Biota Dose Assessment Guidance for the INEEL

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Acronyms

ANL-W Argonne National Laboratory- West
BDAC Biota Dose Assessment Committee
BCG Biota Concentration Guide
CERCLA Comprehensive Environmental Response, Compensation, and Liability Act
CFA Central Facilities Area
DOE U.S. Department of Energy
IAEA International Atomic Energy Agency
INEEL Idaho National Engineering and Environmental Laboratory
INTEC Idaho Nuclear Technology and Engineering Center
MDiff Mesoscale Diffusion Model
NOAA National Oceanic and Atmospheric Administration
NRF Naval Reactors Facility
RWMC Radioactive Waste Management Complex
SDA Subsurface Disposal Area
SOF Sum of Fractions
TAN Test Area North
TRA Test Reactor Area
Definitions

Aquatic Animals  Animals which carry out their normal life cycle fully or partially submerged in surface water.

Aquatic Plants  Plants which carry out their normal life cycle fully or partially submerged in surface water.

Biota Concentration Guide (BCG)  The limiting concentration of a radionuclide in soil, sediment, or water that would not cause dose limits for protection of aquatic and terrestrial biota to be exceeded.

Biota Dose Assessment  As used in this guidance, the process of determining whether radiation doses to populations of non-human organisms exceed dose limits for protection of aquatic and terrestrial biota. More generally, the process of measuring or modeling radiation doses to populations of non-human organisms.

Conceptual Model  A written description and/or visual representation of predicted relationships between ecological entities and the stressors to which they may be exposed.

Contaminated Area  As used in this guidance, a piece of landscape assumed contaminated with a given set of radionuclides within given concentration limits. It is distinguished from other such areas in either the list of radionuclides, their concentrations, or both.

Evaluation Area  A piece of landscape within which biota dose assessment is conducted. In this guidance, they are determined by the intersection of contaminated areas and habitats.

Graded Approach  The approach to biota dose assessment described in DOE (2002a) and applied in this guidance.

Habitat  As used in this guidance, a piece of landscape assumed to have uniform ecological structure and function which is different from other habitats. These areas must be defined and justified by the biota dose assessors.

Distribution Coefficient ($K_d$)  The ratio of the mass of a solute species absorbed or precipitated on the soil or sediment to the solute concentration in the water.

Lumped Parameter  The ratio of the contaminant concentration in the organism to the contaminant concentration in the environmental medium (soil, sediment, or water) resulting from the uptake of the contaminant through one or more routes of exposure.

Kinetic/Allometric Method  A modeling approach using first order kinetic equations to estimate radionuclide concentrations in the organism and allometric equations to determine the intake and loss rates necessary for the kinetic equations (DOE 2002a).

Receptor  An organism determined to be of interest and used as an indicator for other similar organisms in a biota dose assessment.

Riparian Animals  Animals which carry out their normal life cycle primarily in riparian areas. See definition for Riparian Plants.

Riparian Plants  Plants which carry out their normal life cycle in areas not usually submerged in surface water but which derive their water from a surface water body, the saturated zone surrounding surface water, or the capillary fringe. The presence of these plants defines a riparian area.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>Screening</td>
<td>The process of ruling out significant impacts from environmental radioactivity by demonstrating that impacts don’t exist under conditions in which the receptor experiences greater exposures than they actually experience.</td>
</tr>
<tr>
<td>Sum of Fractions (SOF)</td>
<td>The ratio of tissue concentration to limiting environmental concentration (BCG) summed over all radionuclides.</td>
</tr>
<tr>
<td>Terrestrial Animals</td>
<td>Animals which are neither aquatic nor riparian.</td>
</tr>
<tr>
<td>Terrestrial Plants</td>
<td>Plants which are neither aquatic nor riparian.</td>
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Executive Summary

In July 2002, The U.S. Department of Energy (DOE) released a new technical standard entitled *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2002a). The Graded Approach provides dose evaluation methods that can be used to meet the requirements of DOE Order 5400.5 “Radiation Protection of the Public and the Environment” (DOE 1990) and DOE Order 450.1 “Environmental Protection Program” (DOE 2003). DOE facilities are required to demonstrate in their Annual Site Environmental Reports that routine radioactive releases from their sites are protective of non-human receptors. Sites are encouraged to use the Graded Approach for this purpose. The purpose of this project was to complete these necessary activities and incorporate their results into an Idaho National Engineering and Environmental Laboratory- (INEEL-) specific guidance document. Four tasks were completed to appropriately evaluate the current monitoring program.

Task 1. Develop Conceptual Models And Evaluate Exposure Pathways.
Task 2. Define INEEL Evaluation Areas.
Task 3. Evaluate Sampling Locations And Media.
Task 4. Evaluate Data Gaps.

This guidance manual describes the application of the Graded Approach at the INEEL. All of the information developed in the four steps is incorporated, data sources are identified, departures from the Graded Approach are justified, and a step-by-step procedure for biota dose assessment at the INEEL is specified.

The conceptual model includes eleven compartments. Accompanying the conceptual model is a pathway diagram which outlines the sources of contamination, the mechanisms of transport between compartment, and the potential mechanisms by which receptors may be exposed.

The recommended, 3-step procedure for identifying assessment areas is to 1) determine and map the boundaries of contaminated areas, 2) determine and map the boundaries of habitat types, and 3) overlay the maps to identify the intersections. For this assessment, contaminated areas were defined by isopleths of air concentration from the National Oceanic and Atmospheric Administration’s MDiff model results, the boundaries of water bodies routinely measured for radionuclides, and the boundaries of the Subsurface Disposal Area (SDA). Habitat types were defined by a simplified vegetation type map. The intersection of these areas resulted in 37 discrete terrestrial evaluation areas on the INEEL. Depending on the extent to which ponds and rivers are filled, there may be up to ten more aquatic evaluation areas.

On the INEEL, soil samples are primarily taken from locations near facilities such as the Idaho Nuclear Technology Engineering Center (INTEC), the Test Reactor Area (TRA), and the Radioactive Waste Management Complex (RWMC) and very few sampling locations are in the more remote locations of the site. Thus, many of the assessment areas are not represented by soil samples. Sediment and surface water samples are not routinely taken from any of the natural waters on the site. The Argonne National Laboratory – West (ANL-W) ponds are the only waste ponds on site where surface water samples are routinely taken (although effluent samples are taken at the others) and sediment samples are not collected at any pond. Lack of appropriate soil, sediment, and water samples means some areas will not be appropriately assessed.

While methods are available to work around these data gaps, they may result in overly-conservative screening, causing unwarranted
failure and unnecessary expense. In order to properly implement the Graded Approach at the INEEL, it will be necessary to collect at least one surface soil sample in each numbered assessment area and analyze it for the expected radionuclides. For statistical validity we suggest that a minimum of ten soil samples be collected from each area. These samples should be spatially distributed in such a way as to incorporate variability due to soil type, topographic features and other sources of variability.

It will also be necessary to collect co-located surface water and sediments whenever water is present in the natural water bodies of the site. If the waste ponds on the site are to be included in the analysis, co-located water and sediment samples from these ponds will be required.

