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INITIAL ANALYSIS OF SELECTED SITE-SPECIFIC DOSE ASSESSMENT PARAMETERS AND EXPOSURE PATHWAYS APPLICABLE TO A GROUNDWATER RELEASE SCENARIO AT YUCCA MOUNTAIN

Prepared for

Nuclear Regulatory Commission
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P.A. LaPlante
S.J. Maheras
M.S. Jarzemba

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ABSTRACT

The Nuclear Regulatory Commission (NRC) is conducting a total system performance assessment for the proposed high-level radioactive waste (HLW) repository at Yucca Mountain (YM). The future U.S. Environmental Protection Agency (EPA) standard applicable to HLW disposal may require a dose or risk limit, and thus, this study was conducted to enhance the NRC understanding of site-specific input parameters for the calculation of doses or risks from the groundwater pathway. YM site-relevant data was obtained for irrigation, agriculture, resuspension, crop interception, and soil characteristics. A Monte Carlo based sensitivity analysis was used to identify predominant parameters. In this analysis, the GENII-S code was used to generate individual annual Total Effective Dose Equivalents (TEDEs) for 20 radionuclides and 43 sampled parameters based upon unit groundwater concentrations. Scatter plots and partial rank correlation coefficients were calculated and results indicate the crop interception fraction, irrigation rate, and grain consumption rate are correlated with TEDEs for specific radionuclides. Moderate correlations include the animal uptake scale factor and human consumption rates. Influential parameter groups correspond to expected pathway behavior of specific radionuclides. Results for radionuclides which transfer more readily to plants, such as ^{99}Tc, indicate crop ingestion pathway parameters are most highly correlated with TEDE and those which transfer to milk, such as ^{59}Ni, or beef (e.g., ^{79}Se, ^{129}I, ^{135}Cs, and ^{137}Cs) show predominant correlations with animal ingestion pathway parameters. Such relationships provide useful insights to parameters and exposure pathways applicable to doses from specific radionuclides.

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ACRONYMS

CNWRA	Center for Nuclear Waste Regulatory Analyses
DITTY	Dose In Ten Thousand Years
DOE	U.S. Department of Energy
DWM	Division of Waste Management
EPA	U.S. Environmental Protection Agency
FDA	U.S. Food and Drug Administration
GEMS	Graphical Exposure Modeling System
GIS	Geographic Information System
HLW	High-level radioactive waste
IAEA	International Atomic Energy Agency
IPA	Iterative Performance Assessment
IUR	International Union of Radioecologists
KTU	Key Technical Uncertainty
LHS	Latin Hypercube Sampling
LLW	Low-level radioactive waste
NAS	National Academy of Sciences
NCDC	National Climatic Data Center
NMSS	Office of Nuclear Material Safety and Safeguards
NOAA	National Oceanographic and Atmospheric Administration
NRC	Nuclear Regulatory Commission
NTS	Nevada Test Site
NTIS	National Technical Information Service
ORNL	Oak Ridge National Laboratory
PA	Performance Assessment
PRCC	Partial rank correlation coefficient
SCS	Soil Conservation Service
SNL	Sandia National Laboratories
SUNS	Sensitivity and Uncertainty Analysis Shell
TEDE	Total effective dose equivalent
TGEMS	Test Graphical Exposure Modeling System
TSPA	Total System Performance Assessment
USDA	U.S. Department of Agriculture
WIPP	Waste Isolation Pilot Plant
YM	Yucca Mountain

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QUALITY OF DATA, ANALYSES, AND CODE DEVELOPMENT

DATA: CNWRA-generated original data contained in this report meet quality assurance requirements described in the CNWRA Quality Assurance Manual. Sources for other data should be consulted for determining the level of quality for those data.

ANALYSES AND CODES: The GENII-S computer code (Leigh et al., 1993; Napier et al., 1988) was used for analyses contained in this report. This computer code is not controlled under the CNWRA Software Configuration Procedures.

1 INTRODUCTION

1.1 BACKGROUND AND JUSTIFICATION

The Energy Policy Act of 1992 (U.S. Congress, 1992) directed a National Academy of Sciences (NAS) committee to review certain aspects of the U.S. Environmental Protection Agency (EPA) standards applicable to licensing a high-level radioactive waste (HLW) repository. The committee recently completed their recommendations to the EPA which favor application of a risk standard based upon calculation of dose to an average member of a maximally exposed critical group (National Research Council, 1995). As a result, compliance demonstration by the U.S. Department of Energy (DOE) and compliance review by the Nuclear Regulatory Commission (NRC) could involve calculation of doses and risks to potentially affected individuals in a local critical group. Dose assessment results will be influenced primarily by input parameter values, assumptions, and models used in the assessments. Therefore, it is important to collect site-specific information to determine applicable local characteristics and parameter values and make valid decisions on important modeling assumptions.

The NRC Division of Waste Management (DWM) initiated dose assessment analyses for Yucca Mountain (YM) in Phase 2 of their Iterative Performance Assessment (IPA) (Nuclear Regulatory Commission, 1995a). This effort included a dose assessment code (DITTY—a module of GENII) (Napier et al., 1988) to estimate population doses from assumed release scenarios. At the conclusion of this work, the NRC recognized the need to gain a better understanding of the input parameters applicable to the YM site.

While the NRC has documented acceptable values for generic input parameters (Kennedy and Strenge, 1992; Nuclear Regulatory Commission, 1994; Daily et al., 1994), more credible doses could be calculated with site-specific input parameter values. Furthermore, recommendations from IPA Phase 2 work suggest existing parameter values may require adjustment or documented concurrence for continued use in IPA and parameter uncertanties and sensitivities need to be determined. The sensitivity analysis is conducted to identify those parameters that appear to have the most influence on variation in dose results. The results from a literature search for parameter information and a quantitative sensitivity analyses provide useful insights into dose assessment for YM which can aid current and future PA dose assessment activities. Results will support IPA Phase 3 dose assessment work and help prioritization of future effort with respect to estimation of parameters, enhance the DWM capability to review DOE dose assessments, and conduct more realistic confirmatory analyses of DOE work.

1.2 SCOPE OF WORK

In response to the need for site-specific input parameter information, this report provides a review of currently available information for determining particular site-specific parameter values. These parameter values are used in the GENII-S code (Leigh et al., 1993; Napier et al., 1988) for an analysis of parameter variation and sensitivity. A number of these parameters are also applicable to the DITTY (Napier et al., 1988) dose assessment code and can also be applied to other dose assessment codes based on similar conceptual models. Sections 2.2 and 3.2.4 provide details on methods used which further define the scope of work for this report.

This initial analysis is limited to scatterplot and correlation analysis. This type of analysis preserves the option to conduct more precise and detailed analyses in the future and is an efficient, albeit preliminary, means of gaining insights into the relationship between parameter variation and code results. Geometric means and geometric standard deviations of the doses are calculated for unit groundwater concentrations to improve dose estimates in the future when more precise values for radionuclide concentrations at the accessible environment are available.

The authors recognize radiological assessment is a diverse and growing field that offers a variety of techniques and methodologies. An equally diverse body of opinion exists regarding which approaches are best suited for a particular use. The DWM has not made decisions about which dose assessment code or procedures are best suited to YM analyses. Therefore, the authors of this report have selected methods that appear to have general acceptance in the field and have tried to clearly identify where assumptions and speculative judgments have been made. In many cases, parameter distributions are estimated and the methods and rationale are documented. Methods for selecting the parameter distribution types are generally consistent with methods identified in recent dose reconstruction work at Hanford, Washington (Snyder et al., 1994). In addition, parameters where no site-specific information could be obtained are noted in the text of the report. The scope of this activity did not permit application of expert elicitation techniques when information was limited. In such cases, generic parameter values from current NRC sources (Kennedy and Strenge, 1992) are used. Use of generic parameters is not a favored approach, but is considered a reasonable compromise in this analysis.

The GENII-S code was chosen for the quantitative analysis because it met the current needs for this project. Other equally valid methods and computer codes may exist that the DOE and the NRC could use to determine the values for uncertain parameters and conduct dose assessment calculations. When possible, the original data are provided to allow the option to use a different approach to dose assessment than is presented here.

1.3 STATUS OF NATIONAL ACADEMY OF SCIENCES COMMITTEE RECOMMENDATIONS TO U.S. ENVIRONMENTAL PROTECTION AGENCY

The Energy Policy Act of 1992 (U.S. Congress, 1992) directed the EPA to contract with the NAS/National Research Council for a study to provide findings and recommendations on reasonable safety standards for the disposal of HLW at the proposed YM repository site. A central issue is whether a health-based standard, based on doses to individual members of the public, would be reasonable. To address this question, the NAS proceeded to: (i) explore the technical bases for the current EPA standards for disposal of radioactive wastes; (ii) examine populations or individuals at risk, such as global or regional populations or the average or maximally exposed individual; and (iii) explore the development and status of health-based standards in different countries for high-level and alpha-bearing radioactive wastes. After receipt of the NAS findings and recommendations, the EPA will promulgate regulatory standards for the protection of the public from releases of radioactivity stored or disposed of in the proposed repository at the YM site. The NRC is then required to modify its technical requirements and criteria to be consistent with the final EPA standards.

The NAS recommendations are important to this report because they pertain to the type of dose and risk calculation(s) which may be required by forthcoming EPA standards. The choice of calculation impacts the selection of relevant dose assessment codes and, subsequently, the associated parameter information needs. Delays in the schedule resulted in recent publication of the recommendations and they therefore could not be reviewed completely for this writing. Nevertheless, the suggested approach involving calculation of doses to an individual member of a maximally exposed critical group appears to have many elements in common with the approach used in this report, even though the critical group concept was not formally employed in the analysis and the scope is more limited than that outlined by the NAS. The farming scenario was chosen for this analysis with the intent that the farmer would receive a maximal exposure relative to other individuals in the area, however, the characteristics of the farming individual (e.g., consumption rates, water use) were sampled from parameter distributions which include a range of possible values. In general, the results of this initial report are considered to be useful for supporting dose and risk assessment activities which follow from the NAS recommendations.

2 SITE-SPECIFIC CHARACTERISTICS AND PARAMETER VALUES

2.1 INTRODUCTION

The NRC/Center for Nuclear Waste Regulatory Analyses (CNWRA) IPA Phase 2 modeling activities introduced a dose calculation into the total performance calculation. To improve the realism of these calculations, some information on site-specific parameters was used. Recommendations from the IPA Phase 2 effort stressed the importance of additional work to confirm existing site-specific data and gather more information. The following literature search supports the need to enhance IPA Phase 3 dose analyses and gain a better understanding of available site-specific data sources.

2.2 METHODS

Prior to beginning the information search, the scope of the information needs was determined. While there are many general similarities in dose assessment codes, specific parameter data needs for a given analysis are determined by the dose assessment code. A detailed review of available risk assessment codes is not within the scope of the present task. Nonetheless, both the DITTY code (which was used for IPA Phase 2 analyses) and the more detailed GENII-S code are currently viewed as possible candidates for future dose assessments by the NRC. Both DITTY and GENII-S have overlapping parameter data needs, however, GENII-S is far more specific and data input intensive. Therefore, information requirements are established by considering the input requirements of GENII-S, to be inclusive of both codes.

A list of input parameters for both codes was created and reviewed for parameters likely to be influenced by site-specific conditions. General information categories were determined, and a list of keywords developed (see Appendix A) to conduct automated literature searches of major scientific literature databases. These databases include: NTIS (U.S. Government Abstracts: 1964-94), INSPEC (Science Abstracts: 1970-94), EI COMPENDEX-PLUS (Engineering Index: 1970-94), ENERGY SCITECH (Energy and Science Abstracts: 1974-94), POLLUTION ABS (Pollution Abstracts: 1970-94), and AGRICOLA (Agricultural Abstracts: 1979-94). Searches were further limited to 1989-94 to restrict the number of abstracts to a manageable number of recent articles (approximately 350). Abstracts were reviewed and relevant references were obtained for further review. Following this, an additional database search was conducted on well known authors involved in environmental research at the Nevada Test Site (NTS). This search yielded 100 additional abstracts that were also reviewed. Additional contacts with government agencies and individual researchers were made as necessary to facilitate the information gathering. The literature search results are presented in Section 2.3.

2.3 RESULTS

2.3.1 Population

While the EPA is likely to require calculation of an individual dose in its future HLW regulations, there is a possibility that a population dose may also need to be calculated. Therefore, population information is presented in this report as a reference, but is not used in the individual dose calculations discussed in Section 3. A population dose was calculated in IPA Phase 2 dose analyses and parameters were determined using the reference biosphere assumption (i.e., current estimates of biosphere parameters are assumed for long-term calculations since it is problematic to predict future states and human activity). Consistent with this concept, current estimates of the local population were used in the long-term dose assessments in IPA Phase 2.

The population information used in IPA Phase 2 was adopted from Logan et al. (1982). The original grid was updated with additional population counts for some of the major towns within the 100-km radius of the site (U.S. Department of Energy, 1988a). Logan determined the population by allocating counts of major population centers (such as the towns of Mercury, Beatty, Amargosa Farms, and Indian Springs) to the appropriate sectors of the grid. In addition, a 0.1 person/km^2 density was added to these populations to account for commuters, visitors on recreational activities, and ranchers. The population of areas between the population centers was determined by allocating average population densities to the number of acres per sector. This is a conservative estimate of the local population since it is likely that sectors exist that have no residents. Comparison of the total population in the IPA Phase 2 grid (22,421 residents) with 1990 census figures for Nye and Lincoln counties combined (21,556 residents) (U.S. Department of Commerce, 1990) shows the conservatism of the prior estimates of population size.

To determine more precise population figures for the area around YM, a new grid was developed from 1990 census population statistics at the census block level (see Figure 2-1). The values used in IPA Phase 2 analyses are shown in parentheses for comparison. An EPA Geographic Information System (GIS) population database and the information retrieval system known as Graphical Exposure Modeling System (GEMS) (Hunt et al., 1989) were used to generate the new grid. To obtain access to 1990 census data, it was necessary to use the test version of GEMS (TGEMS) that is a version of GEMS where new features are made available after they have been tested, but before all aspects are fully operational. The TGEMS code generates circular population grids by comparing grid coordinates with geographic population information to determine the number of population centroids that fall within each grid sector. A population centroid is the geographic center of a census block to which the population total is associated. TGEMS sums the population totals for each centroid within a grid sector to determine a sector population total. Thus, the TGEMS grid provides results which are geographically representative of the actual population at the census block level—the lowest level of stratification—at which the census collects population data for Nye County (U.S. Department of Commerce, 1990). When compared to the grid used in IPA Phase 2 dose assessments (22,421 residents), the total population estimate for the same area (14,441 residents) is lower in the TGEMS grid, as expected.

The population estimates used in IPA Phase 2 allocate population to all grid areas when it is likely that some areas are not populated. It is also true that the centroid based census methods in GEMS tend to aggregate dispersed population to a central location within the block. Nonetheless, the census data are based upon actual counts for each block rather than weighted estimates and are therefore expected to be more representative of the actual geographic population distribution in 1990.

The 100-km radius grid covers four counties in Nevada (Nye, 61-percent coverage; Clark, 0.4-percent coverage; Esmerelda, 0.01-percent coverage; and Lincoln, 2.46-percent coverage) and one county in California (Inyo, 2.52-percent coverage). The center of the grid was placed at the YM site which was interpreted from available maps to be at the coordinates of 36° 50′ 00" latitude and 116° 30′ 00" longitude. Areas of population concentration (i.e., cities or towns) which are included in the grid are Death Valley and Shoshone, California; and Indian Springs, Beatty, Lathrop Wells, Mercury, and Pahrump, Nevada. There were 30 census blocks included in the grid and each sector with a

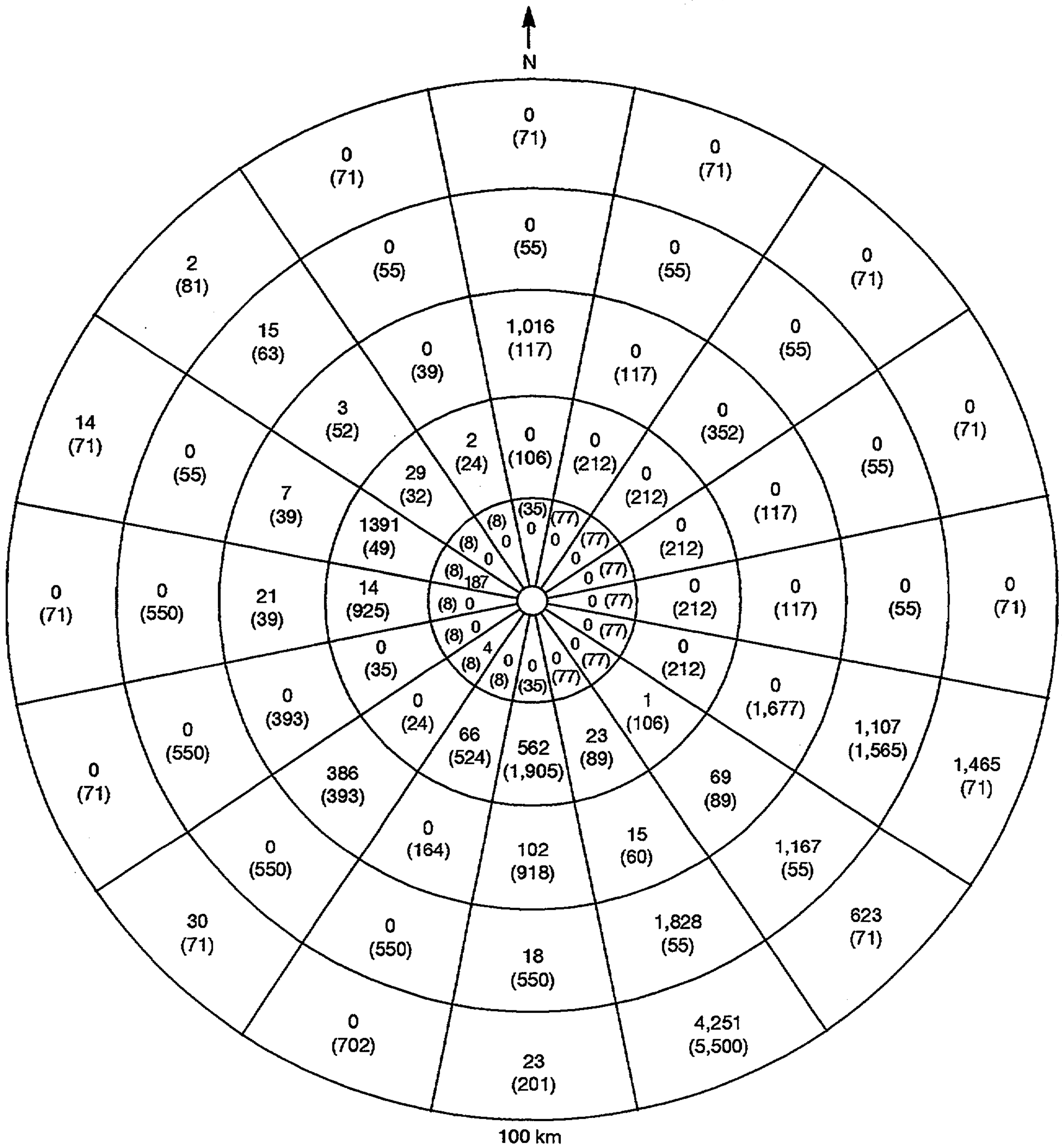

Figure 2-1. Population counts for Yucca Mountain region from 1990 census data and estimates from Iterative Performance Assessment Phase 2 dose assessment (in parentheses). The center of the map is at Yucca Mountain.

population value above zero contained one census block centroid.

2.3.2 Agricultural Information

2.3.2.1 Agriculture in Southwestern Nevada

IPA Phase 2 work was successful at gathering some local information on agricultural parameters. Personal communications with agencies involved in collecting agricultural information and literature search results indicate the principal sources of population based agricultural information for Nevada and the counties surrounding the site have not changed since IPA Phase 2. These sources include the U.S. Census Bureau (U.S. Department of Commerce, 1989), and the Nevada Department of Agriculture in cooperation with the U.S. Department of Agriculture and the University of Nevada (Nevada Agricultural Statistics Service, 1988). The Census Bureau conducted its latest agricultural census and state agencies reported agricultural statistics for the region most recently in 1987. This information was useful for establishing a general understanding of the agricultural community in the counties of southwestern Nevada.

The area of southern Nevada that surrounds the proposed YM site, located in Nye County, does not have farms which sell food crops for export[1], but does have farms which grow feed crops for livestock which is sold on the open market. The census indicates predominant livestock in Nye County are cattle and calves, with 79 farms (58 percent of total) reporting cattle/calf ownership, and 73 farms (53 percent of the total) raising an average of 163 head for sale per farm in 1987 in Nye County (U.S. Department of Commerce, 1989). This includes 51 percent of the total farms raising an average of 191 beef cows per farm, and 11 percent of the total farms raising an average of 2 milk cows per farm. Hogs and pigs are grown for sale on 9 farms (6 percent of total) with an average of 27 animals per farm sold in 1987. Chickens were raised on 22 farms (16 percent of total farms) with an average of 35 chickens per farm, but no poultry meat was sold on the open market.

Crops in general were harvested on 94 farms (69 percent) in 1987 on an average area of 123 acres/farm. Hay production, including alfalfa, small grain, grass silage, and green chop accounted for 88 percent of the harvested cropland, while wheat and barley for grain sale represented only 3 percent (the remaining 9 percent of harvested cropland is not accounted for in the census statistics). Thus, alfalfa is clearly the dominant crop in Nye County. Activities limited to pasture and grazing occurred on 54 farms that also grew crops (46 percent of cropland) and 39 farms exclusive of cropland and woodland. Total pastureland in Nye County accounted for 347,433 acres in 1987 on 75 farms (an average of 4632 acres per farm). Vegetable production for market included 1 farm (1 percent of harvested land is vegetables, sweet corn, and melons) and 1 farm for fruits, nuts, and berries. Thus, vegetable production for market is negligible in Nye County.

Despite low levels of vegetable production, local gardeners can grow a variety of vegetables. The local agricultural extension office in Nye County no longer has any agricultural production staff, but does have staff which focus on horticulture possibly indicating a higher demand for such information. The extension office provides guidelines for desert gardening (Mills, 1993) which were used in IPA Phase 2 analyses to determine home gardening related parameter values and are also used in this study.

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[1] Personal communication: Las Vegas Agricultural Extension Office, Nevada, January 27, 1995.

The crop ingestion pathway is a source of human exposure to radioactive material released to air and water. Farming practices vary with geographic region and crop types, therefore site-specific information helps to reduce uncertainties in the input data. Also, radiobiological parameters are crop specific, and understanding the types of crops grown locally will aid the selection of appropriate parameter values. A farming scenario similar to that used in IPA Phase 2 is used in this study. A farmer who grows alfalfa for livestock feed, and vegetables and grains for personal consumption, appears consistent with available information. Section 2.3.2.2 discusses individual site-specific agricultural parameters and parameter values in greater detail.

2.3.2.2 Terrestrial Crop Growing Times

The growing time for specific crops is used in GENII-S to calculate the concentration of radionuclides in crops for the ingestion pathway dose calculation. For dose calculations, growing time represents the amount of time an edible crop is exposed to deposition of radionuclides from resuspended soil and contaminated irrigation water. The growing time is dependent on plant species and also varies within plant species depending on genetic and environmental growing conditions. NUREG/CR-5512 (Kennedy and Strenge, 1992) provides generic minimum growing time values for broad categories of crops, however, these point estimates are not useful for stochastic analyses where uncertainty must be characterized. Ranges of growing times from planting to harvest for a variety of vegetables are found in a comprehensive gardening manual by professional botanical gardeners (Chambers and Mays, 1994). The information is considered high quality as it was developed and reviewed by people with years of experience in gardening.

Crops likely to be grown in local vegetable gardens are selected from Mills (1993) and cross referenced to the growing period information in Chambers and Mays (1994). Crops are then grouped into categories (leafy vegetable, fruit, and root vegetable) used in the GENII-S and DITTY codes. The minimum and maximum growing times for any vegetable in each crop category are considered to characterize the full range of variation in growing periods for all the vegetables in a category. A uniform distribution is assumed for these ranges given no information as distribution shape was identified. Growing time ranges for selected individual garden crops are also considered, as well as information from NUREG/CR-5512 on minimum growing times for each crop category. The information is summarized in Table 2-1.

As expected, the minimum growing times from NUREG/CR-5512 generally fall within the range determined from the information in Chambers and Mays (1994). The wide ranges in growing times are a result of aggregating the information from a variety of crops to account for the uncertainty in knowing which crops a hypothetical vegetable gardener would choose to grow. To limit this variation, specific representative crops (e.g., corn, onions, beans, garlic) could be chosen rather than using the full range of possibilities. Note that cantaloupe was the only fruit plant mentioned in the desert gardening tips in Mills (1993), however, water use information from the Nevada Department of Resource Conservation suggest some permitted water users grow fruit trees (Nevada Division of Water Resources, 1995a).

2.3.2.3 Terrestrial Crop Yield

Terrestrial crop yields are used in GENII-S to determine the concentration of radioactive contaminants on crops from direct irrigation water or aerosol deposition. The crop yield specifies the plant weight per square meter of soil which (along with other parameters) allows conversion of the deposition rate of radionuclides (Ci/m^2/sec) to a crop concentration in units of Ci/kg of plant.

Table 2-1. Comparison of growing period ranges with NUREG/CR-5512 point estimates

Crop Group (one crop)	Growing Period Range (days)*	NUREG/CR-5512 (minimum days)
Leafy vegetables (corn)	40 - 120 70 - 100	45
Root vegetables (onions)	25 - 120 90 - 120	90
Grain	60 - 90	90
Fruit (cantaloupe)	65 - 95	90

* Source: Chambers and Mays, 1994

Table 2-2. Comparison of crop specific yields from Nevada with general values from NUREG/CR-5512

Crop	Minimum Yield from NUREG/CR-5512 (kg/m^2)	Yield Reported for Nevada (kg/m^2)*
Wheat	1.0 (grains)	0.47 - 0.60
Potatoes	4.0 (other vegetables)	3.80
Onions	4.0 (other vegetables)	5.59
Garlic	4.0 (other vegetables)	1.57
Fruit	2.0	None

* Source: Nevada Agricultural Statistics Service, 1988

Discussions with local staff at the Nevada Agricultural Extension office indicate the Nevada Agricultural Statistics Service (1988) to be the only familiar source of local yield information. Terrestrial crop information includes state yields for wheat, barley, potatoes, garlic, and onions. While none of these crops are grown in Nye County for market (U.S. Department of Commerce, 1989), it is possible they could be grown in small personal gardens and therefore the information is provided in Table 2-2.

The local vegetable yields are in general agreement with the NUREG/CR-5512 values, that account for yields among crops with considerable biologic variabilities in mass (i.e., garlic versus onion). A locally determined range for wheat with a uniform distribution is assumed because local variation data are available and wheat is not aggregated with other crops as are the vegetables. The uniform distribution for wheat is arbitrarily assigned due to lack of more detailed data to characterize the actual distribution.

Table 2-3. Vegetable yields from NUREG/CR-5512 with assumed geometric standard deviation

Food	Yield (kg/m^2)	Geometric Standard Deviation	Range
Leafy vegetables	2	1.82	0.618 - 6.47
Other vegetables	4	2.32	0.769 - 20.8

Source: Hoffman et al., 1982

Local point estimates for specific vegetables are not used in favor of more comprehensive values found in NUREG/CR-5512 for crop categories used in GENII-S (i.e., leafy vegetables, root vegetables). The point estimates of yield for leafy and other vegetables are 2 and 4 kg/m^2, respectively (Kennedy and Strenge, 1992). As no distribution information is provided in Kennedy and Strenge (1992), the yields are assumed to be distributed lognormally as reported in Hoffman et al. (1982). The ranges for the yields presented in Table 2-3 are based on a 95-percent confidence interval.

As indicated in Table 2-2, local agricultural statistics sources for Nye County and Nevada do not contain yield information for fruit. This is probably due to the low level of fruit production in the region. The 1987 Agricultural Census indicates only one farm selling products in the general category of fruits, nuts, and berries (U.S. Department of Commerce, 1989). Water permit data (discussed in Section 2.3.3) indicate at least three properties with fruit trees in the Amargosa Valley area. Possibly, fruit trees are used for domestic consumption rather than for market. Despite the low level of production, the potential exists to grow fruit in the region and thus it is included in our analysis. Snyder et al. (1994) report a maximum fruit tree yield estimate from analysis of agricultural survey data from Yakima, Washington. Snyder determined the data are consistent with a triangular distribution and a range of 0.3 to 2.0 kg/m^2, with a mean of 0.54 kg/m^2.

2.3.2.4 Terrestrial Crop and Animal Product Consumption Rates

Terrestrial crop consumption rates are used in GENII-S to determine the amount of contaminated food products which are ingested by the target individual. No information sources are identified for recent local consumption rates. As a result, consumption rates for the general United States population for leafy vegetables, other vegetables, fruit, grain, beef, and milk in Kennedy and Strenge (1992) are used. To determine sampling distributions, the consumption rates are assumed to be distributed lognormally, with geometric standard deviations applicable to consumption rates in Hoffman et al. (1982). The range for the consumption rates is based on a 95-percent confidence interval. Table 2-4 shows the resulting ranges for various consumption rates.

2.3.2.5 Forage Growing Time

The forage pathway is another route of potential exposure to air and waterborne contamination. The growing time for a forage crop is used to determine the amount of material which can be deposited on forage crops from air or irrigation sources prior to consumption. Growing time varies with forage crop type, and therefore information on the types of forage crops grown in the vicinity of YM is essential to determining a meaningful growing time (see general discussion of agricultural crops in Section 2.3.2.1).

