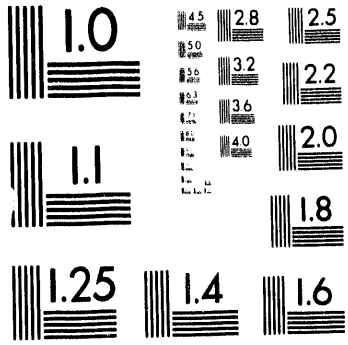
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2.8
2.5
3.2
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1.25
1.4
1.6

1 of 1

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Effects of the Loss of Correlation Structure on Phase I Dose Estimates

Hanford Environmental
Dose Reconstruction Project

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November 1991

Prepared for
the Technical Steering Panel

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MASTER

EFFECTS OF THE LOSS OF CORRELATION
STRUCTURE ON PHASE I DOSE ESTIMATES

November 1991

This document has been reviewed
by the Technical Steering Panel
and is approved for public release.

J. E. Till, Chairman
Technical Steering Panel
Hanford Environmental
Dose Reconstruction Project

November 10, 1991
Date

Foreword

This report is a description of work performed for the Hanford Environmental Dose Reconstruction (HEDR) Project. The HEDR Project was established to estimate radiation doses to individuals resulting from releases of radionuclides from the Hanford Site since 1944, when facilities there first began operating.

Preliminary radiation doses were estimated and reported during Phase I of the HEDR Project. The technical objectives of this initial phase were to 1) determine whether sufficient historical information could be found or reconstructed for use in dose estimation, and 2) develop and test conceptual and computational models for calculating credible dose estimates. Preliminary dose estimates were made in this phase because they were needed to achieve these objectives; however, it was realized that improvements would be needed. As the project has progressed, additional information regarding the magnitude and timing of the releases has been developed, difficulties in implementation of the original conceptual models have been uncovered, and the general scope of the required calculations has been enhanced.

A number of investigations were made using the Phase I dose estimates. The adequacy of the Phase I models was evaluated in terms of accuracy, precision, and reproducibility of the results. Potential improvements were identified in the areas of spatial and temporal resolution, model internal structure, and propagation of uncertainties. The major investigations are documented in this report and "Dose Estimate Variability Caused by Air Model Uncertainties" (Simpson 1991).

This report ("Effects of Loss of Correlation Structure on Phase I Dose Estimates") deals with the impacts on the dose estimates of the actual computational structure of the Phase I computer code. The companion report (Simpson 1991) deals with the impacts on the dose estimates of certain assumptions made in coupling the various portions of the computer code. Both reports indicate that algorithms and parameter distributions used in Phase I could be improved. Neither individual report completely defines the total impact the problems identified have on the dose estimates. Full quantification of this impact awaits the implementation of the recommendations of these reports.

At the direction of the HEDR Technical Steering Panel (TSP), the recommendations of this report and its companion (Simpson 1991) are being incorporated in the revised HEDR Project model. The recommendations involve a major redesign of the project model. This redesign is documented in Napier et al. (1991), a report outlining the full set of equations and solution algorithms of the new model.

Appendix B is a record of TSP comments and Battelle's responses; the TSP has reviewed and approved Battelle's responses to its comments. The comment numbers appear in the left margin next to the paragraph in which the corresponding comment was addressed. Changed text is shown in italics. In addition to responding to TSP comments, some changes were made to correct errors or for further clarification.

Summary

5, 24 *In Phase I of the Hanford Environmental Dose Reconstruction Project, a step-by-step (modular) calculational structure was used. This structure was intended 1) to simplify the computational process, 2) to allow storage of intermediate calculations for later analyses, and 3) to guide the collection of data by presenting understandable structures for its use. To a large extent, the Phase I code achieved these goals. However, the implementation of this modular structure resulted in the loss of correlation among inputs and outputs of the code, resulting in less accurate dose estimates than anticipated.*

The study documented in this report investigated two types of correlations in the Phase I model: temporal and pathway. Temporal correlations occur in the simulation when, in the calculation, data estimated for a previous time are used in a subsequent calculation. If the various portions of the calculation do not use the same realization of the earlier estimate, they are no longer correlated with respect to time. Similarly, spatial correlations occur in a simulation when, in the calculation, data estimated for a particular location are used in estimates for other locations. If the various calculations do not use the same value for the original location, they are no longer correlated with respect to location. The loss of correlation structure in the Phase I code was caused by the use of intermediate histograms to store the output from each module of the code. Subsequent modules independently sampled these intermediate histograms, and at that point the correlation structure was lost.

6 *The loss of the correlation structure in the Phase I code resulted in dose estimates that are biased. In general, small values of certain parameters should occur concurrently with relatively small values of other parameters, and large values should occur concurrently with other relatively large values. Because they did not, small values were often associated inappropriately with large ones. The net result is a general overestimation of mean and median dose for a number of exposure pathways.*

It is recommended that the air pathway dose model be restructured and the intermediate histograms eliminated. While the restructured code may still contain distinct modules, all input parameters to each module and all output from each module should be retained in a database such that subsequent modules can access all the information necessary to retain the correlation structure.

Contents

Foreword iii

Summary v

1.0 Introduction 1.1

2.0 Quality Assurance 2.1

3.0 Results 3.1

3.1 Submersion and Inhalation 3.1

3.2 Groundshine 3.1

3.3 Fruits and Vegetables 3.2

3.4 Milk 3.3

4.0 Conclusions and Recommendations 4.1

5.0 References 5.1

Appendix A - Figures and Tables A.1

Appendix B - Summary of TSP Comments and Battelle Responses B.1

Figures

A.1 Location of HEDR Phase I Census Divisions A.1

A.2 HEDR Phase I Iodine-131 Inhalation Dose Estimate CCDF with Band from Non-Modular Code for Infants in Kittitas 7 . . . . . A.2

A.3 HEDR Phase I Iodine-131 Groundshine Dose Estimate CCDF with Band from Non-Modular Code for Infants in Kittitas 7 . . . . . A.3

A.4 HEDR Phase I Iodine-131 Groundshine Dose Estimate CCDF with Band from Non-Modular Code Using "Uncorrelated" Months for Infants in Kittitas 7 . . . . . A.4

A.5 HEDR Phase I Iodine-131 Vegetable Dose Estimate CCDF with Band from Non-Modular Code for Infants in Kittitas 7 . . . . . A.5

A.6 HEDR Phase I Iodine-131 Vegetable Dose Estimate CCDF with Band from Non-Modular Code with "Uncorrelated" Months for Infants in Kittitas 7 . . . . . A.6

A.7 HEDR Phase I Iodine-131 Vegetable Dose Estimate CCDF with Band from Non-Modular Code with "Uncorrelated" Months and Vegetation Types for Infants in Kittitas 7 . . . . . A.7

Tables

A.1 Percent of the Phase I CDF for the Iodine-131 Dose from the Submersion Pathway that is Above or Below the CDF Band from the Non-Modular Code A.8

A.2 Percent of the Phase I CDF for the Iodine-131 Dose from the Inhalation Pathway that is Above or Below the CDF Band from the Non-Modular Code A.9

A.3 Percent of the Phase I CDF for the Iodine-131 Dose from the Groundshine Pathway that is Above or Below the CDF Band from the Non-Modular Code A.10

A.4 Percent of the Phase I CDF for the Iodine-131 Dose from the Fruit and Vegetable Pathway that is Above or Below the CDF Band from the Non-Modular Code A.11

A.5 Percent of the Phase I CDF for the Iodine-131 Dose from the Milk (Cow Feeding Regime 1) Pathway that is Above or Below the CDF Band from the Non-Modular Code A.12

A.6 Percent of the Phase I CDF for the Iodine-131 Dose from the Milk (Cow Feeding Regime 2) Pathway that is Above or Below the CDF Band from the Non-Modular Code A.13

A.7 Percent of the Phase I CDF for the Iodine-131 Dose from the Milk (Cow Feeding Regime 3) Pathway that is Above or Below the CDF Band from the Non-Modular Code A.14

A.8 Percent of the Phase I CDF for the Iodine-131 Dose from the Milk (Cow Feeding Regime 4) Pathway that is Above or Below the CDF Band from the Non-Modular Code. A.15

1.0 Introduction

The Phase I air pathway dose code was constructed in modules. Intermediate modules output 40-bin histograms, which were used as input to subsequent modules. The bin widths (or intervals) were 1/40 of the range between the minimum and maximum results of the module. The first bin's left-hand side was the minimum and the 40th bin's right-hand side was the maximum. The height of the bins were the number of results that were contained within each bin. These histograms did not include information about the correlations that existed within the dose model. Accordingly, this study was designed to determine the extent to which Phase I iodine-131 dose results were affected by the loss of the correlation structure.

For the *present* analysis, a non-modular program was coded. This program used the same equations and was run with the same inputs as the Phase I code. Therefore, the differences in the results between the Phase I code and the non-modular code were caused by the loss of the correlation structure in the Phase I code.

The non-modular code calculated the doses for one census *division* at a time. Therefore, this non-modular code did not have grocery milk or stored *dairy products* components, because these pathways involve using a number of census *divisions* simultaneously.

9 For *the* selected census *divisions shown in Figure A.1*, seven *down*wind and seven *up*wind, this code was run for both adults and infants (for a total of 28 different combinations). The 3-year total doses from submersion, groundshine, inhalation, fruit and vegetable ingestion, and the four milk regimes (the backyard cow feeding regimes only) were calculated for each combination.

, 11 The Phase I dose code was simulated 200 times for each of the five milk regimes, four backyard cow feeding regimes and the grocery milk. Therefore, the non-modular code was also simulated 200 times for the four backyard cow feeding regimes. For *the* submersion, groundshine, inhalation and vegetation pathways, the runs consisted of 1000 simulations *each*, because the Phase I results were a combination of the results from the five different milk regimes.