Included in this document is a recommended step-by-step process for applying the Graded Approach at the INEEL. The process is used for applying the approach at the site-wide level, but it is equally applicable for applying the approach at smaller scales with minor modifications. The Graded Approach is not intended to be applied blindly or in cookbook fashion. The steps presented here can be followed with little or no additional guidance. If the assessors find it necessary to deviate from this guidance, it will be necessary to seek additional guidance from ecologists familiar with the site and from those familiar with environmental contamination (e.g., the ESER program).
1. Introduction

1.1 Purpose And Scope Of The Guidance Document

In July 2002, The U.S. Department of Energy (DOE) released a new technical standard entitled *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2002a). The so-called “Graded Approach” was developed by the Biota Dose Assessment Committee (BDAC), a technical standards topical committee organized under the Department of Energy Technical Standards Team. The BDAC was led by Mr. Stephen Domotor, U.S. Department of Energy Air, Water, and Radiation Division, and its core membership consisted of technical experts from throughout the Department and its contractors, including this author. The Graded Approach has also been discussed in Jones et al. (2003), Higley et al. (2003), Higley, Domotor, and Antonio (2003a, 2003b).

The Graded Approach provides dose evaluation methods that can be used to meet the requirements of DOE Order 5400.5 “Radiation Protection of the Public and the Environment” (DOE 1990) and DOE Order 450.1 “Environmental Protection Program” (DOE 2003). DOE facilities are required to demonstrate in their Annual Site Environmental Reports that routine radioactive releases from their sites are protective of non-human receptors. Sites are encouraged to use the Graded Approach for this purpose.

The Graded Approach and its companion tool, the *RAD-BCG Calculator*, are effective, easy to use, and intuitive. However, as the Graded Approach makes clear, there are a number of ancillary issues and preparatory activities that must be evaluated and completed before the results from the approach can be considered definitive and reliable. These include such things as evaluating the environmental monitoring program to determine whether pathways relevant to non-human receptors are being sampled, and establishing appropriate assessment areas for non-human receptors. The purpose of this project is to complete these necessary activities and incorporate their results into an Idaho National Engineering and Environmental Laboratory- (INEEL-) specific guidance document.

The INEEL, like virtually every other DOE facility, designed their environmental monitoring program to evaluate potential radiation doses to humans. This was appropriate under the then-existing paradigm that protecting humans provided adequate protection to non-human biota. However, in recent years it has become clear that this is not always correct. One of the primary reasons for this new understanding is the observation that non-human species may be exposed to radioactivity through environmental pathways not available to, or generally monitored by, humans. Thus, while the Graded Approach is designed to make use of data currently collected by the INEEL, its correct application is predicated upon evaluating the current monitoring program to determine whether the appropriate samples are being collected.

Four tasks were completed to appropriately evaluate the current monitoring program. The results of these tasks and recommendations based on the results are reported in this document.

Task 1. Develop Conceptual Models And Evaluate Exposure Pathways.

Under this task, conceptual models and exposure pathways were developed for potential exposure of non-human biota to radioactive releases from routine INEEL operations. The conceptual models used for ecological risk assessment on the INEEL were evaluated to determine their utility for biota dose assessment and they were used as a starting point. Because, in the screening phases, the Graded Approach does not
evaluate specific receptors, the pathways identified must be rather all-encompassing. If it becomes necessary to apply the Graded Approach beyond the screening phases, target species may be selected. Therefore, this task also identified potential target species (based on previous ecological risk assessment work on the INEEL) and their exposure pathways.

Task 2. Define INEEL Evaluation Areas.

All phases of the Graded Approach involve some degree of spatial averaging of contaminant or biological data. For this reason, it is important to define spatial areas that are similar, over which averaging is appropriate. In the Graded Approach these areas are called “Evaluation Areas.” In the initial screening phase, the appropriate evaluation area is the entire INEEL. However, if the initial screen fails, it will be necessary to define smaller evaluation areas. Therefore, in this task, we defined evaluation areas for the INEEL, using the procedure outlined in the Graded Approach.

Task 3. Evaluate Sampling Locations And Media.

After the exposure pathways and evaluation areas are defined, the current sampling locations and media sampled were evaluated to determine whether the current monitoring data support the Graded Approach at the INEEL. We evaluated the uncertainty introduced into the INEEL’s evaluation of biota doses by the deficiencies we identified and we identified appropriate changes in the monitoring program and/or the Graded Approach as applied at the INEEL.

Task 4. Evaluate Data Gaps.

As the three steps identified above were carried out, data gaps were identified that, if filled, would improve the INEEL’s biota dose assessment. These gaps are described in detail and, where possible, work-arounds were identified. New studies that will adequately fill the gaps are briefly described where necessary and appropriate.

This guidance manual describes the application of the Graded Approach at the INEEL. We have not attempted a reinvention of the Graded Approach. Rather, the INEEL guidance is a supplement to the current technical standard and references it heavily. All of the information developed in the four steps is incorporated, data sources are identified, departures from the Graded Approach are justified, and a step-by-step procedure for biota dose assessment at the INEEL is specified.

1.2 Introduction To The Graded Approach

The Graded Approach is composed of three phases designed to guide a user from an initial, conservative screening using easily available data to, if necessary, a rigorous analysis using site-specific information that may require special studies to generate (Figure 1). The three phases, outlined in more detail below, are Data Assembly, General Screening, and Analysis.

1.2.1 Data Assembly

In this phase, dose assessors assemble and summarize the available information about sources, receptors, and routes of exposure for the area to be evaluated. Measured radionuclide concentrations in water, sediment, and soil are assembled for subsequent screening.

1.2.1.2 General Screening

The General Screening phase is the most conservative assessment of potential doses to non-human receptors. If the evaluated area passes this screen, no further assessment is required. The screen is conducted by comparing the maximum measured radionuclide concentration in each environmental medium (water, sediment, soil) with the appropriate, radionuclide-specific Biota Concentration Guide (BCG).
Biota Concentration Guides, provided in the Graded Approach documentation (DOE 2002a), represent the limiting radionuclide concentration in an environmental medium which would not result in exceeding the recommended dose standards. Biota Concentration Guides were derived for reference organisms representing an aquatic animal, a riparian animal, a terrestrial plant, and a terrestrial animal. The recommended dose standards used to derive the BCGs were 10 mGy d\(^{-1}\) (1 rad d\(^{-1}\)) for aquatic animals and terrestrial plants, and 1 mGy d\(^{-1}\) (0.1 rad d\(^{-1}\)) for riparian and terrestrial animals (IAEA 1992).

This phase, and all subsequent phases, can be completed using the *Rad-BCG Calculator*, a software tool provided with the Graded Approach.

### 1.2.1.3 Analysis

This phase consists of three increasingly detailed, site-specific, and less conservative analysis steps: Site-specific screening, Site-specific analysis, and Site-specific biota dose assessment. At each step, if the measured radionuclide concentrations do not exceed the site-specific BCGs calculated in that step, the process is complete and no further steps are required.
1. **Site-specific screening** – This step uses more realistic site-representative lumped parameters (e.g., bioaccumulation factors) in place of the default parameters used in the general screening phase. In addition, temporal and spatial mean radionuclide concentrations may be used.

