCi/g;
the average in a 3 ha circle, radius 100 m, centered on the firing point is:
U-238 300 pCi/g; U-234 100 pCi/g.

According to RESRAD-BIOTA, if the U-234 activity is 30% of the U-238 activity, the U-234 dose is 10% of the U-238 dose. Therefore, considering the accuracy of this biota dose assessment, the U-234 is negligible.

The reports by Hanson et al. (1976, 1977, and 1978) suggest a concentration ratio for plants to soil of 0.07, but this tentative result was complicated by the presence of particles of uranium sticking to the surface of the plants (Hanson 1976 page 12). In other words, the authors say it is not clear how much was *in* the plants compared with *on* the plants. Animals ingest everything that is either in or on the plants, so next we consider the animal data.

Hanson (1976, 1977, and 1978) also measured the concentration in and on deer mice, separately for each organ or tissue. They measured the concentrations on the pelt (200 pCi/g), in the gastro-intestinal tract (300 pCi/g), in the kidneys (10 pCi/g), in the liver (8 pCi/g), in the lungs (1.5 pCi/g) and in the carcass (1 to 2 pCi/g) (Hanson 1976 and 1978). Assuming these mice live in soil with 250 to 500 pCi/g, the data indicate a concentration ratio, B_{iv} for uranium in mice consistent with the DOE value of 0.004. Therefore, we use the DOE value.

Some of the pieces of uranium shrapnel are as large as 1 cm. This calls into question the external dose from the betas emitted by Pa-234m (which is a decay product of U-238). The DOE method calculates the external dose from the average energy of the betas, which is an over-estimate. Nevertheless, for this dose assessment we include the standard RESRAD-BIOTA calculation of the external dose from betas.

According to the data in the ER database for SWMU 15-004(f)-99 the U-234 is 30% of the U-238. Assuming the maximum soil concentration of U-238 is 1,500 pCi/g and U-234 is 500 pCi/g, the maximum plant and animal dose is 100 mrad/day within a 10 m radius of the firing point.

The firing site is inhospitable, with no water and sparse vegetation. This may be why the home range reported by Hanson et al. is 0.8 ha, which is ten times the home range used in the LANL

Ecorisk model. Nevertheless, we adhere to our standard home range of 0.075 ha. For the maximum animal dose, we assume the soil concentration of U-238 is 1,000 pCi/g and U-234 is 333 pCi/g. The resulting dose is 70 mrad/day.

Our standard population area is 3 ha, which corresponds to a circle with a radius of 100 m. Within a radius of 100 m from the firing site the average U-238 concentration is 300 pCi/g and the average U-234 is 100 pCi/g (Hanson and Miera 1976-8) This causes population doses of 20 mrad/day to plants and animals. This is 2% and 20%, respectively, of the DOE limits.

The dose assessment summarized in the following table is high for two reasons: the external beta dose, 25 mrad/day, is an overestimate; and the alpha dose is calculated with the human radiation-weighting factor of 20, which is also an overestimate.

radionuclide	Soil conc. (pCi/g)	maximum dose (mrad/day)		population dose (mrad/day)	
		Plant	Animal	Plant	Animal
Am-241	0	0	0	0	0
Pu-239	0	0	0	0	0
U-238	300-1,500	100	70	20	20
H-3	0	0	0	0	0
Cs-137	0	0	0	0	0
Sr-90	0	0	0	0	0

References for TA-15

Naomi M. Becker, "Quantification of uranium transport away from firing sites at LANL", LA-UR-92-283 (1992).

DOE/NV/11718-107: "An aerial survey of the Los Alamos National Laboratory and surrounding area, DOE/NV/11718-107 (1998).

A.E. Fritzsche "An aerial radiological survey of TA-15 and surroundings at LANL" EGG-10282-1095 (1989).

WC Hanson and FR Miera, "Long term ecological effects of exposure to uranium", LA-6269 (1976).

WC Hanson and FR Miera, "Continued studies of long term ecological effects of exposure to uranium", LA-6742 (1977).

WC Hanson and FR Miera, "Further studies of long term ecological effects of exposure to uranium", LA-7162 (1978).

LANL 1998: “Work Plan for Pajarito Canyon”, LA-UR-98-2550 (1998).

GC White, ES Gladney, KV Bostick, WC Hanson, "Studies of long term ecological effects of exposure to uranium, IV", LA-7750 (1979).

GC White, JC Simpson, KV Bostick, "Studies of long term ecological effects of exposure to uranium, V", LA-8221 (1980).

TA-16 (S site)

Within the boundary of TA-16, there is a category-2 nuclear facility: TA-16-205, WETF. The primary radionuclide at WETF is tritium, which is controlled to human health standards, disperses rapidly, and contributes negligible biota dose.

TA-16 includes MDA P (SWMU 16-018) and MDA R (SWMU 16-019) containing mostly HE residues. According to the ER database, the maximum uranium concentration at these two sites is 1 pCi/g, which is essentially background.

In summary, there is no significant biota dose.

TA-17 (X site) was never built.

TA-18 (Pajarito Lab.)

According to preliminary draft data in the ER database, in 1996 there may have been 28 pCi/g 90Sr at PRS 18-003(c), which is a septic tank dating to 1952 inside the fence of the SW Casa. This appears to have been remediated in a voluntary corrective action (LA-UR-98-2550). Considering the depth and the site-specific bioaccumulation factor of 1 for Sr-90, there is no significant biota dose.

Reference for TA-18

LA-UR-98-2550, “Work Plan for Pajarito Canyon”, (1998).

TA-19 (East Gate Laboratory until 1962)

TA-19 was at the east end of the mesa containing airport. It is now part of TA-72. There is no significant environmental radioactive contamination and no significant biota dose.

TA-20 (Sandia Canyon site until 1957)

TA-20 was at the location of the PTLA pistol range. It was incorporated into TA-72 in the late 1940s when Jemez Road was built. There were some firing sites and there may be small amounts of residual uranium but there is no significant biota dose.

TA-21 (DP Site)

D-primed or DP Site was built as a replacement for building D at TA-1. It includes the following material disposal areas (MDA) with potential biota dose: MDA A, B, T, U, V. There is also potential biota dose in DP Canyon. Each of these locations is discussed in the following sections.

TA-21, MDA A

MDA A (SWMU 21-014) is a 0.5 ha area established in 1945. It contains two steel tanks known as the General's Tanks, designed to receive plutonium that could not be recovered using the technology available at the time. It was envisioned that the plutonium would be extracted and recycled by future generations.

The concentrations in the tanks are not known, but an estimate based on the estimated inventory and the volume indicates the sum of the ratios to the BCGs is about 100, which technically triggers a site-specific assessment.

The tanks are sealed, so the contents are isolated from biota. Therefore, the biota dose from the contents of the tanks is zero.

The maximum soil concentrations outside the tanks are taken from LA-UR-91-962 (page 16-257) and listed in the table below. These concentrations imply doses of 3 mrad/day to a plant and 1 mrad/day to the most exposed mouse.

Averaged over the MDA, the concentrations and doses are less than half the maximum values. Because the surrounding areas are not pristine, we take this average as the population dose.

In summary, as listed in the table, the population doses are about 1 mrad/day, and are less than 1% of the DOE limits.

radionuclide	Soil conc. (pCi/g)	maximum dose (mrad/day)		population dose (mrad/day)	
		Plant	Animal	Plant	Animal
Am-241	10	<1	<1	0	0
Pu-239	20	2	<1	1	<1
U-238	10	<1	0	0	0
H-3	10	0	0	0	0
Cs-137	1	0	0	0	0
Sr-90	1	0	0	0	0

References for MDA A

LA-UR-91-962, "TA-21 operable unit RFI work plan for ER" (Section 16.8, pages 16-243 to 16-277) (1991).

MA Rogers, "History and environmental setting of LASL near surface land disposal facilities for radioactive wastes (areas A, B, C, D, E, F, G, and T)" LA-6848-MS (page A-9) (1977).

TA-21, MDA B

MDA B (SWMU 21-015) was established in 1944 or 1945. It is a 2.4 ha area along DP Road, estimated to contain 100 g of Pu-239 in pits with a total area of 4,650 m^2 and a volume of 21,240 m^3. It is described in detail in the ER report, LA-UR-91-962, and in M.A. Rogers' report, LA-6848-MS. According to LA-UR-91-962 (chapter 16) the maximum decay-corrected soil concentrations are: Cs-137 66 pCi/g, Sr-90 1 pCi/g, tritium 700 pCi/mL, Pu-239 1,370 pCi/g, Am-241 233 pCi/g, and U-238 300 pCi/g.

The biota were studied by Wenzel et al. (LA-11126-MS, 1987). Although the authors caution that their study could not determine reliable concentration ratios, the data for Pu-239 and U-238 are approximately consistent with the bioaccumulations factors assumed in the DOE standard, while the Cs-137 ratio is consistent with the estimates by White, Hakonson, and Ahlquist (1981), and by Fresquez (LA-13304-MS, 1997). Therefore, we calculate the maximum doses from the soil concentrations, as listed in the table. The total is about 150 mrad/day for a plant and 50 mrad/day for the most exposed mouse.

