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Analysis of the Dose Commitments Resulting from Atmospheric Transport and Deposition from Nuclear Risk Sites in the Russian Far East

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Abstract

The purpose of this study was to estimate the worst-case dose commitments and potential consequences of accidental releases at nuclear risk sites in the Russian Far East. The nuclear risk sites of concern are near Petropavlovsk (52°55'N & 158°30'E) and Vladivostok (42°55'N & 132°25'E). The region of interest includes the territories of the Russian Far East, China, Japan, North and South Korea, State of Alaska, the Aleutian Islands, Mongolia, Burma, Hong Kong, Laos, Taiwan, Thailand, and Vietnam. The transboundary region (i.e., that outside of Russia) is of primary interest because the largest doses resulting from hypothetical releases from these sites would reside in Russia and would be examined using site specific information and detailed models that were unavailable for this study. However, the transboundary region can be examined, in general, using existing information and models. The methodology from the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 1993 Report was used in this study to estimate effective dose commitments. It is recognized that this methodology is not the only acceptable manner to estimate such doses; the methodology was selected because it is independent, defensible, and, because it is based upon a multiplicative model, lends itself to a facile examination of parameter variation.

The research tool used to generate the deposition data used as the basis of this study was a long-range transport model—the Danish Emergency Response Model of the Atmosphere (DERMA)—which was used to simulate the 5-d atmospheric transport, dispersion and deposition of Cs-137 for a one-day release at a rate of 10^{10} Bq s^{-1} for a total “unit hypothetical release” of $8.64 x 10^{14}$ Bq. The meteorological data from the European Center for Medium-Range Weather Forecasts (ECMWF, Reading, UK) based on the ECMWF global model forecast and analysis were used as input data for the model simulation. Using the DERMA model, the total Cs-137 depositions (i.e., sums of pertinent dry and wet deposition values) were computed for over 90% of the days in calendar year 2000. The necessary meteorological data was missing for the remaining days.

In this report, Sr-90 and I-131 were radionuclides that might also have been of concern depending upon the conditions of the study. However, because of a lack of time and resources, the deposition values were not computed for these radionuclides for all calendar year 2000 days. There were Sr-90 and I-131 concentration and deposition data provided for selected days that were considered representative of the variation of the climactic conditions for the region for the year 2000. These data were used to generate simple, linear relationships between the unavailable Sr-90 and I-131 concentration and deposition data and the corresponding Cs-137 data. These relationships were found to be sufficiently accurate for the general examination undertaken in this report and were used to generate the necessary, unavailable data. From an examination of the appropriate source term information and deposition to dose transfer factors from both the UNSCEAR 1993 Report and the worst-case scenario, Cs-137 was determined to be the radionuclide of primary concern for this study. The Cs-137 deposition-to-dose transfer factor was dominated by the external exposure (to ground deposition) pathway.

For the Petropavlovsk nuclear risk site, the maximum Cs-137 total deposition (located in Russia) translated into a worst-case maximum effective dose commitment of 108 mSv per person for the maximum exposed individual (i.e., teen). For the transboundary region (i.e., that

area outside of Russia), the maximum effective dose commitment was 5.0 mSv per teen. This maximum value was located in the State of Alaska; the maximum effective dose commitment for the Aleutian Islands was 3.3 mSv per teen. The maximum effective dose commitments in the effected U.S. territories were generally three to four times higher than those in Japan, the transboundary country with the next highest maximum dose commitments resulting from accidental releases from the Petropavlovsk risk site.

For the Vladivostok nuclear risk site, the maximum Cs-137 total deposition (located again in Russia) translated into a worst-case maximum effective dose commitment of 102 mSv per teen. For the transboundary region, the maximum effective dose commitment for Cs-137 was 27 mSv per teen. These maximum values were located in China, which is proximate to the Vladivostok site. The maximum effective dose commitments for Japan and N. Korea are approximately the same (i.e., within a factor of two) as that for China. Note that the maximum effective dose commitments in the U.S. territories are generally more than a factor of 60 lower than those in China, the transboundary country with the highest maximum dose commitments resulting from accidental releases from the Vladivostok risk site.