2. **Site-specific analysis** – In this step, analysts use a kinetic/allometric modeling tool, provided in the methodology, to modify multiple parameters representing contributions to the internal dose of terrestrial and riparian animal organism types. These parameters include such things as body mass, rate of food/soil consumption, inhalation rate, life span, and biological elimination rate. The parameters are adjusted to represent site and organism-specific characteristics.

3. **Site-specific biota dose assessment** – This step is a full-scale, site-specific assessment involving the collection and analysis of biota samples. It will be consistent with the widely-used ecological risk assessment paradigm involving problem formulation, analysis, and risk characterization as applied on the INEEL (VanHorn et al. 1995). Because these activities are expensive, the purpose of the Graded Approach is to demonstrate true compliance with the standards using existing data from environmental monitoring.
2. INEEL Conceptual Models And Exposure Pathways

In order to answer the question of whether the current environmental monitoring program samples the appropriate pathways, at the appropriate times and places, to evaluate doses to non-human receptors, it is necessary to develop a conceptual understanding of how environmental contamination may be reaching potential receptors. This is accomplished through the use of conceptual models. A conceptual model is a schematic representation of what environmental compartments are believed to be important and how assessors believe contamination moves from compartment to compartment.

It is important to understand that conceptual models are developed to meet specific needs and there is no single conceptual model that will be applicable to every purpose on the INEEL. The model developed for this biota dose assessment (Figure 2) used the conceptual model developed for CERCLA-driven ecological risk assessment on the INEEL as a starting point, but deviated from it where necessary. For example, the Graded Approach specifically excludes immersion in air as an effective pathway for non-human receptors. Thus, this conceptual model does not incorporate that pathway.

The conceptual model includes eleven compartments, defined as follows:

- **Surface Water** – all permanent or perennial, lentic or lotic water above the ground surface.
- **Subsurface water** – all water, except included water, existing below the surface of the soil or sediment.
- **Surface Soil** – all soil in which a profile of $^{137}$Cs from global fallout can generally be identified.
- **Sub-soil** – the layer(s) of mineral and organic material between the surface soil and bedrock.
- **Sediment** – the layer of mineral and organic material below a body of surface water which is saturated when water is present.
- **Aquatic Plants** – plants which carry out their normal life cycle fully or partially submerged in surface water.
- **Aquatic Animals** – animals which carry out their normal life cycle fully or partially submerged in surface water.
- **Riparian Plants** – plants which carry out their normal life cycle in areas not usually submerged in surface water but which derive their water from a surface water body, the saturated zone surrounding surface water, or the capillary fringe. The presence of these plants defines a riparian area.
- **Riparian Animals** – animals which carry out their normal life cycle primarily in riparian areas.
- **Terrestrial Plants** – plants which are neither aquatic nor riparian.
- **Terrestrial Animals** – animals which are neither aquatic nor riparian.

Accompanying the conceptual model is a pathway diagram (Figure 3) which outlines the sources of contamination, the mechanisms of transport between compartment, and the potential mechanisms by which receptors may be exposed.
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Figure 2. Conceptual model of the INEEL environment for use in a biota dose assessment using the Graded Approach (DOE 2002a).
Figure 3. Pathway diagram showing the potential pathways by which non-human receptors could be exposed to environmental radioactivity.
3. INEEL Evaluation Areas

The authors of the Graded Approach recommends against applying it across entire large sites like the INEEL because of the diversity of the environment and the contamination levels across the site. Instead, a procedure for dividing the site into “Evaluation Areas” is recommended. Evaluation areas are loosely defined as spatial areas in which the species and concentrations of contaminants and the ecological components are similar enough that those familiar with the areas are comfortable averaging parameters across the areas. The guidance for developing evaluation areas is not prescriptive and involves a great deal of professional judgment. However, the recommended, 3-step procedure is to 1) determine and map the boundaries of contaminated areas, 2) determine and map the boundaries of habitat types, and 3) overlay the maps to identify the intersections.

3.1 Contaminated Areas

Contaminated areas are defined in the Graded Approach as “areas with similar environmental concentrations of the same radionuclides” (DOE 2002a). Although the Graded Approach is focused on routine radioactive releases, these releases occur against a background of past releases which must be taken into account. Because the CERCLA-driven ecological risk assessments at the INEEL have already determined that past releases have no measurable impact on non-human species, the approach used in developing contaminated areas for this document was to use current, routine releases of radioactivity into the environment to establish contaminated areas. Sampling that might occur in those areas will integrate past and current contamination appropriately.

Three contaminant sources were used to establish contaminated areas at the INEEL: airborne releases, releases into surface water, and waste burial.

3.1.1 Airborne Releases

Each year, the National Oceanic and Atmospheric Administration (NOAA) calculates average atmospheric dispersion coefficients for the INEEL and the surrounding areas using the MDiff model. Isopleths based on the output from this model are published in the INEEL Annual Site Environmental Report (e.g., DOE 2002b) and used to calculate radiation doses to the hypothetical maximally exposed individual. Dispersion coefficients can be easily converted into annual average air concentrations, which can, in turn, be converted into surface soil concentrations. Therefore, the dispersion coefficient maps produced by NOAA from the MDiff model can serve as a surrogate for such concentrations.

Prior to 2001, input to MDiff was a unit release from a single point midway between the Test Reactor Area (TRA) and the Idaho Nuclear Technology and Engineering Center (INTEC). In 2001 and 2002, the MDiff input was a unit release, fractions of which came from TRA, INTEC, Test Area North (TAN), Argonne National Laboratory-West (ANL-W), the Radioactive Waste Management Complex (RWMC), and the Central Facilities Area (CFA). This change in methodology, while it better reflected reality, made it difficult to combine pre-2001 data with post 2001 data to obtain a long-term average dispersion coefficient.

The species of radionuclides potentially released are not distinguished between these facilities in the MDiff modeling. However, the modeled isopleths provide convenient boundaries between areas expected to have different concentrations of radionuclides. Therefore, in this analysis, we used the average dispersion coefficient isopleths from 2001 and 2002 as boundaries of airborne contamination areas.
3.1.2 Surface Water Releases
Gross alpha, gross beta, gross gamma, and tritium are routinely monitored in Industrial Waste Pond and Ditch and the Sanitary Waste Pond at ANL-W. Liquid effluents to the following ponds are also monitored for gross alpha and beta:

- INTEC Sewage Treatment Pond
- Naval Reactors Facility (NRF) Industrial Waste Ditch
- TAN Disposal Pond
- TRA Cold Waste Pond

These surface water bodies are all measured for gross alpha and gross beta and some are measured for specific radionuclides. Because the effluents entering these water bodies are the result of different processes, they are expected to contain different radionuclides in different concentrations. Thus, each of these water bodies was considered a different contamination area for this analysis.

3.1.3 Solid Waste Burial
The only location at the INEEL where solid waste is routinely released into the environment is the SDA. Therefore, the SDA was considered a contamination area in this analysis.

