Evaluating the Probablistic Land-Use Scenarios in the Radiological Dose Assessment for License Termination

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ABSTRACT

A recent trend in establishing regulatory policy regarding environmental cleanup has been the adoption of a risk-informed decision approach. This approach places an emphasis on the development of a defensible technical basis upon which cleanup decisions can be understood and accepted by stakeholders. The process has been exemplified by the U.S. Nuclear Regulatory Commission’s (NRC’s) approach to implement its License Termination Rule in *Title 10, Part 20, Subpart E of the Code of Federal Regulations* (10 CFR 20, Subpart E), for which probabilistic radiological dose assessment has been a key technical element for demonstrating compliance. Further guidance including NUREG-1757 and its supplemental document are also prepared for this purpose. The approach also entails extensive data collection to cover the range of parameter variability, along with interpretations of the probabilistic dose results and demonstration of compliance. One major remaining issue, however, involves the future use of the land following cleanup. Land use is a key factor that may profoundly influence dose assessment, which in turn will affect the level of cleanup and therefore the associated costs. Despite this, incorporation of land-use considerations into the current probabilistic dose assessment approach has not actually been performed in the regulatory process. In order to address the issue, a study was initiated to evaluate the potential influence of land use on dose analysis, to understand the possible ramifications in cleanup decision-making. A probabilistic distribution based on land use was developed as input into the probabilistic RESRAD analysis for the demonstration of this approach.. This results in an understanding of the characteristics of dose distributions as exhibited by various land-use scenarios. By factoring in the probability distribution of land-use scenarios, the potential “levels of conservatism” can be explicitly defined and evaluated. The results allow the quantification of the potential influence of land-use scenario assumptions on the dose and the variations in the results by type of radionuclide as well as by regional land-use patterns. Further improvement of the study can be utilized to support the NRC’s goal in achieving “realistic conservatism” in its license termination activities

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INTRODUCTION

In 2002, the NRC issued NUREG-1757, *Consolidated Nuclear Material Safety and Safeguards (NMSS) Decommissioning Guidance* (NRC 2002a) and, in 2005, its supplement (NRC 2005). This guidance provides the most recent overall framework for dose assessment and regulatory decision-making at sites undergoing decommissioning. It also addresses compliance issues, as well as evaluation and acceptance criteria of the License Termination Rule, 10 CFR Part 20, Subpart E. These regulatory requirements establish a dose criterion (i.e., 25-mrem annual dose to the average member of the critical group) for the release of sites for unrestricted use, and it requires that the residual radioactivity be reduced to levels that are as low as reasonably achievable (ALARA). Subpart E also establishes criteria for license termination with restrictions on future land use, as long as specific conditions are met. Accordingly, the license termination process requires that licensees submit a decommissioning plan (DP) or license termination plan (LTP) to demonstrate that the proposed decommissioning activities will comply with the provisions of 10 CFR Part 20, Subpart E. This process entails a comprehensive radiological dose assessment, as described in NUREG-1757 (NRC 2002a).

In large measure, NUREG-1757 represents part of the NRC's continued effort to support the risk-informed regulatory framework that appears in NRC SECY-98-144 (NRC 1998a). NRC has since made considerable improvement in clarifying its licensing and compliance demonstration processes for license termination. Such effort has been reflected in a series of regulatory initiatives and directives (NRC 1998b; 2000a,b,c; 2003a; 2004). In addition to consolidating the technical guidance on dose assessment, NUREG-1757 also provides general guidance on addressing and resolving some regulatory issues such as the demographical and socio-economical aspects of the site (i.e. probable and credible land-use scenarios).

The unresolved and overriding issues in dose analysis that is crucial for license termination are the potential uncertainty associated with land-use scenarios and how to properly address it, through the use of the RESRAD code (NRC 2000b). However, for lack of specific guidance, the future land-use scenario assumption remains largely a policy issue that is yet to be fully developed (NRC 1994, 2004, Abu-Eid 2005). Under current NRC policy, scenarios fall only in the three general categories: "likely" ("reasonably foreseeable"), "less likely," or "unlikely," which would require further clarification for implementation. Toward this end, current NRC guidance has ranged from a qualitative approach to a more quantitative approach such as the assignment of weighting factors or even a probabilistic analysis (Abu-Eid 2005). This issue is further discussed in a supplement to NUREG-1757 (NRC 2005).