The maximum worst-case dose commitments corresponding to the potential Petropavlovsk and Vladivostok releases for both the regional and transboundary conditions were also compared to various annual reference levels (i.e., 0.15, 1.0, 10, and 100 mSv per person) discussed in the International Commission on Radiological Protection (ICRP) 82 Report pertaining to practices and interventions and the annual background radiation dose (i.e., 2.4 mSv per person) provided in the UNSCEAR 1993 Report. These comparisons were conservative because the effective dose commitments computed in this report are being compared to annual reference values and background doses. The worst-case maximum dose commitments from the Petropavlovsk site for the transboundary region on over 99% of all year 2000 days studied are less than the average annual background radiation dose. For the Vladivostok releases, the worst-case maximum dose commitments are less than the average annual background radiation dose for more than 44% of all year 2000 days studied. Furthermore, the maximum dose commitments corresponding to the Vladivostok releases for more than 90% of the year 2000 days studied are less than the annual 10 mSv per person level in which interventions are rarely justified and are all less than the annual 100 mSv per person level in which interventions are almost always justifiable according to ICRP 82. Therefore, the impacts from the adjusted Vladivostok releases would be, in general, more significant than those from Petropavlovsk (even though the Petropavlovsk releases translate into the maximum, worst-case dose commitment). The more significant impacts of the potential Vladivostok releases were compounded by the fact that many more people were impacted than from the corresponding hypothetical Petropavlovsk releases. However, the dose commitments from the potential Vladivostok releases could be considered negligible when compared to the 10 mSv per person level in which interventions are rarely justified.

The maximum collective dose commitments corresponding to the worst-case dose commitments were also computed. The results indicate that even though the maximum effective dose commitments from the Petropavlovsk and Vladivostok releases were similar, the larger populations impacted by the Vladivostok releases generally resulted in significantly larger collective dose commitments and thus potential mortalities than those for the Petropavlovsk releases. For example, the maximum number of additional mortalities on a regional basis resulting from the worst-case Petropavlovsk scenario would be 355 with as many as 329 in Japan, 83 in China, 18 in the State of Alaska, and 10 in S. Korea. However, for the Vladivostok releases, there could be as many as 9771 additional mortalities on a regional basis, and the additional mortalities for Japan, China, N. Korea, S. Korea, Russia, and Taiwan would be 9501, 8575, 2485, 2436, 1614, and 318, respectively. The U.S. territories and Hong Kong might have an additional two mortalities each. However, even though these mortality numbers may appear large, it should be noted that none of the transboundary values exceed 9 mortalities per 100 000 persons, which is found in N. Korea resulting from the worst-case Vladivostok scenario.

Because the aggregation of doses over large areas is contrary to the recommendation of the ICRP, a series of threshold values were imposed on the worst-case results to determine whether the conclusions would change dramatically. The impact on the maximum worst-case collective dose commitments for the Petropavlovsk releases would be significant. For example, if a threshold of 1 mSv per person is imposed on the collective dose computation, then the collective dose commitment for all transboundary areas except for the U.S. territories falls to zero (and this includes Japan, which had the largest collective dose commitment). However, the impact of imposing such thresholds on the collective dose commitments from the Vladivostok releases was much less profound than that for the corresponding Petropavlovsk dose commitments; in fact, the imposition of thresholds up to 1 mSv per person had little impact on the collective dose commitments for most countries in the region of interest. Even though the impact on the collective doses related to the Vladivostok releases was small, it remains true that the worst-case impacts of the effective dose commitments for the releases from both the Vladivostok and Petropavlovsk sites were negligible when compared to metrics such as the average annual background dose and other causes of death in the affected countries.

Acknowledgments

The computer facilities at the International Institute of Applied Systems Analysis (IIASA, Laxenberg, Austria) were extensively used in this study. The meterological data archives from the Danish Meterological Institute (DMI, Coenhagen Denmark) and European Center for Medium-Range Weather Forecasts (ECMWF, Reading, UK) were used for atmospheric transport and dispersion modeling that provided the input data to this study.