Table 2-4. Consumption rates for major food groups from NUREG/CR-5512 and lognormal distribution information from Hoffman et al. (1982)

Food	Consumption Rate	Geometric Standard Deviation	Range
Leafy vegetables	11 kg/yr	1.62	4.27-28.3
Other vegetables	51 kg/yr	2.16	11.3-231
Fruit	46 kg/yr	2.16	10.2-208
Grain	69 kg/yr	2.16	15.3-312
Beef	59 kg/yr	1.65	22.1-157
Milk	100 L/yr	2.23	20.8-482

Alfalfa production is associated with southern Nevada agriculture by various sources including Federal and State census data (U.S. Department of Commerce, 1989; Nevada Agricultural Statistics Service, 1988), communications with agricultural extension agents, water use data for the Amargosa Valley (Nevada Division of Water Resources, 1995a), and an NTS dose assessment (Breshears et al., 1989) and, therefore, is considered a primary forage crop.

At state and local agricultural extension offices, personal communication with extension agents indicates a lack of documented information on alfalfa growing parameters. A local extension agent, nontheless, indicated the growing season is May through October and three to four cuttings occur during that time. This information is compared with that used by Breshears et al. (1989) who report a season from June to mid-December with three to five cuttings. Thus, it appears the growing season for alfalfa is approximately 6 mo. If the growing time is taken to be the time between cuttings, the growing time ranges from 37 to 62 days. Stichler (1991) provides information to determine the time and number of cuttings based upon the growing stage of the plant and indicates exact figures do not apply to all situations due to the impacts of variations in climate and management practice. Generally, cutting takes place after bloom which is after 30 days. This value is consistent with the generic beef/dairy forage minimum growing time provided by Kennedy and Strenge (1992). Thus, a reasonable lower bound for alfalfa growing time is 30 and a reasonable upper bound is 62 days. Since there are insufficient data to develop a more detailed distribution, a uniform distribution is assumed.

2.3.2.6 Forage Yield

Forage crop yield is used in GENII-S to determine the radionuclide concentration in forage crops from surficial deposition from air and irrigation water. Yields for alfalfa hay and other hay in Nye County for 1986 were 1.23 (dry weight) and 0.34 kg/m^2, respectively (Nevada Agricultural Statistics service, 1988). In 1987, these same yields were 1.21 and 0.36 kg/m^2, respectively. No other local data on yield are identified. Therefore, the range of possible yields for hay, in general, is 0.34 to 1.23 kg/m^2.

2.3.2.7 Fresh Forage Diet Fraction

The fresh forage diet fraction in GENII-S is the fraction of livestock diet consumed fresh from the field. Locally applicable forage information is available in a NTS analysis of food pathways (Breshears et al., 1992). The study focuses on southwestern Nevada agricultural pathways and included information on alfalfa and grain forage, production, and storage. The fresh forage diet fraction is distributed normally, with a mean of 0.55 and a standard deviation of 0.13. This translates to a range of 0.30 to 0.82 at the 95-percent level.

2.3.2.8 Food Transfer Factors

Food transfer factors are used to determine the amount of radioactive material transferred to food and forage plants from soil and to animal products from contaminated water and feed. Concentration ratios for transfer of contamination from soils to plants are likely to be influenced by site-specific conditions such as soil and plant type. The potential source of site-specific food transfer research is the NTS. A number of risk assessments and related documents from the NTS were reviewed and an expert[2] with experience conducting risk assessments for the NTS was contacted.

Many prior dose assessments at the NTS model the effects of A-bomb test fallout and early screening studies have determined the groundwater/ingestion pathway for these scenarios is not a major contributor to dose (Daniels, 1993). Therefore, subsequent studies and research have not focused attention on the soil to food pathway nor the feed to livestock pathway. Similarly, since the test site encompasses a large area restricted from regular civilian uses (e.g., farming), research interest in the development of site-specific transfer and uptake factors is low. An early risk assessment that did consider ingestion included forage and beef cattle pathways. Tabulated parameter values for this study are not referenced to a source and the origin of parameter values cannot be determined from the text (Kercher and Anspaugh, 1984). References by Martin and Bloom were identified (Martin et. al, 1974; Martin and Bloom, 1978) that may contain results of site-specific analyses of these parameters, however, time constraints limited the ability to obtain and review these works and they appear only applicable to plutonium transport, only one of the elements considered in this study. Overall, the NTS is not found to be a major source of transfer factor information for the number of elements considered herein, so other nonsite-specific sources are consulted to obtain values.

Food transfer factors (i.e., concentration ratios and transfer coefficients) are obtained from the International Atomic Energy Agency (IAEA) (1994), published as a collaboration between the IAEA and the International Union of Radioecologists (IUR). The IAEA report is used as the primary source for transfer factors because it represents the most recent thinking from this group of distinguished experts. For some elements and food transfer factors, IAEA (1994) did not present data. In these cases, food transfer factors are obtained from Baes et al. (1982), a primary source for IPA Phase 2 transfer factors. The resulting factors are provided in Table 2-5.

Four types of concentration ratios and four types of transfer coefficients are used in GENII-S. These factors cannot be sampled directly for stochastic analyses in GENII-S without code modifications. Variation in these parameters is modeled using the soil/plant scale factor and the animal uptake scale factor. These scale factors include a nominal geometric mean of 1.0 and a geometric standard deviation

[2] Personal communication: M.D. Otis, SAIC, Idaho Falls, ID

Table 2-5. Concentration ratios and transfer factors by element

Element	Concentration Ratio				Transfer Coefficient	
	Leafy Vegetables	Other Vegetables	Fruit	Grain	Beef	Milk
Am	1.2×10^{-3}	4.7×10^{-4}	4.7×10^{-4}	2.2×10^{-5}	4.0×10^{-5}	1.5×10^{-6}
Cm	1.1×10^{-3}	5.8×10^{-4}	5.8×10^{-4}	2.1×10^{-5}	3.5×10^{-6} (Baes)	2.0×10^{-5} (Baes)
Cs	1.1×10^{-1}	7.2×10^{-2}	7.2×10^{-2}	1.0×10^{-2}	5.0×10^{-2}	7.9×10^{-3}
I	3.4×10^{-3}	2.0×10^{-2}	2.0×10^{-2}	2.0×10^{-2}	4.0×10^{-2}	1.0×10^{-2}
Nb	5.0×10^{-2}	1.7×10^{-2}	1.7×10^{-2}	1.7×10^{-2}	3.0×10^{-7}	3.0×10^{-7}
Ni	1.8×10^{-1} (Baes)	3.0×10^{-2}	3.0×10^{-2}	3.0×10^{-2}	5.0×10^{-3}	1.6×10^{-2}
Np	6.9×10^{-2}	2.7×10^{-2}	2.7×10^{-2}	2.7×10^{-3}	1.0×10^{-3}	5.0×10^{-6}
Pb	1.1×10^{-3}	6.4×10^{-3}	6.4×10^{-3}	4.7×10^{-3}	4.0×10^{-4}	2.5×10^{-4} (Baes)
Pu	3.4×10^{-4}	2.3×10^{-4}	2.3×10^{-4}	8.6×10^{-6}	1.0×10^{-5}	1.1×10^{-6}
Ra	8.0×10^{-2}	1.3×10^{-2}	1.3×10^{-2}	1.2×10^{-3}	9.0×10^{-4}	1.3×10^{-3}
Se	2.5×10^{-2} (Baes)	2.5×10^{-2} (Baes)	2.5×10^{-2} (Baes)	2.5×10^{-2} (Baes)	1.5×10^{-2}	4.0×10^{-3} (Baes)
Tc	7.6×10^{1}	1.1×10^{1}	1.1×10^{1}	7.3×10^{-1}	1.0×10^{-4}	1.4×10^{-4}
Th	1.1×10^{-2}	3.1×10^{-4}	3.1×10^{-4}	3.4×10^{-5}	6.0×10^{-6} (Baes)	5.0×10^{-6} (Baes)
U	2.3×10^{-2}	1.1×10^{-2}	1.1×10^{-2}	1.3×10^{-3}	3.0×10^{-4}	4.0×10^{-4}

that was back-calculated from interpolated transfer factor uncertainty factors provided by the IUR in their 1989 report (International Union of Radioecologists, 1989). The uncertainty factors were reviewed for the radionuclides and crops relevant to this study and a value was chosen that encompassed the uncertainty for the majority of factors. The resulting factor was consistent with a geometric standard deviation of 2.0. A 95-percent confidence interval was used to calculate the ranges for these scale factors that are provided in Table B-1 in Appendix B. The IUR report that provides the uncertainty factors was used previously by the NRC as a source of transfer factors for NUREG/CR-5512 (Kennedy and Strenge, 1992). The uncertainty factors from IUR are based upon the mean of a sample of transfer factors (more than 3 point estimates per sample) and were favored over the recent IAEA uncertainty factors which were based upon point estimates.

2.3.3 Water Use in Southwestern Nevada

Irrigation water from underground wells is also a potentially important pathway for exposure to radioactive contaminants. Primary routes of exposure from water pathways include: internal exposure from drinking water, consumption of crops or animal products which have been directly or indirectly contaminated by irrigation and feedwater, and exposure to external radiation from soils contaminated by deposition from irrigation water. When groundwater is contaminated with known concentrations of radionuclides, then the irrigation rate initially determines the amount of radioactive material available for deposition to soil and plants. Bathing in contaminated water is a potential route of exposure which is not included in this analysis, however, could be modeled in GENII-S by using the swimming exposure model.

Due to uncertainties in determining the anticipated groundwater concentrations at the accessible environment, this report does not attempt to adequately characterize the extent of potential contamination to groundwater sources; rather, release and transport are assumed to take place for the purpose of conducting dose calculations. Given current uncertainties in the understanding of the various factors affecting release and transport, it is prudent to consider release and transport scenarios to the accessible environment.

The DOE reports general groundwater flow as moving south and southeastward from the site (U.S. Department of Energy, 1988a). Thus, any potential releases to groundwater present a possible risk to populations south and southeast of the site. Therefore, dose assessments involving the groundwater pathway should focus on these target populations (or individuals in this case). The Amargosa Valley region, approximately 20 miles south of the YM site, uses groundwater for agricultural irrigation and drinking water consumption and is one reasonable focal point for determining local water use practices. Areas close in proximity to the site are assumed to be most applicable for estimating maximum exposures.

2.3.3.1 Home Irrigation Rate

The home irrigation rate is used in GENII-S to determine the amount of contamination deposited to soils for the purpose of calculating external exposure. Due to the arid climate in the southwestern Nevada region, it is likely home irrigation would be greater than in more moderate climates. Mills (1993) provides estimates of the water required to grow a lawn in Nye County. These estimates are 1 in. wk during the cooler winter months and 4 in. wk during the hot summer months. Mills also indicates that some residents may only care for a lawn in the winter months. A minimum irrigation rate is calculated as 26 in. yr assuming a 6-mo cool season lawn. A maximum value is calculated assuming a year-round lawn with 3 months of summer watering at 4 in. wk and the remaining 9 months at 1 in. wk to arrive at a value of 84 in. yr. A uniform distribution is assumed since there is no information to support a more precise distribution type.

2.3.3.2 Home Irrigation Duration

Irrigation duration is used in GENII-S to calculate an instantaneous deposition rate (Ci/m^2/sec) that is then used to determine the amount of radioactive material deposited to soil in a year for one external dose rate calculation. The irrigation rate is specified on an annual basis and is then divided by the irrigation duration, thus allocating the total amount of water used in a year to the period of irrigation duration. This causes the duration parameter to be inversely proportional to the calculated exposure—a result which appears counterintuitive—because many models start with a short duration irrigation rate (i.e., inches per day or inches per week) that is multiplied by the duration parameter. In this latter case, the duration is positively associated with the calculated exposure. Consistent with the assumption used that a person would grow a lawn for 6 months to a 1 yr, the irrigation duration range is assumed to be 6 months to 1 yr and a uniform distribution is assumed since no information was available that suggests otherwise.

2.3.3.3 Terrestrial and Forage Crop Irrigation Rates

The Nevada Division of Water Resources issues permits and regulates water use for a variety of end uses including domestic consumption and agriculture. Neither they nor the agricultural extension offices systematically collect or summarize information on the irrigation rates for various crops. Therefore, an alternative way to characterize irrigation rates is to consider information from water permits. Permits include all large-quantity users (excepting individual homeowners if they only own one house on the property and do not intend to pump more than 800 ft^3 per day). Local farms are represented in the permit data.

Permits are categorized by end use, so it is possible to determine the permitted rates for agricultural uses, but not for specific crops. IPA Phase 2 analyses used a maximum permitted amount of 60 in. yr (stated as 127 ℓ/m^2 per mo) for the irrigation rate. The Nevada Division of Water Resources does not publish water permit information, however, such information is available upon request (Nevada Division of Water Resources, 1995b). The information is not thoroughly checked for errors and is considered preliminary. Figure 2-2 shows the cumulative distribution of estimated water withdrawals in the Amargosa Valley basin based upon permitted water rights (includes 140 permits). Zero estimates are for sites which have water rights, but no anticipated use, such as abandoned cropland. Available information includes location of use, the number of acres irrigated, and the estimated annual water usage. A remarks section indicates, for some permits, the type of crops grown on farms, but remarks have been made for only a small number of permits. Nonetheless, the remarks do provide some confirmation of the amount of water permitted for different agricultural uses. From this information, two approaches to determine irrigation rates are considered.

The first approach relies upon the aforementioned remarks section of the permit information to establish the maximum permitted irrigation rates for specific crops. While the available data were sparse, seven of seven alfalfa farms, three of three grain farms, one of four vegetable gardens, and one of four fruit tree orchards had a 60 in. yr permitted withdrawal. Therefore, our analysis assumed a permitted amount of 60 in. yr for all crop types. An empirical distribution of irrigation rates was then derived. This distribution, which accounts for the annual irrigation rate minus expected rainfall, is presented in the following paragraph.

To determine the distribution, rainfall predictions from a recent formal expert elicitation for YM during the next 10,000 yr (DeWispelare et al., 1993) are considered. In the elicitation, five experts made four estimates of possible future annual rainfall rates: 5, 6, 8.3, and 11.8 in. yr. Each of these estimates is normally distributed with standard deviations equal to the product of 0.829 (Sandia WIPP Project, 1992) and the mean annual rainfall. This results in values of 4.15, 4.97, 6.88, and 9.78, respectively. Each mean annual rainfall is then subtracted from the irrigation rate resulting in four irrigation minus rainfall adjusted estimates.

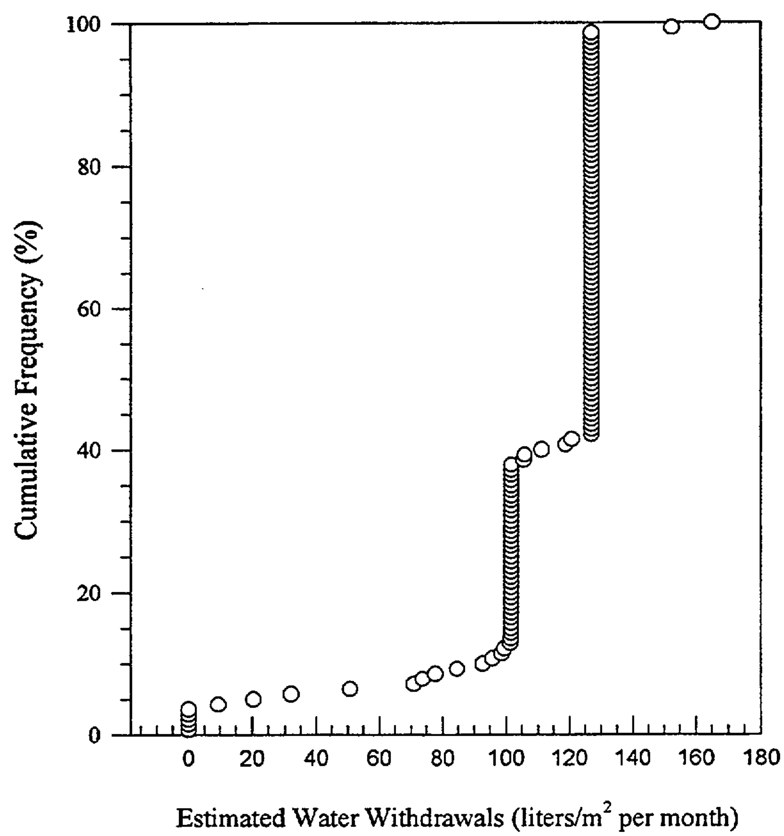


Figure 2-2. Cumulative distribution of estimated water withdrawals in the Amargosa Valley Basin (Data source: Nevada Division of Water Resources, 1995b)

Normal distributions are then estimated about these adjusted estimates using the aforementioned rainfall standard deviations. Each distribution is sampled to create an empirical distribution using GENII-S. Sampling probabilities for each distribution are determined as follows. Probabilities associated with the average annual rainfall values are determined by multiplying the product of the estimated chance of a change in climate (64.4 percent) by the proportion of the elicitation experts who favored a given value for the point estimate. The probability of a change in climate was determined by subtracting the chance of no climate change (Nuclear Regulatory Commission, 1995a) from 1.0. The resulting probabilities are 0.13, 0.36, 0.38, and 0.13 for the adjusted distributions relevant to rainfall rates of 5, 6, 8.3, and 11.8 in. yr, respectively. Sampling to create the empirical distribution is limited to 100 values in GENII-S. Therefore, the sampling probabilities are used to determine the number of values to sample from each of the adjusted distributions. Thus, 13 values are sampled from the irrigation minus 5 in. yr rainfall distribution, 36 values are selected from the irrigation minus 6 in. yr rainfall distribution, and so forth. The resulting distribution is then sampled by GENII-S for regular code runs.

A second approach for determining irrigation rates for the region is to directly use the distribution of permitted annual water use amounts for all farmers pumping groundwater in Nye County or the Amargosa area. The resulting distribution must be used as input for all crop types since the information does not specify the types of crops which are irrigated. Nonetheless, a single distribution calculated from different permit amounts is likely to inaccurately characterize actual water use for end users which have different permitted maximums. Therefore, such calculations are not conducted for this report. Actual use by farmers with different permit levels is probably not amenable to characterization by a single statistical distribution because use levels are likely to be clumped around the permitted maximum rates such that distributions may exist about each permitted amount. If such is the case, then using a single statistical distribution for different permitted amounts may result in a biased characterization of actual use. This concern cannot be verified since the Nevada Division of Water Resources does not collect data on the actual amounts of water pumped at different farms.

2.3.3.4 Terrestrial Crop Irrigation Duration

The terrestrial crop irrigation duration is the number of months per year in which irrigation occurs. In the GENII-S model, the irrigation rate is divided by the irrigation duration to calculate an instantaneous deposition rate (Ci/m^2-sec), which is then used to determine deposition onto soil and crops. The irrigation duration is specified for four crop groups: leafy vegetables, root vegetables, fruit, and grain.

The value for irrigation duration is similar to the growing period, however, crops such as wheat, require a drying out period prior to harvest which reduces the irrigation duration. When contacted, the U.S. Department of Agriculture (USDA) recommended consulting local agricultural extension agents in Nevada for such information. Local agents have no knowledge of documentation providing information on growing times for various crops. It is likely that the USDA publishes manuals or documents which contain generic parameters for crops; however, efforts to obtain nonsite-specific information were limited in order to focus attention on obtaining site information.

Vegetables and fruit are watered until harvest and, therefore, values for irrigation duration are assumed the same as the growing period. Irrigation durations for various crops are calculated by multiplying the growing time per season by the number of seasons per year. The irrigation duration period for wheat is assumed equal to the growing time minus 1 months for drying multiplied by the number of seasons. Growing seasons for each crop group except grain are interpreted from a planting guide provided in Mills (1993). The planting guide shows the months of the year when various vegetable and fruit crops are planted. The irrigation study by English and Nakamura (1989) is used to estimate growing time for wheat. This is a field study in an arid environment approximately 50 miles south of Hanford, Washington. Wheat was grown over a period of 4 months using high fertilizer applications. These experimental conditions are optimal for growth and thus a wider range of 4 to 5 months was assumed for wheat under more variable conditions. This assumption is probably reasonable, however, more detailed generic biological information is likely available for wheat crops, but no such information was found specifically addressing growing seasons for wheat in Nevada. Table 2-6 shows information used for determining the irrigation period for various crops.

2.3.3.5 Consumption Rate for Water

Water consumption in hot, dry regions, such as southwestern Nevada, may be above national average values due to the climate. Therefore, site-specific information is useful. Nonetheless, local information sources for drinking water consumption rates were not identified. As a result, information from Roseberry and Burmaster (1992) is used. This is a reanalysis of data from a nationwide Food and Drug Administration (FDA) food consumption survey conducted in 1977–78 to determine distributions of water intake. Their analysis indicates distributions of water intake are lognormally distributed. The average consumption rate for tap water is reported as 349 ℓ/yr with a geometric standard deviation of

Table 2-6. Factors used to determine irrigation duration for various crops

Crop Type	Number of Seasons/yr	Growing Time per Season (mo/yr)	Total Irrigation Time (mo/yr)
Leafy vegetables	2	1.5 - 4	3 - 8
Root vegetables	2	1 - 4	2 - 8
Fruit	1	1 - 1.5	2 - 3
Grain	2	4 - 5	6 - 8

1.78. The distribution is calculated based on a 95-percent confidence interval. As with other consumption information, these data are old and may not be representative of current consumption rates which tend to change over time. Nonetheless, more recent data were not available. Raw data from the FDA study are available from National Technical Information Service (NTIS).

2.3.4 Soil Characteristics for Southwestern Nevada

Soil characteristics are used in the GENII code to calculate transfer of radionuclides from irrigation water and air deposition to soil and subsequently to crops and feed where it enters the livestock and human food supply. As soils vary with geography, site-specific soil classification information is useful in reducing uncertainties associated with use of generic parameters.

2.3.4.1 Soil Plow Depth

Soil plow depth is used in GENII-S to determine the areal density of the upper layer of soil and is used to define the two compartments for the soil model. Such specific information on farming techniques is not provided in the primary sources of agricultural data (Nevada Agricultural Statistics Service, 1988; U.S. Department of Commerce, 1989) and, therefore, a GENII-S default value of 15 cm is used in our analysis. No information to characterize the variation was found and thus the parameter was not sampled. Subsequent to code runs, a value in Mills (1993) was identified which recommends a till depth of 30.5 cm for local gardens in Nye County. This is offered as a possible locally relevant value.

2.3.4.2 Soil Exposure Time

The soil exposure time is used in GENII-S to calculate the amount of time an individual would be exposed to external radiation from contaminated soils. No information is identified for outdoor activity of farmers—which could be used to determine the soil exposure time. An assumption is made that a farmer is likely to be in close proximity to irrigated (i.e., contaminated) land working out of doors. As a result, the soil exposure time for a farmer is assumed to be equivalent to the outdoor activity time (Section 2.3.5.1) with a minimum of 6.5 hr/day and a maximum of 15 hr/day. Actual survey results of alfalfa/hay farmers would greatly reduce the uncertainty and speculative nature of determining values for this parameter.

2.3.4.3 Areal Soil Density

The GENII-S code uses a two-compartment soil model developed by Anspaugh (Leigh et al., 1993; Napier et al., 1988). The model accounts for differences in densities between the tilled layer of soil and the more dense lower layer beneath the tilled zone. The fraction of roots contacting either zone is set by the user. If a single-compartment model is desired, the root fraction for the tilled layer is set to 1.0 as done for this report. An important note is that alfalfa utilizes a tap root which can grow to a depth of 20 ft (Stichler, 1991). Therefore, the single-compartment assumption is conservative because all roots are assumed to be in the contaminated region of the soil column.

The areal soil density (kg/m^2) is the weight of a block of soil (1 m^2) at the surface to a depth of the plow layer. The deposition of radionuclides (Ci/m^2) (i.e., irrigation water) is divided by the soil density to determine the soil concentration (Ci/kg of soil). The soil concentration is then multiplied by the plant/soil concentration ratio to determine the concentration in forage, feed, and crops. Therefore, a high-density soil, which has less capillary space available than a lower density soil, has less capacity to absorb contaminated irrigation water thereby allowing less contamination to be available for uptake by plant roots.

The U.S Department of Agriculture Soil Conservation Service (SCS) collects and maintains information resources on the nation's soils. Results of a major soil survey of the Amargosa region of Southern Nevada will be available in 1997. Soil characterization information for agricultural sites in the Amargosa Desert is available from the local SCS office in Topopah, Nevada. This information consists of aerial photographs of Amargosa Desert farms with major soil classification regions identified. Supplementary information provides classifications of the soils associated with the regions outlined on the map. The visibility of the farms provides confirmation of the soil types associated with farms. While this information is helpful, the Topopah office does not conduct bulk density measurements on these soils.

The general classifications for these YM farming soils included gravelly sandy loam and fine sandy loam. An average value for dry density of a sandy soil of 1.76 is referenced in Krynine and Judd (1957). An agricultural study for an arid region approximately 50 miles south of Hanford, Washington, reports a range of 1.20 to 1.80 g/cm^3 for a loamy fine sand soil (English and Nakamura, 1989). A soil analyst at the national office of the SCS indicates this range should include any sandy soil. Additional information for each soil type relevant to Amargosa Valley farms is available from the SCS Soil Interpretation Record database which contains estimates of soil densities. Table 2-7 summarizes the information.

Each map unit number area in Table 2-7 represents a unique soil classification area which contains one or more farms. This information is applicable to an area of southwestern Nevada near the Amargosa Desert. The area is bounded by coordinates 116° 37′ 30" to 116° 30′ longitude and 36° 30′ to 36° 35′ latitude. The aerial photograph indicating the location of farms was taken in 1976. While some changes may have taken place since then, the information indicates which types of soils are utilized for farming in the region and allows site-specific determination of soil densities. A range of 1.35 to 1.70 effectively characterizes the uncertainty in the values considered. This range is less uncertain than the values reported by English and Nakamura (1989) (i.e., 1.20 to 1.80 g/cm^3) and the upper bound is close to the value of 1.75 g/cm^3 reported in Krynine and Judd (1957). To obtain the areal bulk density required by the GENII-S code, the soil density is divided by the plow depth of 15 cm and the units are converted to kg/m^2 to arrive at a range of 180 to 270. A uniform distribution is assumed since no information was available to determine a more precise distribution type.

Table 2-7. Primary soil compositions and bulk densities for the soils of three farming areas in Amargosa Valley, Nevada

Map Unit Number	Primary Soil Composition	Percent of Soil	Bulk Density Range (g/cm^3)
2054	Yermo very gravelly sandy loam	55	1.50 - 1.60
2054	Arizo very gravelly sandy loam	30	1.40 - 1.55
2054	Arizo very gravelly loamy sand	5	1.45 - 1.65
2152	Arizo very gravelly sandy loam	85	1.40 - 1.55
2152	Arizo very gravelly loamy sand	5	1.45 - 1.65
2153	Arizo very gravelly sandy loam	35	1.40 - 1.55
2153	Corbilt gravelly fine sandy loam	25	1.35 - 1.50
2153	Commski very gravelly fine sandy loam	25	Data not available
2070	Shamock gravelly fine sandy loam	93	1.50 - 1.70

NOTE: The map unit number defines an area in the Amargosa Valley where the U.S. Soil Conservation Service has characterized soil types.

2.3.5 Meteorology and Air Dispersion Parameters

The air dispersion model is not emphasized in the literature review due to the conclusion from the IPA Phase 2 dose work indicating this pathway to be of much lower significance to the calculated dose relative to the groundwater pathway. Nonetheless, the resuspension pathway is part of the groundwater exposure scenario (see Figure 2-2), therefore some parameters were considered.

Meteorological information used in IPA Phase 2 analyses was generated by the National Climatic Data Center (NCDC) of the National Oceanographic and Atmospheric Administration (NOAA) from monitoring data at the Desert Rock station in Nevada. Another data collection station exists in Beatty, Nevada; however, both are near the YM site and the merits of using data from one over the other are not readily apparent. The CNWRA is working with information from the Beatty station for other projects, however, the data are not directly comparable with the information provided by NCDC for IPA Phase 2 analyses so no comparisons are made. The EPA has compiled atmospheric data for Yucca Flats, Nevada (approximately 35 km NW of YM) for its CAP88 air dose assessment code (U.S. Environmental Protection Agency, 1992). This data includes wind speed, stability class, and frequency data for a standard 16 sector grid. In addition to these data sources, monitoring stations for collection of meteorological information at the YM site have been set up by the DOE and will eventually provide the most relevant, site-specific, meteorological information for dose assessments. The other sources of data may be useful for conducting reviews of DOE data collected at nearby sites when such data are available.

2.3.5.1 Inhalation Exposure Time

The inhalation exposure time is used in calculating the dose from inhalation of aerosolized radioactive material and is based upon the time spent indoors and out. For a groundwater exposure scenario, the inhalation exposure component is due to resuspended material deposited from irrigation of soils. In a recent risk assessment conducted for the NTS (Daniels, 1993), human outdoor activity fractions for indoor and outdoor activities are reported from birth to 70 yr. The original source of this information is Wiley et al. (1991) and is based upon activity patterns of California residents. The outdoor activity patterns of farmers, however, is much higher than average residents who are likely to be involved in indoor occupations. Anspaugh (Daniels, 1993) affirms this view when reporting difficulty in finding activity data for individuals living on farms—"a population likely to spend much more time outdoors."

IPA Phase 2 analyses assume 73 percent of a farmer's time is spent indoors (Nuclear Regulatory Commission, 1995a). A 0.5 indoor exposure factor is used to account for the reduced airborne exposure indoors. This results in a value of 5,548 hr/yr for the inhalation exposure time. If the primary occupation is farming, it is possible much more time will be spent out-of-doors. Without further information, other than anecdotal information from an individual with a farming background, a maximum value was assumed to be equivalent to a 15-hr day, 7 days/wk which results in 7,117 hr/yr when the 0.5 indoor exposure factor is used. A triangular distribution is assumed sloping to the minimum of 5,548 hr/yr from the maximum value under the assumption that the farmer is likely to spend much of the day outdoors.