In light of the NRC's existing policy of risk-informed regulation, it is imperative that a defensible and technically feasible scientific basis be established, to support major NRC policy and guidance on how future land use should be addressed probabilistically in dose analysis to demonstrate compliance with clean up regulations in a realistically conservative manner. This requires the establishment of a conceptual framework for assumptions about probabilistic treatment of land use scenarios and sensitivity analysis of key input parameters that may influence the dose analysis results. An estimate is then made of the "level of conservatism," which represents a measure of the conservatism provided by a particular scenario assumption against a potentially "realistic" scenario. This estimate would provide insight into the understanding of the term "conservatism" and how it may help NRC in developing its policy and guidance on appropriate consideration of land-use scenarios in performing probabilistic dose assessment and demonstrating compliance with clean up regulations. This would in turn assist NRC in achieving "realistic conservatism" in its licensing activities. Finally, through this process, the study also identifies a number of areas for continued future research and development to fill gaps in and update information on potential changes in demographics and socio-economic factors for certain regions of the U.S. to enable future NRC policy and guidance to incorporate these changes in a proactive and timely manner.

FUTURE LAND-USE SCENARIOS IN CLEANUP DECISION-MAKING

Despite the recent developmental efforts and advances in probabilistic assessments methodology, large uncertainties still remain. Such uncertainties are, in part, due to the site-specific information that remains to be developed, such as the distribution coefficients or "K_d factors" for particular radionuclides in the spatially and temporally variable hydrogeochemical regime. In such a situation the estimated doses are very sensitive to the variations in values of the K_d factors used in the dose analysis. However, a single important and overriding factor that has profoundly influenced decision-making in site cleanup regarding compliance with NRC regulations is the assumption about future land-use scenarios which would greatly influence the hydrogeochemical properties of the sites after cleanup and therefore, also the mobility of the residual radioactive materials in the environment, the biosphere and up the human food chain. To be conservative, the traditional default assumption for future land use has typically been the subsistence farmer scenario. In light of the future land-use uncertainty, such a scenario has been deliberately conservative, in that it maximizes the potential exposure pathways to the members of the critical group. However, the effect of such a gross assumption may have contributed to regulatory decision-making which impose unnecessary economic burden and could create or lead to other tremendous and unforeseen ramifications (such as economic or programmatic uncertainties) associated with the cleanup process and operations. Thus, the desire to seek a more definitive characterization of potential future land use has become an urgent issue to be considered in the decision-making for the safe and cost effective clean up process.

TECHNICAL ANALYSIS AND CASE STUDIES

General Approach

The general approach is based on the probabilistic RESRAD (NRC 2000a) analysis, except for the incorporation of the probability distribution of the land-use scenarios as an additional input parameter. Thus,

$$CDF_{composite-land-use,R}(D) = \sum_{land-use(i)} f_{R,i} \bullet CDF_i(D) \qquad (1)$$

where:

$f_{R,\,i}$ is the probability of land-use scenario i for region R,

$CDF_i(D)$ is the cumulative dose distribution function (calculated by the probabilistic RESRAD code) for individual land-use scenario *i*, and

$CDF_{composite\text{-}land\text{-}use,R}(D)$ is the “composite” cumulative dose distribution function for region *R*.