The average dose is less than those listed below, but without a comprehensive survey it is difficult to reach a definitive conclusion. According to the inventory in M.A. Rogers' report, there is 6 Ci of plutonium buried in a volume of 8E9 cm^3. If the density is 1.5 g/cm^3, the average concentration is 6/(1.5*8E9) Ci/g = 500 pCi/g, which suggests the population dose is 500/1370 times the maximum. We have used this estimate in the table below. In summary, the total population dose is about 50 mrad/day for plants and 20 mrad/day for animals. These are 5% and 20% of the DOE limits.

radionuclide	Soil conc. (pCi/g)	maximum dose (mrad/day)		population dose (mrad/day)	
		Plant	Animal	Plant	Animal
Am-241	233	11	6	4	3
Pu-239	1370	108	23	40	8
U-238	300	19	19	7	7
H-3	700	0	0	0	0
Cs-137	66	3	3	1	1
Sr-90	1	0	0	0	0
Approx. total		150	50	50	20

References for MDA B

Fresquez, P.R., et al., "Radionuclide concentrations in pinto beans, sweet corn, and zucchini squash grown in Los Alamos Canyon at LANL", LA-13304-MS (1997).

Fresquez, P.R., D.A. Armstrong, M.A. Mullen, and L. Naranjo, Jr. "The uptake of radionuclides by beans, squash, and corn growing in contaminated alluvial soils at Los Alamos National Laboratory," Journal of Environmental Science and Health B33 (1) 99-115 (1998).

Fresquez, P.R., J.D. Huchton, M.A. Mullen, and L. Naranjo, Jr,. "Pinon pine tree study, Los Alamos National Laboratory: source document," Los Alamos National Laboratory report LA-13693-MS. Los Alamos, NM (2000).

Fresquez, P.R., J. Huchton, M.A. Mullen, and L. Naranjo, Jr,. "Radionuclides in pinon pine (Pinus edulis) tree shoots and nuts from Los Alamos National Laboratory lands," Health Physics 78 (6): S83 (2000).

Fresquez, P.R., J. Huchton, M.A. Mullen, and L. Naranjo, Jr,. "Radionuclides in pinon pine (Pinus edulis) nuts collected from Los Alamos National Laboratory lands and the dose from consumption," Journal of Environmental Science and Health 35 (5): 611–622 (2000).

LA-UR-91-962: "TA-21 operable unit RFI work plan for ER" (Section 16.2, pages 16-24 to 16-95) (1991).

M.A. Rogers, "History and environmental setting of LASL near surface land disposal facilities for radioactive wastes (areas A, B, C, D, E, F, G, and T)" LA-6848-MS (page A-9) (1977).

W.J. Wenzel, T.S. Foxx, A.F. Gallegos, G. Tierney, J.C. Rodgers, "Cesium-137, plutonium-239,240, total uranium, and scandium in trees and shrubs growing in transuranic waste at Area B", LA-11126-MS (1987).

G.C. White, T.E. Hakonson, A.J. Ahlquist, "Factors affecting radionuclide availability to vegetables grown at Los Alamos" Journal of Environmental Quality volume 10 pp 294-299 (1981).

TA-21, MDA T

MDA T (SWMU 21-016) is a 0.9 ha fenced site established in 1945 to receive liquid effluent from the former liquid-waste-treatment facilities in buildings 35 and 257. Starting in 1945, liquid wastes were disposed of in absorption beds 1.2 m deep, and later in shafts 5 to 20 m deep. The absorption beds were later covered with 1.8 m of crushed tuff and the shafts were covered with 0.6 m of concrete and 1.2 m of tuff. Therefore, the largest concentrations of plutonium, up to 40,000 pCi/g, are more than 3 m below the surface (Nyhan 1984) and are not easily accessible to biota.

The maximum concentrations in plants (from LA-UR-91-962 pages 16-124 to 125, converted to wet weight) together with the corresponding internal doses are as follows: Cs-137, 22 pCi/g, 1 mrad/day; Pu-238, 4 pCi/g, 20 mrad/day; Pu-239, 3 pCi/g, 15 mrad/day; and Am-241, 17 pCi/g, 100 mrad/day. These doses are listed for the most exposed plant in the table below, except we have added 2 mrad/day of external Cs-137 dose to the 1 mrad/day listed above.

Averages for plants in the most contaminated 0.06 ha are: Cs-137, 3 pCi/g, 0.1 mrad/day; Pu-238, 0.1 pCi/g, 0.5 mrad/day; Pu-239, 0.4 pCi/g, 2 mrad/day; Am-241, 4 pCi/g, 20 mrad/day. Since the plant data are well known and the effective soil data are not, we work backwards and use the plant concentrations to deduce the effective average soil concentration sampled by the plant roots. These are listed in the soil-concentration column of the table below.

Then from these soil concentrations, we calculate the dose to the most exposed animal, assuming its home range is approximately 0.06 ha. The adjacent areas include MDA A to the east and DP Canyon to the north, so we base the population dose on a conservative average of these areas.

In summary, the soil concentrations represent the effective average sampled by the biota. The resulting biota doses are less than 10% of the DOE limits.

radionuclide	Soil conc. (pCi/g)	maximum dose (mrad/day)		population dose (mrad/day)	
		Plant	Animal	Plant	Animal
Am-241	500	100	10	10	5
Pu-239	50	35	20	1	1
U-238	5	0	0	0	0
H-3	1	0	0	0	0
Cs-137	50	3	2	1	1
Sr-90	5	1	1	1	1
Approx. total		140	33	13	8

References for MDA T

LA-UR-91-962: "TA-21 operable unit RFI work plan for ER" (Section 16.3, pages 16-96 to 16-151) (1991).

JW Nyhan et al., "Distribution of radionuclides and water in Bandelier tuff beneath a former Los Alamos liquid waste disposal site after 33 years", LA-10159-LLWM (1984).

Nyhan, J.W., B.J. Drennon, W.V. Abeele, M.L. Wheeler, W.D. Purtymun, G. Trujillo, W.J. Herrera, and J.W. Booth. "Distribution of plutonium and americium beneath a 33-year-old liquid waste disposal site at Los Alamos, NM," J. Environ. Qual. 14: 501-509 (1985).

M.A. Rogers, "History and environmental setting of LASL near surface land disposal facilities for radioactive wastes (areas A, B, C, D, E, F, G, and T)" LA-6848-MS (1977).

TA-21, MDA U

MDA U (SWMU 21-017) is an inactive area 100 m east of MDA A. It contains two absorption beds with an area of 167 m^2 and a volume of 510 m^3. These were established in 1945 to receive liquid waste from DP East. The primary radionuclide was Po-210, which has decayed away. In 1953, 2.5 Ci of Ac-227 was released to these beds; the Ac-227 contaminated soil was removed and transported to MDA G in 1985 (LA-UR-90-3400). In summary, the residual radioactive material is small and the biota dose at MDA U is estimated to be essentially zero.

TA-21, MDA V

MDA V (SWMU 21-018(a)) was used from 1945 to 1961 for the disposal of contaminated waste water from the laundry at building TA-21-20. The area is 1,400 m^2 and the volume is 4250 m^3. The area has been remediated and there are no indications of residual contamination that would lead to measurable biota dose.

TA-21, DP Canyon

DP Canyon, north of TA-21, is a tributary of Los Alamos Canyon. It was contaminated more than 20 years ago, primarily by the outfall from TA-21-257 at PRS 21-011(k).

The area near the outfall was studied by Miera and Hakonson in 1978, who concluded that most of the dose was from external Cs-137 radiation. This radiation caused a dose of 26 mrad/day to harvest mice, 8 mrad/day to deer mice, 2 mrad/day to pinon mice, and 1 mrad/day to chipmunks.

Since that time, the area was remediated in 1996 (ER ID 55648) and again in 2003 (LA-UR-03-7293). The most recent concentrations (95% upper-confidence-level) for the 0.74 ha area are reported in LA-UR-03-7293 and are listed in the table below.

Miera and Hakonson (1978) determined that less than 2% of the Cs-137 dose is internal dose, i.e., the bioaccumulation factor is less than 0.02. This is consistent with the estimates by Hakonson (Hakonson 1973, LA-5282-MS), and by Fresquez (Fresquez 1997, LA-13304-MS). As discussed previously, whether we choose a bioaccumulation factor of 0.1 or 0.02 makes no significant difference, so we choose 0.1 to be conservative.

Throughout LANL, the bioaccumulation factor for Sr-90 is between 0.1 and 1 (see Fresquez 1997, LA-13304). For the present preliminary assessment, we use a value of 1.