2.3.5.2 Resuspension Factor

The resuspension factor is used to calculate the resuspension rate constant—the amount of the radioactive material initially deposited to soil by contaminated air or water which is resuspended by wind or other disturbance. The resuspended material is then available for inhalation or redeposition to crops which can then contribute to ingestion dose. The resuspension rate constant is the product of the resuspension factor and the deposition velocity.

A number of resuspension models exist which are applicable to the NTS (Anspaugh et al., 1975; Sehmel, 1980; Eckhart and Chen, 1993). Resuspension is an uncertain parameter due to the number of variables which contribute to the amount of material resuspended at a given site. Eckart and Chen (1993) illustrate these factors in a resuspension model for soils following site restoration of an arid site. They include soil particle size, surface wind, surface roughness, surface cover, time following disturbance, soil adhesion, and saltation flux. Their model results in a range from approximately 10^{-5} to 10^{-9}. Anspaugh, widely known for his work on resuspension and other risk assessment research, reports values ranging from 10^{-3} to 10^{-7} (Anspaugh et al., 1975), however, the values below 10^{-4} are due to artificial disturbances not considered applicable to a farming analysis (Breshears, et. al 1989). Otis (1983) has reported a lognormally distributed resuspension factor (10^{-5} m^{-1}) and geometric standard deviation (2.5) applicable to the NTS which incorporates the uncertainty associated with the deposition velocity as well as uncertainty in the factor. Both the deposition velocity and resuspension factor are multiplied together to determine the resuspension rate; therefore, it is possible to assign the uncertainty in both parameters to one of the two. The value by Otis (1983) is used because it is applicable to southwestern Nevada (i.e., developed for NTS Dose Assessments), is less uncertain than the other reported factors, and has a standard deviation which allows a distribution to be created for sampling. The resulting range for a 95-percent interval is 6.03E^{-5} to 1.66E^{-6}. The default value from GENII-S for the deposition velocity is then used as a fixed parameter because its variation is accounted for in the resuspension factor.

2.3.5.3 Crop Interception Fraction

The crop interception fraction is the fraction of contamination from rainfall, irrigation, or aerosol deposition which is intercepted by and adheres to the plant surface. Plant surface contamination is then available for ingestion by foraging livestock or human consumers. The interception fraction varies with plant type and therefore is useful to obtain information applicable to crops grown near YM. Anspaugh (1987) summarizes results of 22 laboratory and field studies conducted on a variety of crops in different geographic locations, including the NTS. Approximately half of these studies used artificial sprays while the other half are conducted under natural conditions. Many of the studies focus on Cs and Sr elements, however a few studies include Pb, I, Ce, Mn, as well. Crops considered include pasture grasses and alfalfa (primarily), but also rye, wheat, barley, corn (and corn silage), beans, cabbage, and potatoes. Anspaugh (1987) summarizes data for grass and alfalfa to determine an interception fraction for forage crops in general, and mentions values for other crops are not much different than the forage crop values.

The forage crop value is relevant to YM since alfalfa and grasses represent a major proportion of Nye County cropland. A recommended range for retention is 0.4 to 0.5, but Anspaugh (1987) mentions a value of 1.0 as not unreasonable for a conservative analysis—particularly in high-density vegetation situations. The lowest value reported is 0.06. Therefore, without additional information about the distribution shape other than a range and central value, a triangular distribution is used with a best estimate of 0.40 and a range from 0.06 to 1.0.

Chambers and Mays (1994) discuss home desert gardening and suggest some home gardeners in arid regions cover their vegetable gardens with a sun screening cloth (propped up over the bed about 3 ft) to avoid overexposure to sunlight and quick drying of soil. Such a screen would likely affect the amount of airborne material which can settle onto crops. This is an example of a potential site-specific practice which may influence dose modeling calculations. However, since the screen would have the effect of lowering estimated dose, failure to account for this practice would be conservative and serve to overestimate actual exposures.

3 ANALYSIS OF PARAMETER UNCERTAINTY AND SENSITIVITY

3.1 INTRODUCTION

While obtaining site-specific parameter information is an important part of improving dose assessments, an uncertainty analysis is useful to estimate the range of uncertainty in doses calculated with the new parameter information and a sensitivity analysis provides insights into which parameters have the greatest influence on dose. While identification of the true parameter uncertainty is outside the scope of this report and is the ultimate responsibility of the DOE, conservative ranges established from reviewing site-specific information provide reasonable initial estimates of parameter uncertainties for use in this analysis. Results can support future decision-making on resource allocations for parameter uncertainty reduction efforts. These analyses are conducted using a Monte Carlo approach with Latin Hypercube Sampling (LHS) of parameters. Scatterplot analysis and partial rank correlation are chosen as efficient methods for assessing the sensitivity of parameters.

3.2 METHODS

A number of methods are available for conducting sensitivity and uncertainty analysis for radiological dose assessments. These methods are summarized by Helton et al. (1991) and Iman and Conover (1982). As the proposed scope for this activity is limited in nature, it is important to choose methods which provide useful insights into the data and are efficient to conduct using available tools.

A Monte Carlo analysis is favored because: (i) parameter uncertainty information is obtained directly from code outputs without use of time consuming or complex analysis procedures, (ii) sampling is conducted on the full range of input distributions allowing the full range of results to be analyzed, and (iii) results are compatible with simple scatterplot and correlation analysis methods and more involved multiple regression techniques. The latter point is important because less resource intensive statistical analysis procedures are applied first in this task and results of these analyses help to determine if more detailed regression analyses are needed in a subsequent task. Correlation for ranked data is preferred because the ranked correlation coefficient behaves the same for all types of input distributions (Iman and Conover, 1982). The partial correlation coefficient is used because it removes the effects of the other parameters' correlations with the parameter of interest and with dose for a given comparison. For this application, the partial rank correlation coefficient (PRCC) will serve to explain the extent to which variation in an input parameter and variation in calculated dose are related (in an ordinal sense). The PRCC indicates the strength (i.e., in terms of level of certainty) and direction of a linear relationship between two rank-transformed variables, but does not directly indicate the magnitude of an association. The scatterplot, which can indicate the slope of a correlation, helps provide useful insight into the effect of a parameter's variation on dose. When a number of uncertain parameters are sampled, a highly correlated parameter has an association with the calculated dose that is greater than the totality of output variation induced by variation of the other input parameters. Thus, correlation results provide insight into the relative importance of parameters on the calculated result. This measure of importance is influenced by many factors (input parameter ranges, code algorithms, and the number of applicable pathways included in the dose calculations) and this analysis cannot determine the influence of each.

To avoid the undesirable effects of multi-colinearity, parameters which are independent in nature (i.e., the sampled value of x_1 does not influence the sampled value of x_2) should be independent in the modeling analysis. Furthermore, for best results, parameters which are correlated in nature should be modeled in a way which accounts for these correlations. While GENII-S allows user specification of such parameter correlations and some correlations are likely to exist, the actual values of these correlations are unknown and are, therefore, not accounted for in this analysis.

3.2.1 Sampling Methods and Sample Size

The LHS method is used to ensure full stratification across the range of each variable. A sample size of 125 is chosen because tests indicated this is the maximum size the available computer memory would process. With 43 sampled parameters, the chosen sample size is well above the minimum sample estimated by Eq. (3-1) provided by the developers of GENII-S (Leigh, 1992), and within range of 2 to 3 times the number of variables (86 to 129) Iman and Conover (1982) suggest for best results using LHS for correlation analyses.

$$N = (4/3)(n) \tag{3-1}$$

where N is the estimated minimum sample size, and n is the number of sampled parameters.

3.2.2 Rationale for Code Selection

The scope of this activity does not allow a comprehensive review of available dose assessment codes. The GENII-S code is selected for the dose calculations for many reasons. Important considerations include: compatibility with anticipated EPA HLW disposal regulations, applicability to a variety of scenarios relevant to HLW disposal, availability of software, extensive documentation, established reputation, and inherent capabilities for LHS and correlation analysis.

A primary advantage of GENII-S is the capability to calculate an annual individual total effective dose equivalent (TEDE). This dose is required by current EPA regulations for the Waste Isolation Pilot Plant (WIPP) site in 40 CFR 191 (U.S. Environmental Protection Agency, 1994) and many other standards and thus may be required for a HLW facility. Furthermore, GENII-S includes the Sensitivity and Uncertainty Analysis Shell (SUNS) statistical analysis software with capabilities for pre- and post-processing of data for sampling and subsequent statistical analysis of results. In contrast, the DITTY long-term dose assessment module used in IPA Phase 2 does not calculate an annual individual TEDE and requires development of pre- and post-processors to handle input and output functions for stochastic runs. The DITTY module also contains many hard-coded parameter values which cannot be altered by the user without source code modification and which cannot be analyzed stochastically, thereby limiting sensitivity analysis capabilities. The GENII-S code does not contain hard coded parameters (Leigh et al., 1993). Nonetheless, GENII-S does have some disadvantages. A much larger number of input parameters than DITTY necessitated limiting the depth of literature review of any one parameter value to ensure all site-specific parameters were investigated to some degree. GENII-S is also designed for short-term (i.e., 100 yr) dose calculations, whereas DITTY is uniquely capable of calculating long-term doses (i.e., 10,000 yr). Long-term dose calculations are likely to be required in the HLW program. If the EPA requires an annual individual dose, it is possible DITTY could be used to determine the 70-yr period of maximum population dose within the 10,000-yr time span and GENII (or GENII-S) could then be used to calculate annual individual doses for that period. Despite the lack of a single code which meets all the dose assessment needs of the program, GENII-S was considered the best choice for this task.

3.2.3 Consideration of Potential Code Deficiencies

A recent code comparison exercise conducted by Oak Ridge National Laboratory (ORNL) for low-level radioactive waste (LLW) Performance Assessments (PAs) contains critical comments and what are termed "potential code deficiencies" with the GENII code (Melescue and Fields, 1994). The comments in this document were reviewed to determine relevancy to the present code use. Most comments relate to needs which are specific to LLW intended uses which are not applicable to YM dose scenarios (e.g., cannot customize pathways to allow doses from contamination of aquatic life from airborne deposition to surface water). Other comments relate to insufficient documentation to explain all aspects of code operation and calculations. GENII documentation has limitations, however, consultations with the code developer can clarify questions. An additional comment claims use of identical dose conversion factors for ingestion and inhalation in the ^{14}C model as incorrect but does not clarify why this is so. Both the DOE dose conversion factor handbook (U.S. Department of Energy, 1988b) and EPA Federal Guidance No. 11 developed by ORNL scientists (Eckerman et al., 1988) have identical values for this parameter. This may be a professional difference of opinion, but should not be considered a code deficiency. Additional comments related to stochastic modeling capabilities and input parameter modification options not available in GENII have been added in the GENII-S version adopted by Sandia National Laboratories (SNL) which is used for this task.

A comment suggesting a potential error in the code, claims "the dry-to-wet plant weight ratio for hay for the milk cow uses the grain dry food transfer factor, yet the dry-to-wet plant weight ratio for hay for the beef cow uses the leafy vegetable dry food transfer factor." Tests conducted to verify this found GENII-S uses the concentration ratio (i.e., a type of food transfer factor) for grain if the feed is designated "stored feed" and two "stored feed" dry-to-wet conversion factors (one for beef cows and one for milk cows). If the feed is designated "fresh forage," then GENII-S uses the concentration ratio for leafy vegetables and two dry-to-wet conversion factors (one for beef cows, another for milk cows). This allows a user to model fresh forage and stored feed using different concentration ratios if an assumption is made that fresh forage consists of leafy plant material and stored feed consists of grain. It is possible the ORNL analysis compares transfer factors used for a fresh forage eating beef cow with a stored feed eating milk cow and expects them to be identical when they should not be. This report assumes all feed is fresh so the leafy vegetable concentration ratio and corresponding dry-to-wet factors for beef and milk are used as expected. In summary, the noted "potential code deficiencies" do not appear to apply to the present application of the code nor do they have any detrimental impacts on the quality of results obtained in the analysis.

3.2.4 Dose Assessment Scenario and Assumptions

3.2.4.1 Determination of the Appropriate Dose Endpoint

To determine an appropriate scenario for conducting the uncertainty and sensitivity analysis calculations it is necessary to speculate on the type of standards which are likely to be developed by the EPA for the HLW program. The most recent standards promulgated by EPA which are relevant to radioactive waste disposal are in 40 CFR 191 (U.S. Environmental Protection Agency, 1994) as they apply to the WIPP site in New Mexico. The individual protection requirements in §191.15 require a disposal system be designed to:

"...provide a reasonable expectation that, for 10,000 yr after disposal, undisturbed performance of the disposal system shall not cause the annual committed effective dose, received through all potential pathways from the disposal system, to any member of the public in the accessible environment, to exceed 15 millirems."

By specifying the dose to any individual, the dose is assumed applicable to a maximally exposed individual. Therefore, the endpoint of interest for this analysis is annual TEDE to a maximally exposed individual. This dose represents the sum of external deep dose for 1 yr plus the 50 yr committed effective dose equivalent from 1 yr of intake. This is consistent with the TEDE defined by the NRC in 10 CFR Part 20 (Nuclear Regulatory Commission, 1995b), however more current exposure-to-dose conversion factors are used in calculations for this report. Recently developed Federal guidance on external dose factors (Eckerman and Ryman, 1993) was used to update code defaults. These factors were not available for use in either IPA Phase 2 or 10 CFR Part 20. Default values (in GENII-S) for internal dose and inhalation factors were not changed. These factors are consistent with factors in U.S. Department of Energy (1988b) and are similar to factors in Federal Guidance 11 (Eckerman et al., 1988) which were used in 10 CFR Part 20.

3.2.4.2 The Target Individual: Resident Farmer

The scenario developed for a maximally exposed individual consists of a farmer living at the southern boundary of the proposed YM site. The scenario is similar to that used in the IPA Phase 2 dose assessment. The southern boundary was chosen because groundwater flows in a south and southeasterly direction from YM (U.S. Department of Energy, 1988b), and any potential release of radionuclides is more likely to contaminate groundwater south of the site than other areas. The farmer is assumed to grow alfalfa which is used for beef and milk cow feed. A garden plot is used to grow vegetables, fruits, and grain for personal consumption. While available information from Mills (1993) and local water permit records support the assumption that the farmer grows fruits and vegetables, there is less support for the assumption that grain is grown. Nonetheless, agricultural statistics do indicate a small amount of grain farming in Nye County (Section 2.3.2.1), and the assumption is consistent with the concept of maximum individual dose and the need to consider a range of exposure pathways in the sensitivity analysis. All food (i.e., grain, vegetables, fruits, milk and beef) is assumed grown by the farmer for personal consumption. Drinking and irrigation water is assumed to be pumped from a groundwater well at the farmer's residence. Specific parameter values are discussed in Section 2 and are summarized in Table B-1 in Appendix B.

3.2.4.3 Initial Groundwater Concentrations

In IPA Phase 2 analyses, a series of codes modeling release and transport generated estimates of radionuclide concentrations at the accessible environment prior to dose calculations. Results of the groundwater concentration calculations were not archived for later use. Thus, no estimates or distributions of groundwater concentrations from IPA Phase 2 analyses are available. As a result, it is necessary to assume some release and transport to the accessible environment occurs. Detailed release and transport analyses are not within the scope of this activity, and speculative or limited calculations of groundwater concentrations might bias sensitivity results. Such problems are addressed by using unit groundwater concentrations of 1 pCi/ℓ for each radionuclide at the accessible environment.

The unit concentration assumption requires stratification of results by radionuclide. Failure to do so allows the constant concentrations and radionuclide specific differences in sensitivity to bias sensitivity results. This is because setting the concentrations of all radionuclides to 1 creates an erroneous representation of the relative concentrations of all radionuclides which leads to calculation of a total dose which is not representative of actual relative radionuclide concentrations. Parameter sensitivities calculated on such a dose will thus be biased. Stratification also allows determination of radionuclide-specific differences in parameter sensitivities.

3.2.4.4 Selection of Radionuclides for Analysis

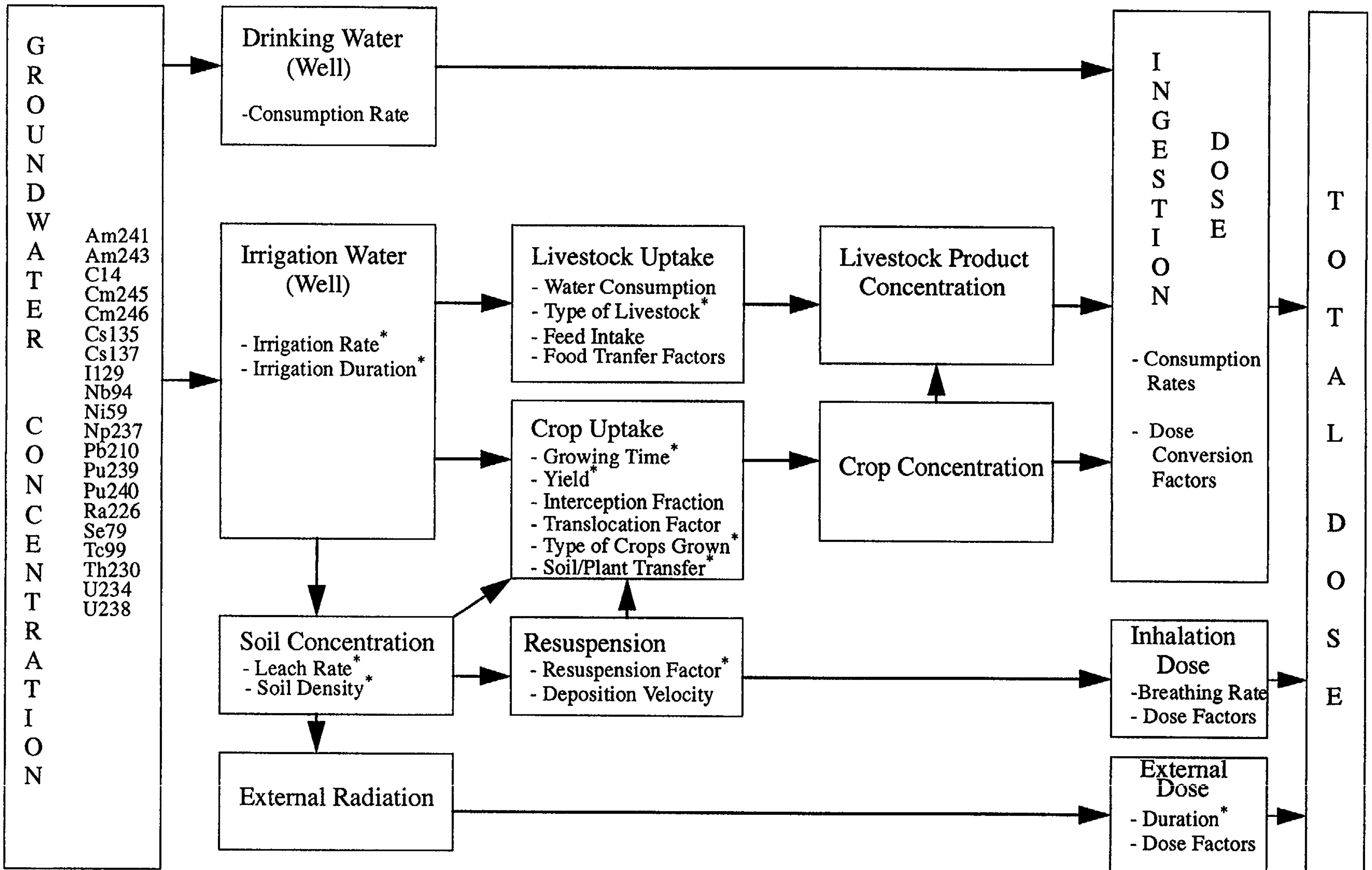
The choice of radionuclides to consider for inclusion in the analysis was initially determined by reviewing other relevant PAs (Sandia WIPP Project, 1992; Eslinger et al., 1993; Duguid et al., 1993; Sandia National Laboratories, 1994; Nuclear Regulatory Commission, 1995a) to achieve a consensus among sources regarding which radionuclides are considered important for release and transport under relevant conditions. Differences among radionuclide lists are associated with different underlying assumptions for release and transport analyses (for example, accounting for the effects of retardation). Such issues are key technical uncertainties and work is ongoing to reduce these uncertainties to improve modeling assumptions. Until a better understanding of such issues exists, it is difficult to determine with confidence the predominant radionuclides in release and transport scenarios. To obtain more comprehensive results, the initial list was expanded to account for additional radionuclides in the radionuclide inventory used in IPA Phase 2 analyses (Nuclear Regulatory Commission, 1995a) (see Figure 3-1). Expanding the list is necessary because the NRC staff have chosen to focus on these radionuclides in IPA analyses and this activity is being conducted to support IPA Phase 3 work.

3.3 PROPAGATION OF PARAMETER UNCERTAINTY ESTIMATES

GENII-S runs were completed and descriptive statistics were calculated for the annual individual TEDE distributions for each radionuclide (see Table 3-1). Cumulative log probability plots of TEDE distributions (in Appendix C) suggest most are lognormally distributed as is characteristic of results of multiplicative models (Hoffman and Hammonds, 1992). Curve fitting analyses were not conducted on all these distributions, but would improve accuracy of predictions based upon these data. Both the arithmetic and geometric means and corresponding standard deviations are provided in Table 3-1 to preserve options for later analysis. Equations for the geometric mean (x_g) [Eq. (3-2)] and geometric standard deviation(s_g) [Eq. (3-3)] are discussed in NUREG/CR-3332 (Till and Meyer, 1983):

$$x_g = \text{antilog}\left(\frac{\sum \log x_i}{n}\right) \tag{3-2}$$

$$s_g = \text{antilog}\sqrt{\frac{\sum (\log x_i - \mu)^2}{n}} \tag{3-3}$$



*Examples of Site Specific Parameters

Figure 3-1. Human exposure pathways and parameters applicable to a groundwater release scenario

Table 3-1. Arithmetic and geometric means and standard deviations calculated from unit groundwater concentrations of 1 pCi/ℓ

Radionuclide	Annual TEDE (rem) Arithmetic		Annual TEDE (rem) Geometric	
	Mean	Standard Deviation	Mean	Standard Deviation
^{234}U	6.05×10^{-5}	2.20×10^{-5}	5.67×10^{-5}	1.44
^{238}U	7.32×10^{-5}	2.59×10^{-5}	6.79×10^{-5}	1.43
^{230}Th	1.17×10^{-3}	4.37×10^{-4}	1.09×10^{-3}	1.45
^{99}Tc	8.43×10^{-6}	2.94×10^{-6}	7.95×10^{-6}	1.41
^{79}Se	5.24×10^{-5}	2.61×10^{-5}	4.66×10^{-5}	1.64
^{226}Ra	2.78×10^{-3}	9.34×10^{-4}	2.63×10^{-3}	1.41
^{239}Pu	1.09×10^{-4}	4.05×10^{-5}	1.02×10^{-4}	1.45
^{240}Pu	1.09×10^{-4}	4.05×10^{-5}	1.02×10^{-4}	1.45
^{210}Pb	1.32×10^{-2}	4.79×10^{-3}	1.24×10^{-2}	1.44
^{237}Np	1.25×10^{-2}	4.58×10^{-3}	1.17×10^{-2}	1.45
^{59}Ni	1.40×10^{-6}	8.22×10^{-7}	1.21×10^{-6}	1.72
^{94}Nb	2.02×10^{-4}	5.79×10^{-5}	1.93×10^{-4}	1.35
^{129}I	3.13×10^{-3}	1.86×10^{-3}	2.65×10^{-3}	1.80
^{137}Cs	7.61×10^{-4}	4.21×10^{-4}	6.64×10^{-4}	1.69
^{135}Cs	1.01×10^{-4}	6.11×10^{-5}	8.52×10^{-5}	1.81
^{246}Cm	8.11×10^{-3}	3.04×10^{-3}	7.58×10^{-3}	1.45
^{245}Cm	8.04×10^{-3}	3.01×10^{-3}	7.52×10^{-3}	1.45
^{14}C	1.90×10^{-5}	5.09×10^{-6}	1.84×10^{-5}	1.32
^{243}Am	7.91×10^{-3}	2.95×10^{-3}	7.39×10^{-3}	1.45
^{241}Am	7.90×10^{-3}	2.96×10^{-2}	7.38×10^{-2}	1.45

where

μ = the mean of log-transformed TEDE values for a given radionuclide

n = the number of TEDE values for a given radionuclide (i.e., realizations)

x_i = a single TEDE value for a given radionuclide

The range of annual individual TEDEs resulting from the 125 realizations of sampled runs per radionuclide are shown as Figure 3-2 box plots for each radionuclide. These plots show the results of propagating input parameter uncertainty estimates to generate the TEDE ranges for each radionuclide and indicate the relative variability in magnitudes of TEDEs across radionuclides. The boxes represent values at 25 and 75 percentiles and the error bars extend to 10 and 90 percentiles with circles representing outlying values beyond the error bars. A log plot is used because the variation in TEDE among all radionuclides was too wide for a linear scale and the TEDEs are approximately log-normally distributed.

Visual inspection of the box plots shows the estimated total TEDE uncertainty for most radionuclides to be approximately 1 order of magnitude; while the variation among radionuclides is about 5 orders of magnitude. The wider uncertainty range for ^{135}Cs, ^{137}Cs, ^{129}I, and ^{59}Ni may be due to the relatively high transfer rates of these radionuclides into the beef and milk food products. The consumption rates for both beef and milk are highly uncertain and are a likely cause for the increased uncertainty in the TEDEs for these radionuclides. Correlation results confirm this interpretation (Section 3.4) by showing these consumption rates to be high on the lists of parameters ordered by correlation coefficients (actual coefficients are moderately low but not relatively so).

Figure 3-2 provides insight into which radionuclides contribute to relatively higher radionuclide-specific doses when the influence of initial concentration is removed. This information should not be interpreted to mean that those radionuclides at the low end of the chart will not contribute to potentially significant doses or those at the high end will contribute to high doses because these results are relative and the magnitude of the initial radionuclide concentrations in the groundwater at the accessible environment will determine the magnitude of actual dose estimates. Nonetheless, the figure does provide insight into how the totality of radionuclide-specific dose assessment characteristics (excepting initial groundwater concentration) relatively affect the magnitude of calculated dose.

While relative differences in the magnitudes of radionuclide-specific TEDEs would change with different initial concentration levels, such changes can be easily determined from the information provided in this report when better estimates of initial concentrations for these radionuclides are available. A review of GENII-S calculations indicates the initial concentration parameter occurs only in arithmetic (i.e., linear) calculations. Therefore, mean TEDEs in Table 3-1 (which are reported on a per pCi/ℓ of initial concentration basis) can be multiplied by values of radionuclide-specific initial concentration estimates to determine the mean dose for the new initial concentration levels. The standard deviations can be used to determine the distributions for these point estimates. Refer to the latter part of this section for a discussion of estimating total (non-nuclide-specific) doses using similar methods.

For radionuclide-specific doses which are lognormally distributed (see probability plots in Appendix C), the geometric mean TEDE can be multiplied by the new concentration value to determine a new mean TEDE and the original geometric standard deviation can be applied to this new mean TEDE. To determine a 95-percent confidence interval for the new geometric mean TEDE, use the following

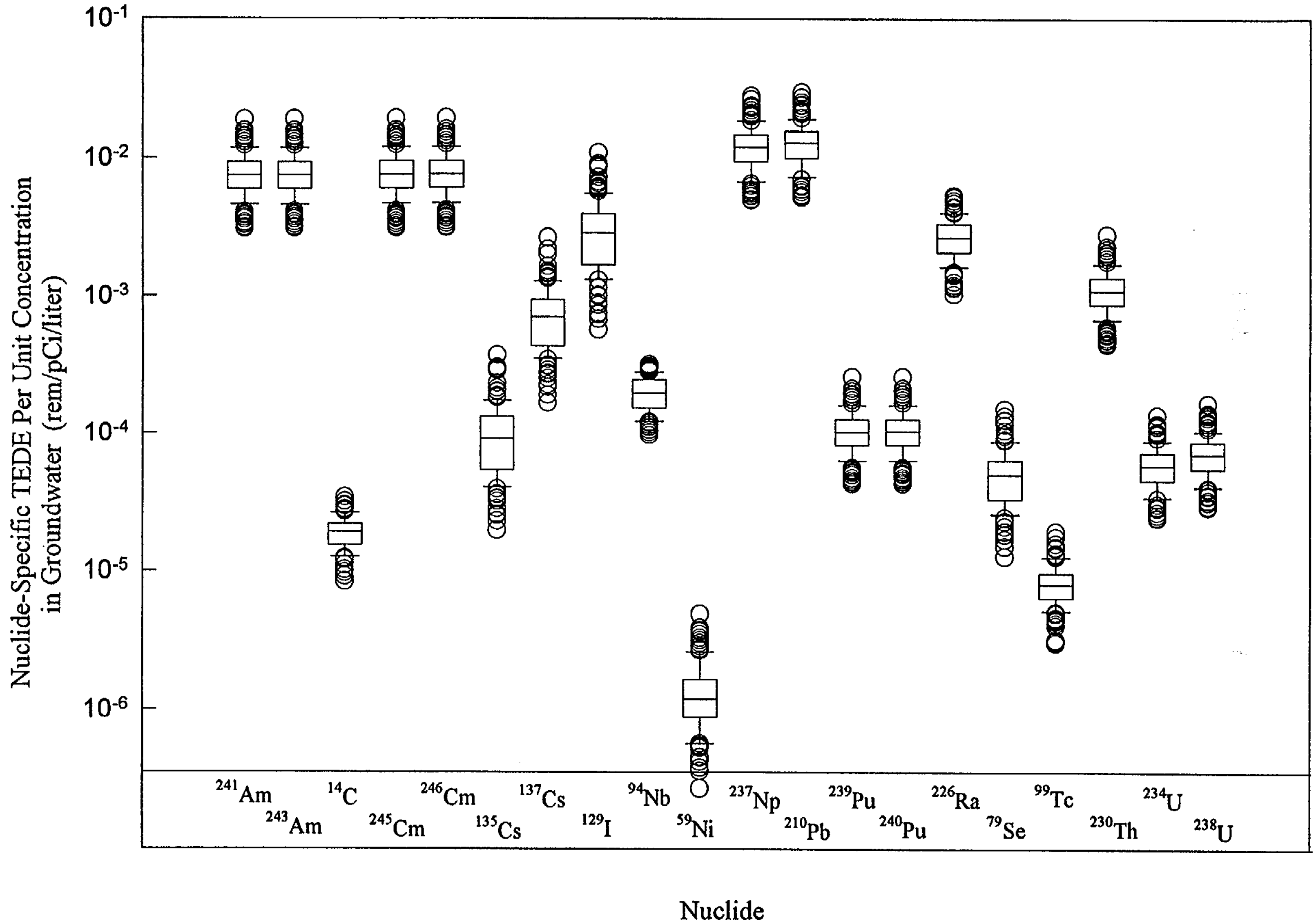


Figure 3-2. Total effective dose equivalent distributions for each radionuclide (125 realizations)

equations:

Upper 95-percent limit:

$$x_{gi} \cdot s_{gi}^{1.96} \tag{3-4}$$

Lower 95-percent limit:

$$x_{gi}/s_{gi}^{1.96} \tag{3-5}$$

where x_{gi} is the geometric mean and s_{gi} is the geometric standard deviation for radionuclide i.