If the non-modular code is run only once, the resulting cumulative distribution function (CDF) would be different from the Phase I CDF because of the stochastic nature of the model, and there would be no way to determine whether the two different codes produced the similar results. Therefore the non-modular code was run 19 times for each combination. These 19 runs were used to produce a band around the results. The results of each of the 19 runs were ordered from the smallest to the largest dose. Then the smallest and largest minimum doses

from the 19 runs were selected. These two values formed a band around the minimum dose. This procedure was then repeated for the other 199 or 999 (depending on the pathway) ordered doses.

12 The bands around the non-modular results were used as a reference for comparing the results of the Phase I and non-modular codes. *The Phase I results in this report are the same results used in the Summary Report (HEDR Staff 1991a) and the Air Pathway Report (HEDR Staff 1991b) for Phase I.* The results for each pathway are shown in Tables A.1 through A.8 in Appendix *A*. These tables display the percent of the Phase I CDF of the 3-year iodine-131 doses that are outside the bands and the size of the deviation *to the left or right of* the band at given percentiles (5th, 10th, 25th, 50th, 75th, 90th and 95th) of the Phase I CDF. The size of the deviation is the percentage difference between the Phase I dose and the maximum (or minimum) of the band when the Phase I dose was outside the bands. Figures A.2 through A.7 in Appendix A present examples of these results graphically for the iodine-131 dose to infants in Kittitas 7.

2.0 Quality Assurance

The work described in this report was performed in accordance with the requirements of ANSI/ASME NQA-1 1986 Edition, Quality Assurance (QA) Program Requirements for Nuclear Facilities, as interpreted by Pacific Northwest Laboratory's QA program. The non-modular code used the same algorithms and parameters that were used in the Phase I atmospheric release model (Napier 1990). The results of the non-modular code were verified by comparisons with the results of the Phase I atmospheric release model.

Drafts of this document underwent internal independent technical review. Comments from the reviewers were satisfactorily resolved, and there were no controversial resolutions to the comments.

3.0 Results

3.1 Submersion and Inhalation

For the submersion and inhalation pathways (Tables A.1 and A.2, respectively), there should be no effects from the loss of correlations in the Phase I model. Submersion is simply the multiple of time-integrated iodine-131 air concentration (chi/Q), source term (Q) and dose factor, and inhalation is the multiple of chi/Q, Q, dose factor and breathing rate. There are no correlations here to be lost.

As seen in Tables A.1 and A.2, for many of the 28 different combinations, the bands enclosed more than 95% of the Phase I CDF. However, there were a number of cases where more than 20% of the Phase I CDF was outside the band, but for most cases, the deviations of the Phase I CDF from the band were small, except for the extreme upper percentiles (90th and 95th). The deviations in the upper percentiles of the CDF are not unexpected. As the percentile increases, the variability in the estimate of that percentile also increases. For adults *in Kittitas 7*, the deviations were quite large, a result that occurred for all the pathways. The reason for this result is unknown.

Figure A.2 shows the Phase I complementary CDF (CCDF) for the inhalation dose pathway and the band from the non-modular program for infants in *Kittitas 7*.

3.2 Groundshine

For groundshine, there was an effect resulting from the loss of correlations (see Table A.3). This effect was greater for the upwind census tracts than the downwind tracts. The upwind census tracts have a larger proportion of their Phase I CDFs outside the non-modular bands and the percent difference between the CDF and the band was larger. The difference in the upwind and downwind census tracts was caused by the larger variances in the month-end soil concentrations from the air model for the upwind census tracts.

Figure A.3 shows the groundshine dose CCDF for the infants in Kittitas 7 from the Phase I program and the band from the non-modular program. We see that much of the Phase I CDF was substantially outside the non-modular band.

The groundshine dose is the product of month-end iodine-131 surface concentration (MSC) and dose factor. However, the MSC is "accumulated" over the months in the code. A given

month's MSC is the sum of the new MSC and the MSC after decay from previous months. Although iodine-131 goes through about *four* half-lives in a month, there is enough carryover to make the monthly doses correlated.

14 To check the above assertion that ignoring monthly (temporal) correlations caused the bias in the Phase I groundshine doses, the results of the non-modular program were uncorrelated by *a systematic* "shuffling" *of* the 36 months used to calculate the 3-year total so that they came from different runs. *That is, the first 3-year total used month 1 from run 1, month 2 from run 2, ..., month 36 from run 36. Then the second 3-year total used month 1 from run 2, month 2 from run 3, ..., month 36 from run 37. Because the runs are independent, this "shuffling" makes the months uncorrelated.* This was done for the infants in four census tracts, *Benton 4 and 5* downwind and *Kittitas 1 and 7* upwind. These monthly "uncorrelated" results are labeled "unc_m" in the tables.

As seen in Figure A.4, the band for the "uncorrelated" results now contains the biased groundshine dose CDF from Phase I for the infants in *Kittitas 7.* The "unc_m" results in Table A.3 show both a drastic decrease in the percentage of the Phase I CDFs that were outside the non-modular bands and a decrease in the deviation between the Phase I CDF and the band, when the Phase I CDF was outside the bands.

Note that for the four tracts that were considered, there are two independent estimates of the bands from the non-modular program. These duplicate bands do agree fairly well with each other.

3.3 Fruits and Vegetables

The vegetation (fruits and vegetables) dose was the sum of the doses from the ingestion of four different food types (leafy vegetables, other vegetables, fruits, and grains). Each of the food type doses was the product of the food type concentration, dose factor, and amount eaten. The food type concentration was the sum of the current month's concentration and the previous month's concentration decayed over time.

The vegetation dose was affected greatly by the loss of correlations (see Table A.4). The deviations of the Phase I CDFs were much greater for the upwind tracts than for the downwind tracts. Additionally, the effects appear to be greater for infants than for adults. Infants' diets have a relatively larger variance for the amount of the different food types eaten than the adults' diets. Figure A.5 shows the difference between the Phase I CDF and the non-modular band for the infants in *Kittitas 7.*

When the non-modular results are "uncorrelated" over time (see "unc_m" results in Table A.4), the band is only slightly closer to the estimated dose from Phase I (see Figure A.6). However, when the non-modular results are also "uncorrelated" across vegetable types (see "unc" in Table A.4), the non-modular band is closer to the Phase I CDF (see Figure A.7). This result indicates that the correlation among vegetation types has more effect on the dose estimates than the temporal correlations.

As seen in Table A.4, not all of the differences between the Phase I CDF and the non-modular bands can be explained by the lost correlations. There is a possible explanation for the remaining problem. The Phase I histograms used only a small number of bins (between three and five bins for the downwind tracts and between six and eight bins for the upwind tracts). With so few bins, the finer structure of the distribution was lost. For the downwind tracts, more structure was lost, and the results are noticeably worse than the results for the upwind tracts.

3.4 Milk

,17 *Four prototypical feeding regimes are considered for milk cows (Beck et al. 1991).* The iodine-131 doses from the milk pathway for feeding regimes 1 and 2 (Tables A.5 and A.6, respectively) show little evidence of an effect due to the lost correlations. These *two* regimes were dominated by fresh pasture *for which the* concentration, during the growing season, was dominated by the average deposition rate. However, the concentration of iodine-131 in the fresh pasture did lose the temporal correlation from the carryover of undecayed iodine-131 to the next month. The effects of this lost correlation may be overshadowed by the other sources of variability in the model. The absence of the stored *dairy products* pathway in the non-modular program was not noticeable, indicating the small impact that stored *dairy products* had on the milk dose for these regimes.

For iodine-131 doses from the milk pathway for feeding regimes 3 (alfalfa hay), and 4 (grass hay), there was evidence of an effect from the loss of correlations (Tables A.7 and A.8). These correlations were from the decaying of the concentrations of iodine-131 in the hay over time. In the non-modular program, it was the same "batch" of hay that has iodine-131 decayed over time, while in the Phase I program a different "batch" of hay was used each month. There may also be correlations between the different types of feed (grain and hay) if they were harvested during the same month.

For the adults in regimes 3 and 4, the differences seen in Tables A.7 and A.8 were primarily due to the lack of the stored milk pathway in the non-modular program. Adults consume only a small amount of stored *dairy products* (e.g., cheese) each month. However,

the stored milk has the potential of having a much higher iodine-131 dose than the fresh milk from regimes 3 or 4 because the stored milk comes from the grocery, which uses milk primarily from "fresh pasture" regimes 1 and 2. Additionally, the stored milk has been stored on average only 1 month, while the hay used in regimes 3 and 4 has been stored for *several* months.

4.0 Conclusions and Recommendations

The loss of the correlation structure in the Phase I dose code causes dose estimates that are unrealistically large for a number of different exposure pathways.

The loss of the correlation structure in the Phase I dose code was caused by the use of intermediate histograms to store the output from each module of the code. Subsequent modules independently sampled these intermediate histograms and at that point the correlation structure was lost.

It is recommended that the air pathway dose model be restructured and the intermediate histograms eliminated. While the restructured model will still contain distinct modules, all input parameters to each module and all output from each module will be retained in a data base such that subsequent modules can access all the information necessary to retain the correlation structure.