With these assumptions, the dose to the maximally exposed animal is 3 mrad/day from Cs-137, 3 mrad/day from Sr-90, 0.3 mrad/day from Am-241, 0.1 mrad/day from Pu-239, and 0.01 mrad/day from Pu-238. The total dose is 6.4 mrad/day.

The contaminated area (0.74 ha) is one quarter of the population area (3 ha) so the population dose is one quarter of 6.4 mrad/day, i.e., about 2 mrad/day.

Recently, DP Canyon was subjected to a detailed ecological assessment in the "Los Alamos and Pueblo Canyons Investigation Report", LA-UR-04-2714, which concluded "Adverse ecological effects were not observed within terrestrial and aquatic systems." (page 9-3). Downstream of PRS 21-011(k), the maximum concentrations are at location DP-4, where Cs-137 is 40 pCi/g and Sr-90 is 7 pCi/g. Thus, the biota doses in other parts of DP Canyon and Los Alamos Canyon are less than those calculated here for PRS 21-011(k).

The following table summarizes the data in LA-UR-03-7293 and the dose assessments discussed above. The resulting population doses are less than 2% of the DOE limits.

radionuclide	**Soil conc. (pCi/g)**	**maximum dose (mrad/day)**		**population dose (mrad/day)**	
		Plant	**Animal**	**Plant**	**Animal**
Am-241	10	1	0	0	0
Pu-239	10	1	0	0	0
U-238	1	0	0	0	0
H-3	0	0	0	0	0
Cs-137	60	3	3	1	1
Sr-90	15	3	3	1	1
Approx. total		8	6	2	2

References for DP Canyon

PR Fresquez et al., "Radionuclide concentrations in pinto beans, sweet corn, and zucchini squash grown in Los Alamos Canyon at LANL", LA-13304-MS (1997).

Fresquez, P.R., D.A. Armstrong, M.A. Mullen, and L. Naranjo, Jr. "The uptake of radionuclides by beans, squash, and corn growing in contaminated alluvial soils at Los Alamos National Laboratory," Journal of Environmental Science and Health B33 (1) 99-115 (1998).

Fresquez, P.R., J.D. Huchton, M.A. Mullen, and L. Naranjo, Jr,. "Pinon pine tree study, Los Alamos National Laboratory: source document," Los Alamos National Laboratory report LA-13693-MS. Los Alamos, NM (2000).

Fresquez, P.R., J. Huchton, M.A. Mullen, and L. Naranjo, Jr,. "Radionuclides in pinon pine (Pinus edulis) tree shoots and nuts from Los Alamos National Laboratory lands," Health Physics 78 (6): S83 (2000).

Fresquez, P.R., J. Huchton, M.A. Mullen, and L. Naranjo, Jr,. "Radionuclides in pinon pine (Pinus edulis) nuts collected from Los Alamos National Laboratory lands and the dose from consumption," Journal of Environmental Science and Health 35 (5): 611–622 (2000).

T.E. Hakonson, L.W. Nyhan, L.J. Johnson, K.V. Bostick, "Ecological investigation of radioactive materials in waste discharge areas at Los Alamos", LA-5282-MS (1973).

LA-UR-91-962, "TA-21 operable unit RFI work plan for ER" (section 16.5) (1991).

LA-UR-95-2053, "Task/Site Work Plan for Operable Unit 1049, Los Alamos and Pueblo Canyon," (1995).

LA-UR-03-7293: "Voluntary corrective measure completion report for SWMU 21-011(k) at TA 21", ER2003-0633, RRES-RS (2003).

LA-UR-04-2714, "Los Alamos and Pueblo Canyons Investigation Report", (2004).

F.R. Miera and T.E. Hakonson, "Radiation dose to rodents inhabiting a radioactive waste receiving area," Health Physics 34, pp 603-609 (1978).

M.A. Rogers, "History and environmental setting of LASL near surface land disposal facilities for radioactive wastes (areas A, B, C, D, E, F, G, and T)" LA-6848-MS (1977).

TA-22 (TD Site)

TA-22 (TD or Trap Door Site) is on Two-Mile Mesa. There may some small residual amounts of uranium, but no significant biota dose.

TA-23 (Nu Site, now in TA-9)

Nu Site was a firing site until 1950. It is now in TA-9. There may some small residual amounts of uranium, but no significant biota dose.

TA-24 (T Site, now in S Site)

T Site was a firing site. It now lies within TA-16. There may some small residual amounts of uranium, but no significant environmental radioactive contamination. According to the ER database (PRS 16-034(b)-99) the maximum concentrations are about 2 pCi/g uranium and 1 pCi/g Cs-137. There is no significant biota dose.

TA-25 (V Site, now in S Site)

V Site was constructed in 1944 and is now part of S Site (TA-16.) There may some small residual amounts of uranium, but no significant biota dose.

TA-26 (D site until 1966, now in TA-73)

D Site was at East Gate, where the guard tower still stands tall, within the present TA-73. There may some small residual amounts of uranium (<1000 dpm per100 cm^2) in the rubble from a concrete vault that was demolished in 1966 and now rests on a ledge half-way down the side of Los Alamos Canyon. There is no significant biota dose.

TA-27 (Gamma site until 1945)

Gamma site was a firing site in Pajarito Canyon, established in 1944 a mile southeast of TA-18. It was abandoned in 1947 and is now in TA-36. The present Pajarito Road (constructed in 1960) covers some of the site. There are residual amounts of uranium and thorium but no significant biota dose.

TA-28 (Magazine Area A)

TA-28 is an enclave of TA-16. It contains no SWMUs and no known environmental radioactive contamination. There is no biota dose from LANL.

TA-29 (Magazine Area B)

TA-28 was in the southwest corner of TA-16 until 1957. The structures were removed in 1959. It contains no SWMUs and no known environmental radioactive contamination. Therefore, there is no biota dose from LANL.

TA-30 (Electronics test area)

TA-30 was an electronics test area in TA-3, built in 1945 and decommissioned in 1948. There is no radioactive contamination and so no biota dose from LANL.

TA-31 (East receiving yard)

TA-31 was a receiving yard near the west end of the airport, The buildings were removed in 1954 and the site now contains private houses. There is no radioactive contamination and so no biota dose from LANL.

TA-32 (Medical Research Lab until 1954)

The TA-32 medical research lab was south of Trinity drive and is now occupied by the County roads department. Short-lived radionuclides were used and buried at the site.
There is no significant environmental radioactive contamination or biota dose.

TA-33 (HP Site)

In the past, TA-33-86 was the site of a high-pressure tritium facility. This is now decommissioned and awaiting reclassification from a nuclear facility to a less hazardous category.

TA-33 includes MDA D (SWMU 33-003), MDA E (SWMU 33-001), and MDA K (SWMU 33-002), which contain uranium (Margaret Anne Rogers, LA-6848-MS).

LA-10721-ENV Table G-35 page 178 showed bee and honey data: 99,000 pCi/g at TA-33 during 1984. According to the DOE Standard Module 3 Tables 2.3 or 2.4 the dose was 30 mrad/day. The tritium facility at TA-33 has now been decommissioned so this dose does not apply to the present. At present, the biota dose at TA-33 from LANL is expected to be essentially zero.

References for TA-33

LA-10721-ENV, “Environmental Surveillance at Los Alamos During 1985”.

M.A. Rogers, LA-6848-MS.

TA-34 was to be a warehouse area but was canceled and does not exist.

TA 35 (Ten Site)

Ten Site may have been so named because of its association with TA-10 and the radioactive lanthanum (RaLa) project. The radioactive liquid waste treatment plant that was east of TA-35-2 supported the RaLa work. The Lanthanum was derived from barium, and barium is chemically similar to strontium, so strontium-90, Sr-90, is a byproduct of the RaLa work. Residual Sr-90 persists east of TA-35-2, see the section on Pratt Canyon, below.

TA-35 also includes several MDAs, notably MDA W, discussed in the following section.

TA-35, MDA W

MDA W is the disposal site of two stainless steel tubes from the LAMPRE-1 reactor. The tubes are 37 m long, 0.2 m diameter, buried vertically and encased in a vault of 0.2-m-thick concrete. The area will be investigated in 2005 to ensure that the vault is secure. Meanwhile, pending these results, we conclude the radioactive material is isolated from biota and therefore the biota dose is zero.

TA-35, Pratt Canyon

Pratt Canyon, a.k.a. SWMU 35-003(d) and 35.003(r), extends from the east end of the paved area of TA-35 for about 200 m parallel to and north of Ten-site Canyon before it joins Ten-Site Canyon at the old lagoons (Figure 3.4.3-1 of LA-UR-97-3291). Pratt Canyon is described in Sections 2.4.4.1, 3.4.3, and 3.4.5 of the ER report “Work Plan for Mortandad Canyon”, LA-UR-97-3291 (1997) and also in the "RFI Work Plan for Operable Unit 1129", LA-UR-92-800 (1992). It was contaminated between 1951 and 1963, primarily with 0.2 Ci of Sr-90, from a liquid waste treatment plant east of TA-35-2 (see page 6 of LA-13206-MS).