In order to analyze the land-use scenarios, it is essential to develop a probabilistic dose analysis for a set of baseline land-use scenarios from which appropriate pathways and parameters can be assigned, as conceptualized in the above equation. For this purpose, these scenarios are chosen to represent a broad spectrum of scenarios of various land uses. These are represented by the following four categories (for a total of six scenarios that will be analyzed in the following sections): (1) recreationist scenario, (2) industrial worker scenario (indoor and outdoor), (3) residential scenario (urban and suburban), and (4) subsistence farmer scenario. Of course, a larger number of scenarios can potentially be derived as variations of these general categories. However, for the sake of simplicity, no attempt is made to further refine these scenarios. Furthermore, one primary objective of the study is to evaluate the potential levels of conservatism rendered by the gross assumption using the subsistence farmer scenario that is routinely used in regulatory applications. Specifically, the subsistence farmer scenario is to be compared with the other (supposedly less conservative) scenarios in the analysis, from which the appropriate “level of conservatism” can be properly defined and quantified. As noted above, understanding the levels of conservatism represented by a particular land-use scenario is a key for deciding which future land-use scenario should be properly chosen and on what basis. Thus, the approach to this study consists of four major steps: (a) develop an approach to analyzing the doses for individual categories of land-use scenarios, (b) construct a probability distribution to represent these scenarios for a specific region of concern, (c) identify a “realistic scenario” by integrating (a) and (b) into the probabilistic dose analysis, and (d) compare the potential departure of an assumed scenario (such as the subsistence farmer scenario) and infer the potential level of conservatism. The following paragraphs describe the details of these steps.

Pathway Parameters and Input Assumptions for the Probabilistic RESRAD Analysis

To perform the dose analysis for different scenarios, the probabilistic RESRAD code was used, which was developed by Argonne National Laboratory (ANL) for the U.S. Department of Energy (DOE) (Yu et al. 2001) and the NRC (2000a). Since the RESRAD code analyzes doses to on-site individuals, the standard on-site land-use scenarios were selected that cover many activities that someone on a piece of decontaminated land might do: reside, work, recreate, and grow food. These were captured in the following land-use scenarios: subsistence farmer, suburban resident, urban resident, recreationist, and industrial worker. These scenarios cover the spectrum of scenarios ranging from land uses for a sparsely used site (such as the recreational scenario) to one with very frequent use (such as the subsistence farmer scenario). The idea was not to analyze all possible scenarios but to analyze some typical land-use scenarios for this exercise. Table I shows the potential human exposure routes and the applicable environmental pathways that correspond to these baseline land-use scenarios.

To establish a proper set of input parameters for the probabilistic dose analysis, ten radionuclides were chosen to represent the three basic categories of radionuclides: the beta emitters (represented by Sr-90 and Tc-99), the alpha emitters (represented by Pu-238, Po-210, U-238, Am-241, Th-232), and the gamma emitters (represented by Co-60, Cs-137, Eu-152). The relative importance of the pathways for these radionuclides is different, e.g., beta and alpha emitters cause a higher dose if they enter the body through inhalation or ingestion. In conjunction with these source radionuclides, the parameters are then developed for the four categories of land-use scenarios discussed above.

Each scenario was then translated from its potential transport and environmental pathways into a specific set of parameter values. The RESRAD code includes about 150 input parameters that can be classified as metabolic, behavioral, and physical. A metabolic parameter represents a metabolic characteristic of the potential receptor, and its value is independent of the scenario but may be different for different population groups. Behavioral parameter values depend on the receptor's behavior in the scenario (e.g., parameter values for a recreationist scenario could be different from those for a subsistence farmer scenario). The physical parameters are source- and site-specific, and their values do not change for a different group of receptors. In this analysis, for the metabolic and behavioral parameters, mean or median values, depending on the scenario, were used to represent an average member of the critical group. For physical parameters, distributions from the NUREG/CR-6676 report (NRC 2000b) were used. The parameter distributions assigned in that report were selected to be representative of adult males for generic site conditions that might be found on average throughout the United States. Many parameters and distributions are common to all scenarios. In general, most of the parameter values and distributions used in this study are RESRAD default values (NRC 2002b and Yu et al. 2001).

Since the peak dose depends linearly on radionuclide concentration, the analysis was done for unit concentration of each radionuclide for six land-use scenarios. For this analysis, 3,000 realizations (1,000 samples and 3 repetitions) were generated. For each set of sampled parameter values, peak doses in the time interval 0–1,000 years were calculated.

Constructing the Probability Distribution

Developing the probability distribution is key to the probabilistic analysis for scenarios. Since this is an area that is yet to be fully studied and refined, a number of assumptions are made. The assumptions are based on the following: land-use scenarios follow the regional land-use patterns that can be compiled from regional socioeconomic statistical data, and also that specific land-use scenarios (as discussed above) can be derived from the land-use patterns of a specific region, as shown from recent data published by the U.S. Department of Agriculture (Vesterby and Krupa 2001). Based on these assumptions, a few regional examples are analyzed, using a few representative states exhibiting contrasting land-use patterns: Connecticut, New Jersey, Iowa, and California.