For those TEDEs which approximate normal distributions, both the arithmetic mean and arithmetic standard deviation (separately) would be raised by the factor of the new concentration value and the following equation would be used to determine a 95-percent confidence interval about the new arithmetic mean:

$$x_i \pm (1.96)s_i \, , \tag{3-6}$$

where x_i is the arithmetic mean and s_i is the arithmetic standard deviation for radionuclide i.

To confirm these techniques are consistent with actual results, the code runs for ^{241}Am were repeated with 2, 3, and 10 pCi/ℓ initial concentration values. The resulting arithmetic and geometric mean and standard deviations are shown in Table 3-2. These results show proportional increases in the arithmetic mean and standard deviation with increases in initial concentration and proportional increases only to the geometric mean while the geometric standard deviation remains unchanged.

The aforementioned method of estimating TEDE distributions for new initial radionuclide concentrations bypasses the need to set up new code runs and re-process output data when radionuclide-specific doses need to be calculated for new groundwater concentration estimates. Such a method may also have applications for calculating annual individual doses in Total-System Performance Assessment (TSPA) analyses without having to incorporate a large code such as GENII-S into the main module.

There may also be interest in determining the total TEDE from all radionuclides combined. An example application would be to compare results determined from new groundwater concentrations with regulatory dose standards. This could be accomplished by adjusting the original output doses by the new initial concentration value and recalculating the mean and standard deviation from the sum of all adjusted radionuclide-specific dose totals. For a given vector, each radionuclide-specific TEDE would be multiplied by the new initial concentration value and then all adjusted TEDEs for the vector would be summed to determine the adjusted total TEDE for that vector. The process could be repeated for all vectors to generate the distribution of all adjusted total TEDE values. Summary statistics then can be calculated using this distribution. Limiting the summation to individual runs ensures sampled parameter values are consistent for each summed dose (except the few radionuclide-specific factors which were sampled). Such calculations can be programmed into a spreadsheet to improve efficiency. If distributions of groundwater concentrations are available, such calculations could be accomplished by using a commercial software package which integrates spreadsheet calculations with sampling routines. Use of

Table 3-2. Effect of increases in groundwater concentrations of ^{241}Am on total effective dose equivalent means and standard deviations

Radionuclide Concentration (pCi/ℓ)	Annual TEDE (rem) Arithmetic		Annual TEDE (rem) Geometric	
	Mean	Standard Deviation	Mean	Standard Deviation
1	7.9×10^{-3}	2.9×10^{-3}	7.38×10^{-3}	1.45
2	1.6×10^{-2}	5.9×10^{-3}	1.48×10^{-2}	1.45
3	2.4×10^{-2}	8.9×10^{-3}	2.22×10^{-2}	1.45
10	7.9×10^{-2}	2.9×10^{-2}	7.38×10^{-2}	1.45

the current data to generate new results in this manner may save time by avoiding the need to rerun the code and reprocess large amounts of raw data. A similar concept could be applied to providing total dose capabilities in the IPA code.

3.4 CORRELATION ANALYSIS RESULTS

This section presents the results of the correlation analysis with emphasis on those parameters which have relatively high PRCCs. Given that many parameters are relevant to specific exposure pathways, groups of parameters which have the highest correlations with a radionuclide-specific TEDE are analyzed to determine if potentially important exposure pathways are evident.

The SUNS software shell of GENII-S is used to calculate simple and partial rank correlation coefficients for comparisons between each individual parameter distribution and the relevant radionuclide-specific TEDE distribution. Scatterplots of selected comparisons are provided in Appendix D and full correlation results for all sampled parameters are provided in tables in Appendix E. The parameters are ranked by simple correlation coefficients, however, because the PRCCs for most comparisons are the same or very similar to the simple coefficients, the ranking applies to both simple and partial results. A few parameters for a small number of radionuclides show evidence of colinearity which can lead to biased interpretations.

Initial consideration of the PRCCs indicates a large number of comparisons with low values. In general, PRCCs below 0.70 are insufficient to establish an association with reasonable certainty, but can provide insights into the relative influence of individual parameters on the TEDE. Consideration of scatterplots helps visualize the uncertainty and relationships in the data which are not evident from the coefficients. To limit the number of plots to a reasonable number, and to simplify consideration of results, the ranked parameters for each radionuclide are reviewed and placed into groups of radionuclides; each with the same order of parameter rankings for approximately the top 10 parameters (below which, PRCCs are very low). The radionuclides forming a group are expected to have similar characteristics or exhibit similar behavior with respect to dose calculation if they exhibit the same order of correlated parameters with the same values for PRCCs. The results include the six groups of radionuclides shown in Table 3-3. For the purpose of discussion, each group is identified by the first radionuclide appearing in the table.

Scattterplots for one radionuclide from each group are presented for comparisons involving the highest four parameter/dose correlations (see Appendix D). One radionuclide is considered sufficient to represent a group due to the assumption that group members should exhibit similar behavior with respect to their association with dose. The top four parameter correlations are selected for plotting because plots of comparisons with PRCCs below the fourth ranked parameter in any group were uncertain and unlikely to provide meaningful information. In examples reviewed, comparisons with PRCCs below 0.30 do not exhibit discernable relationships in a scatterplot while those above show generally positive or negative trends. The plots are used to verify whether a trend was apparent in the data and, if so, a visual interpretation of the slope is used to order parameters by the magnitude of their influence on TEDE results. This information is provided in the last column of Table 3-3.

When the radionuclides in each group are considered together with the ordered parameters, some biologically relevant relationships are apparent (see Table 3-3). These relationships enhance the validity of sensitivity analysis results. Consider the U-238 group which is largely composed of transuranic alpha emitters which do not readily transfer from the soil to plants relative to the other radionuclides. Alpha particles cannot penetrate the skin and therefore must be ingested or inhaled to produce a dose. The parameters which show elevated correlations with the radionuclide-specific TEDEs, such as the crop interception fraction, and to a reduced degree the resuspension factor, and grain and fruit consumption rates are consistent with a suggestion that surficial deposition of radioactive material onto crops is dominating the calculated dose for this group of radionuclides. The model used in GENII-S to estimate radionuclide concentrations in edible plants is a variant of the model in the NRC Regulatory Guide 1.109 (Nuclear Regulatory Commission, 1977). This model accounts for both direct deposition from air and water and uptake through roots from contaminated soil. Consideration of the soil to plant concentration ratios in Table 2.5 shows relatively low values for these radionuclides—particularly for grain transfer—which minimizes the soil pathways influence on dose for these radionuclides. The very low correlation of the plant/soil transfer scale factor is consistent with the expectation of low influence of soil uptake on the TEDEs for this group.

The ^{129}I group has much different results. This is expected since these radionuclides transport through the food chain more readily than the ^{238}U group. Considering the transfer coefficients in Table 2-5, I, Cs, and Se show relatively high transfer factors to beef; and I in particular has relatively high transfer to milk. The elevated PRCCs for crop interception and animal uptake factor followed to a lesser degree by beef consumption rate and beef feed irrigation duration and a relatively very low PRCC for soil transfer are consistent with pathways for these radionuclides comprising surficial deposition to feed crops, animal ingestion with high relative uptake to meat, and subsequent human consumption. Whicker et al. (1990) has conducted a similar type of partial correlation analysis for the air exposure pathway at the NTS adjacent to YM using the PATHWAY model (which is based upon a different mathematical design than GENII-S). Whicker's analysis focuses on the behavior of ^{136}Cs, ^{137}Cs, and ^{131}I. Results show the crop interception fraction to have a consistent high correlation with dose (around 0.70) which is generally consistent with the results of the present study. Whicker also reports very low significance of the plant/soil transfer factors for Cs and I, which is also consistent with the results in this report. While this analysis, unlike Whicker, is focused on the groundwater pathway, the function of the

Table 3-3. Correlation analysis results

Nuclides in Group	Parameters	PRCC	Scatterplot Results* (ordered)
^{238}U, ^{234}U, ^{230}Th ^{241}Am, ^{243}Am, ^{245}Cm, ^{246}Cm, ^{226}Ra, ^{239}Pu, ^{240}Pu, ^{210}Pb, ^{237}Np	Crop interception fraction	0.77	Linear (1)
	Crop resuspension factor	0.32	Uncertain
	Grain consumption rate	0.24	Uncertain
	Fruit consumption rate	0.22	Uncertain
^{129}I, ^{135}Cs, ^{137}Cs, ^{79}Se	Crop interception fraction	0.60	Linear (2)
	Animal uptake scale factor	0.59	Linear (1)
	Beef consumption rate	0.27	Uncertain
	Beef feed irrigation duration	-0.25	Uncertain
^{14}C	Grain consumption rate	0.75	Linear (1)
	Surface soil density	-0.32	Linear (2)
	Fruit consumption rate	0.29	Uncertain
	Beef consumption rate	0.25	Uncertain
	Root vegetable cons. rate	0.20	Uncertain
	Beef feed irrigation time	-0.20	Uncertain
^{99}Tc	Soil/plant transfer factor	0.54	Linear (1)
	Crop interception fraction	0.46	Linear (2)
	Root vegetable consumption rate	0.37	Uncertain
	Fruit consumption rate	0.31	Uncertain
	Leafy vegetable consumption rate	0.21	Uncertain
	Grain Consumption Rate	0.20	Uncertain
^{59}Ni	Crop interception fraction	0.61†	Linear (2)
	Animal uptake scale factor	0.47	Linear (1)
	Milk consumption rate	0.44	Linear (3)
	Crop resuspension factor	0.20	Uncertain
	Milk feed irrigation duration	-0.20	Uncertain
^{94}Nb	Home Irrigation Rate	0.98†	Linear (1)
	Soil Exposure Duration	0.19	Uncertain

* These results are based upon visual interpretation, therefore the reader may prefer to view the scatterplots in Appendix D to independently review the interpretations. The number in parentheses represents relative order (descending) based upon interpretation of linear trends in the scatterplots.

† Simple rank correlation coefficients are given for ^{59}Ni and ^{94}Nb due to evidence of possible colinearity with other parameters.

crop interception fraction is essentially the same for both air and water deposition models and thus the comparison is valid.

^{14}C is unique among the radionuclides as it is readily incorporated into human and biological systems as carbon dioxide gas or carbohydrates. As such, a separate specific activity model in GENII-S is used for ^{14}C dose analysis. All inhaled or ingested ^{14}C is assumed to be absorbed immediately by the lungs and gastrointestinal tract. The code developers recognize plants acquire most of their carbon by air but the model assumes the specific activity of ^{14}C of the environmental media (plants, animals) is equivalent to that of the contaminating medium (air or water) and adds a correction factor for the water/plant transfer. The correlated parameter results, unlike those for the other groups, do not include transport mechanism related parameters, rather, the ^{14}C is readily incorporated into plants and animal tissues causing the consumption rates to have the only discernable correlation with dose for this radionuclide. The appearance of soil density as a moderately correlated parameter is due to its use in the denominator of the equation to calculate plant ^{14}C concentration (thus the negative correlation). The equation determines the amount of carbon in the soil which is available for plant uptake and, as the soils becomes more dense, there is less available volume for contaminated water.

^{99}Tc is a beta emitting radionuclide which transports readily through the food chain, but unlike the ^{129}I group, has very high concentration ratios for soil to plant transfer for all plants considered. As a beta emitter, ^{99}Tc must be ingested to obtain a dose. Moderately elevated PRCC for soil to plant transfer, crop interception, and to a reduced extent fruit and root vegetable consumption rates are consistent with potential preferential pathways for ^{99}Tc via both external deposition and soil uptake to crops that are then consumed by the resident farmer.

Ni is the element most readily transferred to milk of the 15 elements considered in this analysis (excepting ^{14}C, which uses a different model). The elevated PRCCs for Ni-59 include the crop interception fraction followed by animal uptake, crop resuspension, and milk consumption at a more reduced level, while the soil to plant transfer factor is relatively much more reduced. This arrangement is consistent with a potential preferential pathway involving deposition to milk cow feed (alfalfa) crop surface, some resuspension related contamination as well, and subsequent human consumption of the contaminated milk. Differences between the partial and simple correlation coefficients for the top two parameters suggest potential colinearity which could bias results.

Finally, ^{94}Nb is a gamma emitter which does not transfer readily into animal products (it has the lowest milk and beef transfer coefficient of the elements considered). As a gamma emitter, external dose is likely to be more of a concern than with the other radionuclide groups. This is borne out in the results which show a high PRCC for home irrigation rate and soil exposure duration at a much more reduced yet relatively elevated value. These parameters are relevant to the dose calculation for external exposure from air and water deposition of radionuclides to soil. An analysis of dose results for ^{94}Nb indicates external dose is 91.5 percent of the TEDE, thus ^{94}Nb is the only radionuclide, of the 20 radionuclides considered, where external exposure predominates. Large differences between the simple and partial correlation coefficients for parameters such as soil exposure time and crop interception fraction are an indication of colinearity and potential for bias of the results (thus, the simple correlation coefficients were used). Overall, the correlation results suggest a predominance of external exposure to soil contaminated by irrigation.

4 CONCLUSIONS

4.1 CORRELATION ANALYSIS

Analysis of the box plot, scatterplots, and correlation coefficients clearly indicate a large amount of variation exists in calculated TEDEs. While it is not uncommon for dose assessment sensitivity analyses to determine that a relatively small group of important parameters exist among many less important ones, the choice to sample over 40 parameters has propagated large uncertainties in the input parameters to the calculated doses. Such uncertainty in the TEDEs could be reduced by focusing on specific pathways to limit the number of sampled parameters, or by reducing the uncertainty in parameter values by obtaining better data. In addition, the large number of parameters in the GENII-S model may have reduced the influence of any one parameter on the final calculated dose. An illustrative example is the irrigation rate for forage and other crops which is divided into six components—a separate rate for each type of crop. If this latter point is correct, then reduction in input value variation may not resolve the issue of low correlations. Despite the variation in the results, there are some conclusions which can be drawn from the analysis:

A conservative interpretation of the correlation analysis would discount those associations with PRCCs which are below 0.70. Under such conditions, the following conclusions are:

- The crop interception fraction is correlated with the TEDE for ^{238}U, ^{234}U, ^{230}Th, ^{241}Am, ^{243}Am, ^{245}Cm, ^{246}Cm, ^{226}Ra, ^{239}Pu, ^{240}Pu, ^{210}Pb, and ^{237}Np. This correlation indicates the crop interception fraction has a strong influence on the calculated TEDE value for the groundwater contamination scenario. It is also possible a relationship between the interception fraction and TEDE is more evident for these radionuclides due to inherent limiting of available pathways that results in reduced propagation of input parameter uncertainties from a reduced suite of applicable parameters (see Section 3.4, page 3-11).

- The home irrigation rate is correlated with the TEDE for ^{94}Nb. This parameter has a clearly discernable linear association with TEDE and scatterplot results lack the wide range of variation seen in many of the plots for other radionuclides. A likely explanation for this effect is the limited applicable exposure pathways for this radionuclide and the resulting limitations in propagation of input parameter uncertainty from other parameters. The primary route of exposure for ^{94}Nb is found to be external exposure to contaminated soil due to its low capabilities to transport through the food chain (see Section 3.4, page 3-13).

- The grain consumption rate is correlated with the TEDE for ^{14}C. The relatively strong association is likely due to the combination of the metabolic significance of ^{14}C and thus high transfer to plants and the wide range and high maximum value for grain consumption relative to the other consumption rates (see Section 3.4, page 3-13).

With a more relaxed interpretation of the correlation results (focusing mainly on the relative magnitude of PRCCs rather than absolute) the following additional conclusions can be made:

- When parameters are ordered by descending PRCCs, the group of the top four or five parameters are relevant to specific exposure pathways (see Section 3.4).

- For the 20 radionuclides considered, an inclusive list of potentially important parameters can be found in Table 3-3. This includes the crop interception fraction, resuspension factor, terrestrial crop consumption rates (particularly grain/fruit), the animal uptake scale factor, milk and beef consumption rates, milk and beef feed irrigation duration, and the home irrigation rate and soil exposure duration. More informative estimates of important parameters can be determined by using initial groundwater concentration estimates to generate new TEDE distributions which can be ranked by magnitude and used as a basis for selecting those radionuclides (and thus parameters) which dominate the dose calculations (see Section 3.3).

- General trends for potential preferential pathways include surficial deposition from irrigation water to plant surfaces for most radionuclides. Beef uptake appears to be important for the ^{129}I, ^{135}Cs, ^{137}Cs, and ^{79}Se group, soil uptake to crops for ^{99}Tc, milk uptake for ^{59}Ni, and external gamma radiation exposure for ^{94}Nb (see Section 3.4).

- Variation in calculated doses presents the potential for alternative interpretations of the data. Further analysis of the results with more sophisticated multiple regression techniques, or reiteration of GENII-S runs with modifications to reduce variation may clarify some of the ambiguities associated with the current approach and results.

4.2 UNCERTAINTY ANALYSIS

Uncertainty in individual parameter values was determined by reviewing available data and selecting ranges conservatively with the intent of determining crude estimates of the true parameter uncertainty. Propagation of the uncertainty of each sampled parameter in the model generates TEDE distributions which reflect the total uncertainty contributed to the output from the sampled input parameters. While the current results have limitations, due to the inability to fully characterize true parameter uncertainties, this analysis goes beyond IPA Phase 2 dose assessment analyses which did not propagate any variation in dose assessment input parameters (other than initial groundwater and air concentration outputs from other codes). The following conclusions from the present analysis are:

- Variation in radionuclide-specific TEDE distributions resulting from propagation of input parameter uncertainty estimates is approximately 1 order of magnitude for most radionuclides. Wider variation in TEDEs for Cs, I, and N, may be explained by propagation of uncertainty from a larger suite of applicable input parameters which results from a relatively larger suite of relevant exposure pathways as determined by relatively high transfer coefficients for these radionuclides compared to others. Similarly, the limited variation shown for ^{94}Nb may be the result of limited input parameter uncertainty from few relevant pathways due to low biologic mobility.

- Figure 3-2 can be used to visualize uncertainties within and variation among radionuclide-specific TEDE distributions and to understand the combined effects of radionuclide-specific properties (independent of initial concentration) in the dose model which increase or decrease TEDE results.

- Most TEDE distributions are approximately lognormally distributed as expected for a multiplicative type of model (Hoffman and Hammonds, 1992) as shown in the nearly linear log probability charts in Appendix C. Curve fitting techniques can be applied to the data to more accurately model the distributions.

- Available arithmetic and geometric means and standard deviations can be used to efficiently calculate new TEDE distributions when estimates of initial radionuclide concentrations are available. This can be accomplished without additional code runs and processing of raw data. Results of such calculations can be used to rank results by magnitude of TEDE (or recreate Figure 3-2) to determine the relative importance of specific radionuclides to the TEDE. Other potential applications include efficient determination of individual dose estimates and distributions for comparison with EPA standards and addition of individual dose calculation capabilities (not available in DITTY) in the IPA code.

- Use of the TEDE means and standard deviations to calculate actual TEDEs may have cost effective applications for TSPA code modifications to address potential new demands from revised EPA HLW regulations.

4.3 SUMMARY

The results obtained from both the literature search for parameter information and the quantitative analyses provide useful insights into dose assessment for YM which can aid current and future PA dose assessment activities. The sensitivity analysis, despite its limitations and uncertainties, was able to identify some parameters which were well correlated with TEDE for specific radionuclides. These included the crop interception fraction, the home irrigation rate, and the grain consumption fraction. The results should be interpreted with caution, however, because they are radionuclide-specific, based upon fictitious normalized concentrations, and only relative importance of parameters and radionuclides can be considered with the current information. The actual importance of certain radionuclides and also certain parameters to a calculated TEDE can only be determined when reliable estimates of initial radionuclide concentrations are available. Nonetheless, the results in this report provide a framework for analyzing such information in the future.

The literature search results for the crop interception fraction (Section 2.3.5.3) were successful at obtaining a range of values from a considerable body of field research. Some of this research was conducted at the NTS using alfalfa, which is a predominant forage/feed crop grown locally in Nye County. These results, however, range from 0.06 to 1.0 which is practically the entire range of possible values. Given the importance of this parameter to the TEDE calculation, it may be helpful to re-assess the data to determine if the range can be more limited or consider the possibility of recommending that additional research be conducted at the site.

The home irrigation rate (Section 2.3.3.1) was another site-specific parameter which was highly correlated with TEDE for only one radionuclide-specific dose. This association is thought to be related to the lack of food chain mobility of ^{94}Nb, which thereby removed the uncertainty associated with the food pathway parameters. The value for this parameter is also based upon site-specific information, although this was limited to water requirements for growing a lawn in Nye County. The uncertainty associated with this parameter is difficult to reduce due to the likely variabilities in home water use. This and similar local parameter information would ideally be collected by the DOE in household surveys to obtain the most accurate information. It is possible such information has already been incorporated in the DOE socioeconomic studies to date, but such information was not reviewed in this task.

The grain consumption rate (Section 2.3.2.4) was also highly correlated with TEDE for the ^{14}C model. Consumption rates are highly variable as indicated by the value used from Hoffman et al. (1982) which ranged from 15.3 to 312 kg/yr. Based upon review of the literature, it does not appear likely that better values can be readily found. Due to the variabilities in eating habits and dieting, and the ever changing suite of popular foods, it is likely this parameter will remain highly variable.

Of the other parameters which appear potentially correlated with TEDE, the resuspension factor (Section 2.3.5.2), and milk and beef feed irrigation duration (Section 2.3.3.4) are based upon reasonably good quality site specific data sources and in the case of the resuspension factor are fundamentally uncertain parameters which are impacted by a number of uncertain variables and processes. The animal uptake scale factor distribution was interpolated from recent IAEA (1994) information and is considered to be reasonable, albeit not site-specific. The remaining potentially correlated parameters include milk and beef consumption rates (Section 2.3.2.4), and soil exposure duration (Section 2.3.4.2). The consumption rates are fundamentally variable due to differences in eating habits of the general public. The soil exposure duration is also difficult to characterize, however, little data were found in the literature survey for activity patterns of farmers who, based upon their occupational conditions, would be expected to spend considerable time outdoors. The assumed distribution with a maximum equivalent to 15 hr/day outdoors is probably an overestimate of the actual value and therefore the uncertainty could be reduced if new information became available or a less conservative assumption was used. Socioeconomic studies conducted in agricultural areas may contain such information and it may be preferable to search for additional data on this parameter. The DOE socioeconomic studies may be a source of additional information on this parameter.

4.4 RECOMMENDATIONS

- Improved estimates of groundwater concentration at the accessible environment and at locations where water is currently being pumped would be useful for determining the dose-based importance of specific radionuclides. Results from this study can be used to supplement recent CNWRA efforts to determine important radionuclides for PA by broadening the exposure pathways considered for little additional effort and cost.

- A review of the NAS recommendations on EPA radiation protection standards to determine the impact on results of this study would be valuable.

- Interactions with the DOE to discuss their dose assessment parameter information would be helpful for: (i) obtaining additional information on dose parameters which was not obtained in the present task, and (ii) gaining a better understanding of the DOE progress to date and current insights into dose assessment parameters and techniques they plan to apply to YM PA. No attempt was made in the current study to obtain unpublished data from the DOE or to discuss recent studies which may have been conducted by the DOE for the HLW program. Therefore, a review of currently available information in the DOE databases should be conducted to provide insights into current information.

- Information in this report, in conjunction with knowledgeable judgments and combined with future results of reviews of the DOE dose assessment activities, can be used to determine if additional site-specific dose parameter research is necessary to reduce uncertainties in important parameters and validate dose assessment assumptions.

- Should the NRC become involved in activities to determine a reference biosphere for dose assessment at YM, the information contained in this report can be used as a reference for relevant site parameter values. Such information can aid the NRC in reviewing the final dose parameters determined by the DOE for their TSPA dose assessments.

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APPENDIX A

AUTOMATED LITERATURE SEARCH CRITERIA

Logon file001 05nov94 09:58:00

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File   2:INSPEC  1969-1994/Oct W5
File   8:Ei Compendex*Plus(TM)  1970-1994/Dec W1
File   6:NTIS  1964-1994/Dec B2
File 103:Energy SciTec  1974-1994/Oct B2
File  41:Pollution Abs  1970-1994/Oct
File  10:AGRICOLA  1979-1994/Sep
    Set  Items  Description
    ---  -----  -----------
    EXS SD036/1-31
    SELECT response set to SHORT.
    S1   10344  NEVADA()TEST()SITE OR YUCCA()MOUNTAIN
    S2   53625  DOSE()ASSESSMENT OR RISK()ASSESSMENT
    S3 1071019  PARAMETER? ?
    S4   44162  PATHWAY? ?
    S5   40784  ENVIRONMENTAL()TRANSPORT
    S6   11641  RADIOACTIVE AND (FALLOUT OR DISPERSION)
    S7      95  S1ANDS2AND(S3ORS4ORS5ORS6)
    S8   18920  RADIOACTIVE AND CONTAMINATION
    S9   20770  PLANT? ? AND UPTAKE
   S10   34595  VEGETABLE? ?
   S11   11318  ALFALFA
   S12     118  FEED()CROP? ?
   S13   16298  FORAGE
   S14   44367  FRUIT? ?
   S15  195815  GRAIN? ?
   S16   18965  BEEF
   S17   20026  POULTRY
   S18   41769  MILK
   S19   23823  EGG OR EGGS
   S20     396  SOIL()LEACH?
   S22      48  SOIL()UPTAKE
   S23      64  DESERT()AGRICULTURE
   S24     882  MUNICIPAL()WATER AND (DETECT? OR TREAT? OR REMOVAL)
   S25    1364  S8AND(S9ORS10ORS11ORS12ORS13ORS14ORS15ORS16ORS17ORS18ORS-
                19ORS20ORS22ORS23ORS24)
   S26       5  (GENII OR DITTY) AND (PARAMETER? ? OR SENSITIVITY)
   S27    1462  S7ORS25ORS26
   S28    1188  S27/ENG
   S29     449  S28/1989:1994
   S30     956  RD S28 (unique items)

   S31     352  S30/1989:1994  [Off-line prints ordered]

   S32     604  30NOT31
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APPENDIX B

INPUT PARAMETER VALUES

Table B-1. Input parameter information

Parameter	Minimum	Best Estimate	Maximum	Distribution	Comments
Population/Soil/Scenario Data					
Population Scale Factor		1.0		Fixed	
Soil/Plant Transfer Scale Factor	0.26		3.9	Log Normal	Section 2.3.2.8
Animal Uptake Scale Factor	0.26		3.9	Log Normal	Section 2.3.2.8
Human Dose Factor Scale Factor		1.0		Fixed	
Surface Soil Plow Depth (cm)		15		Fixed	Section 2.3.4.1
Surface Areal Soil Density (kg/m2)	180		270	Uniform	Section 2.3.4.3
Deep Areal Soil Density (kg/m3)		1500		Fixed	N/A due to 0 percent Deep Soil Root Fraction Assumed
Roots in Upper Soil (Fraction)		1.0		Fixed	Conservative Assumption—All roots in upper soil
Roots in Deep Soil (Fraction)		0.0		Fixed	Conservative Assumption—No roots in deep soil
Biotic Transport/Near Field					
Burial Time Before Intake (yr)		0		Fixed	Not applicable for contaminated ground water
Waste Form/Pack Half-Life (yr)		0		Fixed	Not applicable for contaminated ground water
Waste Thickness (m)		0		Fixed	Not applicable for contaminated ground water
Soil Overburden Depth (m)		0		Fixed	Not applicable for contaminated ground water
Manual Redistribution Factor		0		Fixed	Not applicable for contaminated ground water
Biotic Transport Time Prior to Intake (yr)		0		Fixed	Not applicable for contaminated ground water
Contaminated Source Area (m2)		0		Fixed	Not applicable for contaminated ground water
External/Inhalation Exposure					
Chronic Plume Exposure (hr)	5548	7116	7117	Triangular	Section 2.3.5.1
Acute Plume Exposure (hr/phr)		0.0		Fixed	Acute Air Releases Not Modeled
Inhalation Exposure (hr/yr)	5548	7116	7117	Triangular	Section 2.3.5.1
Mass Load(g/m3)		5.0E-5		Fixed	Mass loading model used
Transit Time to Recorded Site (hr)		0		Fixed	No recreational exposures
Swimming Exposure Time (hr)		0		Fixed	No recreational exposures
Boating Exposure Time (hr)		0		Fixed	No recreational exposures