3.2 Habitat Types
Habitat types are defined in the Graded Approach as follows: “Within a habitat type, one assumes that ecological structure and function are sufficiently homogeneous to be represented by a single parameter and that the species of concern are distributed throughout the habitat type. Between habitat types one assumes structure and function are dissimilar” (DOE 2002a).

For this guidance these habitat types were identified by condensing the 1990 INEEL vegetation map (Anderson et al. 1996) to seven habitats (Table 1).

Except for wetlands, habitat types of less than 10 m² were not considered discrete habitat types in this analysis.

3.3 Evaluation Areas
Following the Graded Approach, evaluation areas were determined by overlaying the map of contaminated areas and the map of habitat types (Figure 4). Each area of discrete habitat that lay within a discrete contaminated area was defined as an evaluation area. In many cases, boundaries were drawn around areas that were

| Table 1. Habitat types defined for biota dose assessment and the original vegetation classifications (Anderson et al. 1996) included in them. |
|---|---|
| Habitat Type | Original Vegetation Classifications |
| Facilities | Facilities |
| Lava | New Lava, Basalt Rubble, Old Lava |
| Grassland | Basin Wildrye, Grassland, Recent Fires |
| Sagebrush Steppe off Lava | Steppe, Sagebrush Steppe off Lava, Sagebrush Rabbitbrush, Steppe Small Sagebrush (Steppe) |
| Sagebrush Steppe on Lava | Sage, Lowsage, Rabbitbrush on Lava, Sagebrush Steppe on Lava |
| Juniper Woodlands | Juniper Woodlands |
| Wetlands | Wetlands |
| Other | Shadow, Unknown, Sagebrush/Winterfat, Playa-Bare ground/Gravel-Borrow Pits, Old field-Disturbed Seedings, Salt Desert Shrub, Agriculture |
Figure 4. INEEL Biota Dose Evaluation Areas and Soil Sample Locations.
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mixtures of habitats, too fragmented to separate on this scale. This resulted in 35 discrete terrestrial evaluation areas on the INEEL. Depending on the extent to which ponds and rivers are filled, there may be up to eight more aquatic evaluation areas.

This process is effective at the scale of the entire INEEL but may break down in local assessments. Check with a competent ecologist (Section 8) to determine whether the habitats in your area require a more refined analysis.
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4. INEEL Receptors

The Graded Approach provides limited guidance for selecting site-specific receptors, including recommendations for INEEL-specific organisms (DOE 2002a, page M2-15ff.). These recommendations were based on BDAC member’s experience and rationale for their selection is found in the Graded Approach (DOE 2002a, page M2-15). In the following list, the organisms recommended in the Graded Approach are in bold type. The other receptors listed would also meet the criteria and may be preferable in some evaluations.

4.1 Aquatic Habitat

Except for waste ponds, aquatic habitat on the INEEL is ephemeral and there are few choices of potential receptors. Organisms present in waste ponds generally include only aquatic invertebrates and algae. In the natural, but ephemeral, waters fed by the Big Lost River and Birch Creek, the following organisms may serve as receptors, depending on the duration of the wet period.

- Aquatic Animals – Freshwater Amphipods (Gammarus sp.), Great Basin Spadefoot tadpole (Scaphiopus intermontanus), Shorthead Sculpin (Cottus confusus), waterfowl might be considered as aquatic or riparian animals.
- Aquatic Plants – cattail (Typha latifolia), common spike-rush (Eleocharis palustris)

4.2 Riparian Habitat

Small areas of natural riparian habitat exist along the banks of the Big Lost River and Birch Creek. In addition, areas along the banks of some waste ponds may be considered as riparian areas for the purpose of this evaluation. Exercise caution, however, to be certain that the species identified here are actually present in these areas.

- Riparian Animals – Great Basin Spadefoot adult (Scaphiopus intermontanus), waterfowl might be considered as aquatic or riparian animals
- Riparian Plants – Cottonwood (Populus deltoides), Western wheatgrass (Pascopyrum smithii)

4.3 Terrestrial Habitat

Virtually all of the INEEL is terrestrial habitat, making this group of organisms the most useful group. As before, enlist the help of competent ecologists (Section 8) to ensure the species listed here are present in your area.

- Terrestrial Animals – Deer mouse (Peromyscus maniculatus), Coyote (Canis latrans), Sage grouse (Centrocercus urophasianus)
- Terrestrial Plants – Sage brush (Artemisia tridentata), Rabbitbrush (Chrysothamnus viscidiflorus), Basin wild rye (Leymus cinereus)
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5. INEEL Sampling Locations and Media

Until 2001, the INEEL Environmental Monitoring Program routinely collected soil samples at various locations around the INEEL (Figure 4). However, Walker (2000) demonstrated soil concentration could reliably be determined using an in situ gamma spectrometry technique, and that procedure has replaced routine soil collection. A detector positioned one meter above the ground, facing downwards, is used to measure the radiation from gamma emitting nuclides present in the soil. Soils from grids related to each onsite facility are sampled on a two-year rotating basis. All sites are analyzed in-situ for gamma emitting radionuclides and 90Sr. Approximately 10 percent of the sites have a sample collected for laboratory analysis of gamma-emitting and transuranic radionuclides. Samples are collected from 0–5 cm (0–2 in.) and sieved at the sample site with the 35-mesh fraction being collected. The INEEL Environmental Monitoring Program also performs annual sampling of the CFA sewage treatment plant irrigation spray field to show compliance with the Wastewater Land Application Permit.

Argonne National Laboratory-West collects soil samples annually at locations along the major wind directions and at crosswind locations. Samples are analyzed for low-level alpha-, beta-, and gamma-emitting radionuclides.

Neither sediment nor surface water samples are routinely collected from the INEEL and analyzed for radionuclides. Gross alpha, gross beta, and gross gamma are measured in liquid effluents from some facilities, but these are not useful for biota dose assessment using the Graded Approach. More detail about the samples collected can be found in DOE 2002b.

5.1 INEEL Data Gaps

Soil samples are primarily taken from locations near facilities such as INTEC, TRA, and RWMC (Figure 4) and very few sampling locations are in the more remote locations of the site. Thus, many of the evaluation areas identified in Section 3.3 are not represented by soil samples. Sediment and surface water samples are not routinely taken from any of the natural waters on the site. The ANL-W ponds are the only waste ponds on site where surface water samples are routinely taken (although effluent samples are taken at the others) and sediment samples are not collected at any pond. Lack of appropriate soil, sediment, and water samples means some areas will not be appropriately assessed.

Because soil samples are taken near facilities, those areas with the expected highest concentrations can be assessed. Soil concentrations in areas where samples are not available can be estimated using the modeled air concentrations from MDiff and literature-derived deposition velocities for the vegetation types in the various assessment areas. Provided conservative values of the deposition velocities are used, this should result in conservative, or “safe” errors in screening. However, it may result in overly-conservative screening, causing unwarranted failure and unnecessary expense.