TABLE I. Human Exposure and Environmental Pathways Used in the Subsistence Farmer, Suburban/Urban Resident, Indoor/Outdoor Industrial Worker, and Recreationist Scenarios

Human Exposure Pathways	Environmental Pathways		Subsistence Farmer	Suburban/Urban Resident	Industrial Worker Indoor/Outdoor	Recreationist
External radiation	Direct exposure		X[a]	X	X	X
Inhalation of dust	Resuspended dust		X	X	X	X
Ingestion of plant food	Irrigation		X	X/NA[b]	NA	NA
	Foliar deposition		X	X/NA	NA	NA
	Root uptake		X	X/NA	NA	NA
Ingestion of meat	Livestock water		X	NA	NA	X
	Livestock soil		X	NA	NA	X
	Fodder	Foliar deposition	X	NA	NA	X
		Root uptake	X	NA	NA	X
		Irrigation	X	NA	NA	NA
Ingestion of milk	Livestock water		X	NA	NA	NA
	Livestock soil		X	NA	NA	NA
	Fodder	Foliar deposition	X	NA	NA	NA
		Root uptake	X	NA	NA	NA
		Irrigation	X	NA	NA	NA
Ingestion of water	Surface water		NA	NA	NA	NA
	Ground water		X	NA	NA	NA
Ingestion of fish	Surface water		X	NA	NA	X
Ingestion of soil	Surface soil		X	X	X	X

[a] X = scenario is active.
[b] NA = scenario is not active.

An example utilizes the land-use probability distribution shown in Figure 1 for the State of New Jersey. For this region, there was a 0.14% probability that the land would be used for subsistence farming activities, 17% probability for use as suburban residences, 24% probability for use as urban residences, 9% probability that the industrial work would be conducted outdoors, 9% probability that the industrial work would be conducted indoors, and finally a 40% probability that the land would be used for some recreational activities.

Independently, regions were selected and the fractions of land used for various purposes were identified. In this particular example, statewide averages for California (CA), Connecticut (CT), Iowa (IA), and New Jersey (NJ) were constructed to roughly represent recreation, suburban, rural, and urban/industrial settings, respectively. The fractions of land in each state for cropland, grassland/ranges, forest, recreation, and urban settings were also compiled.