There are currently five distinct modules that the restructured model should contain. The first module, SOURCE, simulates the time and amounts of each release of iodine-131. The data base produced by SOURCE is then used in the second module, DISPERSION. DISPERSION is the climatological dispersion model that computes the air concentration and deposition of iodine-131 for each simulation, time period, and location. The data base produced by DISPERSION is then used by the third module, CONCENTRATIONS. This module calculates the concentrations in soil, fruit, vegetables and milk for each simulation, time period, and location. The fourth module, MILK-TRANSPORT, uses the data base produced by CONCENTRATIONS to calculate the concentrations of "grocery" milk, which are a mixture of milk concentrations from different locations and time periods. MILK-TRANSPORT creates a data base of milk and other dairy product (e.g., cheese) concentrations for each simulation, time period, creamery and grocery store. The final module, DOSE, uses the individual or population life-style profiles to gather information from the DISPERSION, CONCENTRATION and MILK-TRANSPORT data bases and then calculate the appropriate dose. The profiles used in DOSE allow the subject to move to different locations within the HEDR Project study domain and to change diets and age.

As the time period, locations, and radionuclides considered by the HEDR Project are expanded, the data bases are also expanded. As new pathways are developed, such as meat ingestion, new modules are added to the model that use the existing data bases. The output from the new modules *is* added to the appropriate data bases used by DOSE.

As seen above, this restructuring of the model will produce a number of large data bases that will require fast and efficient data management tools and large data storage devices. Before this approach to the restructuring of the model is undertaken, a feasibility study must be performed to determine *whether* the necessary data management tools exist and *to verify* that the costs of the large data storage devices are within the budgetary constraints of the HEDR Project.

If this approach is not feasible, other approaches to the restructuring of the model will need to be considered. One alternative is to reduce the number of modules in the restructured model. For example, the CONCENTRATION module *could* be added to the MILK-TRANSPORT and DOSE modules. This *would* eliminate the need to store the CONCENTRATION data base, which would be the largest data base. However, the CONCENTRATION module would have to be run more than once. Also, algorithms would need to be developed to synchronize the runs so that all individuals who are at the same location during the same time period ingest food products with the same concentrations. Additionally, as new radionuclides are considered by the HEDR Project, either the CONCENTRATION-DOSE modules will need to be expanded and rerun or the new radionuclide modules will have to be synchronized with previous modules so that the correlations among radionuclides are not lost.

A second alternative would be to increase the time period for storing the data. For example, although the CONCENTRATION module would calculate the concentration in the food products on a daily basis, only the average weekly concentrations would be retained. This approach would reduce the size of the CONCENTRATION data base by a factor of seven.

5.0 References

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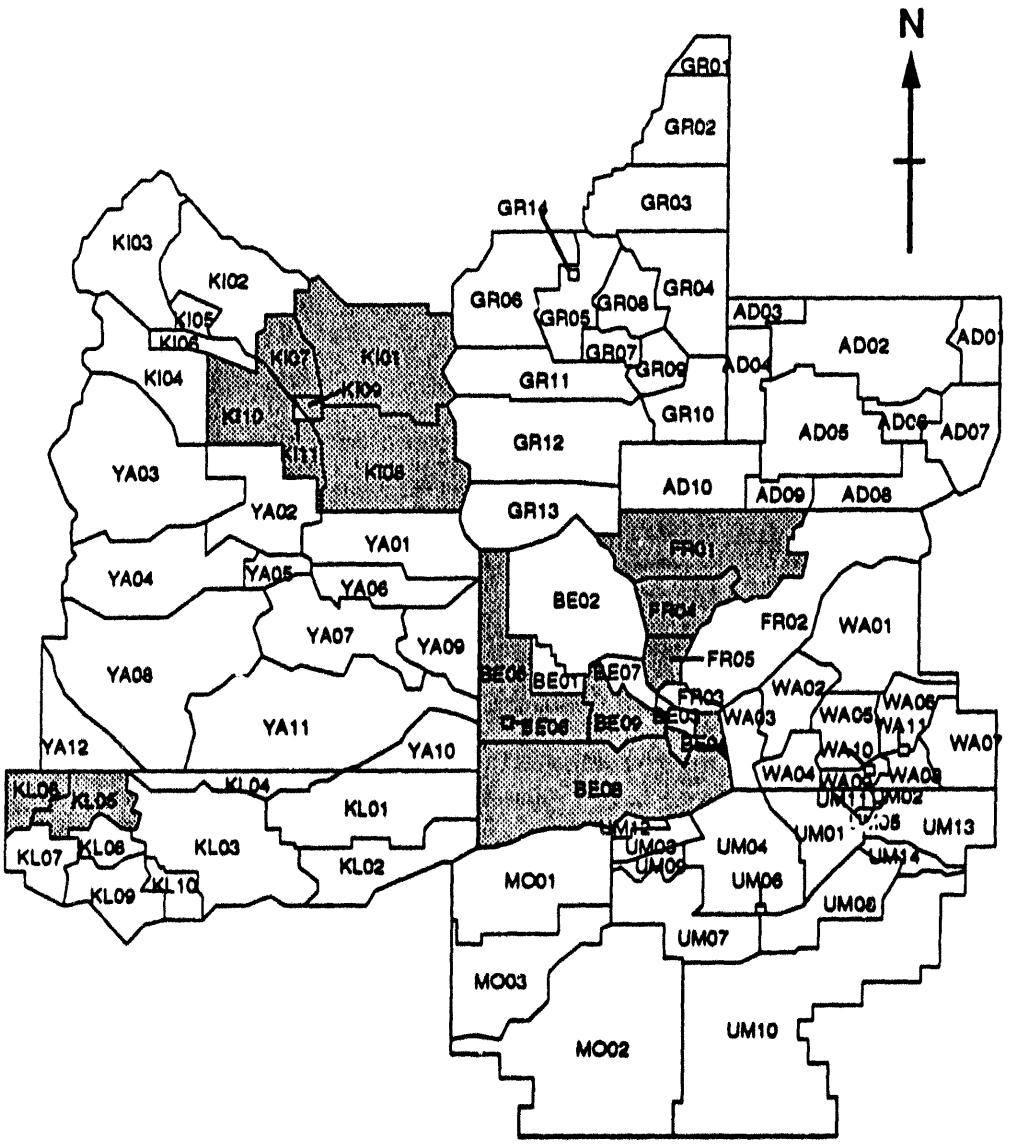
Appendix A

Figures and Tables



UPWIND CENSUS TRACTS	DOWNWIND CENSUS TRACTS
KI01 = Kittitas 1	BE04 = Benton 4
KI07 = Kittitas 7	BE05 = Benton 5
KI08 = Kittitas 8	BE08 = Benton 8
KI09 = Kittitas 9	BE09 = Benton 9
KI10 = Kittitas 10	FR01 = Franklin 1
KL05 = Klickitat 5	FR04 = Franklin 4
KL06 = Klickitat 6	FR05 = Franklin 5

Figure A.1. Location of HEDR Phase I Census *Divisions*

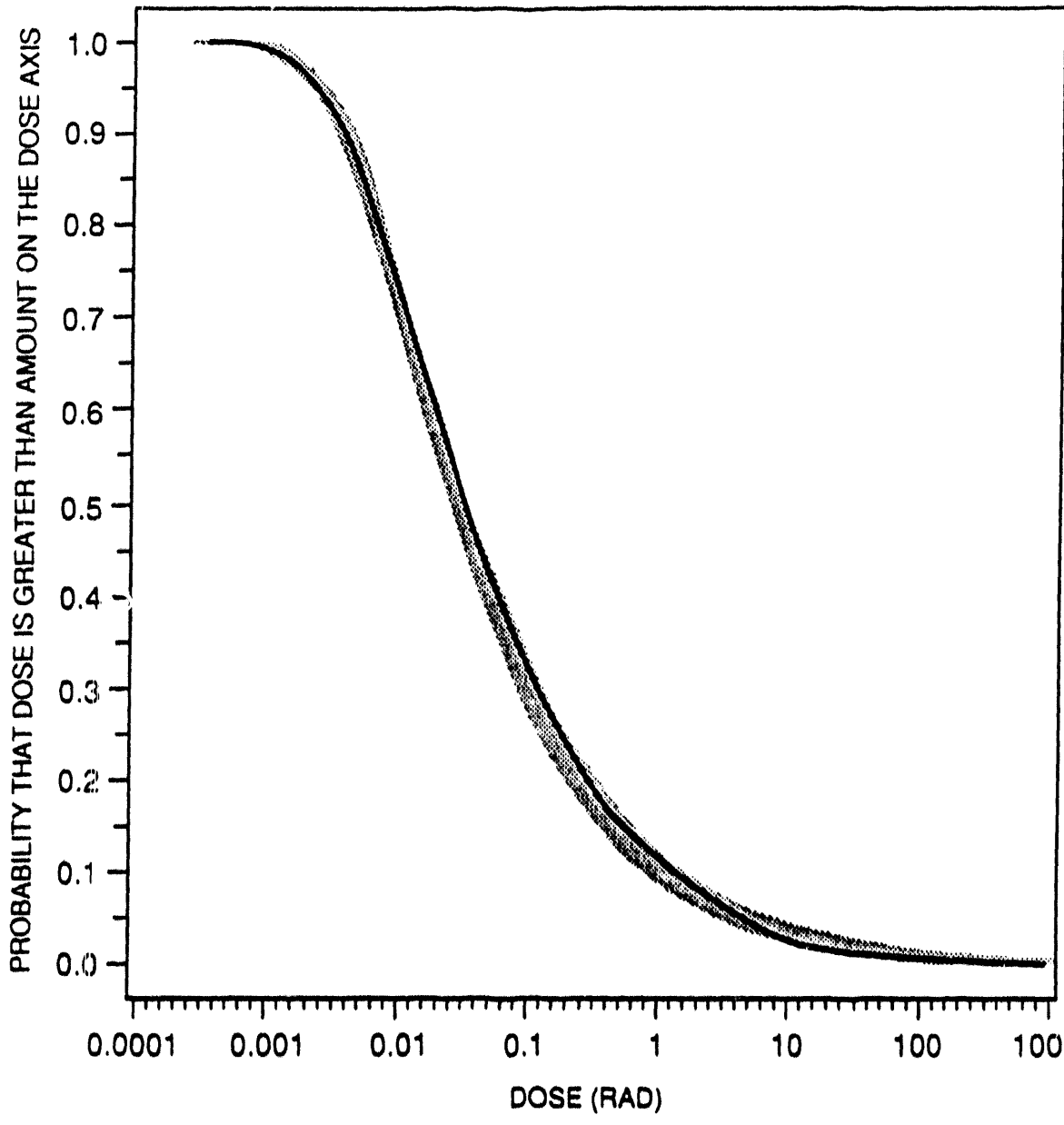


Figure A.2. HEDR Phase I Iodine-131 Inhalation Dose Estimate CCDF with Band from Non-Modular Code for Infants in *Kittitas 7*