Effluent samples can be used in place of surface water samples for most waste ponds on site, recognizing that effluents will likely have higher concentrations of radionuclides than the surface waters into which they are discharged. However, with few exceptions, radionuclides in effluents are reported as gross, alpha, beta, and gamma rather than as individual radionuclides. These can be used for screening by making conservative assumptions about the constituents, but this may result in overly-conservative screening, causing unwarranted failure and unnecessary expense. The lack of co-located sediment samples also introduces uncertainty because the spreadsheets assume sediment concentrations using a most probable distribution coefficient (Kd).

No samples are routinely collected from natural surface waters on the site, or their sediments, and analyzed for radionuclides. In most years,
this is not of major concern because of the lack of natural surface water. In wet years, however, it may introduce a high degree of uncertainty. This is because, when surface water is present, it represents a highly attractive and important resource for the native organisms. When water is present in the Big Lost River, the Sinks, or the Spreading Areas, animals may be attracted to the site which would not otherwise be present. Resident animals may reduce their normal home range, and migratory animals may stay in the area longer to take advantage of the water resource. All of these conditions may result in higher doses to a variety of organisms.

5.2 Recommendations
In order to properly implement the Graded Approach at the INEEL, it will be necessary to collect at least one surface soil sample in each numbered assessment area and analyze it for the expected radionuclides. For statistical validity we suggest that a minimum of ten soil samples be collected from each area. These samples should be spatially distributed in such a way as to incorporate variability due to soil type, topographic features and other sources of variability.

It will also be necessary to collect co-located surface water and sediments whenever water is present in the natural water bodies of the site. If the waste ponds on the site are to be included in the analysis, co-located water and sediment samples from these ponds will be required.
6. Step-By-Step Guidance For Applying The Graded Approach At The INEEL

This guidance is a recommended process for applying the Graded Approach. The process is used for applying the approach at the site-wide level, but it is equally applicable at smaller scales with minor modifications. These modifications will be pointed out as appropriate.

The Graded Approach is not intended to be applied blindly or in cookbook fashion. The steps presented here can be followed with little or no additional guidance. If the assessors find it necessary to deviate from this guidance, it will be necessary to seek additional guidance from ecologists familiar with the site and from those familiar with environmental contamination (e.g., the ESER program). See Section 8 for contact information of people who can assist you.

The following step descriptions are related by number to a flow chart of this process (Figure 5).

6.1 Phase 1 – Data Assembly

6.1.1 Develop a Conceptual Model
This first step requires the assessors to assemble knowledge about the sources, receptors, and routes of exposure into a conceptual model of how radioactivity might be transported through the site and what effects it may have. The level of detail required may increase as one progresses through the Graded Approach. Thus, although this step is placed at the beginning of the flow chart, it may have to be revisited at various stages of the assessment. For general screening in the site-wide assessment, the conceptual model developed in this guidance (Section 2) fulfills this requirement. For more detailed assessments, this conceptual model can be used as a base from which to develop more detailed models. If you find it necessary to develop a new conceptual model, we recommend you seek assistance from ecologists and monitoring specialists.

6.1.2 Determine Evaluation Areas
Evaluation areas have already been defined in this guidance (Section 3) for the site-wide assessment. If you are performing an assessment for an individual facility or operation, these evaluation areas may be defined at too coarse a scale and it is important to evaluate whether they are applicable. Consult with an ecologist and a contaminant specialist. If the pre-defined evaluation areas are not appropriate, define new areas using the procedure outlined in the Graded Approach and in Section 3 of this guidance.

6.1.3 Assemble Soil, Sediment, and Water Data
The next step is to assemble and organize data for concentrations of radionuclides in soil, sediment, and surface water. For aquatic and riparian areas, co-located water and sediment samples will produce the most meaningful results. If the water and sediment data are not co-located, the RAD-BCG calculator will calculate the missing sediment and or water concentrations based on a default $k_d$.

6.1.4 Match the Data With the Areas
It is important to have relevant data for each of the evaluation areas in your assessment. If such data are available, move on to step 6.2.1. If some areas have no relevant data, it may be necessary to return to step 6.1.2 to reevaluate the evaluation areas, identify new data sources, or develop and justify work-arounds.
6.2 Phase 2 – General Screening

6.2.1 Identify the Highest Concentration

For general screening, the highest concentration of each radionuclide, in each medium, in each Evaluation Area should be identified and entered into the RAD-BCG Calculator. The highest concentrations provide the most conservative case, which is appropriate for general screening.

6.2.2 Run the RAD-BCG Calculator

A sum of fractions (SOF) approach is used to compare measured radionuclide concentrations with BCGs provided in look-up tables in the Graded Approach. Although the necessary math can be done by hand, the RAD-BCG Calculator is a convenient spreadsheet-based software tool that can simplify this process and reduce human caused error. The Graded Approach Provides instructions for running the RAD-BCG Calculator (see, for example, the box on page M1-34 of DOE 2002a). In the General Screening phase, the RAD-BCG Calculator calculates the Sum of Fractions (SOF) using default parameters and the highest concentrations in each Evaluation Area as defined in step 6.2.1.

6.2.3 SOF < 1?

If the SOF calculated by the RAD-BCG Calculator is less than 1, all that remains is to document your assumptions and results. You have demonstrated compliance with the dose rate limits defined in Section 1.2.1.2. However, an SOF greater than 1 does not necessarily indicate a failure to comply, but only that further analysis is required. In this case, move on to step 6.2.4.

6.2.4 Determine SOF for Background Concentrations

If you have established a representative reference area, radionuclide concentrations from that area may be used to account for the possible existence of a naturally high background. Determine the concentrations of the relevant radionuclides in soil, sediment, and water from the reference area, enter these concentrations into the RAD-BCG Calculator, and determine the SOF for the background concentrations.

6.2.5 Background SOF ≥ Measured Media Concentrations?

If the SOF from the background concentrations is greater than or equal to the SOF calculated in step 6.2.2, document your assumptions and results. If the SOF from the background concentrations is less than the SOF calculated in step 6.2.2, there may be a greater than background risk. In this case, move on to the Analysis Phase in step 6.3.

6.3 Phase 3 – Analysis

6.3.1 Evaluate Input Data

The highest concentrations used in the general screening phase may not be representative of the true spatial and temporal variability of the contamination in the evaluation area. Thus, each of the factors in steps 6.2.5 through 6.3.1.3 should be considered to determine whether they might improve the degree to which your data represent the evaluation area. These factors should be considered at the same time rather than in sequence.