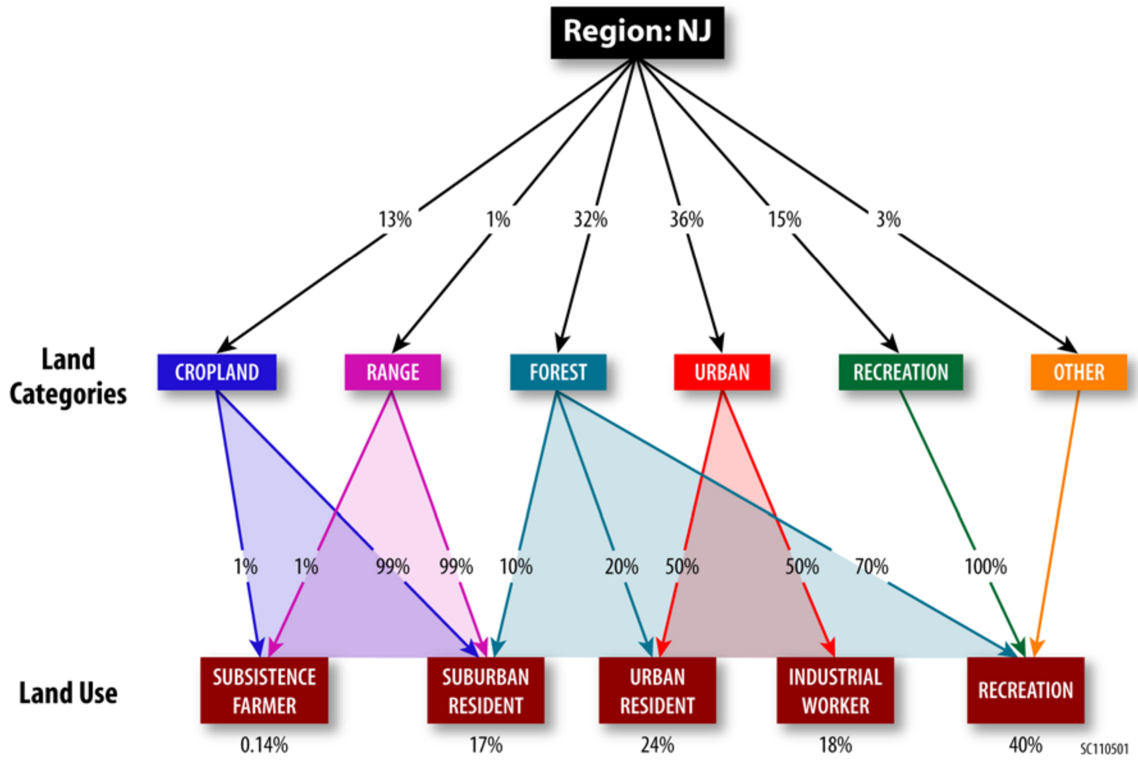

Fig. 1. An example of constructing a probability distribution from regional land-use data

To connect these land uses with the land-use scenarios, additional assumptions were made: (1) cropland and ranges can be used in farming activities; (2) forested areas can be used by suburban residents 10% of the time, by residents who do not grow food on-site (urban resident) 20% of the time, and the rest (70%) can be used for recreational activities; (3) recreational and other areas can be used for recreational activities; (4) urban areas are used by urban residents (50%) and for industrial activities (50%); (5) 1% of the farmers are subsistence (i.e., farms can be large commercial enterprises, but the condition for the subsistence category is that the farmer ingests half of his food from the site, which is only met by 1% of the farmers); (6) the remaining farmers (99%) maintain a garden that provides 10% of their food (suburban resident); and (7) half (50%) of the industrial workers are involved in indoor activities and half (50%) in outdoor activities. Such data has been adjusted to consider: special ethnic groups (Powell and Powell 2005); poverty-level farm families (Offutt and Gunderson 2005); farm populations (Dunbar-Ortiz 2005); and government statistics (USDA 2004).

RESULTS OF CASE STUDY AND DISCUSSION

Analysis and Results

The RESRAD (version 6.3 of NRC 2000a) was used to analyze all six land-use scenarios. The time frame used was up to 1,000 years, and the peak dose in this time horizon was used in the analysis. The analysis was conducted for all land-use scenarios and associated pathways listed in Table I, and for the ten radionuclides discussed earlier. Additionally, the case study was conducted to assess the composite dose presented by regional land-use patterns, as described by Equation 1.

The resulting probabilistic dose distributions for different land-use scenarios in New Jersey are shown in Fig. 2. for Am-241, where the maximum dose is observed in the subsistence farmer scenario; followed by the suburban resident, urban resident, outdoor worker, and indoor worker; and the minimum dose is observed in the recreationist scenario. Fig. 2. shows the dose distribution for Am-241 for different land-use scenarios along with the composite dose distribution [i.e., $CDF_{composite\text{-}land\text{-}use,R}(D)$ in Eq. 1] for the NJ regional land-use scenario.

Estimating the Levels of Conservatism

The level of conservatism (LC) is defined as the ratio of dose in the subsistence farmer scenario to the dose in the regional composite land-use scenario. The following equation defines the “level of conservatism,” $LC_{s,n}$, as:

$$LC_{s,n} = D_{s,n} / D_{c,n} \qquad (2)$$

where:

$D_{s,n}$ is the dose (or the cumulative probability of dose) evaluated for scenario s at the nth percentile, and

$D_{c,n}$ is the dose (or the cumulative probability of dose) evaluated for the composite land-use scenario c at the nth percentile.