Section 3.4.5 and Figure 3.4.5-2 of LA-UR-97-3291 show ^{90}Sr contamination of up to 6,000 pCi/g in an area of about 100 m^2 along the south-east headwall of upper Pratt Canyon. There is also about 100 pCi/g of Cs-137, mostly to the east along the stream channel. These concentrations are greater than the biota concentration guide of 20 pCi/g so Pratt Canyon fails the level-1 general screening mandated by the DOE Standard.

Sr-90 has been taken up from the soil into the trees: a douglas fir and several gambel oaks contain about 3,000 pCi/g of Sr-90. Comparison with the soil concentration of 6,000 pCi/g indicates a bioaccumulation factor of 0.5. Using 6,000 pCi/g and the external dose coefficient in the DOE Standard Module 3 Table 2.3, we estimate the external dose rate to these individual trees is 350 mrad/day, which is about 100 rad/year. (We don’t add the internal dose obtained from 3,000 pCi/g and Table 2.4 because both the external and internal dose calculations assume an infinite medium; if we assume two infinite media, one for internal and one for external, we would be double counting.)

The douglas fir tree is now dead, while the gambel oaks are still alive. These observations are consistent with the discussion in the UNSCEAR 1996 report, which notes that gymnosperms in general and the pine family in particular are more radiosensitive than angiosperms. The chronic lethal dose to pine and spruce trees is estimated to be about 5,000 rad. After correcting for the decay of Sr-90, this may be comparable to the total dose received by the douglas fir. Many years of radiation may have killed the tree, or weakened it and made it vulnerable to attack, for example by bark beetles as discussed on page 48 of the UNSCEAR-1996 report.

There are no measurements of the radionuclide concentrations in animals within Pratt Canyon. However, Bennett, Biggs, and Fresquez (LA-13104, 1994) measured the concentrations in rodents in Mortandad Canyon, 1.3 km to the east. Based on their data, corrected for the ratio of wet to dry weight (LA-UR-04-4122), the bioaccumulation factors are about 0.02 for Cs-137 and 0.5 for Sr-90.

The area of Pratt Canyon that has more than 1,000 pCi/g of Sr-90 is about 0.01 ha, which is small compared with the home ranges of most animals: 0.075 ha for mice, 3 ha for rabbits, and 1,000 ha for foxes. Therefore, for the Sr-90 exposure we use an area factor of 0.1 for the most exposed animal (MEA), and an area factor of 1 for the most exposed plant (MEP). For the population doses, we use our standard population area of 3 ha.

Using an area factor of (0.01 ha)/(3 ha) = 0.003, the population dose for both animals and plants is 1 mrad/day, which is 1% of the DOE standard. These assessments are summarized in the following table.

radionuclide	Soil conc. (pCi/g)	maximum dose (mrad/day)		population dose (mrad/day)	
		Plant	Animal	Plant	Animal
Am-241	0	0	0	0	0
Pu-239	0	0	0	0	0
U-238	1	0	0	0	0
H-3	0	0	0	0	0
Cs-137	20	1	1	0	0
Sr-90	6,000	350	35	1	1

References for Pratt Canyon

Bennett, K., J. Biggs, and P. Fresquez. "Radionuclide contaminant analysis of small mammals, plants and sediments within Mortandad Canyon, 1994," Los Alamos National Laboratory report LA-13104-MS. Los Alamos, NM (1996).

Fresquez, P.R., D.A. Armstrong, M.A. Mullen, and L. Naranjo, Jr. "The uptake of radionuclides by beans, squash, and corn growing in contaminated alluvial soils at Los Alamos National Laboratory," Journal of Environmental Science and Health B33 (1) 99-115 (1998).

Fresquez, P.R., J.D. Huchton, M.A. Mullen, and L. Naranjo, Jr,. "Pinon pine tree study, Los Alamos National Laboratory: source document," Los Alamos National Laboratory report LA-13693-MS. Los Alamos, NM (2000).

Fresquez, P.R., J. Huchton, M.A. Mullen, and L. Naranjo, Jr,. "Radionuclides in pinon pine (Pinus edulis) tree shoots and nuts from Los Alamos National Laboratory lands," Health Physics 78 (6): S83 (2000).

Fresquez, P.R., J. Huchton, M.A. Mullen, and L. Naranjo, Jr,. "Radionuclides in pinon pine (Pinus edulis) nuts collected from Los Alamos National Laboratory lands and the dose from consumption," Journal of Environmental Science and Health 35 (5): 611–622 (2000).

Fresquez, P.R., J.K. Ferenbaugh, and L. Naranjo, Jr. "Moisture Conversion Ratios for the Foodstuffs and (Nonfoodstuffs) Biota Environmental Surveillance Programs at Los Alamos National Laboratory (Revision 2)," Los Alamos National Laboratory report LA-UR-04-4122. Los Alamos, NM. (2004).

D. Jarmer and J. Lyman, "Human dose assessment for the radionuclides 90Sr and 90Y at TA-35 SWMU 35-003r and Ten Site Canyon" LA-13206-MS (1997).

LA-UR-92-800, "RFI Work Plan for Operable Unit 1129", (1992).

LA-UR-97-3291, "Work Plan for Mortandad Canyon", (1997).

UNSCEAR 1996: "Sources and effects of ionizing radiation", UNSCEAR 1996 (ISBN 92-1-142219-1).

TA-35 Waste Water Treatment Plant

SWMU 35-003(a)-99 is the location of the former waste water treatment plant east of TA-35-2. The primary radionuclide is Sr-90. When the tanks and pipes were removed in the 1980s, the Sr-90 concentration in the soil at some locations was about 5,000 pCi/g, especially in underground locations and rock fractures that are difficult to excavate. Sr-90 has not been detected at the surface or in biota, so the biota dose is estimated to be essentially zero.

TA-36 (Kappa Site)

Kappa Site was established in 1950 and contains several high-energy radiographic x-ray devices. Also, in 2001 the HSR-4 calibration facility was relocated from TA-3-130 to a new building close to TA-36-1. TA-36 contains firing sites and residual uranium.

MDA AA is in TA-36. It may contain small amounts of uranium and thorium.

The concentrations are much smaller than at EF Site (TA-15) so there is no significant biota dose.

TA-37 (Magazine Area C)

TA-37 is east of TA-11 and TA-16. There is no known environmental radioactive contamination so the biota dose from LANL is zero.

TA-38 (Monte Rey site) was canceled and does not exist.

TA-39, Ancho Canyon

In 1994, preliminary data indicated 34 pCi/g ^{137}Cs at PRS 39-001(a), which is a 9 ft deep disposal pit under a paved volleyball court north of TA-39-69. In addition to the Cs-137, Co-60 was detected with a decay-corrected concentration of 7 pCi/g. No other radionuclides were detected except for natural terrestrial material.

These data have not been released and may not be used for a dose assessment at this time. Therefore, a dose assessment will not be performed for the environmental surveillance report until the data are verified. When a dose assessment is performed, the 9 ft depth will preclude external dose from Cs-137, and the site-specific bioaccumulation factor of 0.01 to 0.1 will preclude internal dose, so the biota dose is expected to be zero.

Note: MDA Y is in TA-39. It received wastes from the TA-39 firing sites, including uranium. The amounts and concentrations are much smaller than at EF Site (TA-15) and there is no significant biota dose.

TA-40 (DF Site)

TA-40 (Detonator Firing or DF Site) is on Two-Mile Mesa and was built in 1950 as a firing site. There is no known radioactive contamination and there is no biota dose.

TA-41 (W site)

TA-41-1 and TA-41-4 were nuclear facilities (primarily tritium) until 1994 but have been decommissioned.

TA-41 also includes the hillsides below the original TA-1 (SWMU 1-001(d)), which are discussed in the TA-1 section. Contamination is on the order of 10 pCi/g Cs-137 and 100 pCi/g Pu-239 in a few spots about 10 m beyond the fence, and 300 pCi/g Pu-239 20 m beyond the fence, below the south-east corner of TA-1. These areas are fenced off.

As discussed in the TA-1 section, the doses from Pu-239 are:
most exposed plant: 24 mrad/day;
most exposed mouse: 1 mrad/day;
population doses to plants and animals: 0.

TA-42 (Incinerator site until 1970)

TA-42 is no longer a TA. The location is now part of TA-55, near the edge of Mortandad Canyon north of the plutonium facility. There is no significant environmental radioactive contamination and no significant biota dose.

TA-43 (HRL)

Low levels of radioactive waste from TA-43 were sent by industrial waste lines first to TA-45, and later to TA-50. For a time in 1963, very-low levels of radioactive waste were sent to the Bayo Canyon Sewage plant (SWMU # 0-018). There is no significant environmental radioactive contamination at TA-43 and no significant biota dose.