6.3.1.1 Consider Using a Mean Concentration

If there exist time series data or spatially distributed data of sufficient quantity and quality, it may be possible to use a time or space average, rather than a maximum, to represent the evaluation area. Of course, the applicability of these averages must be carefully considered and justified before using them. Detailed guidance is provided in the Graded Approach (DOE 2002a, page M2-27ff.)
Figure 5. Flow chart of the biota dose assessment process.
6.3.4.2 "Yes"

6.3.5 Run RAD-BCG Calculator Per Area

6.3.6 SOF < 1?

N

Y

Document Assumptions and Results

6.3.4.2 "No"

From 6.3.4.2 "Yes"

6.3.7 Evaluate Kinetic/Allometric Model Parameters

6.3.7.1 Identify Limiting Organism & Medium

6.3.7.1.1 Consider Correction Factor for Residence Time

6.3.7.1.2 Consider Correction Factor for Exposure Area

6.3.7.2 Riparian or Terrestrial Animal?

Y

N

6.3.7.3 Modify Model Parameters as Appropriate

6.3.7.4 Changes Made?

Y

N

6.3.8 Run RAD-BCG Calculator Per Area

6.3.9 SOF < 1?

N

Y

6.3.10 Consider Site Specific Biota Dose Assessment

Figure 5 (continued). Flow chart of the biota dose assessment process.
6.3.1.2 Consider Using a Refined Evaluation Area

The original evaluation areas were defined based upon the spatial distribution of the contaminant data and information about the habitats (primarily the vegetation types). On a smaller scale, it may prove useful to redefine evaluation areas, provided such redefinition can be justified based upon the spatio-temporal distribution of the data, smaller scale refinements of the habitats, or the ecological characteristics of the receptors known to exist in the area. For example, the habitats defined in Section 3.2 lump monocultures of crested wheatgrass and monocultures of cheatgrass into a single habitat category, grasslands. On a smaller scale, it may make sense to divide these into two separate categories. For another example, a small lava outcropping may not have been evident in the large scale map, but may be important for a facility-specific evaluation.

6.3.1.3 Consider Obtaining Additional Data

Additional radionuclide concentration data may help you better represent the range of concentrations in the evaluation area. In addition, for aquatic system evaluations, collocated water and sediment samples will greatly improve the quality of the analysis.

6.3.1.4 Were Changes Made?

If your evaluation indicated it was appropriate to use the mean concentration, refine your evaluation area, or you obtained additional data, move on to step 6.3.2 and rerun the RAD-BCG Calculator using the revised data. If these changes could not be justified, move to step 6.3.4.

6.3.2 Run the RAD-BCG Calculator

After these refinements, run the RAD-BCG Calculator again using the new or newly arranged data.

6.3.3 SOF < 1?

If the SOF calculated by the RAD-BCG Calculator is less than 1, document your assumptions and results and the analysis is complete. You have demonstrated compliance with the dose rate limits defined in Section 1.2.1.2. However, an SOF greater than 1 does not necessarily indicate a failure to comply, but only that further analysis is required. In this case, move on to step 6.3.4.

6.3.4 Evaluate BCG Parameters

The lumped parameters used by default in the RAD-BCG Calculator to estimate internal dose attempt to incorporate all pathways of intake by an organism. These parameters are intended for screening and are, therefore, conservative. However, they are not intended to represent specific conditions or receptors. In the next few steps, site-specific lumped parameters are selected and used to calculate site-specific BCGs. After you select site-specific receptors in step 6.3.4.1, your evaluation of site-specific lumped parameters (step 6.3.4.1.1) and site-specific KdS (step 6.3.4.1.2) should proceed in tandem rather than in sequence.

6.3.4.1 Identify Radionuclide-Specific Limiting Organism and Medium

In the “Data Entry” pages, the RAD-BCG Calculator identifies the limiting organism type from which the BCGs were derived for each environmental medium and radionuclide. For each of these limiting organisms, select a site-specific receptor you will use to evaluate radiation doses. The Graded Approach provides guidance for selecting site-specific receptors (DOE 2002a, p. M1-45 and M2-15). However, application of this guidance will probably require the support of ecologists and radioecologists (see Section 8).

INEEL-specific receptors are suggested in Section 4. These suggestions should be applied with care at specific locations on the INEEL to ensure that the receptors meet the requirements at that location.
6.3.4.1.1 Select Site-Specific Lumped Parameters

Once the site-specific receptors are chosen, the default lumped parameters can be compared with those developed specifically for the receptors under site-specific environmental conditions. These can be your own site-derived parameters or values published in the scientific literature or databases for receptors and conditions similar to those at your site. Be careful to avoid the temptation to select a different value for the lumped parameter just because it will raise the BCG. Any deviation from the default values must be justified as better representing your site. Site-specific lumped parameters should be entered into the appropriate organism type page in the RAD-BCG Calculator.

6.3.4.1.2 Select Site Specific Kd's

For aquatic system evaluations where co-located water and sediment samples are not available, the RAD-BCG Calculator uses a most probable Kd value to calculate the radionuclide concentration in the missing water or sediment component. In this step, if appropriate for your system, select site-specific Kd's for each radionuclide and enter them into the Dose Factors and Common Parameters page of the RAD-BCG Calculator. Site-specific Kd's can be your own site-derived parameters or values published in the scientific literature or databases for conditions similar to those at your site. Be careful to avoid the temptation to select a different value for the lumped parameter just because it will raise the BCG. Any deviation from the default values must be justified as better representing your site.

6.3.4.2 Were Changes Made?

If you identified and used appropriate site-specific lumped parameters or Kd's, move on to step 6.3.5 and rerun the RAD-BCG Calculator using the revised data. If these changes could not be justified, move to step 6.3.7.

6.3.5 Run the RAD-BCG Calculator

After these refinements, run the RAD-BCG Calculator again using the new data.

6.3.6 SOF < 1?

If the SOF calculated by the RAD-BCG Calculator is less than 1, document your assumptions and results and the analysis is complete. You have demonstrated compliance with the dose rate limits defined in Section 1.2.1.2. However, an SOF greater than 1 does not necessarily indicate a failure to comply, but only that further analysis is required. In this case, move on to step 6.3.7.

6.3.7 Evaluate Kinetic/Allometric Model Parameters

At this stage of the analysis, you have determined that models based on lumped parameters (e.g. Concentration Factors) may be too conservative to appropriately estimate radionuclide concentrations in your receptors and that you need to use more site- and receptor-specific modeling. However, rather than collect these data, you may take an intermediate step by estimating concentrations using a kinetic/allometric approach. The following steps guide you through this process. After you confirm your selection of site-specific receptors in step 6.3.7.1, consideration of correction factors for residence time (step 6.3.7.1.1) and exposure area (step 6.3.7.1.2) should proceed in tandem rather than in sequence.

6.3.7.1 Identify Radionuclide-Specific Limiting Organism and Medium

At this step, it is necessary to confirm the selection of a site-specific receptors you made in step 6.3.4.1. This is necessary because you may not have the data required for the next steps for the organisms you selected in the previous steps. The RAD-BCG Calculator identifies the limiting organism type from which the BCGs were derived for each environmental medium and radionuclide in the “Data Entry” pages. The
Graded Approach provides guidance for selecting site-specific receptors (DOE 2002a, p. M1-45 and M2-15). However, application of this guidance will probably require the support of ecologists and radioecologists (see Section 8).

INEEL-specific receptors are suggested in Section 4. These suggestions should be applied with care at specific locations on the INEEL to ensure that the receptors meet the requirements at that location.

6.3.7.1.1 Consider Correction Factor for Residence Time

For conservatism, the RAD-BCG Calculator assumes receptors inhabit contaminated areas 100 percent of the time. This may be appropriate for non-migratory animals with small home ranges, but it may not be appropriate if your selected receptor is a large, mobile animal. If the available data allow you to correct for less than 100 percent residence time, you may do so on the appropriate receptor type (e.g., terrestrial animal) page of the RAD-BCG Calculator by setting the default value of 1 to some decimal fraction of 1.