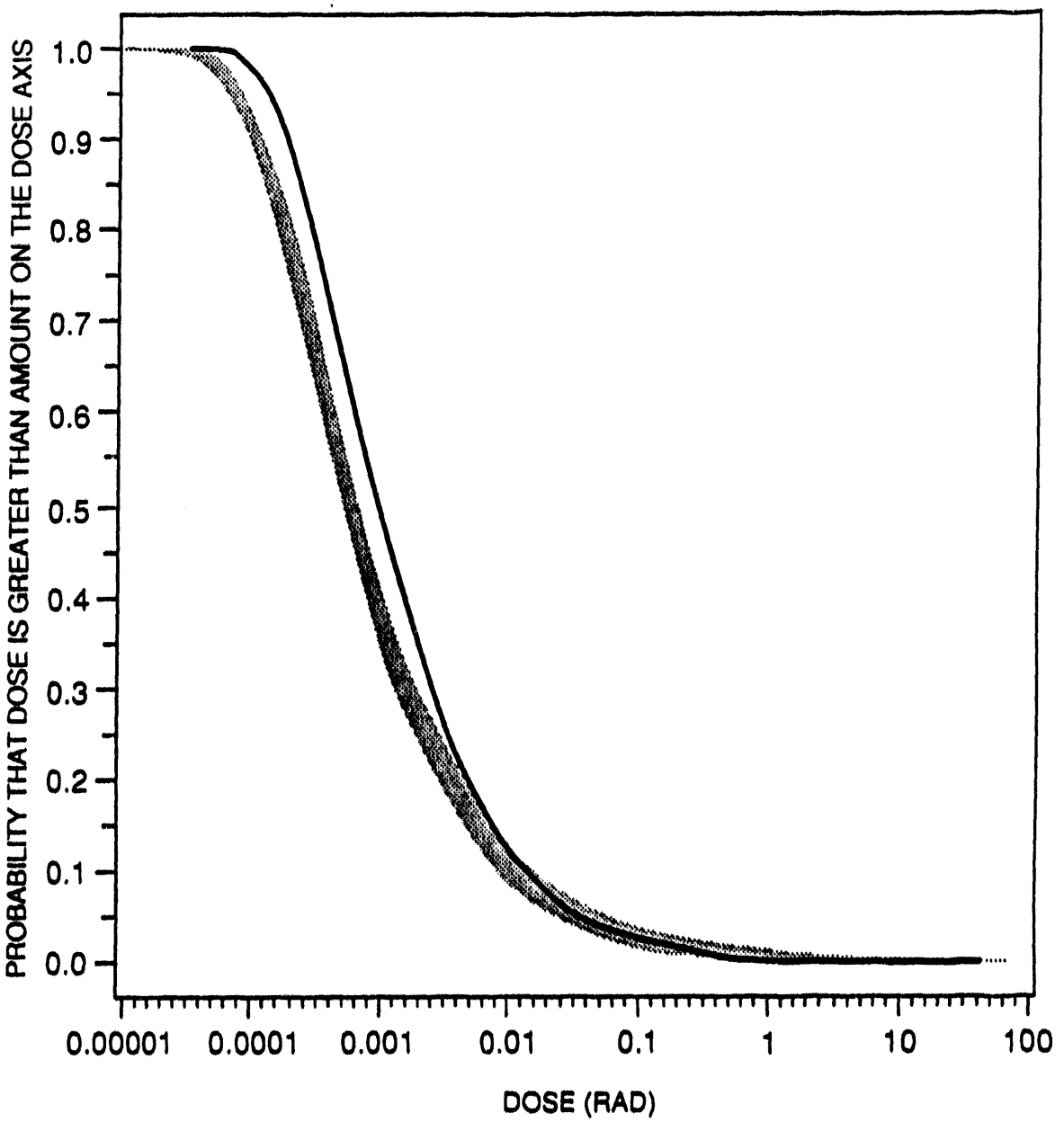


Figure A.3. HEDR Phase I Iodine-131 Groundshine Dose Estimate CCDF with Band from Non-Modular Code for Infants in *Kittitas 7*

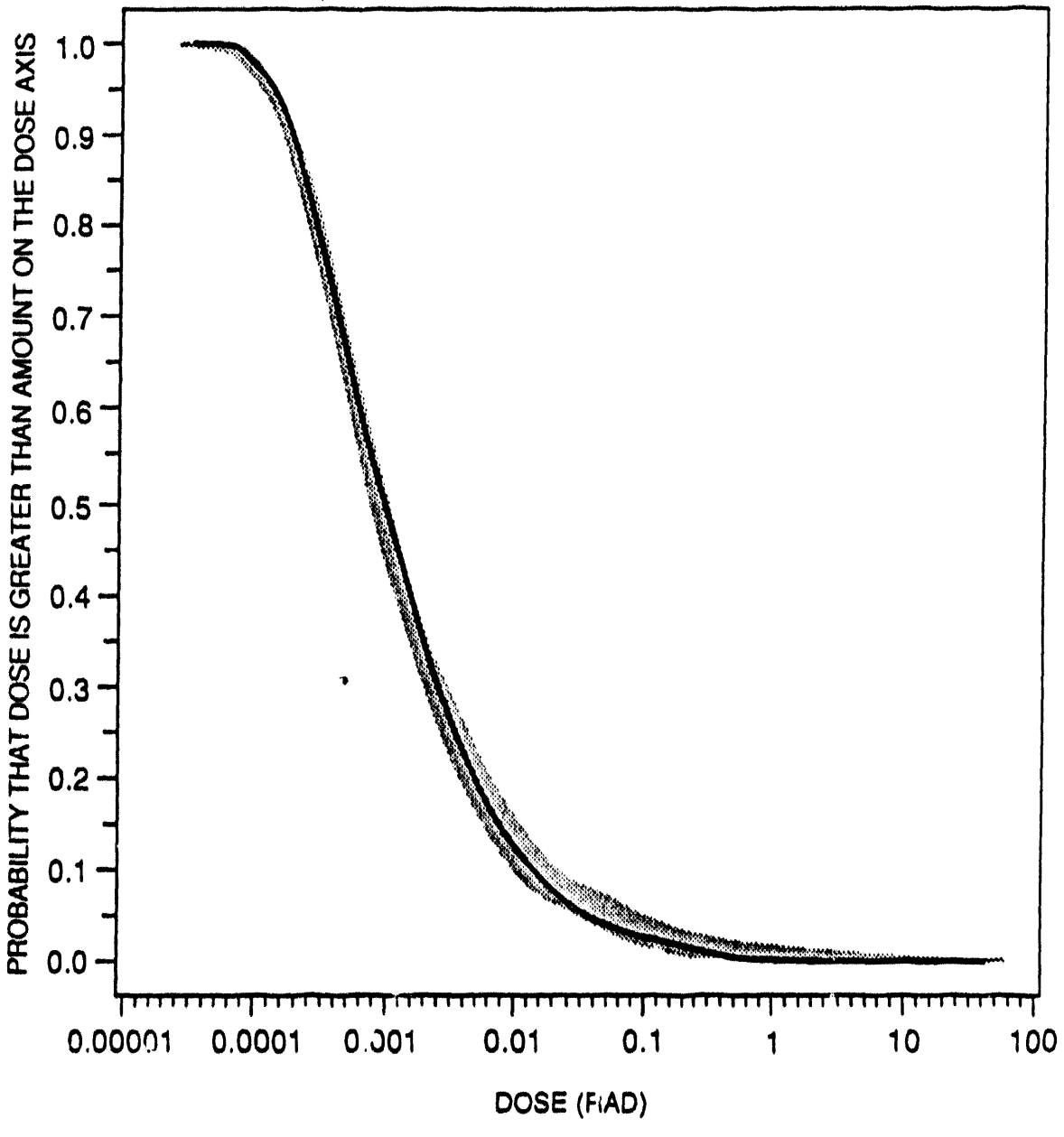


Figure A.4. HEDR Phase I Iodine-131 Groundshine Dose Estimate CCDF with Band from Non-Modular Code Using "Uncorrelated" Months for Infants in *Kittitas 7*