Table B-1 (Cont'd). Input parameter information

Parameter	Minimum	Best Estimate	Maximum	Distribution	Comments
Shoreline Exposure Time (hr)		0		Fixed	No recreational exposures
H2O/Sediment Transfer (l/m2/yr)		0		Fixed	No recreational exposures
Soil Exposure Time (hr)	5548	7116	7117	Triangular	Section 2.3.4.2
Home Irrigation Rate (in/yr)	26		84	Uniform	Section 2.3.3.1
Home Irrigation Duration (mo/yr)	6		12	Uniform	Section 2.3.3.2
Ingestion Exposure					
Food-Weighted Chi/Q (kg-s/m3)		0		Fixed	Not used in individual assessments
Crop Resuspension Factor (/m)	1.66E-6		6.03E-5	Log Normal	Section 2.3.5.2
Crop Deposition Velocity (m/s)		0.001		Fixed	Section 2.3.5.2
Crop Interception Fraction (-)	0.06	0.4	1.0	Triangular	Section 2.3.5.3
Soil Ingestion Rate (mg/day)		410		Fixed	GENII-S Default Data
Swim H_2O Ingestion Rate (l/hr)		0		Fixed	No recreational exposures
Drink Water Holdup Time (days)		0		Fixed	Holdup not applicable for long half life radionuclides
Drink Water Consumption (l/yr)	113		1081	Log Normal	Section 2.3.3.5
Terrestrial Food Ingestion					
Leaf Vegetable-Grow Time (days)	40		120	Uniform	Section 2.3.2.2
Root Vegetable-Grow Time (days)	25		120	Uniform	Section 2.3.2.2
Fruit-Grow Time (days)	65		95	Uniform	Section 2.3.2.2
Grain-Grow Time (days)	60		90	Uniform	Section 2.3.2.2
Leaf Vegetable-Irrigation Rate (in/yr)				Empirical	Section 2.3.3.3 (File IRRIG.DAT)
Root Vegetable-Irrigation Rate (in/yr)				Empirical	Section 2.3.3.3 (File IRRIG.DAT)
Fruit-Irrigation Rate (in/yr)				Empirical	Section 2.3.3.3 (File IRRIG.DAT)
Grain-Irrigation Rate (in/yr)				Empirical	Section 2.3.3.3 (File IRRIG.DAT)
Leaf Vegetable-Irrigation Time (mo/yr)	3		8	Uniform	Section 2.3.3.4
Root Vegetable-Irrigation Time (mo/yr)	2		8	Uniform	Section 2.3.3.4
Fruit-Irrigation Time (mo/yr)	2		3	Uniform	Section 2.3.3.4

Table B-1 (Cont'd). Input parameter information

Parameter	Minimum	Best Estimate	Maximum	Distribution	Comments
Grain-Irrigation Time (mo/yr)	6		8	Uniform	Section 2.3.3.4
Leaf Vegetable-Yield (kg/m2)	0.618		6.47	Log Normal	Section 2.3.2.3
Root Vegetable-Yield (kg/m2)	0.769		20.8	Log Normal	Section 2.3.2.3
Fruit-Yield (kg/m2)	.3	0.54	2.0	Triangular	Section 2.3.2.3
Grain-Yield (kg/m2)	0.471		0.605	Uniform	Section 2.3.2.3
Leaf Vegetable-Production (kg/yr)		0			Not used in individual assessments
Root Vegetable-Production (kg/yr)		0			Not used in individual assessments
Fruit-Production (kg/yr)		0			Not used in individual assessments
Grain-Production (kg/yr)		0			Not used in individual assessments
Leaf Vegetable-Holdup (days)		1		Fixed	NUREG/CR-5512
Root Vegetable-Holdup (days)		14		Fixed	NUREG/CR-5512
Fruit-Holdup (days)		14		Fixed	NUREG/CR-5512
Grain-Holdup (days)		14		Fixed	NUREG/CR-5512
Leaf Vegetable-Consumption Rate (kg/yr)	4.27		28.3	Log Normal	Section 2.3.2.4
Root Vegetable-Consumption Rate (kg/yr)	11.3		231	Log Normal	Section 2.3.2.4
Fruit-Consumption Rate (kg/yr)	10.2		208	Log Normal	Section 2.3.2.4
Grain-Consumption Rate (kg/yr)	15.3		312	Log Normal	Section 2.3.2.4
Animal Product Consumption					
Beef-Consumption Rate (kg/yr)	22.1		157	Log Normal	Section 2.3.2.4
Poultry-Consumption Rate (kg/yr)		0		Fixed	N/A
Milk-Consumption Rate (kg/yr)	20.8		482	Log Normal	Section 2.3.2.4
Eggs-Consumption Rate (kg/yr)		0		Fixed	N/A
Beef-Holdup (days)		20		Fixed	NUREG/CR-5512
Poultry-Holdup (days)		0		Fixed	N/A
Milk-Holdup (days)		1		Fixed	NUREG/CR-5512
Eggs-Holdup (days)		0		Fixed	N/A
Beef-Production (kg/yr)		0		Fixed	N/A Not used in individual assessments

Table B-1 (Cont'd). Input parameter information

Parameter	Minimum	Best Estimate	Maximum	Distribution	Comments
Poultry-Production (kg/yr)		0		Fixed	N/A Not used in individual assessments
Milk-Production (kg/yr)		0		Fixed	N/A Not used in individual assessments
Eggs-Production (kg/yr)		0		Fixed	N/A Not used in individual assessments
Beef-Contaminated Water (Fraction)		1		Fixed	Conservative Assumption—all water from same well
Poultry-Contaminated Water (Fraction)		0		Fixed	N/A
Milk-Contaminated Water (Fraction)		1		Fixed	Conservative Assumption—all water from same well
Eggs-Contaminated Water (Fraction)		0		Fixed	N/A
Fresh Forage Data					
Beef-Dietary Fraction	0.3		0.82	Normal	Section 2.3.2.6
Milk-Dietary Fraction	0.3		0.82	Normal	Section 2.3.2.6
Beef-Grow Time (days)	30		62	Uniform	Section 2.3.2.5
Milk-Grow Time (days)	30		62	Uniform	Section 2.3.2.5
Beef-Irrigation Rate (in/yr)				Empirical	Section 2.3.3.3 (File IRRIG.DAT)
Milk-Irrigation Rate (in/yr)				Empirical	Section 2.3.3.3 (File IRRIG.DAT)
Beef-Irrigation Time (mo/yr)	3		8	Uniform	Section 2.3.3.4
Milk-Irrigation Time (mo/yr)	3		8	Uniform	Section 2.3.3.4
Beef-Yield (kg/m3)	0.34		1.23	Uniform	Section 2.3.2.6
Milk-Yield (kg/m3)	0.34		1.23	Uniform	Section 2.3.2.6
Beef-Storage Time (days)		0		Fixed	Feed Storage N/A for Long Lived Radionuclides
Milk-Storage Time (days)		0		Fixed	Feed Storage N/A for Long Lived Radionuclides
Stored Feed Data					
Beef-Dietary Fraction		0		Fixed	Conservative Assumption—all feed assumed to be locally derived forage
Poultry-Dietary Fraction		0		Fixed	
Milk-Dietary Fraction		0		Fixed	

Table B-1 (Cont'd). Input parameter information

Parameter	Minimum	Best Estimate	Maximum	Distribution	Comments
Eggs-Dietary Fraction		0		Fixed	
Beef-Grow Time (days)		0		Fixed	
Poultry-Grow Time (days)		0		Fixed	
Milk-Grow Time (days)		0		Fixed	
Eggs-Grow Time (days)		0		Fixed	
Beef-Irrigation Rate (in/yr)		0		Fixed	
Poultry-Irrigation Rate (in/yr)		0		Fixed	
Milk-Irrigation Rate (in/yr)		0		Fixed	
Eggs-Irrigation Rate (in/yr)		0		Fixed	
Beef-Irrigation Time (mo/yr)		0		Fixed	
Poultry-Irrigation Time (mo/yr)		0		Fixed	
Milk-Irrigation Time (mo/yr)		0		Fixed	
Eggs-Irrigation Time (mo/yr)		0		Fixed	
Beef-Yield (kg/m3)		0		Fixed	
Poultry-Yield (kg/m3)		0		Fixed	
Milk-Yield (kg/m3)		0		Fixed	
Eggs-Yield (kg/m3)		0		Fixed	
Beef-Storage Time (days)		0		Fixed	
Poultry-Storage Time (days)		0		Fixed	
Milk-Storage Time (days)		0		Fixed	
Eggs-Storage Time (days)		0		Fixed	

APPENDIX C

LOG PROBABILITY PLOTS OF EACH RADIONUCLIDE-SPECIFIC TOTAL EFFECTIVE DOSE EQUIVALENT DISTRIBUTION

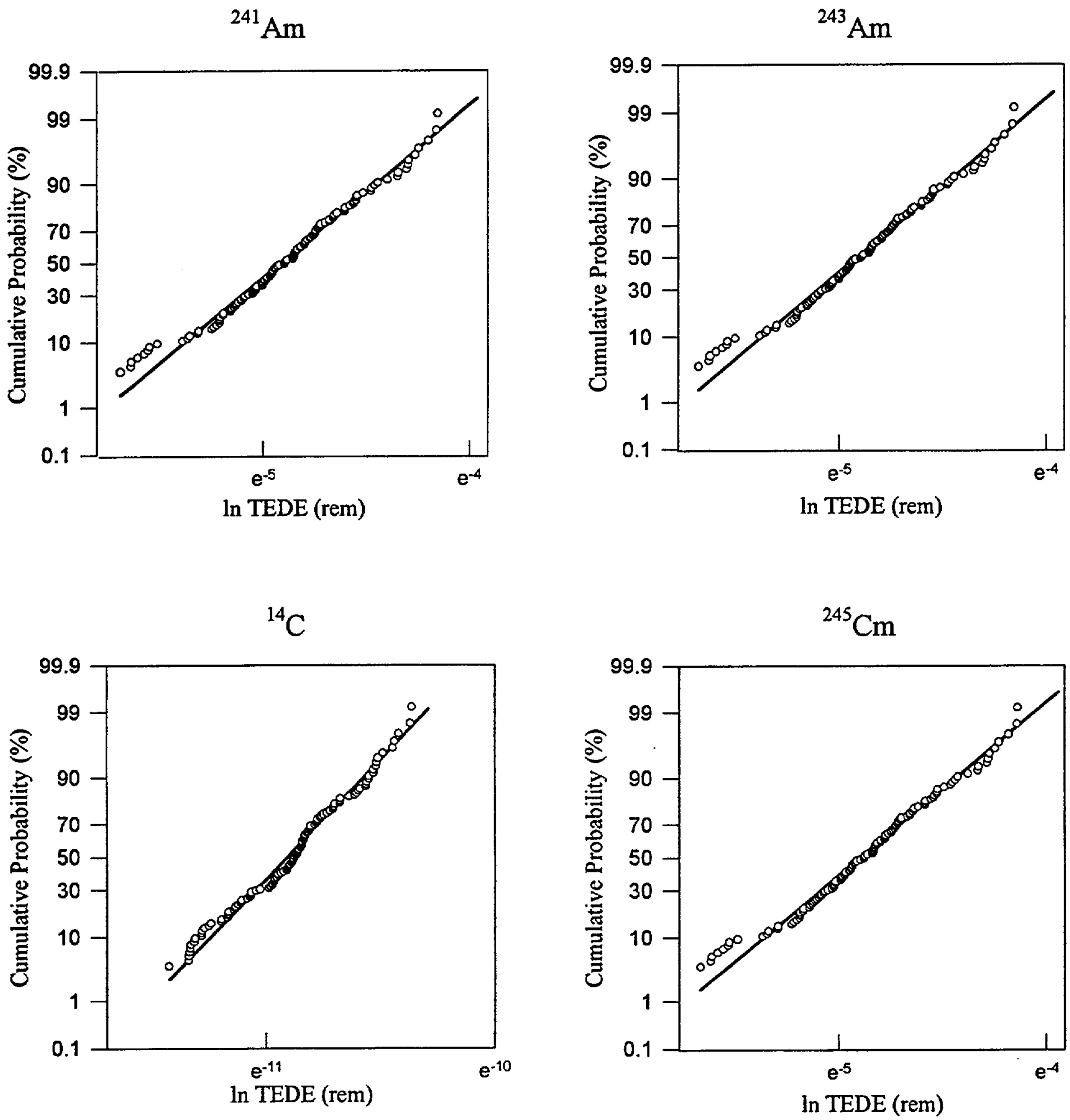

Figure C-1. Log probability plots of radionuclide-specific total effective dose equivalents for ^{241}Am, ^{243}Am, ^{14}C, and ^{245}Cm

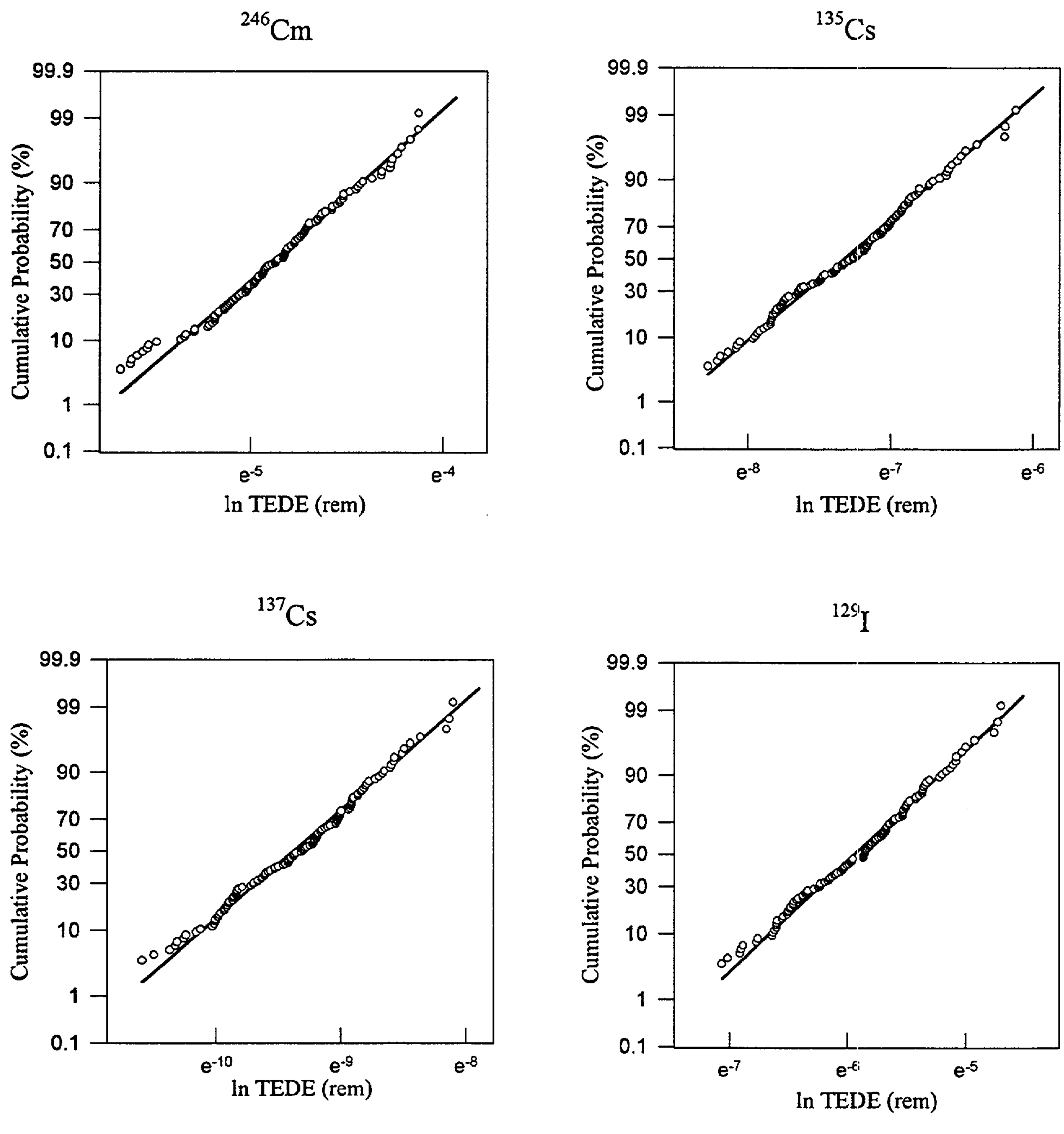

Figure C-1. Log probability plots of radionuclide-specific total effective dose equivalents for ^{246}Cm, ^{135}Cs, ^{137}Cs, and ^{129}I

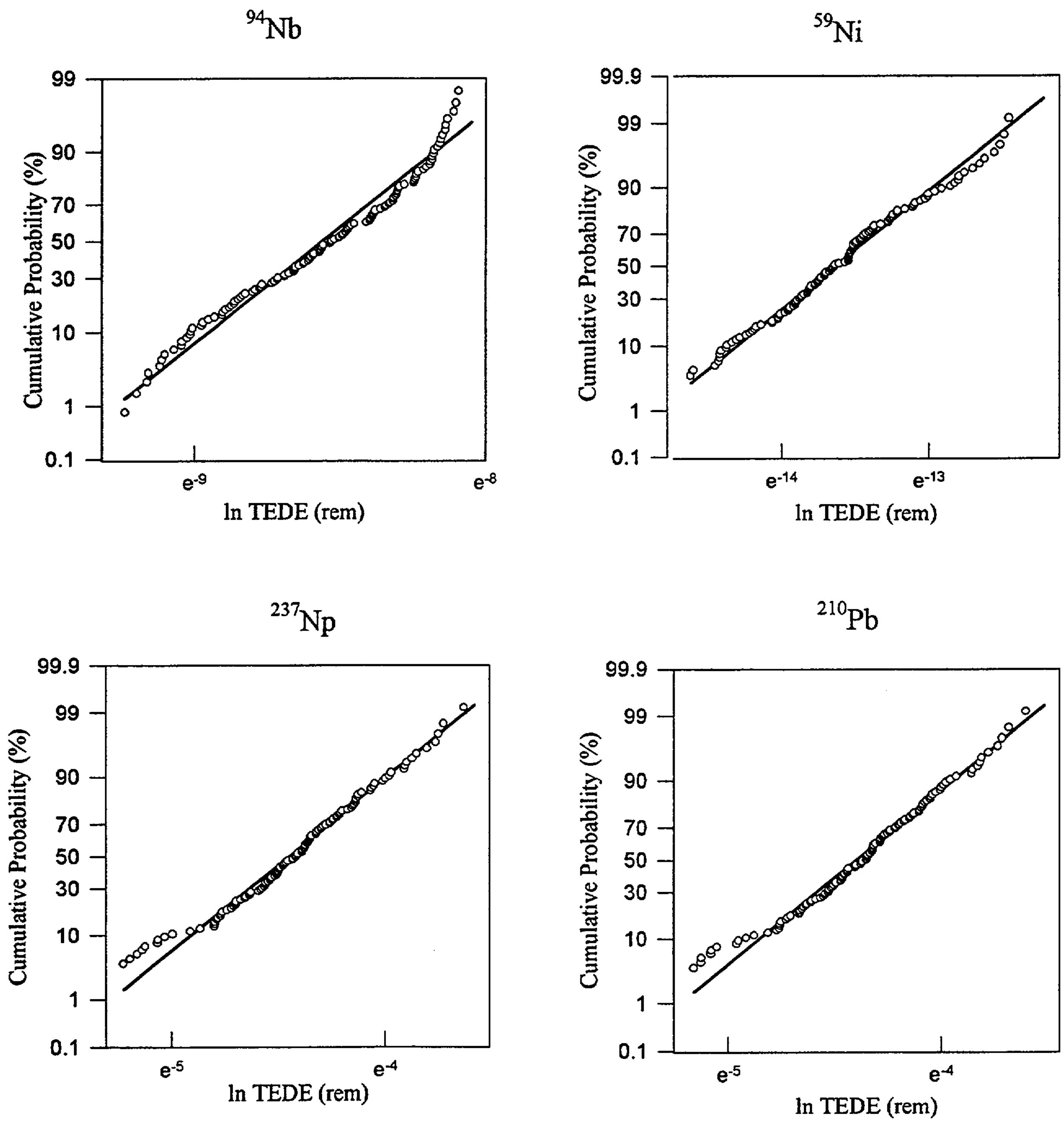

Figure C-1. Log probability plots of radionuclide-specific total effective dose equivalents for ^{94}Nb, ^{59}Np, ^{237}Np, and ^{210}Pb

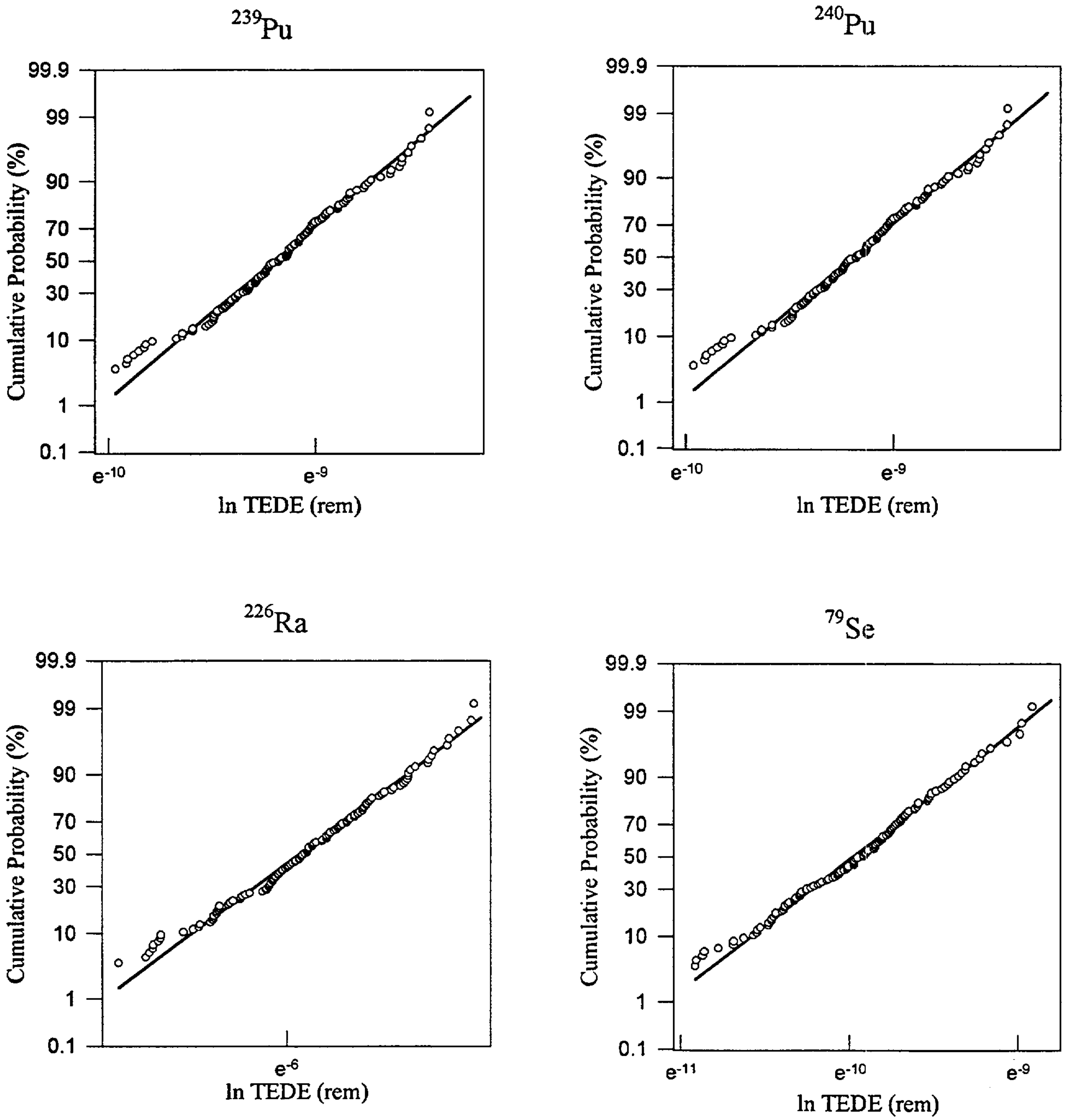

Figure C-1. Log probability plots of radionuclide-specific total effective dose equivalents for ^{239}Pu, ^{240}Pu, ^{226}Ra, and ^{79}Se

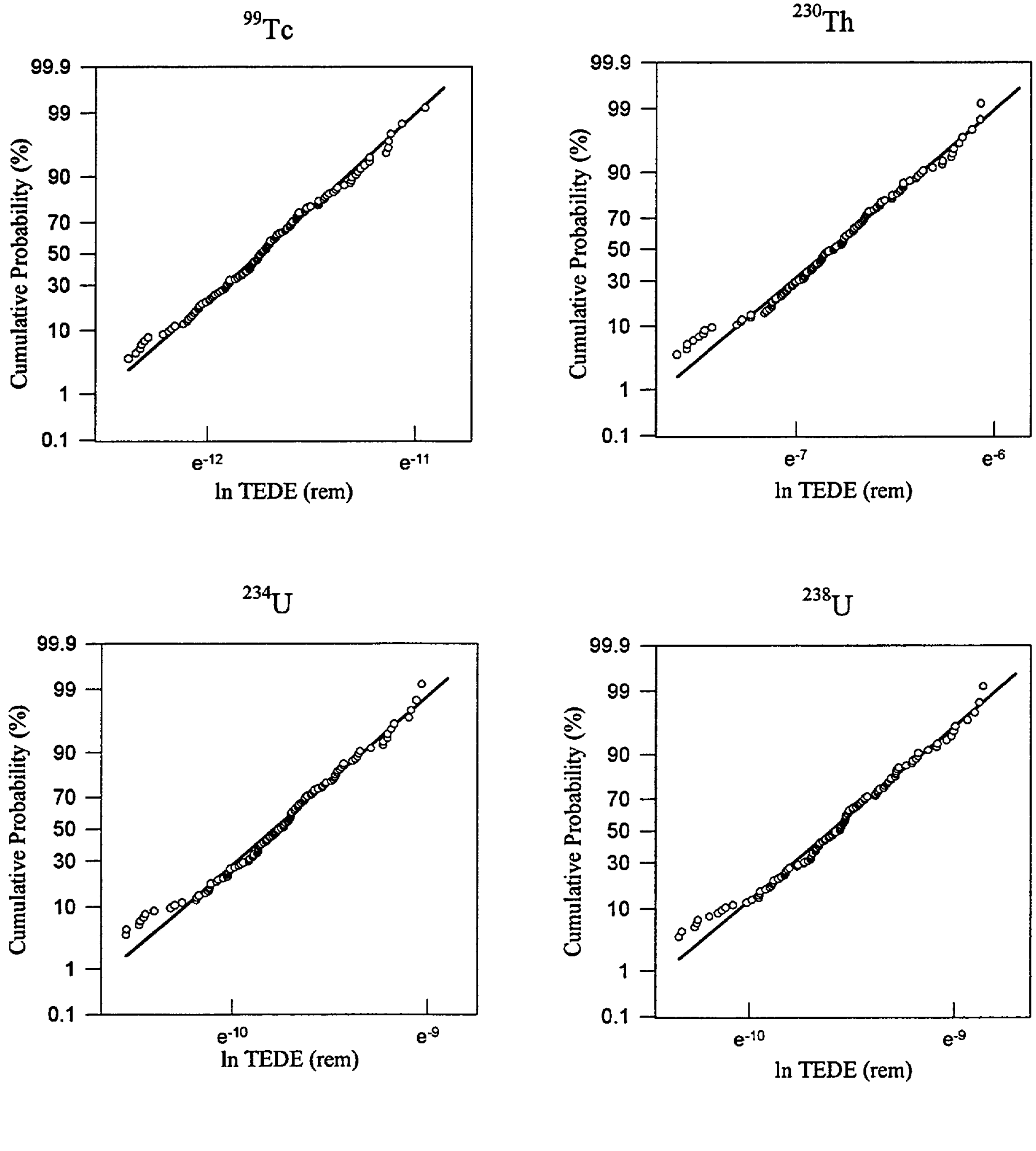

Figure C-1. Log probability plots of radionuclide-specific total effective dose equivalents for ^{99}Tc, ^{230}Th, ^{234}U, and ^{238}U