The composite land-use scenario c represents a scenario weighted by the land-use probability of a particular region of interest. It is to be noted that the composite land-use scenario c is implicitly meant to be “realistic” by assumption, although there may not be a real-world scenario that corresponds to it. Nevertheless, by this definition, the factor represented by $LC_{s,n}$ would serve as a useful yardstick to consistently gauge the potential levels of conservatism represented by a particular choice of scenario. To demonstrate this in the following case examples, the analysis has been conducted on the subsistence farmer scenario about the levels of conservatism at 50th percentile (i.e., $LC_{sfm,50}$) and 75th percentile (i.e., $LC_{sfm,75}$) of the dose (in this case, the scenario *s* above is represented by the *sfm,* subsistence farmer scenario).

An example based on the region represented by New Jersey shown in Figure 2 is used for estimating the level of conservatism *LC*. In Fig. 2., the composite regional land-use scenario’s *CDF* indicates the initial dose contribution by the recreational scenario, which is followed by the indoor industrial worker, outdoor industrial worker, urban resident, suburban resident, and finally the subsistence farmer at a higher percentile. This example also shows that dose at the 50th percentile for this composite land use is about 0.024 compared to the dose at the 50th percentile for the subsistence farmer scenario of 0.43. This results in an estimated conservatism level of about 18.

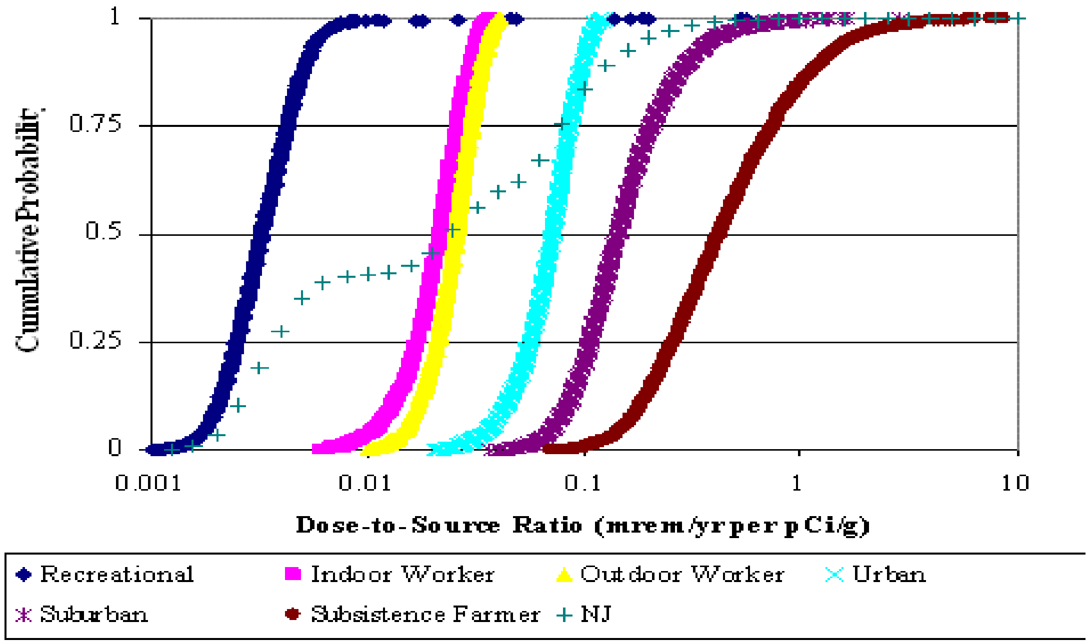

Fig. 2. Probabilistic dose distributions for Am-241 in different land-use scenarios along with the composite regional land-use scenario for NJ

Such information on the level of conservatism was obtained in a similar manner as described earlier and is presented in Table II for the four regions represented by Connecticut (CT), New Jersey (NJ), Iowa (IA), and California (CA), and for the ten radionuclides considered.

Discussion

It is shown in Table II that the dose distribution in the composite land-use scenario depends on the region, as well as on the radionuclide. The results for the alpha emitters, (Pu-238, Po-210, Am-241, Th-232, U-238) beta emitters (Tc-99, Sr-90), and gamma emitters (Co-60, Cs-137, Eu-152) are shown in Table II, to permit comparison of the differences between radionuclides, the regional composite land-use scenario, and various land-use scenarios. It appears that, overall, the estimated level of conservatism is the greatest for the beta emitters, followed by alpha emitters, and the gamma emitters.