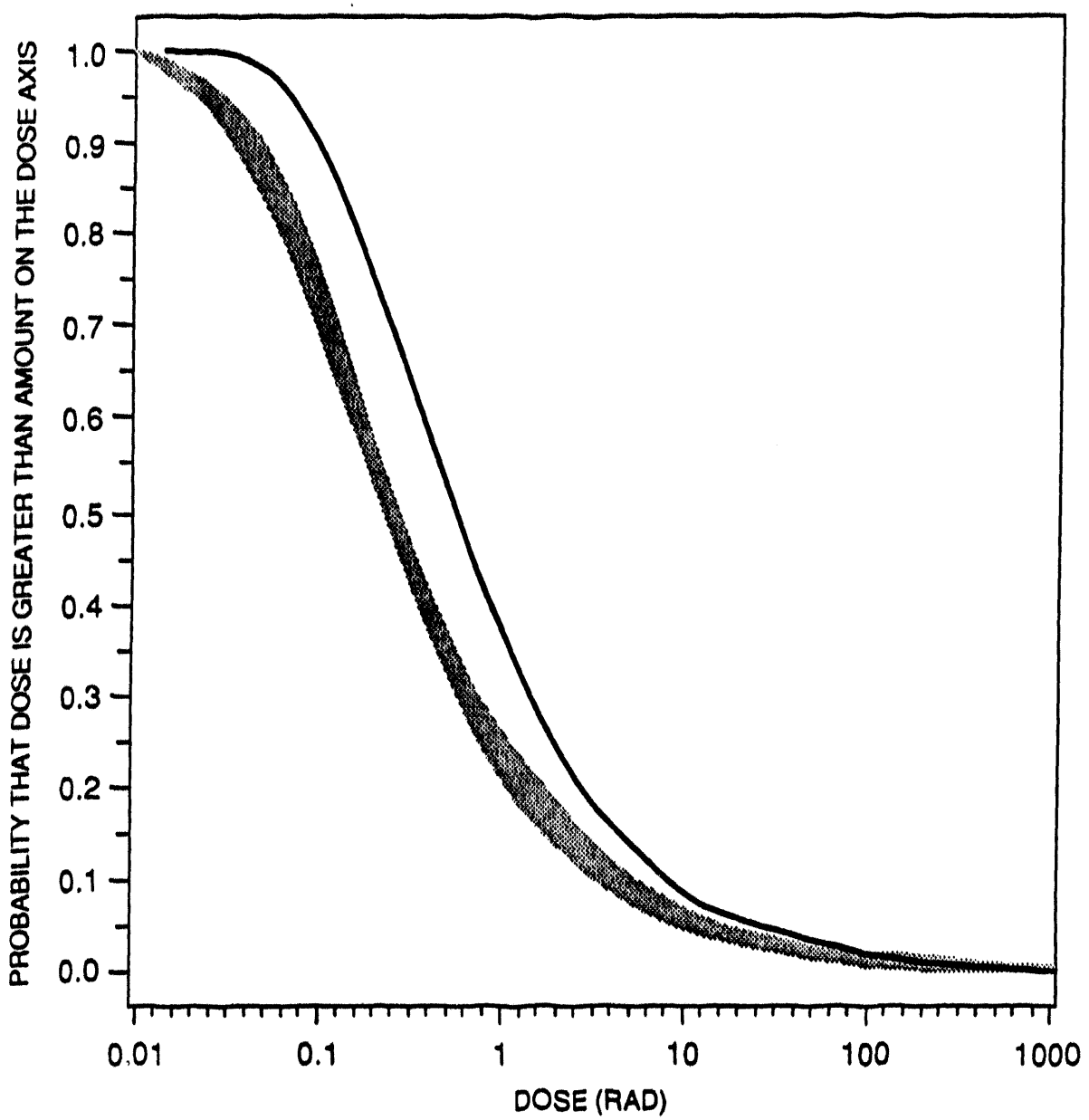


Figure A.5. HEDR Phase I Iodine-131 Vegetable Dose Estimate CCDF with Band from Non-Modular Code for Infants in *Kittitas 7*

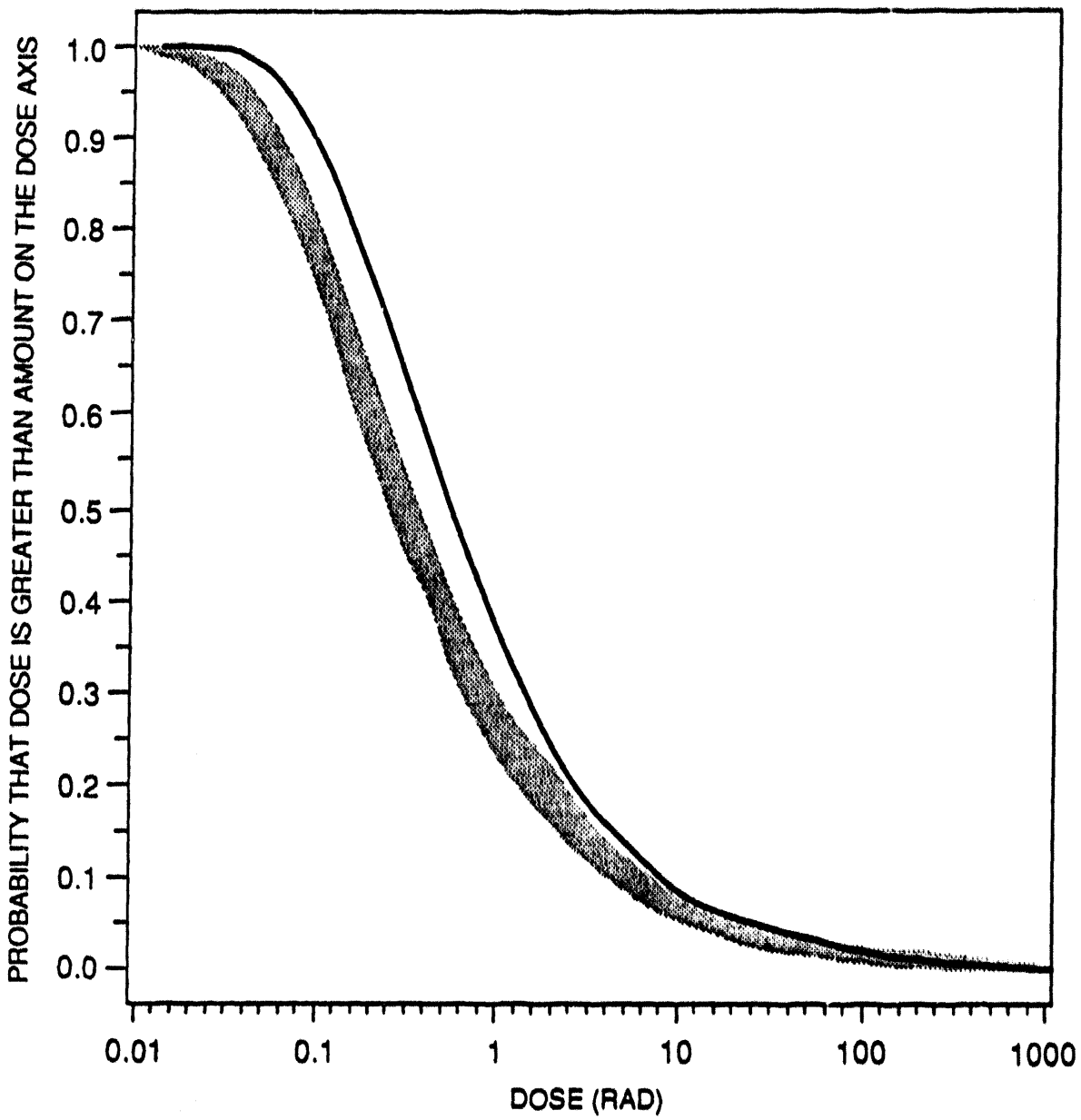


Figure A.6. HEDR Phase I Iodine-131 Vegetable Dose Estimate CCDF with Band from Non-Modular Code with "Uncorrelated" Months for Infants in *Kittitas 7*