TA-44 (Los Angeles shop until 1958)

TA-44 was a machine shop in Los Angeles and is no longer a TA. There are no SWMUs, no contamination, and no biota dose.

TA-45 (Radioactive Liquid Waste)

TA-45 was the site of the first radioactive liquid waste treatment plant (1951-1964) at the top of Acid Canyon.

In the 1940s, before the TA-45 treatment plant was built, Acid Canyon was contaminated with untreated waste from the outfall of the radioactive liquid waste line from TA-1. During the 1950s, the outflow from the liquid-waste treatment plant at TA-45 continued to add to the radioactive inventory in Acid Canyon.

The south fork of Acid Canyon was remediated in 2001, with the result that the 95% upper-confidence-level concentration is 206 pCi/g (Ref: LA-UR-02-5785). If we assume the average concentration is 206 pCi/g over the full root area of a plant, the dose to the most exposed plant is 16 mrad/day. The contamination is a narrow strip about 1 m wide, so averaging over 0.075 ha, the average Pu-239 concentration is less than 30 pCi/g so the dose to the most exposed mouse is essentially zero. Averaging over 3 ha, the population doses are essentially zero.

Reference for TA-45

LA-UR-02-5785 (ER2002-0544) "Interim Action Completion Report for the South Fork of Acid Canyon", Steve Reneau, Tom Benson, Randall Ryti, (2002).

TA-46 (WA site)

TA-46, off Pajarito Road, was the site of the Rover project. There is no significant environmental radioactive contamination and no significant biota dose.

TA-47 (Bruns Railhead in Santa Fe until 1958)

Until 1958, TA-47 was the Bruns Railhead in Santa Fe, near the intersection of Cerillos Road and St Michael's Drive in Santa Fe. It is no longer a TA and there are no SWMUs, no radioactive contamination, and no biota dose.

TA-48 (Radiochemistry)

The radiochemistry laboratory is a category-3 nuclear facility. It was constructed in 1957.

Before the RLWTF was built at TA-50, there were several outfalls into the nearby canyons. There have also been reports of leaks from broken waste lines. Furthermore, the air from the hoods was not cleaned to present-day standards (LA-UR-92-800 and LA-UR-98-2550). (Note: samples upstream of the TA-50 outfall have sometimes been assumed to represent background; this seems unlikely in view of the history.)

TA-48 shows as a hot spot on the 1994 Aerial survey with about 50 micro-R/h of 511-keV in addition to Cs-137 and possibly Na-22. These can be detected with a sodium iodide spectrometer. TA-48 remains to be investigated, but at present there are no reports of radioactive material approaching the BCGs. Therefore, pending further investigation, we conclude the biota dose is much smaller than the DOE limits.

References for TA-48

LA-UR-92-800, "RFI Work Plan for Operable Unit 1129", (1992).

LA-UR-98-2550, “Work Plan for Pajarito Canyon”, LA-UR-98-2550 (1998).

TA-49 (Frijoles Mesa)

From the perspective of biota dose, the only significant site at TA-49 is MDA AB, which is discussed next.

TA-49, MDA AB

MDA AB is a 20-ha fenced area enclosing three clusters of 30-m-deep shafts that were used for weapon-safety tests in 1962. According to LA-11135-MS, the estimated Pu-239 concentration at the bottom of these shafts is 500 nCi/g. In comparison, other radionuclide concentrations are small.

The area has been monitored frequently, as described in LA-11135-MS, LA-UR-80-3110, LA-UR-90-3283, and the annual environmental surveillance reports. There is some surface contamination, apparently brought to the surface by human actions such as drilling rather than by biota. According to Tierney and Foxx (1984 and 1987) the deepest roots at Los Alamos are 3 m, one tenth of the depth of the shafts, so it is unlikely there is a direct connection between the radionuclides at the bottom of the shafts and biota.

According to the data in LA-UR-90-3283, the average plutonium concentrations at Areas #2 and #11 is 5 pCi/g in the soil and 0.7 pCi/g ash in the vegetation. According to Fresquez 2004 (LA-UR-04-4122) the ash-to-wet conversion factor is 0.03, so the plutonium concentration in vegetation is 0.7*0.03 = 0.02 pCi/g wet. Therefore, the ratio of vegetation to soil is 0.02/5 = 0.004. This ratio is somewhat smaller than the default ratio of 0.01 in the DOE Standard and RESRAD-BIOTA, which supports the hypothesis that the plutonium measured in the vegetation is from contamination near the surface and not from the bottom of the shafts.

To estimate the biota dose, we use the average soil concentrations at Areas #2 and #11 listed in Table 13 of Soholt 1987 (LA-UR-90-3283): Pu-239 5 pCi/g, Am-241 2 pCi/g, uranium 2 pCi/g, and Cs-137 0.7 pCi/g. For the bioaccumulation factors, we use 0.1 for Cs-137, and the DOE defaults for the others. Finally, we assume the contaminated area is 1,000 m^2, which is about the home range of a mouse. The resulting dose is less than 1 mrad/day, both to the maximally exposed mouse and the maximally exposed plant. The population doses are about a factor of 40 smaller. Thus, as summarized in the table, the biota doses are much less than 1% of the DOE limits.

radionuclide	Soil conc. (pCi/g)	maximum dose (mrad/day)		population dose (mrad/day)	
		Plant	Animal	Plant	Animal
Am-241	2	0	0	0	0
Pu-239	5	0	0	0	0
U-238	2	0	0	0	0
H-3	1	0	0	0	0
Cs-137	1	0	0	0	0
Sr-90	1	0	0	0	0

References for MDA AB

TS Foxx, GD Tierney and JM Williams, "Rooting depths of plants on Low-level waste disposal sites" LA-10253-MS (1984).

TS Foxx, GD Tierney and JM Williams, "Rooting depths of plants relative to biological and environmental factors" LA-10254-MS (1984).

PR Fresquez, JK Ferenbaugh, L Naranjo, Jr., "Moisture conversion ratios for the foodstuffs and nonfoodstuffs biota environmental surveillance programs at LANL" LA-UR-04-4122 (2004).

WR Hansen, DL Mayfield, LJ Walker, "Interim environmental surveillance plan for LASL radioactive waste areas" LA-UR-80-3110 (1980).

WD Purtymun, AK Stoker, "Environmental status of TA-49" LA-11135-MS (1987).

LF Soholt et al., "Environmental Surveillance of low-level radioactive-waste-management areas at Los Alamos during 1987", LA-UR-90-3283 (1990).

GD Tierney and TS Foxx, "Root lengths of plants on Los Alamos National Lab. Lands" LA-10865-MS (1987).

TA-50 (Waste Management)

The discussion of TA-50 is divided into the aquatic system of Effluent Canyon, the terrestrial system near TA-50-1, and the terrestrial system of MDA C, as follows.

TA-50, Effluent Canyon (aquatic)

The Radioactive Liquid Waste Treatment Facility, RLWTF, at TA-50 discharges treated liquid waste through a permitted outfall into Effluent Canyon, north of TA-50-1. Effluent Canyon flows into Mortandad Canyon. The concentrations listed in the table, below, are from the report Environmental Surveillance at Los Alamos during 2004.

For Cs-137, we use the LANL Ecorisk bioaccumulation factor for daphnia and aquatic snails, which is 100. With this assumption, the biota concentration is 100*42 pCi/L, which is approximately 4 pCi/g. This is approximately the highest concentration ever measured at LANL (Hakonson1973, LA-5282-MS). The internal dose from this concentration of Cs-137 is 0.2

mrem/day. Therefore, pending further investigation, we estimate the dose to terrestrial animals from Cs-137 in the water of Effluent Canyon is less than 1 mrad/day.

The doses from the other radionuclides are calculated using the defaults in RESRAD-BIOTA. The total dose to terrestrial animals is 5 mrad/day, which is 5% of the DOE limit. The dose to aquatic animals (daphnia and aquatic snails) was calculated by RESRAD-BIOTA (using the default distribution coefficient, K_d, for sediment) and is listed in the table below. The total dose, 85 mrad/day, is less than 10% of the DOE limit.

radionuclide	Water conc. (pCi/L)	Aquatic dose (mrad/day)	Terrestrial animal (mrad/day)
Am-241	8	18	1
Pu	10	54	2
U	3	13	0
H-3	13,000	0	0
Cs-137	42	1	1
Sr-90	4	0	1

Reference for Effluent Canyon

T.E. Hakonson, J.W. Nyhan, L.J. Johnson, K.V. Bostick "Ecological Investigation of Radioactive Materials in Waste Discharge Areas at Los Alamos", LA-5282-MS, (1973).

TA-50, Radioactive Liquid Waste Treatment Facility (soil)

The contamination at PRS 50-006(a), at the head of Ten-Site Canyon, resulted from a 1974 spill of radioactive liquid waste that spread a few hundred meters east of TA-50-1 (ref: LA-UR-96-1283 Appendix I.) The ER database shows one soil sample with a decay-corrected Sr-90 concentration of 45 pCi/g. This is greater than the DOE default BCG of 20 pCi/g so it triggers a site-specific assessment.