APPENDIX D

SELECTED SCATTERPLOTS OF PARAMETER VERSUS TOTAL EFFECTIVE DOSE EQUIVALENT DISTRIBUTIONS

^{238}U

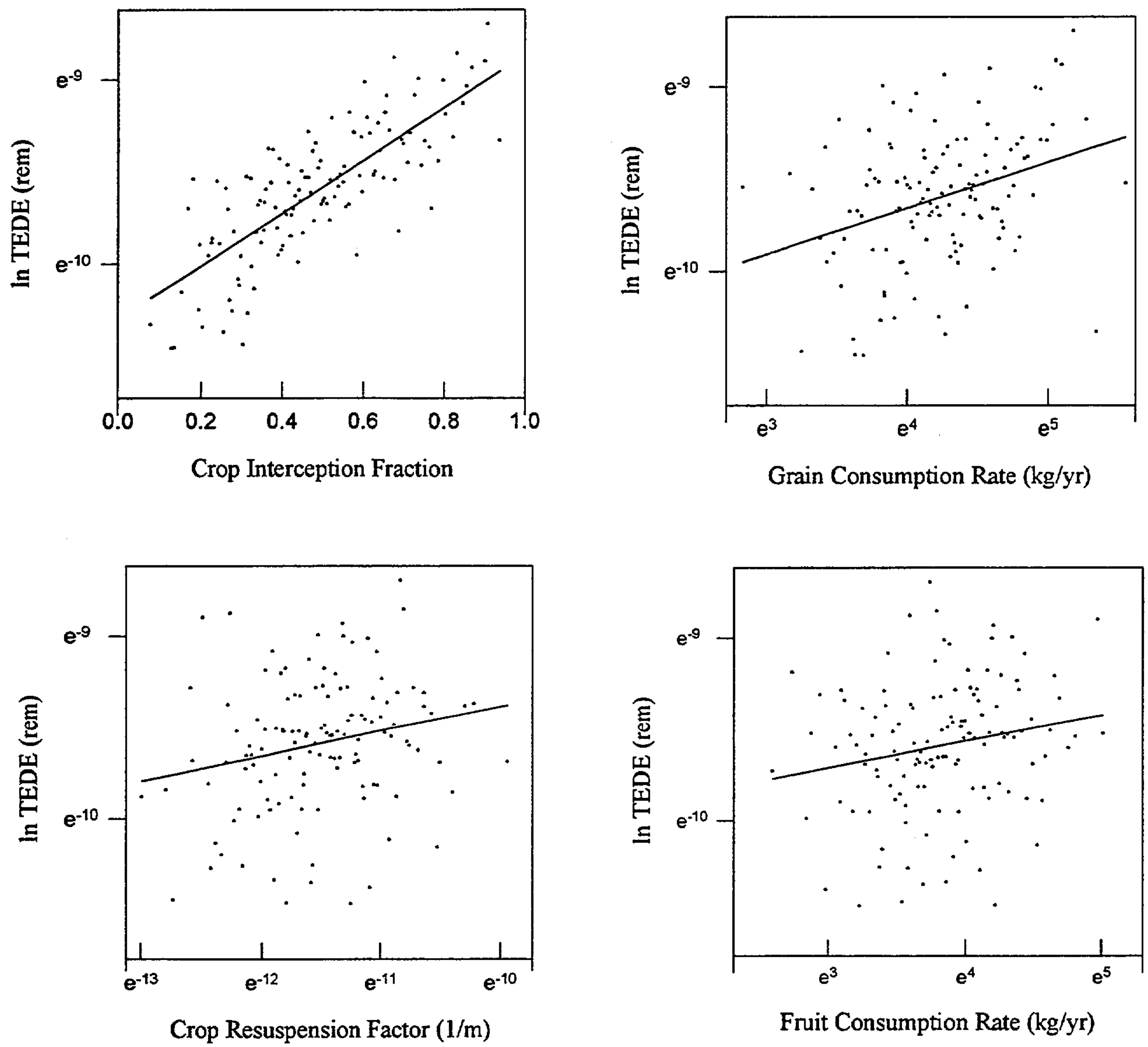

Figure D-1. Scatterplots of input parameters versus ^{238}U TEDE distribution for the top four correlated parameters

^{129}I

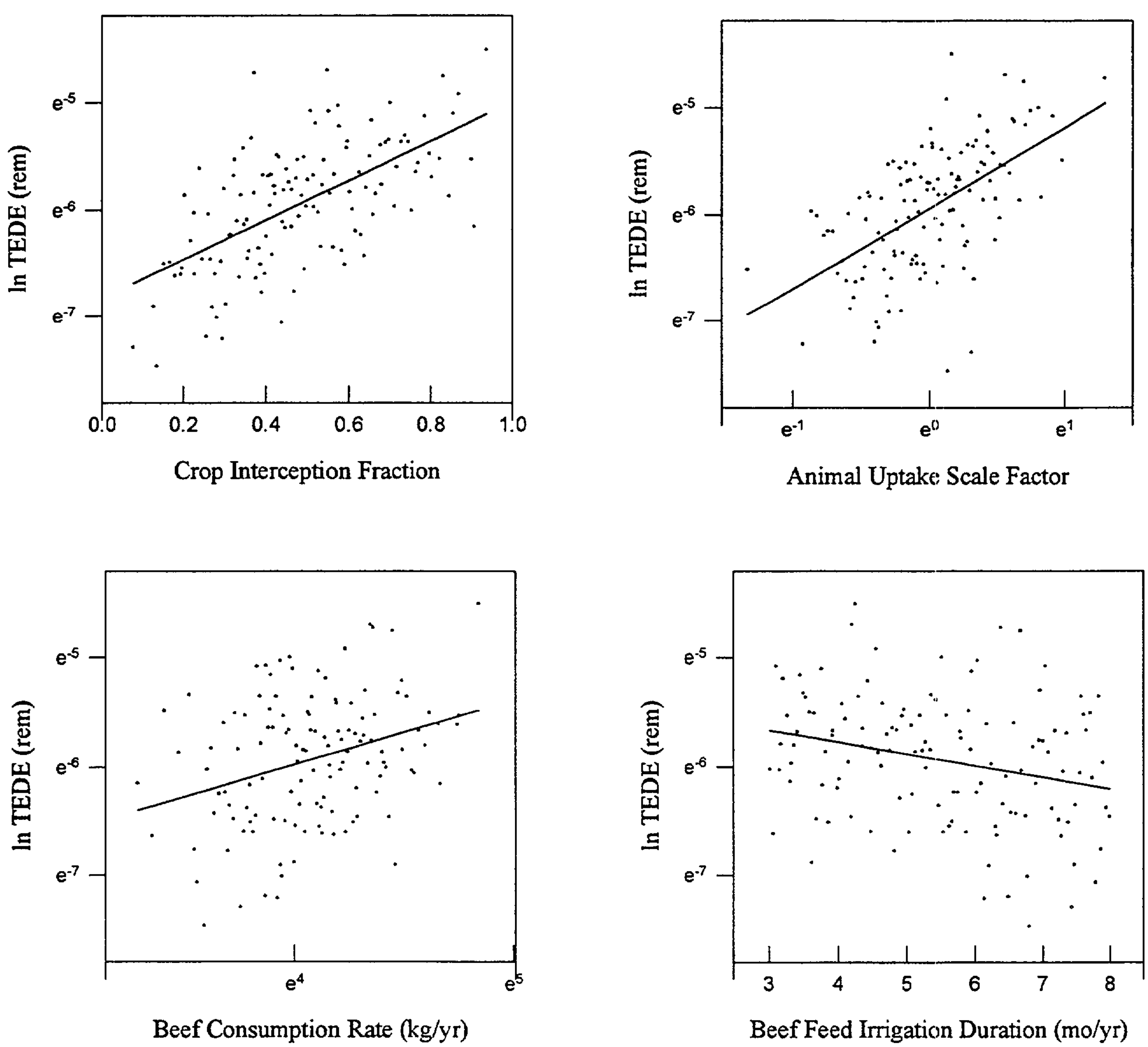

Figure D-2. Scatterplots of input parameters versus ^{129}I TEDE distribution for the top four correlated parameters

^{14}C

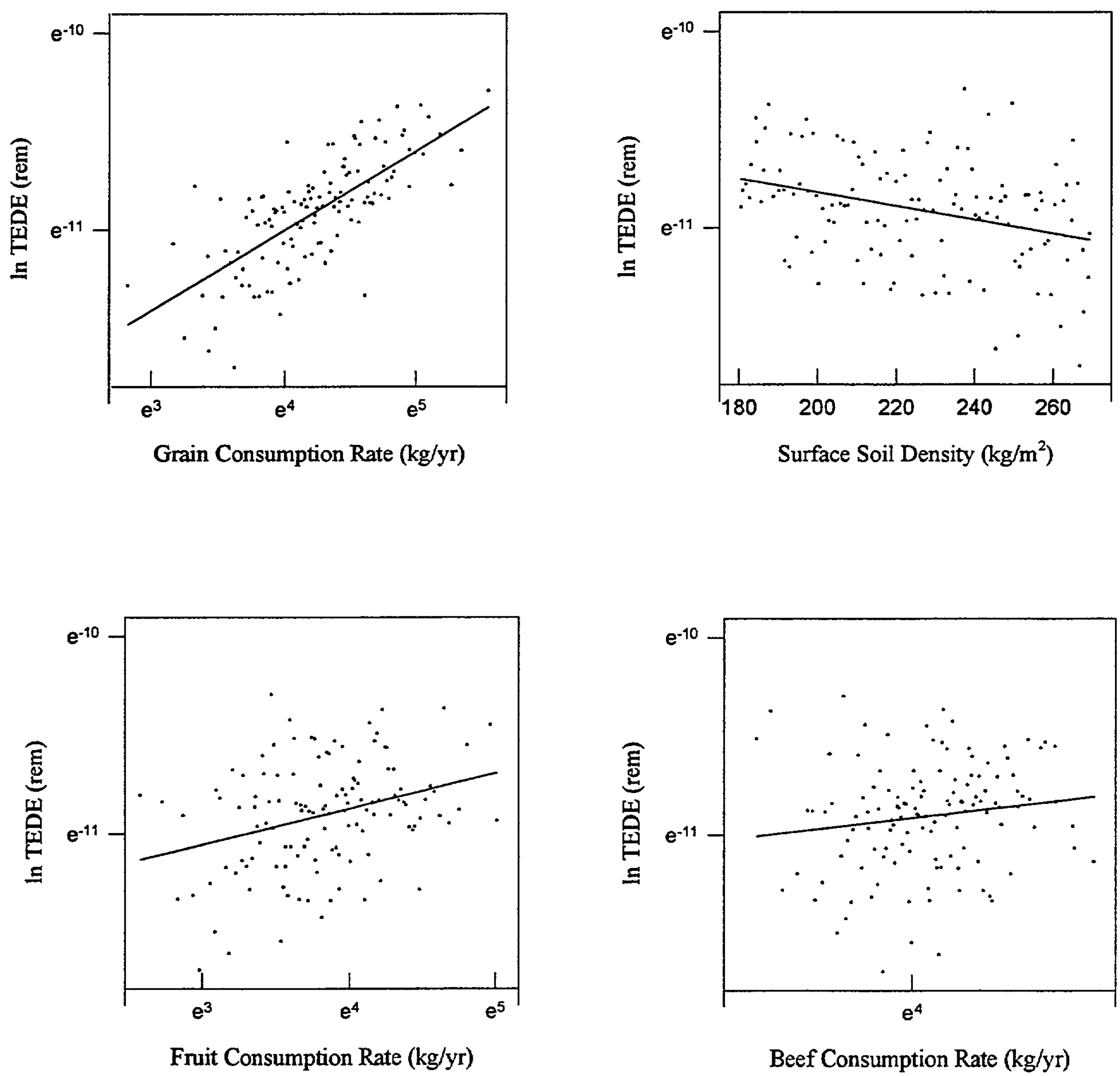

Figure D-3. Scatterplots of input parameters versus ^{14}C TEDE distribution for the top four correlated parameters

^{99}Tc

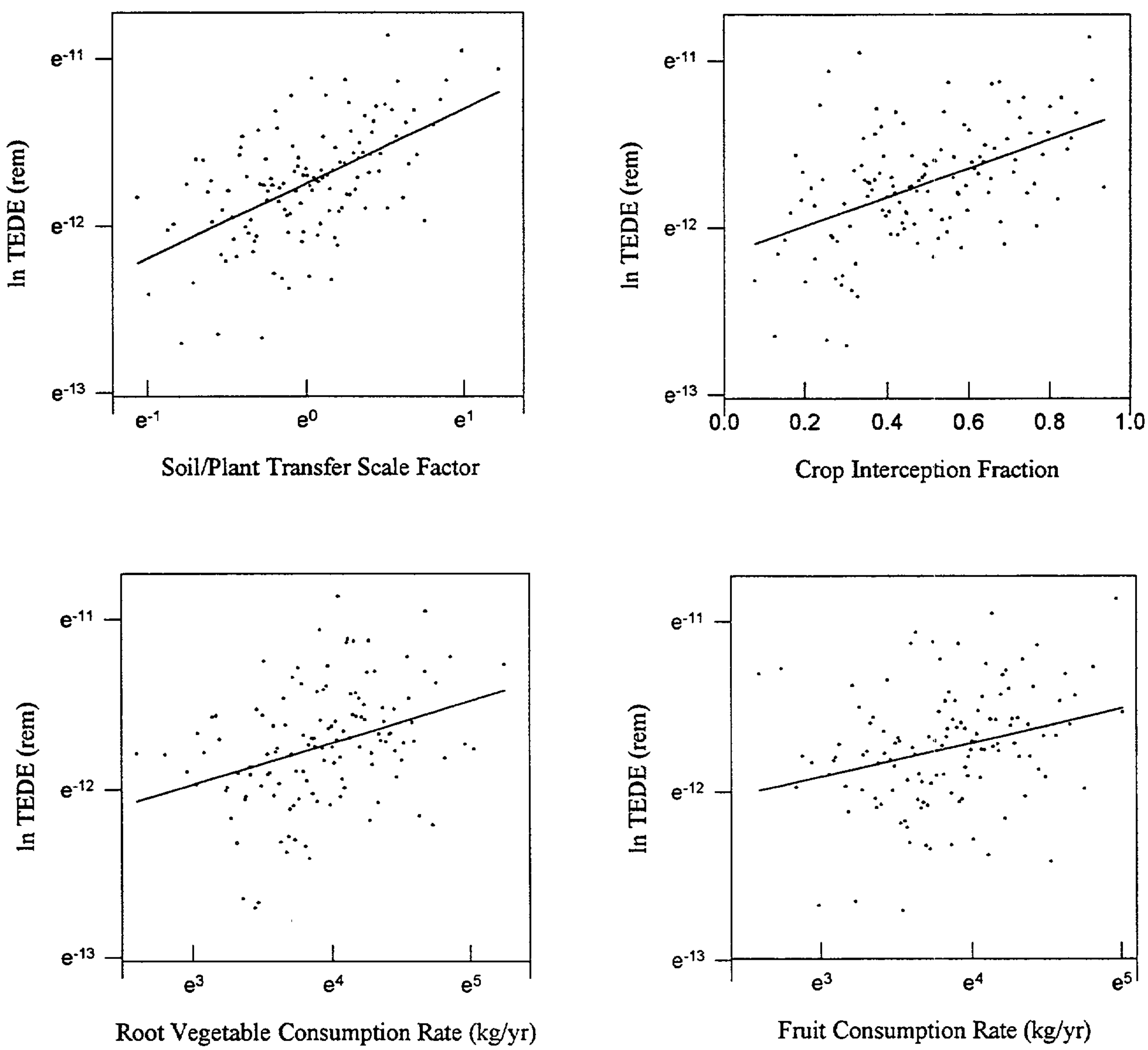

Figure D-4. Scatterplots of input parameters versus ^{99}Tc TEDE distribution for the top four correlated parameters

^{59}Ni

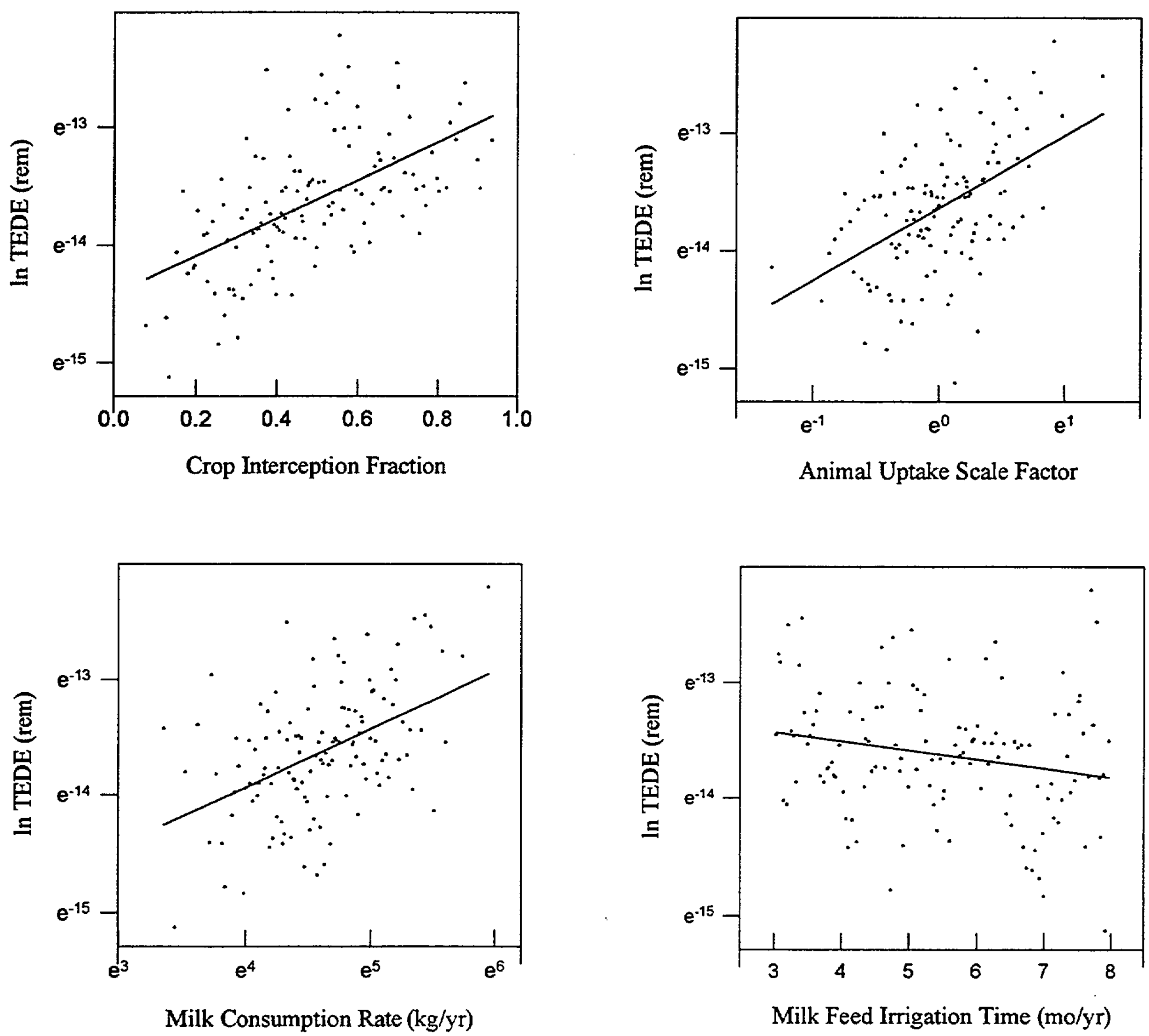

Figure D-5. Scatterplots of input parameters versus ^{59}Ni TEDE distribution for the top four correlated parameters

^{94}Nb

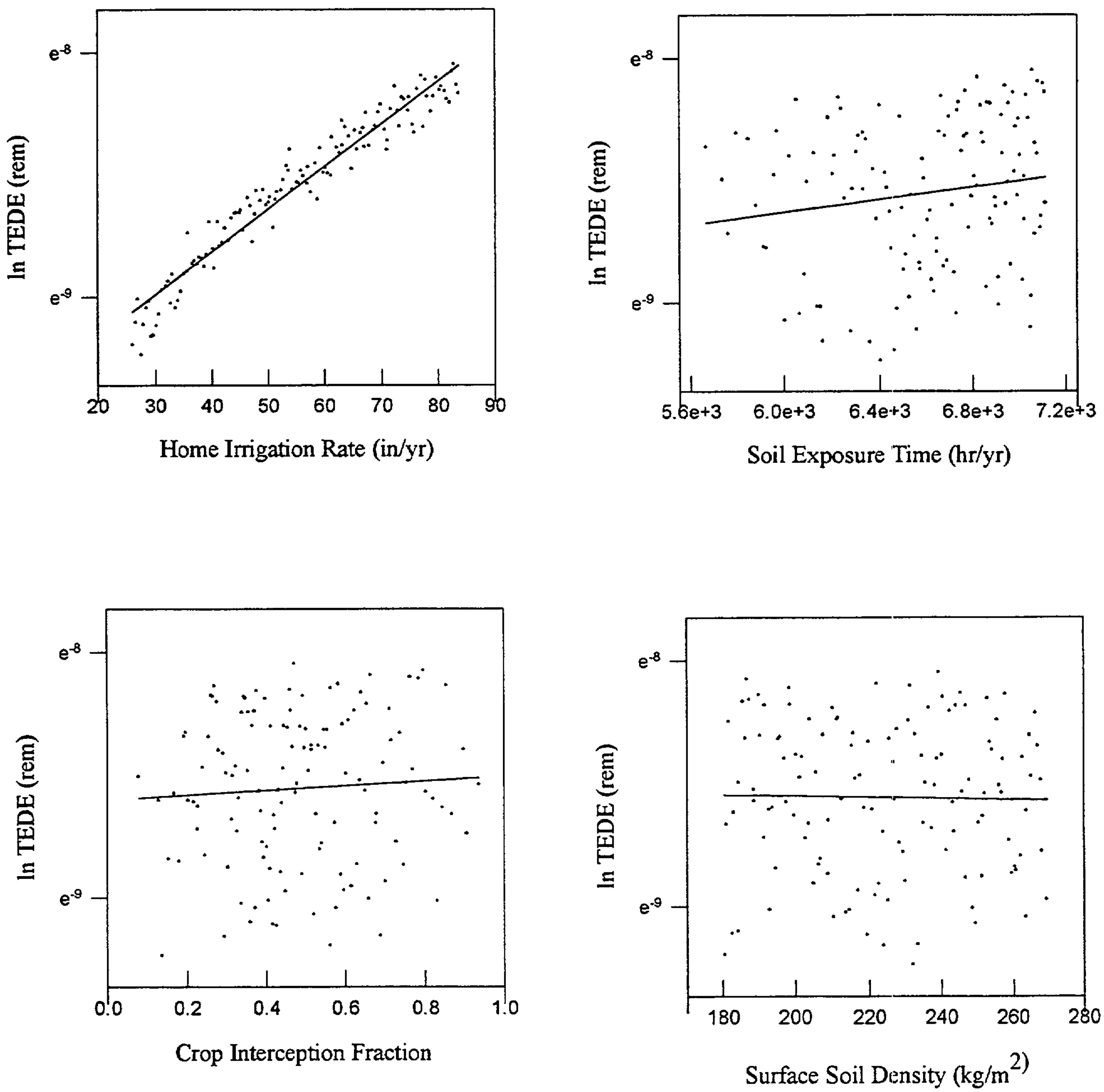

Figure D-6. Scatterplots of input parameters versus ^{94}Nb TEDE distribution for the top four correlated parameters

APPENDIX E

SIMPLE AND PARTIAL CORRELATION RESULTS FOR ALL SAMPLED PARAMETERS

Correlation coefficients on ranks for Annual EDE
from output block Stat. Committed Dose Summary (rem)
AM241.INP Created 23:46:28 on 03-19-1995. Run 23:46:33 on 03/19/95.

	Partial	Simple	Abs. Simple
Crop Interception Fraction (-)	0.77	0.76	0.76
Grain -Cons. Rate (kg/yr)	0.33	0.33	0.33
Crop Resuspension Factor (/m)	0.29	0.21	0.21
Fruit -Cons. Rate (kg/yr)	0.21	0.20	0.20
Drink Water Consumption (l/yr)	0.19	0.18	0.18
Leaf Veg-Cons. Rate (kg/yr)	0.17	0.17	0.17
Leaf Veg-Irrn. Time (mo/yr)	-0.18	-0.17	0.17
Root Veg-Cons. Rate (kg/yr)	0.17	0.17	0.17
Root Veg-Irrn. Time (mo/yr)	-0.12	-0.10	0.10
Grain -Irrn. Time (mo/yr)	-0.07	-0.09	0.09
Beef -Yield (kg/m3)	-0.08	-0.08	0.08
Leaf Veg-Irrn. Rate (in/yr)	0.07	0.07	0.07
Grain -Irrn. Rate (in/yr)	0.08	0.07	0.07
Milk -Irrn. Rate (in/yr)	-0.05	-0.06	0.06
Surface Soil Density (kg/m2)	0.08	0.05	0.05
Root Veg-Grow Time (days)	-0.03	-0.05	0.05
Grain -Yield (kg/m2)	0.05	0.05	0.05
Animal Uptake Scale Factor	-0.03	-0.04	0.04
Milk -Dietary Fraction	0.05	0.04	0.04
Beef -Cons. Rate (kg/yr)	0.01	0.03	0.03
Milk -Irrn. Time (mo/yr)	0.03	0.03	0.03
Leaf Veg-Grow Time (days)	0.04	0.03	0.03
Leaf Veg-Yield (kg/m2)	0.02	0.02	0.02
Beef -Grow Time (days)	-0.02	-0.02	0.02
Soil/Plant Transfer Scale Fac.	-0.03	-0.02	0.02
Milk -Cons. Rate (kg/yr)	0.02	0.02	0.02
Grain -Grow Time (days)	0.02	0.02	0.02
Fruit -Irrn. Time (mo/yr)	-0.03	-0.02	0.02
Fruit -Irrn. Rate (in/yr)	-0.02	-0.02	0.02
Fruit -Grow Time (days)	0.02	0.02	0.02
Beef -Irrn. Time (mo/yr)	0.02	0.01	0.01
Beef -Dietary Fraction	-0.01	0.01	0.01
Beef -Irrn. Rate (in/yr)	-0.01	-0.01	0.01
Chronic Plume Exposure (hr)	-0.02	0.01	0.01
Fruit -Yield (kg/m2)	0.01	0.01	0.01
Root Veg-Yield (kg/m2)	0.01	0.01	0.01
Inhalation Exposure (hr/yr)	0.07	0.01	0.01
Home Irrigation Rate (in/yr)	0.06	0.01	0.01
Home Irriga. Duration (mo/yr)	0.03	0.01	0.01
Milk -Yield (kg/m3)	0.01	0.01	0.01
Soil Exposure Time (hr)	-0.01	0.00	0.00
Milk -Grow Time (days)	-0.01	0.00	0.00
Root Veg-Irrn. Rate (in/yr)	0.00	0.00	0.00

Correlation coefficients on ranks for Annual EDE
from output block Stat. Committed Dose Summary (rem)
AM243.INP Created 23:43:11 on 03-19-1995. Run 23:43:15 on 03/19/95 .

	Partial	Simple	Abs. Simple
Crop Interception Fraction (-)	0.77	0.76	0.76
Grain -Cons. Rate (kg/yr)	0.33	0.33	0.33
Crop Resuspension Factor (/m)	0.29	0.21	0.21
Fruit -Cons. Rate (kg/yr)	0.21	0.20	0.20
Drink Water Consumption (l/yr)	0.19	0.17	0.17
Leaf Veg-Cons. Rate (kg/yr)	0.17	0.17	0.17
Leaf Veg-Irrn. Time (mo/yr)	-0.18	-0.17	0.17
Root Veg-Cons. Rate (kg/yr)	0.17	0.17	0.17
Root Veg-Irrn. Time (mo/yr)	-0.12	-0.10	0.10
Grain -Irrn. Time (mo/yr)	-0.07	-0.09	0.09
Grain -Irrn. Rate (in/yr)	0.08	0.08	0.08
Beef -Yield (kg/m3)	-0.08	-0.08	0.08
Leaf Veg-Irrn. Rate (in/yr)	0.07	0.07	0.07
Milk -Irrn. Rate (in/yr)	-0.05	-0.06	0.06
Surface Soil Density (kg/m2)	0.08	0.05	0.05
Grain -Yield (kg/m2)	0.05	0.05	0.05
Milk -Dietary Fraction	0.05	0.04	0.04
Root Veg-Grow Time (days)	-0.03	-0.04	0.04
Milk -Irrn. Time (mo/yr)	0.03	0.03	0.03
Animal Uptake Scale Factor	-0.03	-0.03	0.03
Leaf Veg-Grow Time (days)	0.04	0.03	0.03
Beef -Cons. Rate (kg/yr)	0.01	0.03	0.03
Leaf Veg-Yield (kg/m2)	0.02	0.02	0.02
Fruit -Irrn. Time (mo/yr)	-0.03	-0.02	0.02
Milk -Cons. Rate (kg/yr)	0.02	0.02	0.02
Home Irrigation Rate (in/yr)	0.06	0.02	0.02
Grain -Grow Time (days)	0.02	0.02	0.02
Fruit -Irrn. Rate (in/yr)	-0.02	-0.02	0.02
Fruit -Grow Time (days)	0.02	0.02	0.02
Soil/Plant Transfer Scale Fac.	-0.03	-0.02	0.02
Beef -Grow Time (days)	-0.02	-0.02	0.02
Beef -Dietary Fraction	0.00	0.01	0.01
Beef -Irrn. Rate (in/yr)	-0.01	-0.01	0.01
Beef -Irrn. Time (mo/yr)	0.02	0.01	0.01
Chronic Plume Exposure (hr)	-0.02	0.01	0.01
Fruit -Yield (kg/m2)	0.01	0.01	0.01
Root Veg-Yield (kg/m2)	0.01	0.01	0.01
Inhalation Exposure (hr/yr)	0.07	0.01	0.01
Home Irriga. Duration (mo/yr)	0.03	0.01	0.01
Milk -Yield (kg/m3)	0.01	0.01	0.01
Soil Exposure Time (hr)	-0.01	0.00	0.00
Milk -Grow Time (days)	-0.01	0.00	0.00
Root Veg-Irrn. Rate (in/yr)	0.00	0.00	0.00

Correlation coefficients on ranks for Annual EDE
from output block Stat. Committed Dose Summary (rem)
C14.INP Created 23:38:37 on 03-19-1995. Run 23:38:41 on 03/19/95 .