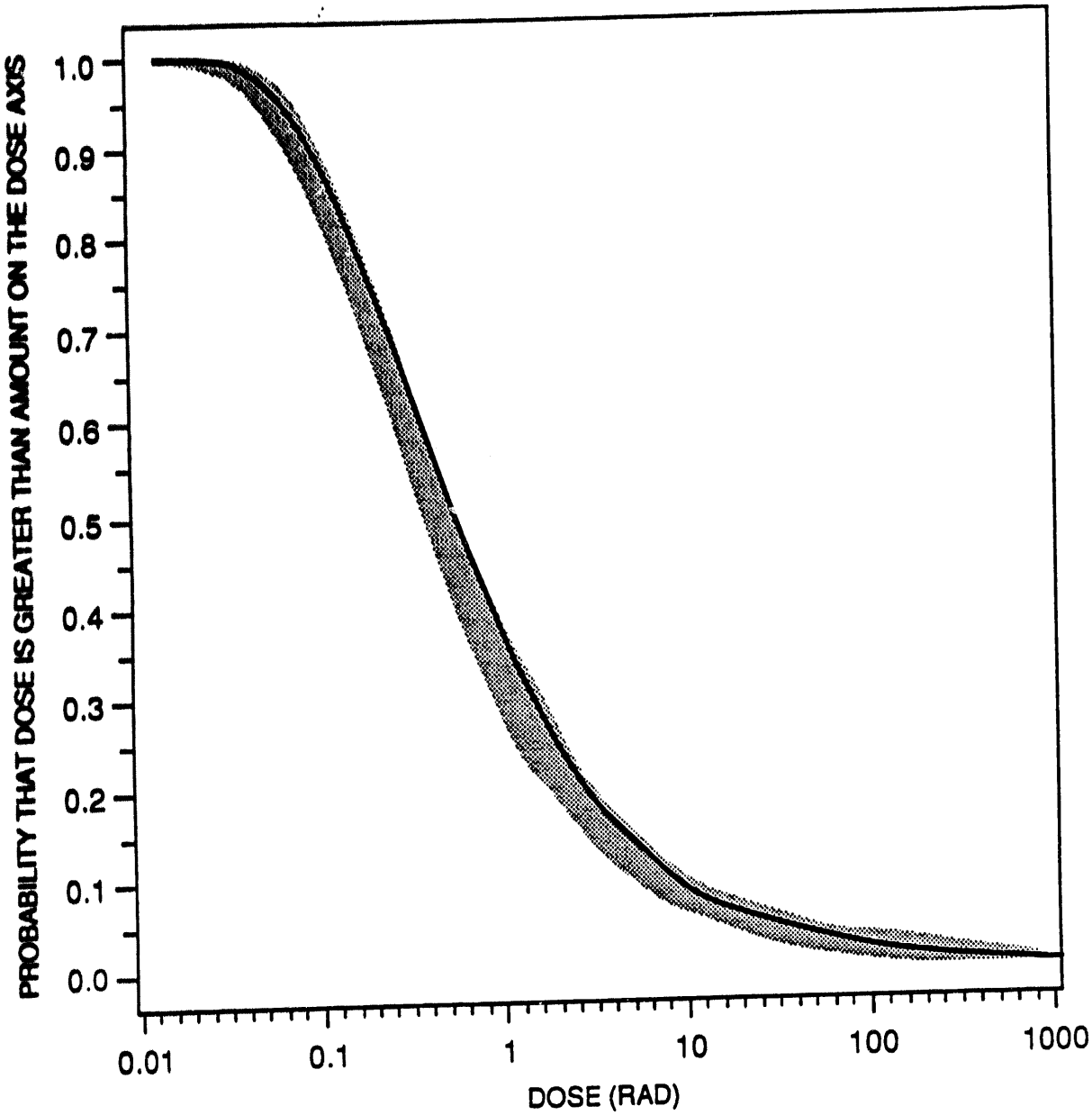


Figure A.7. HEDR Phase I Iodine-131 Vegetable Dose Estimate CCDF with Band from Non-Modular Code with "Uncorrelated" Months and Vegetation Types for Infants in *Kittitas 7*

Table A.1. Percent of the Phase I CDF for the Iodine-131 Dose from the Submersion Pathway that is Above or Below the CDF Band from the Non-Modular Code. Also shown are the percent deviations of the Phase I CDF from the non-modular band at selected percentiles.

				% Deviations at Percentiles						
	Census Tract	% Below	% Above	P5	P10	P25	P50	P75	P90	P95
Infants										
Downwind	BE4	30.7	0.0					-1.6		
	BE5	0.0	10.0							
	BE8	0.0	0.0							
	BE9	51.7	0.0				-0.8	-1.0		
	FR1	28.8	0.0					-0.2	-0.4	
	FR4	0.0	3.4							
	FR5	0.1	0.0							
Upwind	KI1	8.6	0.0							
	KI7	4.2	0.0							-10.4
	KI8	0.1	0.0							
	KI9	2.4	0.0							
	KI10	0.0	23.9			1.0	0.2			
	KL5	0.0	0.2							
	KL6	0.3	0.5							
Adults										
Downwind	BE4	0.0	0.0							
	BE5	0.0	4.9							1.5
	BE8	0.0	1.4							
	BE9	35.7	0.0					-2.1	-1.7	-2.0
	FR1	0.0	0.1							
	FR4	29.1	0.1					-1.3		
	FR5	0.0	0.2							
Upwind	KI1	0.0	0.0							
	KI7	0.1	57.2				7.5	17.2	9.6	
	KI8	1.9	0.0							-3.6
	KI9	27.2	3.8					-1.6	-6.9	-12.8
	KI10	9.0	0.0						4.1	
	KL5	1.2	2.4							
	KL6	0.0	1.6							

Table A.2. Percent of the Phase I CDF for the Iodine-131 Dose from the Inhalation Pathway that is Above or Below the CDF Band from the Non-Modular Code. Also shown are the percent deviations of the Phase I CDF from the non-modular band at selected percentiles.

				% Deviations at Percentiles						
	Census Tract	% Below	% Above	P5	P10	P25	P50	P75	P90	P95
Infants										
Downwind	BE4	3.0	0.0							
	BE5	0.0	10.9							
	BE8	0.0	0.0							
	BE9	7.4	0.0							
	FR1	5.1	0.0							0.9
	FR4	0.0	0.3							
	FR5	0.0	0.0							
Upwind	KI1	21.6	0.0					-0.2	-7.5	-6.1
	KI7	1.8	4.9				0.8			
	KI8	3.8	0.0							-3.3
	KI9	29.2	0.0						-11.6	-15.1
	KI10	0.0	0.1							
	KL5	0.0	2.4							
	KL6	0.6	7.8							
Adults										
Downwind	BE4	3.8	0.0							
	BE5	0.0	5.6							31.7
	BE8	0.0	1.2							
	BE9	23.1	0.0						-2.2	-1.2
	FR1	0.0	0.0							
	FR4	15.0	0.0			-0.2				
	FR5	0.0	0.0							
Upwind	KI1	0.0	0.0							
	KI7	0.1	74.8			5.2	8.0	19.4	31.6	11.1
	KI8	0.0	0.2							
	KI9	11.6	0.0						-0.4	
	KI10	0.0	0.1							
	KL5	3.2	0.0							-3.3
	KL6	6.2	0.1							

Table A.3. Percent of the Phase I CDF for the Iodine-131 Dose from the Groundshine Pathway that is Above or Below the CDF Band from the Non-Modular Code. Also shown are percent deviations of the Phase I CDF from the non-modular band at selected percentiles.

				% Deviations at Percentiles						
	Census Tract	% Below	% Above	P5	P10	P25	P50	P75	P90	P95
Infants										
Downwind	BE4	0.0	90.2	7.2	5.3	2.6	1.3	0.3	1.5	
	BE4	0.0	61.1	5.2	7.0	3.6				
(unc_m)	BE4	0.0	15.2						3.1	1.0
	BE5	1.4	59.5	6.8	8.8	7.3	2.8			
	BE5	0.6	62.0	10.7	8.3	7.7	3.1			
(unc_m)	BE5	0.5	0.0							
	BE8	0.0	77.3	23.1	21.7	14.2	8.8	3.3		
	BE9	0.0	38.1	5.7	4.9	1.6				
	FR1	4.6	46.6	5.4	3.6	1.9				
	FR4	7.8	24.6	5.7	3.4	0.0				
	FR5	17.6	32.6	4.2	1.9	1.2			-2.9	-3.8
Upwind	KI1	0.0	69.1	28.0	36.1	25.9	14.4			
	KI1	0.7	56.9	43.0	40.1	27.4				
(unc_m)	KI1	7.3	0.0							
	KI7	0.5	88.6	55.7	59.0	51.9	42.2	19.2		
	KI7	0.1	85.9	63.5	60.5	38.0	48.5	10.2		
(unc_m)	KI7	0.4	0.0							
	KI8	0.0	90.4	37.2	33.7	27.7	17.6	5.3	3.3	
	KI9	0.0	92.2	48.1	36.9	28.4	13.4	4.7		21.8
	KI10	7.0	80.9	33.7	36.0	36.4	18.1	8.3		-9.2
	KL5	0.0	94.7	42.4	36.0	36.3	25.3	12.9	32.9	
	KL6	0.0	95.4	43.7	37.2	30.6	21.9	17.2	4.2	3.8
Adults										
Downwind	BE4	0.0	23.6	5.0	2.6					
	BE5	0.8	89.6	13.8	12.6	12.2	6.0		4.8	
	BE8	0.0	76.2	8.8	8.6	6.5	5.4	0.6		
	BE9	2.4	21.6	3.3	3.0					
	FR1	0.0	75.5	6.3	1.0	3.3	3.0			
	FR4	0.2	12.0	2.3	1.0					
	FR5	0.5	36.9	4.0	4.4	1.9				
Upwind	KI1	4.5	62.8	37.8	36.7	27.8	8.8			-9.0
	KI7	0.0	89.2	67.6	66.4	59.1	56.4	66.6		
	KI8	0.0	85.0	32.5	28.9	26.1	22.1	3.5		
	KI9	0.0	99.0	50.8	44.8	40.9	30.0	32.6	22.8	19.0
	KI10	0.0	77.6	49.6	41.3	31.1	11.4	2.4		
	KL5	1.0	90.7	46.7	42.3	28.0	27.4	10.9	2.9	
	KL6	0.0	66.4	40.2	39.3	23.0	14.7			

Table A.4. Percent of the Phase I CDF for the Iodine-131 Dose from the Fruit and Vegetable Pathway that is Above or Below the CDF Band from the Non-Modular Code. Also shown are percent deviations of the Phase I CDF from the non-modular band at selected percentiles.