The authors are grateful to the computer consulting services at IIASA and would like to thank in particular Ulli Neudeck (IIASA) for taking care of the administrative issues.

The following software products were used in this study: MatLab, S-Plus, Microsoft Excel, and Corel Draw.

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About the Authors

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Kevin Brown joined the Radiation Safety of the Biosphere Project in August 2002. Previously he worked at the Savannah River Technology Center of the Westinghouse Savannah River Company in Aiken, South Carolina U.S.A. His work for IIASA involved the radiological assessment of potential accident scenarios concerning Russian Far East nuclear risk sites. He has accepted a fellowship in the National Science Foundation (NSF) Integrative Graduate Education and Research Traineeship (IGERT) program and will begin his Ph.D. studies at Vanderbilt University in Nashville, Tennessee starting in August 2003.

Mr. Brown received his B.E. in Chemical Engineering in 1985 and his M.S. in Environmental and Water Resources Engineering in 1987 from Vanderbilt University in Nashville, Tennessee U.S.A. Following graduation, he accepted a job for E. I. du Pont de Nemours (and later Westinghouse) at the Savannah River Site in Aiken, South Carolina U.S.A. Over more than 16 years at the Savannah River Site, his responsibilities included modeling of critical process and product properties (e.g., durability, viscosity, crystallization, etc.), statistical process control (SPC), design of experiments, simulation, software development, and environmental and chemical engineering support. Mr. Brown's primary responsibilities were to provide the necessary technical bases and product control system allowing the Defense Waste Processing Facility (DWPF) to fabricate quality product to a very high degree of confidence in an environment that offers no possibility of product rework or recycle.

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Dr. Compton graduated in 1986 with a bachelor's degree in physics from Rhodes College in Memphis, Tennessee, U.S.A. Following graduation, he served in the US Navy as a nuclear trained submarine officer. After leaving the Navy in 1991, he enrolled in the master's degree program in the Department of Environmental Systems Engineering at Clemson University in Clemson, South Carolina, and then transferred directly into the PhD program. His work at Clemson has focused on the risk assessment of hazardous and radioactive wastes and analytical methods for uncertainty analysis in environmental risk assessment. He has also been involved in evaluating U.S. environmental regulatory requirements for vitrifying hazardous wastes and in evaluating costs and risks associated with the decontamination and decommissioning of uranium enrichment facilities, and maintains an interest in the sociological factors associated with hazardous and radioactive waste management. As a participant in the 1997 Young

Scientist's Summer Program, he was involved in assessing the impact of radioactive discharges into the Yenisei and Tom rivers from nuclear facilities in Siberia. This work involved modeling the impact of normal and extreme (flood) flow transport of contaminated sediments onto floodplains and subsequent contamination of the water and food supplies.

Professor Frank L. Parker, Ph.D.

Professor Frank L. Parker is a Distinguished Professor of Environmental Engineering at Vanderbilt University in Nashville, Tennessee. He received his Bachelor of Science degree from the Massachusetts Institute of Technology and was awarded his Ph.D. at Harvard University.

He has been Head of Radioactive Waste Disposal Research at Oak Ridge National Laboratory, U.S., Head of Radioactive Waste Disposal Research at the International Atomic Energy Agency (IAEA) in Vienna. He was Chairman of the Board of Radioactive Waste Management of the US National Academy of Sciences and a Member of the U.S. National Commission on Radiation Protection, as well as a Member of the Commission on Monitored Retrievable Storage of the U.S. Congress.

Professor Parker is a Member of the U.S. National Academy of Engineering, has been a Senior Fellow at the Beijer Institute of the Swedish Academy of Sciences, and was Senior Fellow at the International Institute for Applied Systems Analysis (IIASA) in Laxenburg since 1995. Since 1996 he has been Principal Investigator of Evaluation Study of IIASA project on Radiation Safety of the Biosphere.

In 1995, Professor Parker was Chairman of the IAEA Seminar on "International Cooperation on Nuclear Waste Management in the Russian Federation." He was Chairman at the opening session and responsible for final comments at the IAEA Seminar on Requirements for the Safe Management of Radioactive Waste. He was a Member of the US Delegation to the ISTC review of Activities with the Russian Federation, Snezhinsk.