The soil concentrations listed in the table are the averages of five samples taken within a span of 5 m. The average of these concentrations are used to calculate the dose to the most exposed plant: 1 mrad/day.

Nearby, within the home range of a mouse, the average Sr-90 concentration is lower, so the dose to the most exposed animal is essentially zero.

PRS 50-006(a) is 50 m north of MDA C, so the 3-ha population area overlaps MDA C. Since MDA C has a much larger area and has much higher concentrations than PRS 50-006(a), we estimate the population dose in this neighborhood is dominated by MDA C, and we defer to the discussions in the next section.

radionuclide	Soil conc. (pCi/g)	maximum dose (mrad/day)		population dose (mrad/day)	
		Plant	Animal	Plant	Animal
Am-241	1	0	0	See MDA C	See MDA C
Pu-239	2	0	0	See MDA C	See MDA C
U-238	2	0	0	See MDA C	See MDA C
H-3	0	0	0	See MDA C	See MDA C
Cs-137	2	0	0	See MDA C	See MDA C
Sr-90	10	1	0	See MDA C	See MDA C

Reference for TA-50 Radioactive Liquid Waste Treatment Facility

LA Emility, "A history of radioactive liquid waste management at Los Alamos" LA-UR-96-1283 (1996) Appendix I.

TA-50, MDA C

MDA C is a 5 ha area containing disposal pits and shafts dating from 1948. It is also known as SWMU 50-009.

The ER database contains gamma spectrometer data and gross alpha and beta measurements for pine needles. The gamma spectrometer data show that the concentrations of Am-241, U-235, and Cs-137 are less than 1 pCi/g. However, the maximum gross alpha measurement is 91 pCi/g and the average is 10 pCi/g. Also, the gross beta maximum is 266 pCi/g and the average is 43 pCi/g.

The gross alpha is not correlated with the gross beta, which indicates the radionuclide is not U-238, so we assume the gross alpha is plutonium. Also, the gamma data show Cs-137 is small so we assume the gross beta is Sr-90. However, in the table below, they are labeled "Gross alpha" and "Gross beta".

Using a bioaccumulation factor of 0.015 for alpha and 1 for beta (Fresquez 1997), we derive the worst-case soil concentrations corresponding to the gross alpha and beta measurements and list them in the table below. We also list the tritium concentration from Rogers 1977 (page C-18) corrected for decay and for the water concentration in plants (Fresquez 2004). The maximum doses are based on these maximum concentrations and the population doses are based on the average concentrations.

The results are summarized in the table below. The assumptions used in this preliminary assessment are based on incomplete information, but they are sufficient to show the population doses are less than 10% of the DOE limits.

radionuclide	Soil conc. (pCi/g)	maximum dose (mrad/day)		population dose (mrad/day)	
		Plant	Animal	Plant	Animal
Am-241	0	0	0	0	0
Gross alpha	6,500	500	100	50	10
U-238	0	0	0	0	0
H-3	20,000	10	10	2	2
Cs-137	0	0	0	0	0
Gross beta	266	15	15	2	2

References for MDA C

P.R. Fresquez et al., "Radionuclide concentrations in pinto beans, sweet corn, and zucchini squash grown in Los Alamos Canyon at LANL", LA-13304-MS (1997).

P.R. Fresquez, J.K. Ferenbaugh, L. Naranjo, Jr., "Moisture conversion ratios for the foodstuffs and nonfoodstuffs biota environmental surveillance programs at LANL" LA-UR-04-4122 (2004).

M.A. Rogers, "History and environmental setting of LASL near surface land disposal facilities for radioactive wastes (areas A, B, C, D, E, F, G, and T)" LA-6848-MS (page C-18) (1977).

TA-51 (Environmental Research Site)

There is no radioactive contamination or biota dose.

TA-52 (Reactor Development Site)

TA-52 housed the UHTREX reactor (LA-3556) that was decommissioned and dismantled in 1970 (LA-12356). There is no known environmental radioactive contamination or biota dose.

TA-53 (LANSCE)

The Los Alamos Neutron Science Center, LANSCE, contains an 800-MeV accelerator and three category-3 nuclear facilities: A6, ER-1, and 1L.

The emissions from routine operations at LANSCE are primarily activated air products, e.g., oxygen-15, nitrogen-13, carbon-11, etc. These are controlled to human health standards and are not a biota-dose hazard.

The lagoons at the east end were monitored by TLDs until they were remediated a few years ago. Residual contamination is no longer detectable with hand-held instruments.

Most of TA-53 is controlled to human health standards. The prominent exceptions are the areas posted as “Radiation Area” or “Very High Radiation Area”, and the resin tank that is designated a Nuclear Environmental Site, NES.

The Radiation Areas and Very High Radiation Areas include small areas with dose rates >500 rad/hour. These dose rates affect individual animals such as moths and mice that find their way through cracks in the walls, but according to DOE-STD-1153-2002, the affect on a population is expected to be small and so it is exempted from the biota dose assessment requirements.

The resin tank that is an NES contains an unknown amount of radioactive material. A reasonable guess is that the major radionuclides are activation products such as cobalt-60 and tritium. The tank is underground and isolated from biota, so the biota dose is essentially zero.

In summary, there is no significant biota dose.

TA-54 (Waste Disposal)

The significant material disposal areas for solid radioactive waste are MDA G and MDA H. These are discussed in the following sections.

TA-54, MDA G

MDA G has been in use since 1957. It is the largest material disposal area at LANL and the only one still in use for radioactive material. A detailed assessment was completed by Hollis et al. in 1997 (LA-UR-97-85.)

Most of the radioactive material is stored in sealed drums that exclude contact with plants or animals. However, there are some locations with soil concentrations greater than the biota concentration guidelines (BCGs). For example, PRS 54-013(b)-99 is a combination of subsurface disposal units, 5 m underground, with maximum concentrations as follows: 69 pCi/g of Cs-137, 137 pCi/g of Sr-90, 6,900 pCi/g of Pu-238, and 2,500 pCi/g of Pu-239. According to the DOE Standard, these concentrations trigger a site-specific assessment.

Soil measurements do not provide a complete picture. In some cases the contamination is several meters below concrete or asphalt where plants and animals have no access. In other cases, plants and animals have found contaminated soil that the scientists have not sampled. For example, on top of the tritium disposal shafts near the south fence, Gonzales et al. (Gonzales 2000, LA-13719-MS) report 522,000 pCi/mL in vegetation but only 56,000 pCi/mL in the soil. Also, recent measurements by Fresquez (2005) show a plutonium concentration of 20 pCi/g on mice (probably on the pelt), which does not correlate with any known soil contamination. These data indicate the presence of underground radioactive material that plants and animals have sampled but scientists have not.

Vegetation and small mammals at MDA G are sampled regularly (Fresquez 2003, 2004, 2005) and for the most part the data show that the biota dose is small. The average concentrations in mice are: 1,000 pCi/mL tritium, 0.1 pCi/g Pu-238, 0.3 pCi/g Pu-239, and 0.3 pCi/g Am-241. These concentrations result in an average dose rate of 5 mrad/day (Fresquez 2005).

However, there are two cases that suggest larger biota doses, the first involving plutonium in mice near pits 17 and 18, and the second involving tritium in gophers near the tritium shafts. These two cases are discussed and summarized in two separate tables, as follows.

Near pits 17 and 18, one sample of mice trapped in 2003 contained the following ash-weight concentrations: Pu-239 301 pCi/g; Pu-238 99 pCi/g; Am-241 13 pCi/g (Fresquez 2005, LA-14193, Table 7a). In the table below, these concentrations are converted to fresh weight and the doses are calculated using the extremely conservative assumption that the transuranics are in the carcass rather than on the pelt.

	Ash weight (pCi/g)	Fresh wt (pCi/g)	DCF (mrad/day)/(pCi/g)	Dose mrad/day
Cs-137	3.10E+01	1.24E+00	4.30E-05	5.33E-05
Sr-90	1.90E+01	7.60E-01	5.80E-05	4.41E-05
Am-241	1.30E+01	5.20E-01	5.70E-03	2.96E-03
Pu-238	9.90E+01	3.96E+00	5.40E-03	2.14E-02
Pu-239	3.01E+02	1.20E+01	5.40E-03	6.50E-02
U	1.00E+00	4.00E-02	4.50E-03	1.80E-04

According to a private communication from Lars Soholt, the mouse carcass contributes 93% of the ash weight and the pelt contributes 7%. If this information is combined with the typical concentrations previously measured in the carcass and on the pelt, it is theoretically possible to deduce the concentration in the carcass and thus refine the dose estimate.