6.3.7.1.2 Consider Correction Factor for Exposure Area

The RAD-BCG Calculator also assumes 100 percent of the assessment area is contaminated 100 percent of the time. While conservative, this is not typically correct and may be adjusted using the same correction factor as that for residence time (step 6.3.7.1.1). These two correction factors are multiplicative. In other words, if the receptor is present on the area only half of the time (CF\textsubscript{residence time} = 0.5) and only half the area is contaminated or it is only contaminated half of the time (CF\textsubscript{exposure area} = 0.5), the correction factor may be calculated as $0.5 \times 0.5 = 0.25$. However, this is a very simplistic example and caution should be used when applying these correction factors as they can be influenced by season of use among other things. Seek the advice of a competent ecologist or radioecologist (Section 8).

6.3.7.2 Is The Limiting Organism a Riparian or Terrestrial Animal?

The correction factors considered in steps 6.3.7.1.1 and 6.3.7.1.2 potentially apply to any limiting organism. However, if the limiting organism is a riparian or terrestrial animal several parameters in the kinetic allometric models can also be modified to reflect site- and organism-specific conditions. If the limiting organism defined in step 6.3.7.1 is a riparian or terrestrial animal evaluate the kinetic/allometric equation parameters in step 6.3.7.3. If not, move on to step 6.3.7.4.

6.3.7.3 Modify Model Parameters as Appropriate

Kinetic/Allometric model parameters subject to revision for site- or organism-specific conditions include:

- Food source bioaccumulation factor ($B_{iv}$)
- Body mass
- Uptake fraction of radionuclide ingested/absorbed ($f_{1}$)
- Biological elimination rate constant ($\lambda_{bio}$)
- Food intake rate and supporting parameters (DOE 2002a, pages M3-56 – M3-57)
- Soil intake rate and supporting parameters (DOE 2002a, pages M3-56 – M3-57)
- Inhalation rate and supporting parameters (DOE 2002a, pages M3-56 – M3-57)
- Soil inhalation rate and supporting parameters (DOE 2002a, pages M3-56 – M3-57)
- Water consumption rate
- Maximum life span

In addition, the form of the default allometric equations can be modified.

As appropriate, modify the model parameters or equations in the RAD-BCG Calculator. This modification requires considerable site-specific knowledge about the environment and the limiting organisms, and should be undertaken only after consultation with ecologists and
radioecologists familiar with the site (see Section 8).

6.3.7.4 Were Changes Made?
If your evaluation indicated it was appropriate to correct for residence time or exposure area, or to modify the parameters of the kinetic/allometric models, move on to step 6.3.8 and rerun the RAD-BCG Calculator using the revised data. If these changes could not be justified, you have exhausted all of your screening possibilities and you must move on to step 6.3.10.

6.3.8 Run the RAD-BCG Calculator
After modifying the model parameters, run the RAD-BCG Calculator again using the new models.

6.3.9 SOF < 1?
If the SOF calculated by the RAD-BCG Calculator is less than 1, document your assumptions and results and the analysis is complete. You have demonstrated compliance with the dose rate limits defined in Section 1.2.1.2. However, an SOF greater than 1 does not necessarily indicate a failure to comply, but only that further analysis is required. In this case, move on to step 6.3.10.

6.3.10 Site-Specific Biota Dose Assessment
This exhausts all of the screening procedures available in the Graded Approach. These screening procedures are based on determination of radionuclide concentrations in environmental media likely already being collected in the site environmental monitoring program. At this stage it is necessary to collect biota from the evaluation area and measure concentrations of radionuclides in their tissues for a realistic evaluation of internal doses to site-specific receptors. Guidance for this process is presented in the Graded Approach (DOE 2002a, page M1-51ff.). However, the site-specific biota dose assessment process should be conducted by a team of ecologists, radioecologists, and ecological risk assessors. See Section 8 for sources of assistance with this process.
7. References


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## 8. Contacts for Assistance

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<tr>
<td>Roger Wilhelmsen</td>
<td>INEEL</td>
<td>208-526-9401</td>
<td>208-526-2448</td>
<td><a href="mailto:rnw@inel.gov">rnw@inel.gov</a></td>
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<td>Tim Reynolds</td>
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Appendix 1: 2002 Case Study

The following case study consists of the actual site-wide biota dose assessment for the 2002 INEEL Annual Site Environmental Report. This assessment will fulfill DOE-ID’s obligation to report impacts to biota. It will also provide both a test of the guidance and a good example of how an assessment is performed and reported. Some of the obstacles and pitfalls that had to be overcome for this assessment are, of course, unique to the site-wide assessment. However, the case study effectively illustrates some of the latitude assessors enjoy, provided their methods are well justified.

A.1 Introduction

The impact of environmental radioactivity at the INEEL on non-human biota was assessed using the Graded Approach procedure detailed in A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota (DOE 2002) and the associated spreadsheet (RadBCG Calculator). The Graded Approach evaluates the impacts of a given set of radionuclides on aquatic and terrestrial ecosystems by comparing available concentration data in soils and water with Biota Concentration Guides (BCGs). A BCG is defined as the environmental concentration of a given radionuclide in soil or water that, under the assumptions of the model, would not result in a dose rate greater than 1 rad/day to aquatic animals or terrestrial plants or 0.1 rad/day to terrestrial animals. If the sum of the measured environmental concentrations divided by the BCGs (the combined sum of fractions) is less than 1, no negative impact to populations of plants or animals is expected. No doses are calculated unless the screening process indicates a more detailed analysis is necessary.

The approach is “Graded” because it begins the evaluation using conservative default assumptions and maximum values for all currently available data. Failure at this general screening step does not necessarily imply harm to organisms. Instead, it is an indication that more realistic model assumptions may be necessary. Several specific steps for adding progressively more realistic model assumptions are recommended. After applying the recommended changes at each step, if the combined sum of fractions is still greater than 1, the Graded Approach recommends evaluating the next step. The steps can be summarized as:

1. Consider using mean concentrations of radionuclides rather than maxima.
2. Consider refining the evaluation area.
3. Consider using site-specific information for lumped parameters, if available.
4. Consider using a correction factor other than 100% for residence time and spatial usage in favor of more realistic assumptions.
5. Consider developing and applying more site-specific information about food sources, uptake, and intake.
6. Conduct a complete site-specific dose analysis. This is may be a large study, measuring or calculating doses to individual organisms, estimating population level impacts, and, if doses in excess of the limits are present, culminating in recommendations for mitigation.

Each step of this Graded Approach requires appropriate justification before it can be applied. For example, before using the mean concentration, assessors must discuss why the maximum concentration is not representative of the radionuclide concentration to which most members of the plant or animal population are exposed.

Evaluations beyond the initial general screening require assessors to make decisions about assessment areas, organisms of interest, and other things. Much of this work has been completed (Morris 2003). Of particular importance for the terrestrial evaluation portion of the 2002 Biota Dose Assessment is the division of the INEEL into evaluation areas based on potential soil contamination and habitat.
types (Figure A1). Details and justification will be provided in Morris 2003.