	Census Tract	% Below	% Above	% Deviations at Percentiles						
				P5	P10	P25	P50	P75	P90	P95
Infants										
Downwind	BE4	0.1	97.0	28.7	28.3	25.6	22.4	20.4	16.3	10.2
	BE4	0.4	97.3	20.9	24.6	28.5	21.8	19.7	21.2	20.0
(unc_m)	BE4	0.4	96.7	19.1	19.1	23.2	22.2	20.7	21.9	21.6
(unc)	BE4	0.3	81.5			6.1	10.1	18.8	32.8	17.3
	BE5	0.0	95.7	36.4	35.2	28.5	23.4	12.3	7.9	3.6
	BE5	0.0	96.4	38.6	33.9	29.3	21.2	9.3	8.8	6.4
(unc_m)	BE5	0.0	97.1	28.2	25.1	22.5	17.3	12.5	10.8	9.5
(unc)	BE5	0.3	69.6				5.5	6.4	12.5	17.8
	BE8	0.0	91.8	45.6	43.9	38.7	29.8	20.9	4.3	
	BE9	0.0	92.4	26.0	25.5	25.7	24.2	11.3	2.5	
	FR1	0.9	97.1	37.0	38.2	34.7	29.1	18.1	17.3	11.1
	FR4	0.0	97.8	32.0	29.5	31.9	24.8	21.8	17.4	17.1
	FR5	0.0	98.1	34.6	29.1	23.5	26.9	29.9	29.7	18.5
Upwind	KJ1	0.0	92.1	147.3	139.2	99.9	81.7	45.2	12.9	
	KJ1	0.0	90.1	155.1	140.2	108.5	80.1	46.6		
(unc_m)	KJ1	0.0	91.4	91.3	89.7	63.1	63.9	40.6	7.2	
(unc)	KJ1	0.0	63.8			2.5	10.9	0.3		
	KJ7	0.0	98.1	121.2	125.3	107.3	90.7	71.0	30.1	19.9
	KJ7	0.0	98.1	128.4	113.4	90.9	98.2	71.9	52.1	38.2
(unc_m)	KJ7	0.0	95.3	54.8	57.3	55.1	49.6	30.5	12.0	
(unc)	KJ7	0.0	10.8				1.0			
	KJ8	0.2	95.4	125.5	114.1	91.1	60.3	36.5	10.5	9.5
	KJ9	0	88.5	119.5	96.6	78.7	71.3	33.5		
	KJ10	0.0	98.8	139.4	126.6	112.2	81.6	51.4	25.6	7.5
	KL5	0.1	96.9	154.0	140.3	100.0	66.8	34.5	23.3	9.9
	KL6	0.0	86.2	120.2	114.8	93.9	58.5	24.7		
Adults										
Downwind	BE4	0.0	58.1	14.7	14.6	13.1	6.2			
	BE5	0.5	76.0	30.4	23.6	18.9	8.3	0.4		
	BE8	1.4	75.9	27.0	18.7	18.1	15.3	1.7		
	BE9	0.1	67.4	18.1	19.3	16.2	7.1			
	FR1	0.2	63.8	29.0	23.9	19.7	7.8			
	FR4	0.9	88.1	22.9	20.6	13.6	8.4	5.2		
	FR4	6.4	66.9	19.1	17.9	12.2	1.2			-5.3
Upwind	KJ1	0.0	98.1	155.2	129.0	97.4	53.3	25.4	14.1	
	KJ7	0.0	95.7	158.9	124.4	109.5	90.7	49.3	29.9	10.9
	KJ8	3.7	91.1	103.3	93.3	54.7	42.5	16.6	6.4	
	KJ9	0.0	94.5	116.9	100.2	76.9	38.2	26.1	13.6	
	KJ10	0.0	87.5	130.4	108.7	74.0	50.5	23.0		
	KL5	0.1	87.7	136.9	100.3	67.7	42.7	13.6		
	KL6	1.2	85.0	110.9	93.5	78.3	58.0	26.6		

Table A.5. Percent of the Phase I CDF for the Iodine-131 Dose from the Milk (Cow Feeding Regime 1) Pathway that is Above or Below the CDF Band from the Non-Modular Code. Also shown are percent deviations of the Phase I CDF from the non-modular band at selected percentiles.

				% Deviations at Percentiles						
	Census Tract	% Below	% Above	P5	P10	P25	P50	P75	P90	P95
Infants										
Downwind	BE4	5.0	0.0							
	BE5	2.5	0.0							-1.3
	BE8	27.5	0.0		-1.0					
	BE9	0.0	0.0							
	FR1	23.0	0.0					-3.7		
	FR4	0.0	33.0					10.6	2.3	
	FR5	53.5	0.0		-7.8	-9.8	-6.1			
Upwind	KI1	1.0	0.5					-0.2		
	KI7	0.0	22.5	17.3	19.5					
	KI8	0.0	2.0							
	KI9	2.5	0.0							
	KI10	8.5	10.0	0.9	9.8				-13.2	-0.1
	KL5	1.0	32.5			3.0				
	KL6	23.5	0.0						-32.1	-26.0
Adults										
Downwind	BE4	9.0	2.0	-4.6	-0.3					
	BE5	22.5	0.0					-1.0		
	BE8	0.0	0.0							
	BE9	0.0	0.0							
	FR1	35.5	0.0	-11.2	-6.4	-1.4	-0.7			
	FR4	2.5	0.0							
	FR5	3.5	0.0	-3.2						
Upwind	KI1	0.0	10.5	3.4	6.9					
	KI7	4.0	18.5	33.9	36.0					-1.6
	KI8	0.0	5.5							
	KI9	8.5	5.0	0.4					-5.7	-4.3
	KI10	1.5	0.5							
	KL5	0.0	0.0							
	KL6	13.0	0.0							

Table A.6. Percent of the Phase I CDF for the Iodine-131 Dose from the Milk (Cow Feeding Regime 2) Pathway that is Above or Below the CDF Band from the Non-Modular Code. Also shown are the percent deviations of the Phase I CDF from the non-modular band at selected percentiles.

				% Deviations at Percentiles						
	Census Tract	% Below	% Above	P5	P10	P25	P50	P75	P90	P95
Infants										
Downwind	BE4	38.5	0.0	-3.2	-3.1	-1.7				
	BE5	10.5	0.0	-6.0						
	BE8	1.5	0.0							
	BE9	66.5	0.0	-11.8	-3.9	-7.0				
	FR1	0.5	18.5					4.1		
	FR4	0.0	21.0					5.2	11.7	
	FR5	28.5	0.0			-1.4				
Upwind	KI1	9.5	2.0							-8.5
	KI7	2.5	8.0		7.6					
	KI8	3.5	0.0							
	KI9	4.5	0.0							
	KI10	0.0	0.0							
	KL5	13.5	0.0						-15.1	-4.9
	KL6	0.0	0.0							
Adults										
Downwind	BE4	30.5	0.0			-2.7				
	BE5	42.0	0.0			-4.7			-3.5	-23.5
	BE8	7.5	0.0			-1.4				
	BE9	1.0	0.0							
	FR1	0.5	0.0							
	FR4	0.5	0.0							
	FR5	4.5	1.0	-2.0						
Upwind	KI1	7.5	0.0							
	KI7	5.0	27.0	10.2	16.1	7.9			-1.8	-1.9
	KI8	2.5	0.0							
	KI9	0.0	9.0	18.9	2.5					
	KI10	16.0	6.5	8.7					-3.6	-13.7
	KL5	11.0	0.0						-4.4	-9.5
	KL6	5.5	0.0							-8.1

Table A.7. Percent of the Phase I CDF for the Iodine-131 Dose from the Milk (Cow Feeding Regime 3) Pathway that is Above or Below the CDF Band from the Non-Modular Code. Also shown are the percent deviations of the Phase I CDF from the non-modular band at selected percentiles.

	Census Tract	% Below	% Above	% Deviations at Percentiles						
				P5	P10	P25	P50	P75	P90	P95
Infants										
Downwind	BE4	0.0	62.5				2.7		1.2	
	BE4	0.0	91.5	0.9	7.9	17.1	13.6	8.6	15.8	14.8
(unc_m)	BE4	0.0	84.5		7.3	3.5	10.6	3.3	20.5	22.0
	BE5	0.0	10.5							
	BE5	0.0	18.0						21.4	
(unc_m)	BE5	0.0	27.0						18.7	
	BE8	3.5	0.0							
	BE9	0.0	60.0			1.3	3.0		11.5	12.0
	FR1	1.5	35.5				3.3			
	FR4	0.0	28.0					1.6		
	FR5	0.0	28.5	4.8				6.5		
Upwind	KI1	0.0	85.0	19.5	34.4	21.9	25.4		15.7	
	KI1	0.0	92.5	38.0	34.4	20.1	2.9	14.7	28.1	
(unc_m)	KI1	0.0	19.5						20.3	
	KI7	0.0	71.0	153.9	152.3	95.8	48.1			
	KI7	0.0	66.5	117.5	145.1	97.8	34.2			
(unc_m)	KI7	0.0	21.5	7.5	6.1	1.9				
	KI8	0.0	84.0	66.5	50.5	36.9	50.1	28.5		
	KI9	0.5	59.5	69.8	40.8	30.1	13.2			
	KI10	0.0	36.5	58.9	30.0	24.9				
	KL5	0.0	67.5	9.6	23.4	41.0	24.4			
	KL6	0.0	38.5	38.3	30.5	32.5				
Adults										
Downwind	BE4	0.0	88.5	9.1	19.3	24.1	21.5	14.8	1.2	
	BE5	0.0	72.0	0.9	13.5	9.7	13.0		1.3	
	BE8	0.0	91.5	52.8	42.0	38.3	29.2	10.5	4.7	
	BE8	0.0	88.5	92.0	65.7	47.2	25.6	7.4		
(unc_m)	BE8	0.0	87.5	64.9	46.8	31.9	20.8	4.8	5.7	
	BE9	0.0	98.0	9.5	9.4	7.3	15.3	21.8	8.5	32.5
	BE9	0.0	90.5	14.5	11.6	4.8	23.8	22.4		42.8
(unc_m)	BE9	0.0	92.5	0.6	10.0	12.2	19.6	23.1	13.7	57.2
	FR1	0.0	94.0	16.7	9.8	17.4	20.0	23.7	25.1	
	FR4	0.0	35.0				0.0			
	FR5	0.0	24.0				4.5			
Upwind	KI1	0.0	68.0	109.6	90.2	36.3	31.1	25.4		
	KI7	0.0	86.5	393.7	248.7	242.9	124.1	32.8		10.9
	KI9	0.0	48.0	25.0	14.3	16.2				
	KI9	0.0	80.5	175.4	114.0	62.1	77.5	27.4		
	KI10	0.0	63.0	126.3	124.3	62.5	21.1			
	KL5	0.0	83.0	49.0	41.8	28.1	21.1	49.6		
	KL6	0.0	93.0	79.2	78.8	52.7	54.3	22.8	35.4	

Table A.8. Percent of the Phase I CDF for the Iodine-131 Dose from the Milk (Cow Feeding Regime 4) Pathway that is Above or Below the CDF Band from the Non-Modular Code. Also shown are the percent deviations of the Phase I CDF from the non-modular band at selected percentiles.