	Partial	Simple	Abs. Simple
Grain -Cons. Rate (kg/yr)	0.75	0.73	0.73
Surface Soil Density (kg/m2)	-0.32	-0.32	0.32
Fruit -Cons. Rate (kg/yr)	0.29	0.28	0.28
Beef -Cons. Rate (kg/yr)	0.25	0.20	0.20
Root Veg-Cons. Rate (kg/yr)	0.20	0.19	0.19
Beef -Irrn. Time (mo/yr)	-0.20	-0.15	0.15
Root Veg-Irrn. Time (mo/yr)	-0.13	-0.12	0.12
Grain -Irrn. Rate (in/yr)	0.13	0.12	0.12
Beef -Yield (kg/m3)	-0.11	-0.11	0.11
Milk -Cons. Rate (kg/yr)	0.15	0.11	0.11
Grain -Irrn. Time (mo/yr)	-0.09	-0.10	0.10
Fruit -Irrn. Rate (in/yr)	0.10	0.10	0.10
Root Veg-Irrn. Rate (in/yr)	0.08	0.08	0.08
Grain -Yield (kg/m2)	0.08	0.08	0.08
Drink Water Consumption (l/yr)	0.08	0.08	0.08
Milk -Grow Time (days)	0.08	0.07	0.07
Leaf Veg-Yield (kg/m2)	0.08	0.07	0.07
Milk -Yield (kg/m3)	0.07	0.07	0.07
Fruit -Irrn. Time (mo/yr)	-0.08	-0.07	0.07
Grain -Grow Time (days)	0.06	0.06	0.06
Beef -Dietary Fraction	0.07	0.06	0.06
Milk -Irrn. Rate (in/yr)	0.09	0.05	0.05
Milk -Dietary Fraction	0.07	0.04	0.04
Leaf Veg-Cons. Rate (kg/yr)	-0.05	-0.04	0.04
Home Irrigation Rate (in/yr)	0.03	0.04	0.04
Crop Resuspension Factor (/m)	-0.04	-0.04	0.04
Beef -Irrn. Rate (in/yr)	0.06	0.03	0.03
Soil/Plant Transfer Scale Fac.	-0.03	-0.03	0.03
Crop Interception Fraction (-)	-0.02	-0.03	0.03
Home Irriga. Duration (mo/yr)	0.03	0.03	0.03
Fruit -Yield (kg/m2)	-0.03	-0.03	0.03
Fruit -Grow Time (days)	-0.03	-0.03	0.03
Leaf Veg-Grow Time (days)	0.02	0.02	0.02
Inhalation Exposure (hr/yr)	0.02	0.02	0.02
Animal Uptake Scale Factor	0.02	0.02	0.02
Soil Exposure Time (hr)	0.02	0.02	0.02
Leaf Veg-Irrn. Rate (in/yr)	0.02	0.02	0.02
Beef -Grow Time (days)	0.03	0.01	0.01
Milk -Irrn. Time (mo/yr)	-0.01	-0.01	0.01
Root Veg-Grow Time (days)	-0.01	-0.01	0.01
Chronic Plume Exposure (hr)	0.00	0.00	0.00
Leaf Veg-Irrn. Time (mo/yr)	0.00	0.00	0.00
Root Veg-Yield (kg/m2)	0.00	0.00	0.00

Correlation coefficients on ranks for Annual EDE
from output block Stat. Committed Dose Summary (rem)
CM245.INP Created 23:35:31 on 03-19-1995. Run 23:35:36 on 03/19/95.

	Partial	Simple	Abs. Simple
Crop Interception Fraction (-)	0.77	0.76	0.76
Grain -Cons. Rate (kg/yr)	0.33	0.33	0.33
Crop Resuspension Factor (/m)	0.29	0.21	0.21
Fruit -Cons. Rate (kg/yr)	0.21	0.20	0.20
Drink Water Consumption (l/yr)	0.19	0.18	0.18
Leaf Veg-Cons. Rate (kg/yr)	0.17	0.17	0.17
Leaf Veg-Irrn. Time (mo/yr)	-0.18	-0.17	0.17
Root Veg-Cons. Rate (kg/yr)	0.17	0.17	0.17
Root Veg-Irrn. Time (mo/yr)	-0.12	-0.10	0.10
Grain -Irrn. Time (mo/yr)	-0.07	-0.09	0.09
Beef -Yield (kg/m3)	-0.08	-0.08	0.08
Grain -Irrn. Rate (in/yr)	0.08	0.08	0.08
Leaf Veg-Irrn. Rate (in/yr)	0.07	0.08	0.08
Milk -Irrn. Rate (in/yr)	-0.05	-0.06	0.06
Surface Soil Density (kg/m2)	0.08	0.05	0.05
Grain -Yield (kg/m2)	0.05	0.05	0.05
Animal Uptake Scale Factor	-0.03	-0.04	0.04
Milk -Dietary Fraction	0.05	0.04	0.04
Root Veg-Grow Time (days)	-0.03	-0.04	0.04
Milk -Cons. Rate (kg/yr)	0.02	0.03	0.03
Milk -Irrn. Time (mo/yr)	0.03	0.03	0.03
Leaf Veg-Grow Time (days)	0.04	0.03	0.03
Leaf Veg-Yield (kg/m2)	0.02	0.02	0.02
Soil/Plant Transfer Scale Fac.	-0.03	-0.02	0.02
Beef -Grow Time (days)	-0.02	-0.02	0.02
Grain -Grow Time (days)	0.02	0.02	0.02
Fruit -Irrn. Time (mo/yr)	-0.03	-0.02	0.02
Fruit -Irrn. Rate (in/yr)	-0.02	-0.02	0.02
Beef -Cons. Rate (kg/yr)	0.01	0.02	0.02
Fruit -Grow Time (days)	0.02	0.02	0.02
Beef -Irrn. Time (mo/yr)	0.02	0.01	0.01
Beef -Dietary Fraction	-0.01	0.01	0.01
Beef -Irrn. Rate (in/yr)	-0.01	-0.01	0.01
Milk -Yield (kg/m3)	0.01	0.01	0.01
Fruit -Yield (kg/m2)	0.01	0.01	0.01
Root Veg-Yield (kg/m2)	0.02	0.01	0.01
Inhalation Exposure (hr/yr)	0.07	0.01	0.01
Home Irrigation Rate (in/yr)	0.06	0.01	0.01
Soil Exposure Time (hr)	-0.01	0.00	0.00
Milk -Grow Time (days)	-0.01	0.00	0.00
Root Veg-Irrn. Rate (in/yr)	0.00	0.00	0.00
Home Irriga. Duration (mo/yr)	0.03	0.00	0.00
Chronic Plume Exposure (hr)	-0.02	0.00	0.00

Correlation coefficients on ranks for Annual EDE
from output block Stat. Committed Dose Summary (rem)
CM246.INP Created 23:32:29 on 03-19-1995. Run 23:32:33 on 03/19/95.

	Partial	Simple	Abs. Simple
Crop Interception Fraction (-)	0.77	0.76	0.76
Grain -Cons. Rate (kg/yr)	0.33	0.33	0.33
Crop Resuspension Factor (/m)	0.29	0.21	0.21
Fruit -Cons. Rate (kg/yr)	0.21	0.20	0.20
Drink Water Consumption (l/yr)	0.19	0.18	0.18
Leaf Veg-Cons. Rate (kg/yr)	0.17	0.17	0.17
Leaf Veg-Irrn. Time (mo/yr)	-0.18	-0.17	0.17
Root Veg-Cons. Rate (kg/yr)	0.17	0.17	0.17
Root Veg-Irrn. Time (mo/yr)	-0.12	-0.10	0.10
Grain -Irrn. Time (mo/yr)	-0.07	-0.09	0.09
Beef -Yield (kg/m3)	-0.08	-0.08	0.08
Grain -Irrn. Rate (in/yr)	0.08	0.08	0.08
Leaf Veg-Irrn. Rate (in/yr)	0.07	0.08	0.08
Milk -Irrn. Rate (in/yr)	-0.05	-0.06	0.06
Surface Soil Density (kg/m2)	0.08	0.05	0.05
Grain -Yield (kg/m2)	0.05	0.05	0.05
Animal Uptake Scale Factor	-0.03	-0.04	0.04
Milk -Dietary Fraction	0.05	0.04	0.04
Root Veg-Grow Time (days)	-0.03	-0.04	0.04
Leaf Veg-Grow Time (days)	0.04	0.04	0.04
Milk -Cons. Rate (kg/yr)	0.02	0.03	0.03
Milk -Irrn. Time (mo/yr)	0.03	0.03	0.03
Beef -Cons. Rate (kg/yr)	0.01	0.03	0.03
Leaf Veg-Yield (kg/m2)	0.02	0.02	0.02
Soil/Plant Transfer Scale Fac.	-0.03	-0.02	0.02
Beef -Grow Time (days)	-0.02	-0.02	0.02
Grain -Grow Time (days)	0.02	0.02	0.02
Fruit -Irrn. Time (mo/yr)	-0.03	-0.02	0.02
Fruit -Irrn. Rate (in/yr)	-0.02	-0.02	0.02
Fruit -Grow Time (days)	0.02	0.02	0.02
Beef -Irrn. Time (mo/yr)	0.02	0.01	0.01
Beef -Dietary Fraction	-0.01	0.01	0.01
Beef -Irrn. Rate (in/yr)	-0.01	-0.01	0.01
Chronic Plume Exposure (hr)	-0.02	0.01	0.01
Fruit -Yield (kg/m2)	0.01	0.01	0.01
Root Veg-Yield (kg/m2)	0.02	0.01	0.01
Inhalation Exposure (hr/yr)	0.07	0.01	0.01
Home Irrigation Rate (in/yr)	0.05	0.01	0.01
Milk -Yield (kg/m3)	0.01	0.01	0.01
Soil Exposure Time (hr)	-0.01	0.00	0.00
Milk -Grow Time (days)	-0.01	0.00	0.00
Root Veg-Irrn. Rate (in/yr)	0.00	0.00	0.00
Home Irriga. Duration (mo/yr)	0.03	0.00	0.00

Correlation coefficients on ranks for Annual EDE
from output block Stat. Committed Dose Summary (rem)
CS135.INP Created 23:23:05 on 03-19-1995. Run 23:23:09 on 03/19/95.

	Partial	Simple	Abs. Simple
Animal Uptake Scale Factor	0.75	0.60	0.60
Crop Interception Fraction (-)	0.73	0.57	0.57
Beef -Cons. Rate (kg/yr)	0.32	0.30	0.30
Beef -Irrn. Time (mo/yr)	-0.30	-0.26	0.26
Beef -Dietary Fraction	0.20	0.15	0.15
Milk -Cons. Rate (kg/yr)	0.15	0.14	0.14
Crop Resuspension Factor (/m)	0.24	0.13	0.13
Beef -Irrn. Rate (in/yr)	0.12	0.09	0.09
Home Irriga. Duration (mo/yr)	-0.10	-0.07	0.07
Milk -Dietary Fraction	0.09	0.06	0.06
Beef -Grow Time (days)	0.07	0.06	0.06
Grain -Cons. Rate (kg/yr)	0.03	0.06	0.06
Milk -Yield (kg/m3)	-0.06	-0.06	0.06
Milk -Irrn. Time (mo/yr)	-0.06	-0.06	0.06
Fruit -Irrn. Rate (in/yr)	-0.05	-0.05	0.05
Home Irrigation Rate (in/yr)	-0.04	-0.04	0.04
Surface Soil Density (kg/m2)	0.07	0.04	0.04
Grain -Irrn. Time (mo/yr)	0.03	0.03	0.03
Fruit -Cons. Rate (kg/yr)	0.04	0.03	0.03
Leaf Veg-Yield (kg/m2)	0.03	0.03	0.03
Soil Exposure Time (hr)	-0.09	-0.03	0.03
Grain -Irrn. Rate (in/yr)	-0.03	-0.03	0.03
Root Veg-Yield (kg/m2)	-0.01	-0.02	0.02
Root Veg-Cons. Rate (kg/yr)	0.02	0.02	0.02
Fruit -Grow Time (days)	-0.02	-0.02	0.02
Milk -Grow Time (days)	-0.03	-0.02	0.02
Root Veg-Irrn. Time (mo/yr)	-0.02	-0.02	0.02
Fruit -Yield (kg/m2)	0.02	0.02	0.02
Leaf Veg-Cons. Rate (kg/yr)	-0.02	-0.02	0.02
Fruit -Irrn. Time (mo/yr)	-0.01	-0.01	0.01
Leaf Veg-Irrn. Rate (in/yr)	0.01	0.01	0.01
Inhalation Exposure (hr/yr)	0.00	0.01	0.01
Milk -Irrn. Rate (in/yr)	-0.02	0.01	0.01
Root Veg-Irrn. Rate (in/yr)	0.00	-0.01	0.01
Grain -Grow Time (days)	0.01	0.01	0.01
Soil/Plant Transfer Scale Fac.	0.00	-0.01	0.01
Chronic Plume Exposure (hr)	-0.05	0.00	0.00
Leaf Veg-Grow Time (days)	0.00	0.00	0.00
Root Veg-Grow Time (days)	0.01	0.00	0.00
Drink Water Consumption (l/yr)	0.00	0.00	0.00
Grain -Yield (kg/m2)	0.00	0.00	0.00
Leaf Veg-Irrn. Time (mo/yr)	0.00	0.00	0.00
Beef -Yield (kg/m3)	0.00	0.00	0.00

Correlation coefficients on ranks for Annual EDE
from output block Stat. Committed Dose Summary (rem)
CS137.INP Created 23:20:02 on 03-19-1995. Run 23:20:06 on 03/19/95.

	Partial	Simple	Abs. Simple
Animal Uptake Scale Factor	0.76	0.60	0.60
Crop Interception Fraction (-)	0.73	0.56	0.56
Beef -Cons. Rate (kg/yr)	0.32	0.30	0.30
Beef -Irrn. Time (mo/yr)	-0.29	-0.26	0.26
Milk -Cons. Rate (kg/yr)	0.15	0.14	0.14
Beef -Dietary Fraction	0.19	0.14	0.14
Crop Resuspension Factor (/m)	0.22	0.12	0.12
Beef -Irrn. Rate (in/yr)	0.11	0.09	0.09
Grain -Cons. Rate (kg/yr)	0.04	0.07	0.07
Home Irriga. Duration (mo/yr)	-0.09	-0.07	0.07
Milk -Dietary Fraction	0.09	0.07	0.07
Beef -Grow Time (days)	0.08	0.06	0.06
Milk -Yield (kg/m3)	-0.05	-0.06	0.06
Milk -Irrn. Time (mo/yr)	-0.06	-0.06	0.06
Fruit -Irrn. Rate (in/yr)	-0.05	-0.05	0.05
Surface Soil Density (kg/m2)	0.09	0.05	0.05
Grain -Irrn. Rate (in/yr)	-0.04	-0.04	0.04
Leaf Veg-Yield (kg/m2)	0.04	0.04	0.04
Milk -Grow Time (days)	-0.03	-0.03	0.03
Root Veg-Irrn. Time (mo/yr)	-0.03	-0.03	0.03
Fruit -Cons. Rate (kg/yr)	0.04	0.03	0.03
Grain -Irrn. Time (mo/yr)	0.04	0.03	0.03
Home Irrigation Rate (in/yr)	0.07	0.02	0.02
Root Veg-Yield (kg/m2)	-0.02	-0.02	0.02
Grain -Grow Time (days)	0.02	0.02	0.02
Fruit -Grow Time (days)	-0.02	-0.02	0.02
Root Veg-Cons. Rate (kg/yr)	0.03	0.02	0.02
Fruit -Yield (kg/m2)	0.02	0.02	0.02
Leaf Veg-Cons. Rate (kg/yr)	-0.02	-0.02	0.02
Soil Exposure Time (hr)	-0.08	-0.02	0.02
Milk -Irrn. Rate (in/yr)	-0.01	0.01	0.01
Leaf Veg-Irrn. Rate (in/yr)	0.01	0.01	0.01
Inhalation Exposure (hr/yr)	0.01	0.01	0.01
Root Veg-Irrn. Rate (in/yr)	0.01	0.01	0.01
Leaf Veg-Grow Time (days)	0.00	-0.01	0.01
Leaf Veg-Irrn. Time (mo/yr)	0.01	0.01	0.01
Soil/Plant Transfer Scale Fac.	0.01	-0.01	0.01
Root Veg-Grow Time (days)	0.00	0.00	0.00
Chronic Plume Exposure (hr)	-0.05	0.00	0.00
Grain -Yield (kg/m2)	0.00	0.00	0.00
Fruit -Irrn. Time (mo/yr)	-0.01	0.00	0.00
Drink Water Consumption (l/yr)	0.00	0.00	0.00
Beef -Yield (kg/m3)	-0.01	0.00	0.00

Correlation coefficients on ranks for Annual EDE
from output block Stat. Committed Dose Summary (rem)
I129.INP Created 23:15:55 on 03-19-1995. Run 23:15:59 on 03/19/95.

	Partial	Simple	Abs. Simple
Crop Interception Fraction (-)	0.76	0.60	0.60
Animal Uptake Scale Factor	0.76	0.59	0.59
Beef -Cons. Rate (kg/yr)	0.29	0.27	0.27
Beef -Irrn. Time (mo/yr)	-0.28	-0.25	0.25
Milk -Cons. Rate (kg/yr)	0.19	0.18	0.18
Beef -Dietary Fraction	0.17	0.13	0.13
Crop Resuspension Factor (/m)	0.19	0.10	0.10
Beef -Irrn. Rate (in/yr)	0.10	0.08	0.08
Milk -Dietary Fraction	0.10	0.08	0.08
Milk -Irrn. Time (mo/yr)	-0.08	-0.08	0.08
Beef -Grow Time (days)	0.08	0.06	0.06
Grain -Cons. Rate (kg/yr)	0.04	0.06	0.06
Home Irriga. Duration (mo/yr)	-0.09	-0.06	0.06
Milk -Yield (kg/m3)	-0.05	-0.06	0.06
Fruit -Irrn. Rate (in/yr)	-0.05	-0.05	0.05
Grain -Irrn. Rate (in/yr)	-0.05	-0.05	0.05
Fruit -Cons. Rate (kg/yr)	0.05	0.04	0.04
Leaf Veg-Yield (kg/m2)	0.04	0.04	0.04
Surface Soil Density (kg/m2)	0.06	0.04	0.04
Home Irrigation Rate (in/yr)	-0.04	-0.04	0.04
Soil Exposure Time (hr)	-0.09	-0.03	0.03
Root Veg-Cons. Rate (kg/yr)	0.03	0.03	0.03
Milk -Irrn. Rate (in/yr)	0.00	0.02	0.02
Leaf Veg-Cons. Rate (kg/yr)	-0.02	-0.02	0.02
Milk -Grow Time (days)	-0.03	-0.02	0.02
Soil/Plant Transfer Scale Fac.	-0.01	-0.02	0.02
Root Veg-Irrn. Time (mo/yr)	-0.02	-0.02	0.02
Root Veg-Yield (kg/m2)	-0.02	-0.02	0.02
Grain -Irrn. Time (mo/yr)	0.03	0.02	0.02
Drink Water Consumption (l/yr)	0.01	0.01	0.01
Chronic Plume Exposure (hr)	-0.06	-0.01	0.01
Inhalation Exposure (hr/yr)	0.01	0.01	0.01
Beef -Yield (kg/m3)	-0.01	-0.01	0.01
Grain -Grow Time (days)	0.01	0.01	0.01
Root Veg-Grow Time (days)	0.01	0.01	0.01
Leaf Veg-Irrn. Rate (in/yr)	0.01	0.01	0.01
Grain -Yield (kg/m2)	0.01	0.01	0.01
Fruit -Yield (kg/m2)	0.01	0.01	0.01
Fruit -Grow Time (days)	-0.01	-0.01	0.01
Leaf Veg-Grow Time (days)	-0.01	-0.01	0.01
Leaf Veg-Irrn. Time (mo/yr)	0.00	0.00	0.00
Fruit -Irrn. Time (mo/yr)	0.00	0.00	0.00
Root Veg-Irrn. Rate (in/yr)	0.01	0.00	0.00

Correlation coefficients on ranks for Annual EDE
from output block Stat. Committed Dose Summary (rem)
NB94.INP Created 23:12:24 on 03-19-1995. Run 23:12:29 on 03/19/95.

	Partial	Simple	Abs. Simple
Home Irrigation Rate (in/yr)	0.99	0.98	0.98
Soil Exposure Time (hr)	0.82	0.19	0.19
Inhalation Exposure (hr/yr)	-0.07	-0.08	0.08
Leaf Veg-Cons. Rate (kg/yr)	0.06	0.06	0.06
Root Veg-Cons. Rate (kg/yr)	0.06	0.06	0.06
Crop Interception Fraction (-)	0.53	0.06	0.06
Grain -Cons. Rate (kg/yr)	0.05	0.05	0.05
Beef -Irrn. Rate (in/yr)	-0.05	-0.05	0.05
Leaf Veg-Grow Time (days)	-0.04	-0.04	0.04
Milk -Dietary Fraction	-0.04	-0.04	0.04
Fruit -Cons. Rate (kg/yr)	0.04	0.04	0.04
Grain -Yield (kg/m2)	0.04	0.04	0.04
Beef -Irrn. Time (mo/yr)	-0.04	-0.04	0.04
Grain -Irrn. Rate (in/yr)	-0.04	-0.04	0.04
Home Irriga. Duration (mo/yr)	0.00	-0.04	0.04
Leaf Veg-Irrn. Time (mo/yr)	-0.04	-0.04	0.04
Drink Water Consumption (l/yr)	0.04	0.04	0.04
Fruit -Grow Time (days)	-0.03	-0.03	0.03
Grain -Grow Time (days)	0.03	0.03	0.03
Leaf Veg-Yield (kg/m2)	0.03	0.03	0.03
Chronic Plume Exposure (hr)	-0.16	-0.03	0.03
Fruit -Irrn. Time (mo/yr)	-0.03	-0.03	0.03
Root Veg-Irrn. Rate (in/yr)	0.03	0.03	0.03
Surface Soil Density (kg/m2)	0.11	-0.03	0.03
Beef -Grow Time (days)	-0.02	-0.02	0.02
Soil/Plant Transfer Scale Fac.	-0.01	-0.02	0.02
Beef -Dietary Fraction	0.02	0.02	0.02
Beef -Yield (kg/m3)	-0.02	-0.02	0.02
Milk -Grow Time (days)	-0.02	-0.01	0.01
Beef -Cons. Rate (kg/yr)	-0.01	-0.01	0.01
Milk -Irrn. Rate (in/yr)	-0.01	-0.01	0.01
Milk -Yield (kg/m3)	-0.01	-0.01	0.01
Milk -Cons. Rate (kg/yr)	0.00	0.01	0.01
Crop Resuspension Factor (/m)	0.11	-0.01	0.01
Grain -Irrn. Time (mo/yr)	0.00	-0.01	0.01
Fruit -Yield (kg/m2)	-0.01	-0.01	0.01
Leaf Veg-Irrn. Rate (in/yr)	0.01	0.01	0.01
Fruit -Irrn. Rate (in/yr)	-0.01	-0.01	0.01
Root Veg-Grow Time (days)	0.02	0.01	0.01
Animal Uptake Scale Factor	0.11	0.01	0.01
Milk -Irrn. Time (mo/yr)	-0.01	-0.01	0.01
Root Veg-Irrn. Time (mo/yr)	0.00	0.00	0.00
Root Veg-Yield (kg/m2)	0.01	0.00	0.00

Correlation coefficients on ranks for Annual EDE
from output block Stat. Committed Dose Summary (rem)
NI59.INP Created 23:08:29 on 03-19-1995. Run 23:08:33 on 03/19/95.

	Partial	Simple	Abs. Simple
Crop Interception Fraction (-)	0.72	0.61	0.61
Animal Uptake Scale Factor	0.63	0.47	0.47
Milk -Cons. Rate (kg/yr)	0.45	0.44	0.44
Milk -Irrn. Time (mo/yr)	-0.20	-0.20	0.20
Crop Resuspension Factor (/m)	0.29	0.18	0.18
Milk -Dietary Fraction	0.19	0.16	0.16
Milk -Irrn. Rate (in/yr)	0.10	0.10	0.10
Grain -Cons. Rate (kg/yr)	0.09	0.09	0.09
Root Veg-Cons. Rate (kg/yr)	0.08	0.08	0.08
Beef -Irrn. Time (mo/yr)	-0.07	-0.08	0.08
Root Veg-Yield (kg/m2)	-0.08	-0.08	0.08
Drink Water Consumption (l/yr)	0.07	0.07	0.07
Beef -Cons. Rate (kg/yr)	0.08	0.06	0.06
Milk -Yield (kg/m3)	-0.05	-0.06	0.06
Beef -Dietary Fraction	0.07	0.06	0.06
Beef -Irrn. Rate (in/yr)	0.09	0.06	0.06
Fruit -Cons. Rate (kg/yr)	0.05	0.05	0.05
Inhalation Exposure (hr/yr)	0.08	0.05	0.05
Leaf Veg-Irrn. Time (mo/yr)	-0.06	-0.05	0.05
Home Irriga. Duration (mo/yr)	-0.04	-0.04	0.04
Fruit -Grow Time (days)	0.04	0.04	0.04
Soil/Plant Transfer Scale Fac.	-0.04	-0.04	0.04
Soil Exposure Time (hr)	-0.09	-0.03	0.03
Home Irrigation Rate (in/yr)	-0.02	-0.03	0.03
Leaf Veg-Cons. Rate (kg/yr)	0.02	0.03	0.03
Root Veg-Irrn. Time (mo/yr)	-0.03	-0.03	0.03
Grain -Irrn. Rate (in/yr)	-0.03	-0.03	0.03
Leaf Veg-Irrn. Rate (in/yr)	0.02	0.03	0.03
Leaf Veg-Yield (kg/m2)	0.03	0.03	0.03
Chronic Plume Exposure (hr)	-0.01	0.02	0.02
Grain -Grow Time (days)	-0.02	-0.02	0.02
Beef -Grow Time (days)	-0.02	-0.02	0.02
Root Veg-Irrn. Rate (in/yr)	0.02	0.02	0.02
Fruit -Irrn. Time (mo/yr)	0.02	0.02	0.02
Fruit -Yield (kg/m2)	0.02	0.02	0.02
Fruit -Irrn. Rate (in/yr)	-0.02	-0.02	0.02
Milk -Grow Time (days)	0.00	-0.01	0.01
Root Veg-Grow Time (days)	0.00	-0.01	0.01
Leaf Veg-Grow Time (days)	-0.02	-0.01	0.01
Surface Soil Density (kg/m2)	0.00	0.01	0.01
Grain -Yield (kg/m2)	0.01	0.01	0.01
Grain -Irrn. Time (mo/yr)	0.01	0.00	0.00
Beef -Yield (kg/m3)	0.00	0.00	0.00

Correlation coefficients on ranks for Annual EDE
from output block Stat. Committed Dose Summary (rem)
NP237.INP Created 23:03:23 on 03-19-1995. Run 23:03:27 on 03/19/95.

	Partial	Simple	Abs. Simple
Crop Interception Fraction (-)	0.80	0.78	0.78
Grain -Cons. Rate (kg/yr)	0.30	0.30	0.30
Crop Resuspension Factor (/m)	0.30	0.21	0.21
Fruit -Cons. Rate (kg/yr)	0.21	0.20	0.20
Root Veg-Cons. Rate (kg/yr)	0.16	0.17	0.17
Leaf Veg-Cons. Rate (kg/yr)	0.15	0.16	0.16
Drink Water Consumption (l/yr)	0.18	0.16	0.16
Leaf Veg-Irrn. Time (mo/yr)	-0.16	-0.15	0.15
Root Veg-Irrn. Time (mo/yr)	-0.11	-0.10	0.10
Beef -Cons. Rate (kg/yr)	0.08	0.09	0.09
Grain -Irrn. Time (mo/yr)	-0.07	-0.08	0.08
Leaf Veg-Irrn. Rate (in/yr)	0.07	0.08	0.08
Grain -Irrn. Rate (in/yr)	0.07	0.07	0.07
Beef -Yield (kg/m3)	-0.07	-0.07	0.07
Animal Uptake Scale Factor	0.13	0.06	0.06
Grain -Yield (kg/m2)	0.05	0.05	0.05
Surface Soil Density (kg/m2)	0.08	0.05	0.05
Root Veg-Grow Time (days)	-0.03	-0.05	0.05
Beef -Dietary Fraction	0.04	0.05	0.05
Milk -Dietary Fraction	0.06	0.05	0.05
Milk -Irrn. Rate (in/yr)	-0.05	-0.04	0.04
Fruit -Yield (kg/m2)	0.04	0.04	0.04
Beef -Irrn. Time (mo/yr)	-0.04	-0.04	0.04
Fruit -Grow Time (days)	0.05	0.04	0.04
Milk -Irrn. Time (mo/yr)	0.03	0.04	0.04
Soil/Plant Transfer Scale Fac.	-0.04	-0.03	0.03
Grain -Grow Time (days)	0.03	0.03	0.03
Root Veg-Irrn. Rate (in/yr)	0.03	0.03	0.03
Leaf Veg-Yield (kg/m2)	0.03	0.03	0.03
Milk -Cons. Rate (kg/yr)	0.02	0.03	0.03
Leaf Veg-Grow Time (days)	0.04	0.03	0.03
Fruit -Irrn. Rate (in/yr)	-0.02	-0.02	0.02
Milk -Grow Time (days)	0.00	0.01	0.01
Beef -Irrn. Rate (in/yr)	0.01	0.01	0.01
Beef -Grow Time (days)	0.01	0.01	0.01
Home Irrigation Rate (in/yr)	0.05	0.01	0.01
Fruit -Irrn. Time (mo/yr)	-0.01	-0.01	0.01
Home Irriga. Duration (mo/yr)	0.04	0.01	0.01
Milk -Yield (kg/m3)	0.01	0.01	0.01
Root Veg-Yield (kg/m2)	0.00	0.00	0.00
Inhalation Exposure (hr/yr)	0.05	0.00	0.00
Soil Exposure Time (hr)	-0.02	0.00	0.00
Chronic Plume Exposure (hr)	-0.03	0.00	0.00

Correlation coefficients on ranks for Annual EDE
from output block Stat. Committed Dose Summary (rem)
PB210.INP Created 22:56:56 on 03-19-1995. Run 22:57:01 on 03/19/95.