Among the radionuclides analyzed, Co-60 shows the lowest level of conservatism, in most cases being lower than a factor of 2. On other hand, relatively high levels of conservatism are found for Tc-99, some exceeding a factor of 7,000 for $LC_{sfm,50}$, for example. Such variations by radionuclide are attributed to their dominant pathways for the scenarios analyzed. That is, since the primary pathway for Co-60 is external radiation, which is a pathway commonly shared by most scenarios, a small variation of doses is obtained. On the contrary, Tc-99 is a beta emitter whose primary pathways are through ingestion of food or water. The pathways for the latter case are not commonly shared by all scenarios, thus resulting in a significant disparity in dose.

Table II. Levels of Conservatism of Regional End-Use Scenarios

	Level of Conservatism at 50%[a]				**Level of Conservatism at 75%[b]**			
Nuclide	**NJ**	**CT**	**CA**	**IA**	**NJ**	**CT**	**CA**	**IA**
Tc-99	>7000	>7000	1954.56	6.55	2811.58	3732.81	16.22	5.84
Sr-90	136.96	125.30	36.46	10.49	57.33	65.16	21.93	9.66
Pu-238	24.50	34.41	35.93	3.75	11.89	13.76	7.37	4.16
Po-210	18.55	16.17	10.66	12.63	11.50	10.04	8.78	12.39
Am-241	17.54	25.57	59.23	3.30	9.51	10.59	6.37	3.87
Th-232	8.17	10.72	8.53	2.91	6.14	6.70	5.09	3.13
U-238	5.52	8.72	9.49	2.04	3.27	3.43	2.88	2.29
Cs-137	4.38	6.99	7.68	1.87	2.70	2.79	2.58	2.14
Co-60	2.55	4.80	16.26	1.20	1.48	1.53	1.43	1.24
Eu-152	2.37	4.13	62.53	1.04	1.26	1.29	1.22	1.03

[a] Defined as $D_{c,50} / D_{sfm,50}$, where *c* represents the composite land-use scenario to be compared to the subsistence farmer scenario, *sub*.

[b] Defined as $D_{c,75} / D_{sfm,75}$, where *c* represents the composite land-use scenario to be compared to the subsistence farmer scenario, *sub*.

The regional land-use influence is also evident in the differences among the four regions analyzed. The regional variations can also be quite significant. In general, where there are significant farmland uses, the levels of conservatism appear to be relatively small (within a factor 5) if the subsistence farmer scenario is assumed. In contrast, for urban or industrial setting like Connecticut (CT) or New Jersey (NJ), such differences tend to be larger, owing to the limited farmland uses.

SUMMARY AND CONCLUSIONS

This study demonstrates the feasibility of applying the probabilistic method to analyzing the conservative attributes of future land-use scenarios. It offers an insight into developing a quantification measure for characterizing the conservative nature of such scenarios, and thereby enabling a future policy decision for the selection of scenarios for site decommissioning. It further explores the potential level of conservatism embedded in the subsistence farmer scenario that has been frequently assumed for reaching such a decision for regulatory applications. The land-use data were collected, as an example, for four representative states. These land-use data were then used to develop probabilities for regional land-use scenarios. The potential land-use scenarios were then analyzed using the probabilistic RESRAD code, and the results were combined with the scenario probability to obtain a composite scenario dose distribution. The level of conservatism was then defined as the quotient of *n*th percentile dose of a scenario to the *n*th percentile dose of the composite scenario.

To derive the level of conservatism (defined at 50th and 75th percentiles) in the regional composite land-use scenario in this analysis, the percentage of the land-use scenario in each region was identified, and from this, the resulting land-use scenario fraction in each region was identified. Finally, the dose distribution of the regional composite land-use scenario was constructed. However, the analysis can be conducted in different ways, and the level of conservatism can also be defined differently. For example, the approach can be modified to explore from another angle, such as construction of a "realistic" critical group, instead of the formation of the composite dose distribution. Such an approach would be much more complex than the approach currently used in this study. Furthermore, more refined data on regional land-use patterns, as well as the specific end-use behaviors of the population need to be further evaluated and developed. Such improvement will further enhance the accuracy in characterizing the basis for future land-use selection and decision.