	Census Tract	% Below	% Above	% Deviations at Percentiles						
				P5	P10	P25	P50	P75	P90	P95
Infants										
Downwind	BE4	0.5	67.5	17.7	9.8	4.2	4.2	1.6		
	BE4	0.5	70.0	30.0	15.1	8.5	22.0			
(unc_m)	BE4	0.0	55.5	11.6	12.6	17.2	12.4			
	BE5	0.0	75.0	3.4	17.4	14.2	15.2	5.3		
	BE5	0.0	68.0	1.6	3.5	12.5	7.2			
(unc_m)	BE5	0.0	40.5				10.5			
	BE8	0.0	61.5	46.1	49.0	17.1	5.5			
	BE9	0.5	0.5							
	FR1	0.0	89.5		9.7	12.4	24.8	22.6	19.7	26.6
	FR4	0.0	38.5				8.1	13.9		
	FR5	0.0	51.0			2.7	17.1			
Upwind	KJ1	0.0	86.5	123.9	99.3	61.4	46.5	36.3		
	KJ1	0.0	61.0	77.6	88.8	66.3	16.3			
(unc_m)	KJ9	0.0	21.0	18.7		9.8				
	KJ7	0.0	71.5	65.4	91.2	69.2	43.1			
	KJ7	0.0	76.5	120.6	104.1	81.8	33.2	5.1		
(unc_m)	KJ7	0.0	56.0	37.5	39.2	36.3	11.6			
	KJ8	0.0	82.5	22.4	28.1	51.2	17.2	17.7		
	KJ9	0.0	84.0	82.9	93.1	73.3	74.1	26.8		
	KJ10	0.5	66.5	188.0	161.4	93.3	16.2			
	KL5	0.0	61.5		8.4	25.2	15.9	10.2		
	KL6	0.0	78.0	41.2	41.0	35.6	30.7	14.0		
Adults										
Downwind	BE4	0.0	77.5	139.0	130.9	79.7	52.2	9.1		
	BE5	0.0	74.0	111.7	91.2	63.5	17.0			
	BE8	0.0	97.5	430.5	393.0	280.9	156.5	83.7	39.7	7.8
	BE8	0.0	97.0	475.5	410.9	280.5	149.4	80.5	22.4	5.2
(unc_m)	BE8	0.0	98.0	413.2	339.2	187.6	138.9	74.6	26.6	22.7
	BE9	0.0	96.5	169.9	141.6	84.4	40.2	23.4	59.0	25.2
	BE9	0.0	96.5	167.4	119.2	74.3	52.1	24.1	44.7	28.9
(unc_m)	BE9	0.0	96.0	166.1	111.8	77.3	64.7	15.9	47.6	50.5
	FR1	0.0	95.0	205.6	156.2	65.6	55.2	29.1	3.7	12.1
	FR4	1.0	57.0	41.9	45.4	27.1	11.0			
	FR5	0.0	12.0		3.0	1.1				
Upwind	KJ1	0.0	86.0	130.0	143.6	109.8	35.9	5.4		
	KJ7	0.0	96.0	773.4	736.1	389.9	257.4	106.0	73.8	
	KJ8	0.0	84.5	183.6	153.3	86.3	85.0	28.6		
	KJ9	0.0	93.0	433.3	348.9	328.3	227.2	109.7	40.4	
	KJ10	0.0	92.0	370.8	371.3	308.8	183.9	125.6	15.4	
	KL5	0.0	96.0	154.4	129.1	55.1	42.0	17.0	57.3	13.6
	KL6	0.0	87.0	73.1	118.3	66.3	26.2	23.5	9.0	

Appendix B

Summary of TSP Comments and Battelle Responses

SUMMARY OF TSP COMMENTS AND BATTELLE RESPONSES

Document Number PNL-7638 HEDR Document Title Effects of the Loss of Correlation Structure on Phase I Dose Estimates

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
1	D.S. Barth (DSB)	Full report	Is it possible to estimate the uncertainties in total Phase I dose estimates for selected census tracts which may have resulted from the loss of correlation structure?	Yes. However, total Phase I dose estimates were never calculated because of the correlation problems. Because the Phase I dose estimates are also impacted by other problems (see, "Dose Estimate Variability Caused by Air Model Uncertainties," PNL-7737 HEDR), further comparisons of Phase I dose estimates with "new" dose estimates should occur after the dose models are restructured.
2	G.S. Roessler (GSR)	Full report	It seems like the effect of loss of correlation structure would be an underestimation. Need a methods section with some mathematical explanation.	See paragraph three of the summary.
3	J.E. Till (JET)	Page iii	1) Rewrite Summary in more basic language. 2) Be more specific about the effect on dose; give limits of the effect for high/low dose ranges. 3) Add the conclusion of study - Recommendation for model restructure. 4) State how changes could impact other radionuclides.	See Summary.
4	GSR	Page iii	Add line to Summary on how the problem was fixed.	See last paragraph of Summary.

NA = No action.

SUMMARY OF TSP COMMENTS AND BATTELLE RESPONSES

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Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
5	K.J. Kopecky (KJK)	Page iii, para 1, last line	"module to module" rather than "model to model"?	Summary rewritten.
6	M.L. Blazek (MLB)	Page iii, para 2, lines 2-3	Document at least some of the actual differences in this report. In fact a range of new estimates and overestimates in the Summary would be helpful.	Summary rewritten. Also see comment 1 above.
7	KJK	Page 1, para 2	"For the present analysis . . ."	Changed.
8	KJK	Page 1, para 4	Recommend including a census tract map that identifies the 14 tracts.	Figure A.1 added.
9	M.A. Robkin (MAR)	Page 1, para 4	"upwind" and "downwind" reversed (see page 5 and Tables).	Changed.
10	JET	Page 1, para 5, line 4	Insert "the" before "submersion."	Changed.
11	KJK	Page 1, para 5	"1000 simulations each."	Changed.

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12	KJK	Page 2, para 2	1) Are the "Phase I" results in this report the same as those in the Phase I reports, or are new realizations produced with the Phase I code? 2) Line 5: Should "above and below" be "to the left or right of"? "Above and below" suggests a vertical deviation on the Figures.	Text changed to address questions.
13	MAR	Page 5, para 1, line 5	"while" is extraneous.	Deleted "while."
14	KJK	Page 6, para 2	Please provide some additional explanation of "shuffling." Was this done in a systematic manner, or by selecting random permutations?	Explanatory text added.
15	KJK	Page 7, para 4	Is it possible to modify the non-modular code to provide better bin sizes, to see if this eliminates the remaining discrepancy?	The non-modular code does not have bins. The non-modular code dose estimates could have been manipulated to see whether bin size was the cause of this discrepancy. However, in light of all the changes to be made in the restructured code (including the elimination of bins), finding this discrepancy seemed unnecessary.

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16	JET	Page 8, para 1,3	The term "stored milk" should be changed to "milk products" or "stored dairy products."	Changed.
17	KJK	Page 7, para 5	1) Provide a reference for definition of the feeding regimes. 2) Line 5: "fresh pasture for which . . ."	Text revised.
18	JET	Page 9, para 1	Delete second sentence. Any reason for changing model should be to provide state-of-the-art science.	Deleted.
19	JET	Page 9, para 4; page 10, para 3	1) If we are designing a system that will require massive data storage and can be operated only by Battelle, we must stop at once. It must be usable by organizations having modest hardware capabilities. 2) How does the reduction in correlation affect dose estimates from other radionuclides (other than iodine-131)? 3) Are we preparing for the impact on data storage when we are calculating doses for many radionuclides simultaneously?	1) The turnover package will be usable by these types of organizations. 2) Unknown, because the dose estimates for other radionuclides have not been calculated yet. 3) Yes.
20	JET	Page 10, para 3	Where is the feasibility study? Will there be a separate report? We have made the decision to proceed without fully documenting this problem first.	See Foreword.
21	JET	All Figures	Change all notation from "rads" to "rad" (singular).	Changed.

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Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
22	JET	Tables	Difficult to determine the overall effect on dose. Although the percentage of doses changed appears high, the percentage change that occurs is not too great.	NA
23	JET		I believe in making the changes to improve the state of the art, but I am not convinced that in the long term it will greatly improve the result.	NA
24	G.G. Caldwell (GGC)	Page v	1) This Summary probably cannot be understood by the majority of non-statisticians. 2) Shouldn't we include the major recommendation here as well?	Summary rewritten.
25	GGC	Page 3, para 1, lines 1-7	The QA program did not prevent this major error; what did the QA program accomplish other than review the documents?	The technical review of the models did find this problem; the quality assurance process did work.
26	GGC	Page 3, para 2, lines 1-3	Did the internal independent technical review find this problem? Why was it not brought to the attention of the TSP before release of the Phase I results?	The potential problems due to the loss of correlation structure were known before the Phase I results were released. As a consequence, the total dose estimate was not calculated. Dr. Kopecky was informed of these problems before the release of Phase I estimates. With the recent expansion of the TSP Quality

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				Assurance and Technical Integration Subcommittee, communication of problems such as this, to the entire TSP, will be more effective.
27	GGC	Page 9, para 1, lines 3-5	Correct this sentence to indicate the change is a mid-course correction required by good science now that the problem has been discovered, not because the doses are "unrealistically large."	Sentence deleted.

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