	Partial	Simple	Abs. Simple
Crop Interception Fraction (-)	0.79	0.77	0.77
Grain -Cons. Rate (kg/yr)	0.30	0.30	0.30
Crop Resuspension Factor (/m)	0.36	0.25	0.25
Fruit -Cons. Rate (kg/yr)	0.22	0.21	0.21
Drink Water Consumption (l/yr)	0.18	0.17	0.17
Leaf Veg-Cons. Rate (kg/yr)	0.16	0.16	0.16
Root Veg-Cons. Rate (kg/yr)	0.16	0.16	0.16
Leaf Veg-Irrn. Time (mo/yr)	-0.15	-0.14	0.14
Root Veg-Irrn. Time (mo/yr)	-0.10	-0.09	0.09
Leaf Veg-Irrn. Rate (in/yr)	0.07	0.08	0.08
Grain -Irrn. Time (mo/yr)	-0.06	-0.08	0.08
Beef -Yield (kg/m3)	-0.07	-0.07	0.07
Milk -Cons. Rate (kg/yr)	0.07	0.07	0.07
Animal Uptake Scale Factor	0.14	0.07	0.07
Grain -Irrn. Rate (in/yr)	0.07	0.06	0.06
Surface Soil Density (kg/m2)	0.09	0.06	0.06
Milk -Dietary Fraction	0.07	0.06	0.06
Grain -Yield (kg/m2)	0.06	0.06	0.06
Beef -Cons. Rate (kg/yr)	0.05	0.06	0.06
Root Veg-Grow Time (days)	-0.03	-0.05	0.05
Fruit -Grow Time (days)	0.05	0.05	0.05
Milk -Irrn. Rate (in/yr)	-0.03	-0.04	0.04
Grain -Grow Time (days)	0.04	0.04	0.04
Leaf Veg-Grow Time (days)	0.05	0.04	0.04
Beef -Dietary Fraction	0.04	0.04	0.04
Milk -Irrn. Time (mo/yr)	0.02	0.03	0.03
Leaf Veg-Yield (kg/m2)	0.03	0.03	0.03
Fruit -Yield (kg/m2)	0.03	0.03	0.03
Beef -Irrn. Time (mo/yr)	-0.02	-0.02	0.02
Fruit -Irrn. Rate (in/yr)	-0.02	-0.02	0.02
Root Veg-Irrn. Rate (in/yr)	0.02	0.02	0.02
Soil/Plant Transfer Scale Fac.	-0.02	-0.02	0.02
Inhalation Exposure (hr/yr)	0.08	0.02	0.02
Beef -Irrn. Rate (in/yr)	0.01	0.01	0.01
Milk -Grow Time (days)	0.00	0.01	0.01
Beef -Grow Time (days)	0.00	-0.01	0.01
Milk -Yield (kg/m3)	0.01	0.01	0.01
Fruit -Irrn. Time (mo/yr)	-0.02	-0.01	0.01
Root Veg-Yield (kg/m2)	0.00	0.00	0.00
Soil Exposure Time (hr)	-0.02	0.00	0.00
Home Irrigation Rate (in/yr)	0.04	0.00	0.00
Chronic Plume Exposure (hr)	-0.03	0.00	0.00
Home Irriga. Duration (mo/yr)	0.03	0.00	0.00

Correlation coefficients on ranks for Annual EDE
from output block Stat. Committed Dose Summary (rem)
PU239.INP Created 22:53:30 on 03-19-1995. Run 22:53:35 on 03/19/95.

	Partial	Simple	Abs. Simple
Crop Interception Fraction (-)	0.77	0.76	0.76
Grain -Cons. Rate (kg/yr)	0.33	0.34	0.34
Crop Resuspension Factor (/m)	0.28	0.21	0.21
Fruit -Cons. Rate (kg/yr)	0.21	0.20	0.20
Drink Water Consumption (l/yr)	0.19	0.18	0.18
Leaf Veg-Cons. Rate (kg/yr)	0.17	0.17	0.17
Leaf Veg-Irrn. Time (mo/yr)	-0.18	-0.17	0.17
Root Veg-Cons. Rate (kg/yr)	0.17	0.17	0.17
Root Veg-Irrn. Time (mo/yr)	-0.12	-0.11	0.11
Grain -Irrn. Time (mo/yr)	-0.07	-0.09	0.09
Beef -Yield (kg/m3)	-0.08	-0.08	0.08
Grain -Irrn. Rate (in/yr)	0.08	0.08	0.08
Leaf Veg-Irrn. Rate (in/yr)	0.07	0.07	0.07
Milk -Irrn. Rate (in/yr)	-0.05	-0.06	0.06
Grain -Yield (kg/m2)	0.06	0.05	0.05
Surface Soil Density (kg/m2)	0.08	0.05	0.05
Milk -Dietary Fraction	0.05	0.04	0.04
Root Veg-Grow Time (days)	-0.03	-0.04	0.04
Animal Uptake Scale Factor	-0.04	-0.04	0.04
Beef -Cons. Rate (kg/yr)	0.01	0.03	0.03
Leaf Veg-Grow Time (days)	0.04	0.03	0.03
Milk -Irrn. Time (mo/yr)	0.03	0.03	0.03
Beef -Grow Time (days)	-0.02	-0.02	0.02
Milk -Cons. Rate (kg/yr)	0.02	0.02	0.02
Leaf Veg-Yield (kg/m2)	0.02	0.02	0.02
Milk -Yield (kg/m3)	0.01	0.02	0.02
Fruit -Irrn. Time (mo/yr)	-0.03	-0.02	0.02
Fruit -Irrn. Rate (in/yr)	-0.02	-0.02	0.02
Soil/Plant Transfer Scale Fac.	-0.02	-0.02	0.02
Home Irrigation Rate (in/yr)	0.07	0.02	0.02
Fruit -Grow Time (days)	0.02	0.02	0.02
Grain -Grow Time (days)	0.02	0.02	0.02
Beef -Irrn. Rate (in/yr)	-0.01	-0.01	0.01
Home Irriga. Duration (mo/yr)	0.03	0.01	0.01
Beef -Dietary Fraction	-0.01	0.01	0.01
Chronic Plume Exposure (hr)	-0.02	0.01	0.01
Beef -Irrn. Time (mo/yr)	0.02	0.01	0.01
Root Veg-Yield (kg/m2)	0.01	0.01	0.01
Inhalation Exposure (hr/yr)	0.07	0.01	0.01
Fruit -Yield (kg/m2)	0.01	0.01	0.01
Root Veg-Irrn. Rate (in/yr)	0.00	0.00	0.00
Milk -Grow Time (days)	-0.01	0.00	0.00
Soil Exposure Time (hr)	-0.01	0.00	0.00

Correlation coefficients on ranks for Annual EDE
from output block Stat. Committed Dose Summary (rem)
PU240.INP Created 22:49:51 on 03-19-1995. Run 22:49:55 on 03/19/95.

	Partial	Simple	Abs. Simple
Crop Interception Fraction (-)	0.77	0.76	0.76
Grain -Cons. Rate (kg/yr)	0.33	0.34	0.34
Crop Resuspension Factor (/m)	0.28	0.21	0.21
Fruit -Cons. Rate (kg/yr)	0.21	0.20	0.20
Drink Water Consumption (l/yr)	0.19	0.18	0.18
Leaf Veg-Cons. Rate (kg/yr)	0.17	0.17	0.17
Leaf Veg-Irrn. Time (mo/yr)	-0.18	-0.17	0.17
Root Veg-Cons. Rate (kg/yr)	0.17	0.17	0.17
Root Veg-Irrn. Time (mo/yr)	-0.12	-0.11	0.11
Grain -Irrn. Time (mo/yr)	-0.07	-0.09	0.09
Beef -Yield (kg/m3)	-0.08	-0.08	0.08
Grain -Irrn. Rate (in/yr)	0.08	0.08	0.08
Leaf Veg-Irrn. Rate (in/yr)	0.07	0.07	0.07
Milk -Irrn. Rate (in/yr)	-0.05	-0.06	0.06
Grain -Yield (kg/m2)	0.06	0.05	0.05
Surface Soil Density (kg/m2)	0.08	0.05	0.05
Milk -Dietary Fraction	0.05	0.04	0.04
Root Veg-Grow Time (days)	-0.03	-0.04	0.04
Animal Uptake Scale Factor	-0.04	-0.04	0.04
Beef -Cons. Rate (kg/yr)	0.01	0.03	0.03
Leaf Veg-Grow Time (days)	0.04	0.03	0.03
Milk -Irrn. Time (mo/yr)	0.03	0.03	0.03
Beef -Grow Time (days)	-0.02	-0.02	0.02
Milk -Cons. Rate (kg/yr)	0.02	0.02	0.02
Leaf Veg-Yield (kg/m2)	0.02	0.02	0.02
Milk -Yield (kg/m3)	0.01	0.02	0.02
Fruit -Irrn. Time (mo/yr)	-0.03	-0.02	0.02
Fruit -Irrn. Rate (in/yr)	-0.02	-0.02	0.02
Soil/Plant Transfer Scale Fac.	-0.02	-0.02	0.02
Home Irrigation Rate (in/yr)	0.07	0.02	0.02
Fruit -Grow Time (days)	0.02	0.02	0.02
Grain -Grow Time (days)	0.02	0.02	0.02
Beef -Irrn. Rate (in/yr)	-0.01	-0.01	0.01
Home Irriga. Duration (mo/yr)	0.03	0.01	0.01
Beef -Dietary Fraction	-0.01	0.01	0.01
Chronic Plume Exposure (hr)	-0.02	0.01	0.01
Beef -Irrn. Time (mo/yr)	0.02	0.01	0.01
Root Veg-Yield (kg/m2)	0.01	0.01	0.01
Inhalation Exposure (hr/yr)	0.07	0.01	0.01
Fruit -Yield (kg/m2)	0.01	0.01	0.01
Root Veg-Irrn. Rate (in/yr)	0.00	0.00	0.00
Milk -Grow Time (days)	-0.01	0.00	0.00
Soil Exposure Time (hr)	-0.01	0.00	0.00

Correlation coefficients on ranks for Annual EDE
from output block Stat. Committed Dose Summary (rem)
RA226.INP Created 22:45:51 on 03-19-1995. Run 22:45:54 on 03/19/95.

	Partial	Simple	Abs. Simple
Crop Interception Fraction (-)	0.81	0.77	0.77
Grain -Cons. Rate (kg/yr)	0.25	0.25	0.25
Crop Resuspension Factor (/m)	0.38	0.24	0.24
Fruit -Cons. Rate (kg/yr)	0.19	0.19	0.19
Animal Uptake Scale Factor	0.34	0.18	0.18
Drink Water Consumption (l/yr)	0.18	0.17	0.17
Milk -Cons. Rate (kg/yr)	0.17	0.17	0.17
Root Veg-Cons. Rate (kg/yr)	0.16	0.16	0.16
Leaf Veg-Cons. Rate (kg/yr)	0.15	0.15	0.15
Leaf Veg-Irrn. Time (mo/yr)	-0.13	-0.11	0.11
Milk -Dietary Fraction	0.10	0.09	0.09
Root Veg-Irrn. Time (mo/yr)	-0.09	-0.08	0.08
Leaf Veg-Irrn. Rate (in/yr)	0.07	0.07	0.07
Beef -Dietary Fraction	0.06	0.07	0.07
Leaf Veg-Yield (kg/m2)	0.06	0.06	0.06
Beef -Yield (kg/m3)	-0.06	-0.06	0.06
Grain -Grow Time (days)	0.06	0.06	0.06
Grain -Yield (kg/m2)	0.07	0.06	0.06
Fruit -Grow Time (days)	0.06	0.06	0.06
Grain -Irrn. Time (mo/yr)	-0.04	-0.05	0.05
Surface Soil Density (kg/m2)	0.09	0.05	0.05
Home Irrigation Rate (in/yr)	0.11	0.04	0.04
Beef -Cons. Rate (kg/yr)	0.03	0.04	0.04
Root Veg-Grow Time (days)	-0.02	-0.04	0.04
Leaf Veg-Grow Time (days)	0.05	0.04	0.04
Inhalation Exposure (hr/yr)	0.10	0.03	0.03
Root Veg-Irrn. Rate (in/yr)	0.03	0.03	0.03
Fruit -Yield (kg/m2)	0.03	0.03	0.03
Grain -Irrn. Rate (in/yr)	0.03	0.03	0.03
Milk -Irrn. Time (mo/yr)	-0.03	-0.02	0.02
Root Veg-Yield (kg/m2)	-0.02	-0.02	0.02
Beef -Irrn. Time (mo/yr)	-0.02	-0.02	0.02
Milk -Grow Time (days)	0.02	0.01	0.01
Milk -Irrn. Rate (in/yr)	0.00	0.01	0.01
Soil Exposure Time (hr)	-0.01	0.01	0.01
Beef -Irrn. Rate (in/yr)	0.02	0.01	0.01
Soil/Plant Transfer Scale Fac.	0.00	-0.01	0.01
Chronic Plume Exposure (hr)	-0.06	-0.01	0.01
Milk -Yield (kg/m3)	0.01	0.01	0.01
Fruit -Irrn. Time (mo/yr)	0.00	0.00	0.00
Beef -Grow Time (days)	0.00	0.00	0.00
Fruit -Irrn. Rate (in/yr)	0.00	0.00	0.00
Home Irriga. Duration (mo/yr)	0.03	0.00	0.00

Correlation coefficients on ranks for Annual EDE
from output block Stat. Committed Dose Summary (rem)
SE79.INP Created 22:42:03 on 03-19-1995. Run 22:42:10 on 03/19/95.

	Partial	Simple	Abs. Simple
Crop Interception Fraction (-)	0.80	0.66	0.66
Animal Uptake Scale Factor	0.73	0.52	0.52
Beef -Cons. Rate (kg/yr)	0.24	0.22	0.22
Beef -Irrn. Time (mo/yr)	-0.24	-0.21	0.21
Milk -Cons. Rate (kg/yr)	0.18	0.17	0.17
Crop Resuspension Factor (/m)	0.29	0.16	0.16
Beef -Dietary Fraction	0.17	0.14	0.14
Grain -Cons. Rate (kg/yr)	0.09	0.11	0.11
Milk -Dietary Fraction	0.11	0.09	0.09
Fruit -Cons. Rate (kg/yr)	0.08	0.08	0.08
Beef -Irrn. Rate (in/yr)	0.09	0.07	0.07
Milk -Irrn. Time (mo/yr)	-0.07	-0.07	0.07
Root Veg-Cons. Rate (kg/yr)	0.06	0.06	0.06
Home Irriga. Duration (mo/yr)	-0.09	-0.06	0.06
Beef -Grow Time (days)	0.07	0.05	0.05
Home Irrigation Rate (in/yr)	-0.06	-0.05	0.05
Leaf Veg-Yield (kg/m2)	0.04	0.04	0.04
Inhalation Exposure (hr/yr)	0.07	0.04	0.04
Surface Soil Density (kg/m2)	0.08	0.04	0.04
Grain -Irrn. Rate (in/yr)	-0.03	-0.03	0.03
Root Veg-Irrn. Time (mo/yr)	-0.03	-0.03	0.03
Drink Water Consumption (l/yr)	0.03	0.03	0.03
Milk -Irrn. Rate (in/yr)	0.01	0.03	0.03
Fruit -Irrn. Rate (in/yr)	-0.03	-0.03	0.03
Leaf Veg-Irrn. Time (mo/yr)	-0.03	-0.03	0.03
Milk -Yield (kg/m3)	-0.03	-0.03	0.03
Soil Exposure Time (hr)	-0.09	-0.02	0.02
Beef -Yield (kg/m3)	-0.02	-0.02	0.02
Fruit -Yield (kg/m2)	0.02	0.02	0.02
Root Veg-Irrn. Rate (in/yr)	0.02	0.02	0.02
Grain -Grow Time (days)	0.02	0.02	0.02
Leaf Veg-Irrn. Rate (in/yr)	0.02	0.02	0.02
Leaf Veg-Cons. Rate (kg/yr)	0.02	0.02	0.02
Root Veg-Grow Time (days)	-0.01	-0.01	0.01
Leaf Veg-Grow Time (days)	-0.01	-0.01	0.01
Milk -Grow Time (days)	-0.02	-0.01	0.01
Grain -Yield (kg/m2)	0.01	0.01	0.01
Grain -Irrn. Time (mo/yr)	0.02	0.01	0.01
Soil/Plant Transfer Scale Fac.	0.01	-0.01	0.01
Root Veg-Yield (kg/m2)	-0.01	-0.01	0.01
Fruit -Grow Time (days)	0.00	0.00	0.00
Fruit -Irrn. Time (mo/yr)	0.00	0.00	0.00
Chronic Plume Exposure (hr)	-0.05	0.00	0.00

Correlation coefficients on ranks for Annual EDE
from output block Stat. Committed Dose Summary (rem)
TC99.INP Created 22:38:27 on 03-19-1995. Run 22:38:31 on 03/19/95.

	Partial	Simple	Abs. Simple
Soil/Plant Transfer Scale Fac.	0.61	0.54	0.54
Crop Interception Fraction (-)	0.55	0.46	0.46
Root Veg-Cons. Rate (kg/yr)	0.39	0.37	0.37
Fruit -Cons. Rate (kg/yr)	0.34	0.31	0.31
Leaf Veg-Cons. Rate (kg/yr)	0.22	0.21	0.21
Grain -Cons. Rate (kg/yr)	0.20	0.20	0.20
Leaf Veg-Irrn. Time (mo/yr)	-0.14	-0.13	0.13
Leaf Veg-Irrn. Rate (in/yr)	0.12	0.12	0.12
Drink Water Consumption (l/yr)	0.14	0.12	0.12
Grain -Irrn. Time (mo/yr)	-0.10	-0.11	0.11
Crop Resuspension Factor (/m)	0.15	0.10	0.10
Milk -Dietary Fraction	0.09	0.08	0.08
Surface Soil Density (kg/m2)	-0.10	-0.08	0.08
Root Veg-Irrn. Rate (in/yr)	0.08	0.08	0.08
Inhalation Exposure (hr/yr)	0.13	0.06	0.06
Milk -Irrn. Time (mo/yr)	0.03	0.04	0.04
Beef -Yield (kg/m3)	-0.04	-0.04	0.04
Milk -Yield (kg/m3)	0.04	0.04	0.04
Chronic Plume Exposure (hr)	0.04	0.04	0.04
Root Veg-Irrn. Time (mo/yr)	-0.06	-0.03	0.03
Beef -Cons. Rate (kg/yr)	0.01	0.03	0.03
Leaf Veg-Yield (kg/m2)	0.03	0.03	0.03
Fruit -Yield (kg/m2)	-0.04	-0.03	0.03
Grain -Irrn. Rate (in/yr)	0.03	0.03	0.03
Milk -Cons. Rate (kg/yr)	0.02	0.02	0.02
Fruit -Grow Time (days)	-0.02	-0.02	0.02
Grain -Yield (kg/m2)	0.03	0.02	0.02
Leaf Veg-Grow Time (days)	0.02	0.02	0.02
Fruit -Irrn. Rate (in/yr)	0.02	0.02	0.02
Beef -Dietary Fraction	0.02	0.02	0.02
Milk -Irrn. Rate (in/yr)	-0.01	-0.01	0.01
Beef -Irrn. Rate (in/yr)	-0.01	-0.01	0.01
Beef -Irrn. Time (mo/yr)	-0.01	-0.01	0.01
Home Irrigation Rate (in/yr)	0.05	0.01	0.01
Root Veg-Grow Time (days)	0.01	-0.01	0.01
Home Irriga. Duration (mo/yr)	0.00	-0.01	0.01
Animal Uptake Scale Factor	0.04	0.01	0.01
Root Veg-Yield (kg/m2)	-0.01	-0.01	0.01
Milk -Grow Time (days)	-0.01	0.00	0.00
Soil Exposure Time (hr)	-0.04	0.00	0.00
Beef -Grow Time (days)	0.00	0.00	0.00
Fruit -Irrn. Time (mo/yr)	-0.01	0.00	0.00
Grain -Grow Time (days)	-0.01	0.00	0.00

Correlation coefficients on ranks for Annual EDE
from output block Stat. Committed Dose Summary (rem)
TH230.INP Created 22:33:02 on 03-19-1995. Run 22:33:50 on 03/19/95.

	Partial	Simple	Abs. Simple
Crop Interception Fraction (-)	0.77	0.76	0.76
Grain -Cons. Rate (kg/yr)	0.33	0.34	0.34
Crop Resuspension Factor (/m)	0.29	0.21	0.21
Fruit -Cons. Rate (kg/yr)	0.21	0.20	0.20
Drink Water Consumption (l/yr)	0.19	0.18	0.18
Leaf Veg-Cons. Rate (kg/yr)	0.17	0.17	0.17
Leaf Veg-Irrn. Time (mo/yr)	-0.18	-0.17	0.17
Root Veg-Cons. Rate (kg/yr)	0.17	0.17	0.17
Root Veg-Irrn. Time (mo/yr)	-0.12	-0.10	0.10
Grain -Irrn. Time (mo/yr)	-0.07	-0.09	0.09
Beef -Yield (kg/m3)	-0.08	-0.08	0.08
Grain -Irrn. Rate (in/yr)	0.08	0.08	0.08
Leaf Veg-Irrn. Rate (in/yr)	0.07	0.07	0.07
Milk -Irrn. Rate (in/yr)	-0.05	-0.06	0.06
Surface Soil Density (kg/m2)	0.08	0.05	0.05
Grain -Yield (kg/m2)	0.05	0.05	0.05
Animal Uptake Scale Factor	-0.03	-0.04	0.04
Milk -Dietary Fraction	0.05	0.04	0.04
Root Veg-Grow Time (days)	-0.03	-0.04	0.04
Milk -Irrn. Time (mo/yr)	0.03	0.03	0.03
Beef -Cons. Rate (kg/yr)	0.01	0.03	0.03
Leaf Veg-Grow Time (days)	0.04	0.03	0.03
Leaf Veg-Yield (kg/m2)	0.02	0.02	0.02
Beef -Grow Time (days)	-0.02	-0.02	0.02
Soil/Plant Transfer Scale Fac.	-0.03	-0.02	0.02
Milk -Cons. Rate (kg/yr)	0.02	0.02	0.02
Grain -Grow Time (days)	0.02	0.02	0.02
Fruit -Irrn. Time (mo/yr)	-0.03	-0.02	0.02
Fruit -Grow Time (days)	0.02	0.02	0.02
Fruit -Irrn. Rate (in/yr)	-0.02	-0.02	0.02
Beef -Irrn. Time (mo/yr)	0.02	0.01	0.01
Beef -Dietary Fraction	-0.01	0.01	0.01
Beef -Irrn. Rate (in/yr)	-0.01	-0.01	0.01
Chronic Plume Exposure (hr)	-0.02	0.01	0.01
Fruit -Yield (kg/m2)	0.01	0.01	0.01
Root Veg-Yield (kg/m2)	0.02	0.01	0.01
Inhalation Exposure (hr/yr)	0.07	0.01	0.01
Home Irrigation Rate (in/yr)	0.06	0.01	0.01
Milk -Yield (kg/m3)	0.01	0.01	0.01
Soil Exposure Time (hr)	-0.01	0.00	0.00
Milk -Grow Time (days)	-0.01	0.00	0.00
Root Veg-Irrn. Rate (in/yr)	0.00	0.00	0.00
Home Irriga. Duration (mo/yr)	0.02	0.00	0.00

Correlation coefficients on ranks for Annual EDE
from output block Stat. Committed Dose Summary (rem)
U234.INP Created 22:28:54 on 03-19-1995. Run 22:28:57 on 03/19/95.

	Partial	Simple	Abs. Simple
Crop Interception Fraction (-)	0.79	0.78	0.78
Grain -Cons. Rate (kg/yr)	0.30	0.30	0.30
Crop Resuspension Factor (/m)	0.33	0.23	0.23
Fruit -Cons. Rate (kg/yr)	0.21	0.20	0.20
Drink Water Consumption (l/yr)	0.20	0.18	0.18
Root Veg-Cons. Rate (kg/yr)	0.17	0.17	0.17
Leaf Veg-Cons. Rate (kg/yr)	0.17	0.17	0.17
Leaf Veg-Irrn. Time (mo/yr)	-0.16	-0.15	0.15
Root Veg-Irrn. Time (mo/yr)	-0.10	-0.09	0.09
Milk -Cons. Rate (kg/yr)	0.08	0.08	0.08
Leaf Veg-Irrn. Rate (in/yr)	0.06	0.07	0.07
Beef -Yield (kg/m3)	-0.07	-0.07	0.07
Grain -Irrn. Time (mo/yr)	-0.06	-0.07	0.07
Grain -Yield (kg/m2)	0.06	0.06	0.06
Grain -Irrn. Rate (in/yr)	0.07	0.06	0.06
Milk -Dietary Fraction	0.07	0.06	0.06
Surface Soil Density (kg/m2)	0.09	0.05	0.05
Animal Uptake Scale Factor	0.11	0.05	0.05
Milk -Irrn. Rate (in/yr)	-0.03	-0.04	0.04
Fruit -Grow Time (days)	0.04	0.04	0.04
Leaf Veg-Grow Time (days)	0.05	0.04	0.04
Root Veg-Grow Time (days)	-0.03	-0.04	0.04
Grain -Grow Time (days)	0.04	0.04	0.04
Beef -Dietary Fraction	0.02	0.03	0.03
Leaf Veg-Yield (kg/m2)	0.04	0.03	0.03
Beef -Cons. Rate (kg/yr)	0.01	0.03	0.03
Beef -Grow Time (days)	-0.01	-0.02	0.02
Inhalation Exposure (hr/yr)	0.08	0.02	0.02
Fruit -Yield (kg/m2)	0.02	0.02	0.02
Milk -Irrn. Time (mo/yr)	0.02	0.02	0.02
Milk -Yield (kg/m3)	0.01	0.01	0.01
Root Veg-Irrn. Rate (in/yr)	0.01	0.01	0.01
Soil/Plant Transfer Scale Fac.	-0.01	-0.01	0.01
Soil Exposure Time (hr)	-0.01	0.01	0.01
Fruit -Irrn. Rate (in/yr)	-0.01	-0.01	0.01
Fruit -Irrn. Time (mo/yr)	-0.02	-0.01	0.01
Chronic Plume Exposure (hr)	-0.04	-0.01	0.01
Beef -Irrn. Rate (in/yr)	0.00	0.00	0.00
Root Veg-Yield (kg/m2)	0.00	0.00	0.00
Milk -Grow Time (days)	0.00	0.00	0.00
Beef -Irrn. Time (mo/yr)	0.01	0.00	0.00
Home Irrigation Rate (in/yr)	0.04	0.00	0.00
Home Irriga. Duration (mo/yr)	0.03	0.00	0.00

Correlation coefficients on ranks for Annual EDE
from output block Stat. Committed Dose Summary (rem)
U238.INP Created 22:23:43 on 03-19-1995. Run 22:23:47 on 03/19/95.

	Partial	Simple	Abs. Simple
Crop Interception Fraction (-)	0.79	0.77	0.77
Grain -Cons. Rate (kg/yr)	0.31	0.32	0.32
Crop Resuspension Factor (/m)	0.35	0.24	0.24
Fruit -Cons. Rate (kg/yr)	0.23	0.22	0.22
Root Veg-Cons. Rate (kg/yr)	0.18	0.18	0.18
Leaf Veg-Cons. Rate (kg/yr)	0.17	0.17	0.17
Drink Water Consumption (l/yr)	0.15	0.14	0.14
Leaf Veg-Irrn. Time (mo/yr)	-0.15	-0.14	0.14
Root Veg-Irrn. Time (mo/yr)	-0.10	-0.09	0.09
Milk -Cons. Rate (kg/yr)	0.07	0.08	0.08
Grain -Irrn. Time (mo/yr)	-0.07	-0.08	0.08
Beef -Yield (kg/m3)	-0.07	-0.07	0.07
Leaf Veg-Irrn. Rate (in/yr)	0.06	0.07	0.07
Grain -Yield (kg/m2)	0.06	0.06	0.06
Surface Soil Density (kg/m2)	0.10	0.06	0.06
Milk -Dietary Fraction	0.07	0.06	0.06
Grain -Irrn. Rate (in/yr)	0.07	0.06	0.06
Home Irrigation Rate (in/yr)	0.11	0.04	0.04
Leaf Veg-Yield (kg/m2)	0.04	0.04	0.04
Milk -Irrn. Rate (in/yr)	-0.04	-0.04	0.04
Animal Uptake Scale Factor	0.09	0.04	0.04
Fruit -Grow Time (days)	0.04	0.04	0.04
Leaf Veg-Grow Time (days)	0.05	0.04	0.04
Root Veg-Grow Time (days)	-0.03	-0.04	0.04
Milk -Irrn. Time (mo/yr)	0.03	0.03	0.03
Grain -Grow Time (days)	0.03	0.03	0.03
Beef -Cons. Rate (kg/yr)	0.02	0.03	0.03
Beef -Dietary Fraction	0.01	0.02	0.02
Beef -Grow Time (days)	-0.02	-0.02	0.02
Soil Exposure Time (hr)	0.01	0.02	0.02
Inhalation Exposure (hr/yr)	0.09	0.02	0.02
Milk -Yield (kg/m3)	0.02	0.02	0.02
Fruit -Yield (kg/m2)	0.02	0.02	0.02
Fruit -Irrn. Time (mo/yr)	-0.03	-0.02	0.02
Fruit -Irrn. Rate (in/yr)	-0.01	-0.01	0.01
Home Irriga. Duration (mo/yr)	0.01	-0.01	0.01
Root Veg-Irrn. Rate (in/yr)	0.01	0.01	0.01
Root Veg-Yield (kg/m2)	-0.01	-0.01	0.01
Soil/Plant Transfer Scale Fac.	-0.01	-0.01	0.01
Milk -Grow Time (days)	-0.02	-0.01	0.01
Beef -Irrn. Time (mo/yr)	0.01	0.00	0.00
Beef -Irrn. Rate (in/yr)	0.00	0.00	0.00
Chronic Plume Exposure (hr)	-0.03	0.00	0.00

CNWRA 95-018

INITIAL ANALYSIS OF SELECTED SITE-SPECIFIC DOSE ASSESSMENT PARAMETERS AND EXPOSURE PATHWAYS APPLICABLE TO A GROUNDWATER RELEASE SCENARIO AT YUCCA MOUNTAIN