Further study is needed to reproduce these unusual measurements and to locate the source of this contamination in soil or plants. The data are summarized in the following table.

radionuclide	Soil conc. (pCi/g)	maximum dose (mrad/day)		population dose (mrad/day)	
		Plant	Animal	Plant	Animal
Am-241	1	0	3	0	2
Pu-239	1	0	86	0	2
U-238	1	0	0	0	0
H-3 (pCi/mL)	1,000	1	1	1	1
Cs-137	1	0	0	0	0
Sr-90	1	0	0	0	0

The second case of high biota dose involves tritium. Tritium concentrations are above the regional background throughout most of MDA G, but the tritium dose rate to individual plants exceeds 0.1 mrad/day only near the tritium disposal shafts along the south fence. In the plants directly above the shafts, the tritium concentration is 522,000 pCi/mL of water (Gonzales 2000), which converts to 355,000 pCi/g of plant tissue. This concentration causes a dose of 100 mrad/day, which is 10% of the DOE limit. There have been no reports of other radionuclides in plants that would cause a dose rate of more than 0.1 mrad/day.

Gophers were studied at five locations near these shafts (Gonzales 2000). At four of the five locations, the average concentrations of tritium in the gophers were less than in the average mice at MDA G, about 1,000 pCi/g. At the fifth location, directly on top of the tritium disposal shafts, the average concentration in gopher carcasses was 168,000 pCi/mL “body water”. Gophers are 75% water (Fresquez 2004) so the activity per body weight is 124,000 pCi/g. Using the dose conversion factor of 2.9E-7 from Table 2.4 of the DOE Standard, the tritium dose rate to individual gophers at this location is 36 mrad/day. At this location, the dose from radionuclides other than tritium is much less than 1 mrad/day, so the total dose is approximately 36 mrad/day.

The area of tritium contamination is about 0.1 ha, so for the population dose we use an area factor of (0.1 ha)/(3 ha) = 0.03. The resulting doses are summarized in the table below.

radionuclide	Soil conc. (pCi/g)	maximum dose (mrad/day)		population dose (mrad/day)	
		Plant	Animal	Plant	Animal
Am-241	1	0	0	0	0
Pu-239	1	0	0	0	0
U-238	1	0	0	0	0
H-3 (pCi/mL)	500,000	100	36	3	1
Cs-137	1	0	0	0	0
Sr-90	1	0	0	0	0

In summary, MDA G is regularly monitored regularly (Fresquez, LA-14091, LA-14095-PR, LA-14108-PR, LA-14181-PR, LA-14193). The data show that individual biota maximum dose rates in some locations are as much as 100 mrad/day, but the population dose rates are less than 5 mrad/day, which is 5% of the DOE limit.

References for MDA G

Bennett, K.D., R.J. Robinson, and P.R. Fresquez. "Radionuclide contaminant analysis of small mammals at Area G, Technical Area-54, 1998 (with cumulative summary for 1994-1998)," Los Alamos National Laboratory report LA-13874-MS (2002).

Budd, R.L., G.J. Gonzales, P.R. Fresquez, and E.A. Lopez. "The Uptake and Distribution of Buried Radionuclides by Pocket Gophers (Thomomys bottae)," Journal of Environmental Science and Health Part A—Toxic/Hazardous Substances and Environmental Engineering, 39(3): 611-625 (2004).

Fresquez, P.R., L. Vasquez-Tator, and E.A. Lopez. "Tritium Concentrations in Vegetation as a Function of Distance from a Low-Level Waste Site at Los Alamos National Laboratory," Los Alamos National Laboratoy report LA-14091-MS (2003).

Fresquez, P.R., J.W. Nyhan, and E. Lopez. "Radionuclide Concentrations in Soils and Vegetation at Low-Level Radioactive Waste Disposal Area G during the 2003 Growing Season," Los Alamos National Laboratory report LA-14108-PR (2004).

Fresquez, P.R. and E. Lopez. "Radionuclide Concentrations in Soils and Vegetation at Low-Level Radioactive Waste Disposal Area G during the 2004 Growing Season," Los Alamos National Laboratory report LA-14181-PR (2004).

Fresquez, P.R., Lars Soholt, and Ed Lopez. "Radionuclide Contaminant Analysis of Small Mammals at Area G, Technical Area 54, 2001 Through 2003 (With a Cumulative Summary for 1994 Through 2003)," Los Alamos National Laboratory report LA-14193-MS (2005).

G.J. Gonzales, R.L. Budd, P.R. Fresquez, W.J. Wechsler, "Source document: the relationship between pocket gophers (Thomomys bottae) and the distribution of buried radioactive waste at the Los Alamos National Laboratory", LA-13179-MS (July 2000)

D Hollis et al., “Performance Assessment and Composite Analysis for LANL MDA G,” LA-UR-97-85 (1997).

Nyhan, J., P.R. Fresquez, R. Velasquez, and E. Lopez. “Radionuclide Concentrations in Soils and Vegetation at Low-Level Radioactive Waste Disposal Area G during the 2001 Growing Season,” Los Alamos National Laboratory report LA-13942-PR (2002).

Nyhan, J., P.R. Fresquez, R. Velasquez, and E. Lopez. “Radionuclide Concentrations in Soils and Vegetation at Low-Level Radioactive Waste Disposal Area G during the 2002 Growing Season. (With a Summary of Radionuclide Concentrations in Soils and Vegetation Since 1980)” Los Alamos National Laboratory report LA-14095-PR, (2004).

W.D. Purtymun, "Underground movement of tritium from solid-waste storage shafts," LA-5286-MS (1973).

Soholt, L., G.J. Gonzales, P.R. Fresquez, K. Bennett and E. Lopez. “Estimating Radiological Doses to Predators Foraging on a Low-Level Waste Management Area. Los Alamos National Laboratory report LA-13999,” (2003).

TA-54, MDA H

MDA H (SWMU 54-004) is a 0.1-ha inactive area with 9 shafts, 18 m deep, capped with 1 m of tuff plus 1 m of concrete (LA-UR-98-2550). Thus, the radioactive material in the shafts is partially isolated from biota. In 1969, moisture samples from a depth of 12 m were reported with 2 million pCi/mL (LA-UR-98-2550). After correcting for decay, this concentration is approximately equal to the BCG. However, biota do not penetrate to a depth of 12 m. At the surface, the only radioactivity above background is tritium at a concentration of 2,500 pCi/g, which results in a dose of 1 mrad/day to the maximally exposed plant and animal. Averaging over 3 ha, the population dose is essentially zero.

radionuclide	Soil conc. (pCi/g)	maximum dose (mrad/day)		population dose (mrad/day)	
		Plant	Animal	Plant	Animal
Am-241	0	0	0	0	0
Pu-239	0	0	0	0	0
U-238	0	0	0	0	0
H-3	2,500	1	1	0	0
Cs-137	0	0	0	0	0
Sr-90	0	0	0	0	0

Reference for MDA H

LA-UR-98-2550, “Work Plan for Pajarito Canyon”, (1998).

TA-55 (Plutonium Facility)

TA-55, established in 1973, is the main plutonium facility at LANL. TA-55-4, also known as PF-4, is a category-2 nuclear facility. There is no significant environmental radioactive contamination or biota dose.

TA-56 (Subterrene Basalt site until 1976)

TA-56 is no longer a TA. It was within TA-39, and does not contain any SWMUs so the biota dose is essentially zero.

TA-57 (Fenton Hill)

There is no radioactive contamination or biota dose.

TA-58 (undeveloped)

TA-58 is an undeveloped area west of TA-3. There are no SWMUs, no environmental radioactive contamination, and no biota dose.

TA-59 (HSR and EM)

There is no significant environmental radioactive contamination or biota dose.

TA-60 (Sigma Mesa)

Sigma Mesa contains several SWMUs. Most of these contain chemicals such as solvents, oil, and sludge, in addition to building materials such as wood, steel, asphalt and concrete debris. A fenced surface impoundment was used in the 1970s as a solar evaporative pond and contains low levels of residual radioactive material, perhaps as much as 30 pCi/g in some places, as discussed in the next section.

TA-60, PRS-60-005(a)

PRS 60-005(a) is a 0.1-ha fenced surface impoundment with dry sludge containing Cs-137. It is next to the old radioactive-liquid-waste line from TA-21 to TA-50, 0.4 mi E of TA-60-35. It was used briefly in the 1970s as a solar evaporative pond for a study with 25,000 gallons of effluent from TA-50. According to preliminary draft data in the ER database, in 1994, one soil sample had a Cs-137 concentration of 35 pCi/g. The status of this preliminary measurement is not clear so for the present it is not included in the ESR.