REFERENCES

1. Abu-Eid, R. (Boby), 2005, "*Realistic Scenarios for Dose Modeling Analysis – Examples of Decommissioning Cases*," DD&R 2005 Conference, Denver, CO, August 7-11.

2. Dunbar-Ortiz, R., 2005, *"Where Have All the Farmers Gone?"* MRzine, August 27. Available at http://mrzine.monthlyreview.org/dunbarortiz270805.html.

3. NRC, 1994, *Scenarios for Assessing Potential Doses Associated with Residual Radioactivity*, Policy and Guidance Directive, PG-8-08, Division of Waste Management, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, DC, May.

4. NRC, 1998a, *Commission Issuance of White Paper on Risk-Informed and Performance–Based Regulation,* SECY-98-144, prepared by Dr. Shirley Ann Jackson, Chairman.

5. NRC, 1998b, *Decision Methods for Dose Assessment to Comply with Radiological Criteria for License Termination*, NUREG/CR-1549, U.S. Nuclear Regulatory Commission, Washington, DC.

6. NRC, 2000a, *Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes,* NUREG/CR-6697 and ANL/EAD/TM-98, prepared by C. Yu et al., Argonne National Laboratory, Argonne, IL, for U.S. Nuclear Regulatory Commission, Washington, DC, Nov.

7. NRC, 2000b, *Probabilistic Dose Analysis Using Parameter Distributions Developed for RESRAD and RESRAD-BUILD Codes,* NUREG/CR-6676 and ANL/EAD/TM-89, prepared by S. Kamboj et al., Argonne National Laboratory, Argonne, IL, for U.S. Nuclear Regulatory Commission, Washington, DC.

8. NRC, 2002a, *Consolidated Nuclear Material Safety and Safeguards (NMSS) Decommissioning Guidance*, NUREG-1757, Vol. 1, Washington, DC, Sept.

9. NRC, 2002b, *Technical Basis for Calculating Radiation Doses for the Building Occupancy Scenario Using the Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Codes,*

NUREG/CR-6755 and ANL/EAD/TM-02-1, prepared by B. Biwer et al., Argonne National Laboratory, Argonne, IL, for U.S. Nuclear Regulatory Commission, Washington, DC, Feb.

10. NRC, 2003, *Realism and Conservatism,* Office of Public Affairs Publication No. S-03-023, remarks by Chairman N. Diaz at the 2003 Nuclear Safety Research Conference, Oct. 20.

11. NRC, 2004, *NRC Regulatory Issue Summary 2004–08, Results of the License Termination Rule Analysis,* Office of Nuclear Material Safety and Safeguards and Office of Nuclear Reactor Regulation, Washington, DC, May.

12. NRC 2005, *Updates to Implement the License Termination Rule Analysis,* NUREG 1757, Supplement 1, Draft Report for Comment, Washington, DC, Sept.

13. Offutt, S., and C. Gundersen, 2005, "Farm Poverty Lowest in U.S. History," Amber Waves. Available at http://www.ers.usda.gov/AmberWaves/September05/Features/FarmPoverty.htm.

14. Powell, K., and A. Powell, 2005, "History of the Amish in America." Available at http://pittsburgh.about.com/cs/pennsylvania/a/amish.htm.

15. USDA (U.S. Department of Agriculture), 2004, Average Farm Size in 2003. Available at http://www.unl.edu/nac/conservation/atlas/Map_Html/Demographics/National/Average_Farm_Size_2003/Average_Farm_Size_2003.htm.

16. Vesterby, M., and K.S. Krupa, 2001, *Major Uses of Land in the United States, 1997,* Statistical Bulletin No. 973, Economic Research Service, U.S. Department of Agriculture, Washington, DC.

17. Yu, C., et al., 2001, *User's Manual for RESRAD Version 6,* ANL/EAD-4, Environmental Assessment Division, Argonne National Laboratory, Argonne, IL, July.