The Graded Approach and the RadBCG Calculator (DOE 2002) are designed to evaluate certain common radionuclides. Thus, this biota dose assessment evaluated potential doses from radionuclides detected in soil or water on the INEEL that are also included in the Graded Approach (Table A1).

Table A1. Radionuclides that can currently be evaluated using the Graded Approach (DOE 2002) compared to those detected in soil or water on the INEEL in 2003. Radionuclides in **bold type** are present in both lists and were included in this assessment.

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<td>$^{137}$Cs</td>
</tr>
<tr>
<td>$^{135}$Cs</td>
<td>$^{60}$Co</td>
</tr>
<tr>
<td>$^{137}$Cs</td>
<td>$^{152}$Eu</td>
</tr>
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<td>$^{40}$K</td>
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<tr>
<td>$^{154}$Eu</td>
<td>$^{239/240}$Pu</td>
</tr>
<tr>
<td>$^{155}$Eu</td>
<td>$^{235}$U</td>
</tr>
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<td>$^{3}$H</td>
<td>$^{233/234}$U</td>
</tr>
<tr>
<td>$^{129}$I</td>
<td>$^{238}$U</td>
</tr>
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</tr>
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<td>$^{65}$Zn</td>
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<td>$^{95}$Zr</td>
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a. Analyzed as $^{239}$Pu.
b. Analyzed as $^{233}$U.

A.2 Aquatic Evaluation

For this analysis, maximum effluent data were used because actual pond water samples were not available. These data are assumed to overestimate actual pond water concentrations due to dilution in the larger volume of the pond. In the absence of measured pond sediment concentrations, the spreadsheet calculates sediment concentrations based on a conservative sediment distribution coefficient ($k_d$). The only available radionuclide specific concentrations were for $^{226}$Ra in TRA effluents and $^{90}$Sr in TAN effluents (Table A2). These data were combined in a site-wide general screening analysis that failed because of the high concentration of $^{226}$Ra in TRA effluents (Table A2, First Screening). The $^{90}$Sr in the TAN pond was low enough to pass the screen and did not contribute significantly to this failure. Assuming dilution in the pond, we reevaluated using an average concentration of $^{226}$Ra in the TRA effluent rather than a maximum. This value also failed the screen (Table A2, Second Screening). The “riparian animal” was identified as the critical organism by the RadBCG Calculator. The TRA pond is lined and not attractive to organisms and is surrounded by a chain-link fence. No riparian animals have been documented to use the pond. Therefore, we made the still-conservative assumption that organisms would only have access to, and use, the pond for 2 weeks out of the year and adjusted the correction factor from a value of 1 to a value of 0.038 (2 weeks/52 weeks). Using these assumptions, the combined sum of fractions was less than 1 and the screen was passed (Table A2, Third Screening).

A.3 Terrestrial Evaluation

For the initial terrestrial evaluation we used maximum concentrations from the M&O contractor 2003 soil sampling (Figure A1; Table A3). These concentrations failed the initial screen (Table A3, First Screening) because of high $^{137}$Cs concentration in a sample from evaluation area 6 (Figures A1 and A2). For this reason, we removed area 6 from the analysis and used the remaining maximum soil concentrations (Table A3, Second Screening). Evaluation of potential harm to non-human biota
Figure A1. Evaluation areas and current soil sampling locations on the INEEL. Areas with the same number are in the same evaluation area (Morris 2003).
Table A2. Effluent data, Biota Concentration Guides, and Sums of Fractions, and Combined Sums of Fractions for biota dose assessment of aquatic ecosystems on the INEEL. See DOE 2002 for definitions and a detailed description of the procedure.

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<thead>
<tr>
<th>Nuclide</th>
<th>Water BCG$^a$ (pCi/L)</th>
<th>Effluent Concentration (pCi/L)</th>
<th>Partial Fraction$^b$</th>
<th>Sediment BCG (pCi/g)</th>
<th>Calculated Sediment Concentration$^c$ (pCi/g)</th>
<th>Partial Fraction$^d$</th>
<th>Sum of Fractions$^e$</th>
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a. Biota Concentration Guide.
b. Effluent Concentration/Water BCG.
c. Calculated by the RadBCG spreadsheet based on the effluent concentration (DOE 2002).
d. Calculated Sediment Concentration/Sediment BCG.
e. Sum of the Partial Fractions.
f. See the text for the rationale for the various screenings.
g. Sum of the Sums of Fractions. If the Combined Sum of Fractions $< 1$, the site passes the screening evaluation.

Figure A2. Histogram of $^{137}$Cs concentration in soils in evaluation area 6 (Figure A1). The histogram bar marked 1 represents the number of samples with concentrations between 0 and 1 pCi/g; the bar marked “2” represents the number of samples with concentrations between 1 and 2 pCi/g; etc.
Table A3. Soil concentration data, Biota Concentration Guides, and Sums of Fractions, and Combined Sums of Fractions for biota dose assessment of terrestrial ecosystems on the INEEL. See DOE 2002 for definitions and a detailed description of the procedure.

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<th>Nuclide</th>
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Second Screening \(^g\)

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\(a\). Biota Concentration Guide.
\(b\). Effluent Concentration/Water BCG.
\(c\). Calculated Sediment Concentration/Sediment BCG.
\(d\). Sum of the Partial Fractions.
\(e\). See the text for the rationale for the various screenings.
\(f\). Sum of the Sums of Fractions. If the Combined Sum of Fractions < 1, the site passes the screening evaluation.

From maximum detected soil and water concentrations over the entire INEEL, with the exception of evaluation area 6, resulted in a combined sum of fractions less than 1.

We evaluated area 6 separately. Because it is a very large area (Figure A1) with wide variation in soil concentrations and few samples with high concentrations (Figure A2), we determined that it was appropriate to use average soil concentrations in this assessment rather than maxima. The average soil concentrations resulted in combined sums of fractions less than 1 (Table A4).

A.4 Conclusion

Based on the results of the Graded Approach there is no evidence that INEEL-related radioactivity in soil or water is harming populations of plants or animals.
Table A4. Soil concentration data, Biota Concentration Guides, and Sums of Fractions, and Combined
Sums of Fractions for biota dose assessment of Evaluation Area 6 (Figure A1) on the INEEL using
spatially averaged soil concentrations. See DOE 2002 for definitions and a detailed description of the
procedure.

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<th>Soil BCG (pCi/g)</th>
<th>Soil Concentration (pCi/g)</th>
<th>Partial Fractionc</th>
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<td>2×10⁻³</td>
<td>5.19×10⁻¹</td>
<td>3×10⁻⁴</td>
<td>3×10⁻⁴</td>
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</tr>
</tbody>
</table>

a. Biota Concentration Guide.
b. Effluent Concentration/Water BCG.
c. Calculated Sediment Concentration/Sediment BCG.
d. Sum of the Partial Fractions.
e. Sum of the Sums of Fractions. If the Combined Sum of Fractions < 1, the site passes the screening
evaluation.

A.5 References


Operations Office.