Averaging the data over the site and correcting for decay, the concentrations are: Am-241 1 pCi/g; Pu-239 2 pCi/g; Cs-137 2 pCi/g; U-234 1 pCi/g; U-238 1 pCi/g. The average concentrations for the other measured radionuclides are less than 1 pCi/g. These concentrations and the associated doses are listed in the table. All are less than 1 mrad/day. We conclude the biota dose for all categories is essentially zero.

radionuclide	Soil conc. (pCi/g)	maximum dose (mrad/day)		population dose (mrad/day)	
		Plant	Animal	Plant	Animal
Am-241	1	0	0	0	0
Pu-239	2	0	0	0	0
U-238	1	0	0	0	0
H-3	0	0	0	0	0
Cs-137	2	0	0	0	0
Sr-90	0	0	0	0	0

TA-61

TA-61 includes the LA County sanitary landfill. There is no significant environmental radioactive contamination or biota dose.

TA-62

TA-62 (northwest of TA-3) is undeveloped except for a water tank. There are no SWMUs, no known environmental radioactive contamination, and no biota dose.

TA-63 (Services)

TA-63 is a base for service organizations such as KSL. There is no significant environmental radioactive contamination or biota dose.

TA-64 (Central Guard Facility)

There is no environmental radioactive contamination or biota dose.

TA-65

TA-65 in an undeveloped area incorporated into TA-51. There is no environmental radioactive contamination or biota dose.

TA-66 (offices)

TA-66 (off Pajarito Road facing TA-50) contains offices and conference rooms. There is no environmental radioactive contamination or biota dose.

TA-67 (Pajarito Mesa buffer zone)

TA-67 (between TA-15 and TA-40) is an undeveloped buffer zone. There is no environmental radioactive contamination or biota dose.

TA-68 (Water Canyon buffer zone)

TA-68 is an undeveloped buffer zone between TA36 and TA-39. There is no environmental radioactive contamination or biota dose.

TA-69 (Anchor North Site)

TA-69 is the entrance station to TA-6, TA-8, etc. There is no significant environmental radioactive contamination or biota dose.

TA-70 (undeveloped buffer zone)

TA-70 is an undeveloped area east of TA-39 and State Road 4. There are no SWMUs and no radioactive contamination or biota dose.

TA-71 (undeveloped buffer zone)

TA-71 Is an undeveloped area south of Pajarito Acres and east of State Road 4. There are no SWMUs and no radioactive contamination or biota dose.

TA-72 (PTLA training)

There is no significant environmental radioactive contamination or biota dose.

TA-73 (Airport)

In 1953, 100 lbs of natural uranium was buried by mistake in the old landfill, SWMU 73-001, north of the airport runway. There are no reports of radioactive contamination near the surface that would lead to biota dose.

TA-74 (Otowi Tract)

TA-74 is an undeveloped area at the north-east boundary of LANL. Most of TA-74 north of the main watercourse was returned to San Ildefonso Pueblo in 2002. There are no SWMUs and no significant environmental radioactive contamination or biota dose.

D. Summary of biota dose assessment at LANL

The biota dose assessments presented above show that the dose rates to all biota populations at LANL are below the limits specified in DOE Order 5400.5 and DOE-STD-1153-2002.

Although the population doses are within limits, the maximum doses to individual plants may, in some cases, cause measurable effects. The alpha doses are unlikely to cause measurable effects because they are calculated with the human radiation-weighting factor of 20, whereas 5 is probably more realistic for biota (DOE-STD-1153-2002 Module 2 Section 7 and UNSCEAR 1996). However, the Sr-90 dose to individual trees at Pratt Canyon (TA-21) is realistic and warrants further study.

The MDAs are a particular concern because deep-rooted plants can find unsuspected pockets of contamination and transport it to the surface, as noted by Foxx and Tierney (1984-7). MDAs A, B, C, T, and G all show signs that plants have penetrated the radioactive material. Plants generally give a better indication than animals because of their fixed locations and higher bioaccumulation factors. More plant data would be an important contribution both to the biota dose assessment and to our understanding of underground contamination at LANL.

References for Section D

DOE Order 5400.5, "Radiation Protection of the Public and the Environment," (1993).

DOE-STD-1153-2002: US Department of Energy, "A Graded Approach for Evaluating Radiation Dose to Aquatic and Terrestrial Biota," US Department of Energy Technical Standard 1153-2002 (August 2000). [Available at *http://homer.ornl.gov/oepa/public/bdac/*].

TS Foxx, GD Tierney and JM Williams, "Rooting depths of plants on Low-level waste disposal sites" LA-10253-MS (1984)

TS Foxx, GD Tierney and JM Williams, "Rooting depths of plants relative to biological and environmental factors" LA-10254-MS (1984)

GD Tierney and TS Foxx, "Root lengths of plants on Los Alamos National Lab. Lands" LA-10865-MS (1987).

UNSCEAR 1996, United Nations Scientific Committee on the Effects of Atomic Radiation (1996).

ATTACHMENT 2

Site-Representative ^{137}Cs BCG for Aquatic System

According to DOE-STD-1153-2002, page M1-38, the default BCG for water is 40 pCi/L. This is derived by assuming the limiting receptor is a riparian (terrestrial) animal and the total concentration ratio is approximately 50,000. With these assumptions, the concentration in the riparian animal is 50,000*40 pCi/L and the dose is approximately 0.1 rad/day, which is the limit for a terrestrial animal.

At Los Alamos National Laboratory (LANL) the ^{137}Cs BCG is greater than 40 pCi/L because of:
1. the potassium concentration in the water,
2. the sediment load in the water, and
3. the scarcity of food for riparian animals.

LANL uses a value of 20,000 pCi/L for the 137Cs BCG. This is justified by the following calculations.

The concentration ratio, C_r, can be estimated from the potassium concentration, K, (micro-mol/L) and the sediment load, SL, (mg/L) using the following equation (F. Ward Whicker, private communication.)

$$\log C_r = 4.332 - 0.718 \log(K) - 0.233 \log(SL).$$

At the LANL location with the largest ^{137}Cs concentration, K = 170 micro-mol/L and SL = 25 mg/L, so C_r = 250. Alternatively, use the equation for invertabrates (F. Ward Wicker, private communication.)

$$\log C_r = 3.628 - 0.583 \log(K)$$

So C_r = 200.

If the 137Cs concentration in the water is 20,000 pCi/L, the concentration in aquatic biota will be 200*20,000 = 4,000,000 pCi/kg = 4,000 pCi/g, which causes a dose of 0.2 rad/day. This is less than the limit of 1 rad/day for aquatic biota.

The contaminated section of the canyon has almost no food for a riparian animal. There is more food available in the uncontaminated upstream wetlands and the nearby human areas, replete with irrigated picnic areas and discarded lunches.

The site-representative riparian animal is the swallow, which has an individual home range of 0.7 ha and a population area of 40*0.7 = 30 ha. The area of the contaminated section of the canyon is about 0.1 ha, which is small compared with the area of the upstream canyon and wetlands. Assume an additional bioaccumulation factor of 3 (F. Ward Wicker, private communication) together with an area factor of 0.1. In this case, the ^{137}Cs concentration in the swallow is 3*0.1*4,000 = 1,200 pCi/g and the population dose is 0.05 rad/day, which is less than the limit of 0.1 rad/day.

Meteorology and Air Quality Group

PROCEDURE TRAVELER

This form is from MAQ-022

Part 1 (completed by any group employee)

Procedure number: MAQ-514 Revision: 0→1

Procedure title: Calculating Dose to Non-Human Biota

Action Requested: ☐ New procedure ☒ Major revision of existing procedure ☐ Deletion of existing procedure

Description of and reason for action: ☐ Quick-change revision of existing procedure (parts 3 and 5 N/A)

Needs revision - determined at annual review

Signature: Terry Morgan Name (print): Terry Morgan Date: 5/12/05

Part 2 (completed by appropriate manager)

I agree with the action requested: ☐ Yes ☐ No If No, enter reasons below.

If Yes, assigned preparer: Mike McNaughton Affected teams, programs, groups, or individuals required to review this procedure and others who should review it (see procedure page 5):

Required reviewers: Optional reviewers:

Signature: [signature] Name (print): MCNAUGHTON Date: 4/12/2006

Part 3 (completed by preparer or other qualified safety reviewer)

I have evaluated, according to MAQ-035 and LIR300-00-01, the risks inherent in performing this procedure and have documented them on the Hazard Control Plan form, or referred to a plan that covers this type of work.

Preparer: [signature] Name (print): Mike McNaughton Date: 4/12/2006

Draft prepared and sent for formal review on: ________. Comments resolved on: 4/12/06. After comments have been resolved with each reviewer, obtain signatures of the reviewers in part 5.

Part 4 (signed by safety officer or group leader)

I agree that the appropriate safety-related activities and appropriate risk level were identified during the hazard evaluation:

Safety officer or group leader: [signature] Name (print): Dianne Wilburn Date: 4/13/06

Part 5 (signed by required reviewers: NA for quick-change revisions)

I attest that all my comments and concerns have been satisfactorily discussed, resolved, and/or incorporated into the final version of the procedure.

Signature	Name (print)	Date
William F. Eisele	William F. Eisele	4/12/2006

Preparer: After all reviewers have signed above section, submit this form with copy of draft and final procedure to records coordinator.