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Alexander Mahura joined the Radiation Safety of the Biosphere (RAD) project in June 2001 as a member of IIASA's Young Scientists Summer Program (YSSP). His current work involves mathematical modeling of atmospheric transport, dispersion, and deposition of atmospheric pollutants (including radionuclides) on local, regional and global scales; evaluating the source-receptor relationship and removal processes for pollutants during atmospheric transport; and assessing the possible impact on the population and environment from potential risk sources in the Euro-Arctic region.

Dr. Mahura received his B.Sc. in Atmospheric Sciences in 1991 from the Leningrad Hydrometeorological Institute, his M.Sc. in Environmental Modeling in 1998 from the University of Alaska Fairbanks, and his Ph.D. in Physics and Mathematics in 2002 from the Russian State Hydrometeorological University.

During the summer of 2001 and the spring and fall of 2002, he performed research in the Far East Coastal Regions Study (FARECS) of the RAD project. Currently he is doing research on the “ARCTIC RISK” Project of the Nordic Arctic Research Programme (NARP) at the Danish Meteorological Institute, Copenhagen, Denmark.

Dr. Vladimir Novikov

Vladimir Novikov joined the Radiation Safety of the Biosphere Project in June 1994 to undertake a feasibility study on the RAD Project and to take part in its management. He is now in charge of the Evaluation Study of the RAD Project.

Professor Novikov previously took part in the IIASA Social and Environmental Dimension of Technology Project and the Risk Analysis and Policy Project within the framework of the cooperation between IIASA and the Russian Research Center "Kurchatov Institute." He undertook research on the economical and ecological aspects of nuclear power in CIS and on the social acceptability of emerging nuclear energy systems.

Professor Novikov studied physics at Moscow State University and received his first degree from the International Institute for Nuclear Research in 1961. He was awarded his Ph.D. in physics and mathematics in 1974 from the Atomic Energy Institute in Moscow. He was the recipient of the Kurchatov Award in Science in 1984.

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His professional activities include research, administration, teaching, and consulting. His special research interests are the sustainable evolution of the nuclear industry and the ecological and social aspects of the nuclear legacy of the Cold War. He has authored and coauthored more than 200 publications, including seven books.

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1 Introduction

Beginning in the year 2000, the Radiation Safety of the Biosphere (RAD) Project of the International Institute for Applied Systems Analysis (IIASA) initiated a study entitled: "Assessment of Impact of Russian Nuclear Fleet Operations on Russian Far East Coastal Regions" Study (FARECS). In that year, research activities concentrated on gathering available information, evaluating these data, and performing preliminary analyses. In 2001, the focus shifted to the analysis, from the probabilistic point of view, of potential danger to the environment and population in countries neighboring Russia due to atmospheric transport [1]. Two nuclear risk sites (NRS) of concern were selected–Petropavlovsk (52°55'N & 158°30'E) and Vladivostok (42°55'N & 132°25'E) NRS, which will be referred to as PRS and VRS, respectively—both located in the Russian Far East (as illustrated in Figure 1). From Figure 1, it should be noted that the following countries (or parts thereof) are within the region of interest:

- Burma
- China
- Hong Kong
- Japan
- Laos
- Mongolia
- North Korea
- Russia
- South Korea
- Taiwan
- Thailand
- Aleutian Islands (U.S.)
- State of Alaska (U.S.)
- Vietnam

The Aleutian Islands will be considered separately from the remainder of the effected U.S. territories in this study to assure that the islands' proximity to the NRS do not overly bias the results. Each of the countries (or parts thereof) will be considered during the analysis. The transboundary region (i.e., those areas outside of Russia) will also be examined to examine the impact of release outside of Russia because those within Russia would likely be analyzed using site-specific information and models.

Beginning in 2002, the focus of study was a probabilistic analysis of atmospheric transport and deposition patterns (employing the methodology described in [2,3,4,5]) to meld the results of atmospheric transport and dispersion modeling. The purpose of this study is to examine potential consequences of accidental releases at these sites via radiological dose estimation using deposition results provided from the previous studies [6] on the people in the region described above.

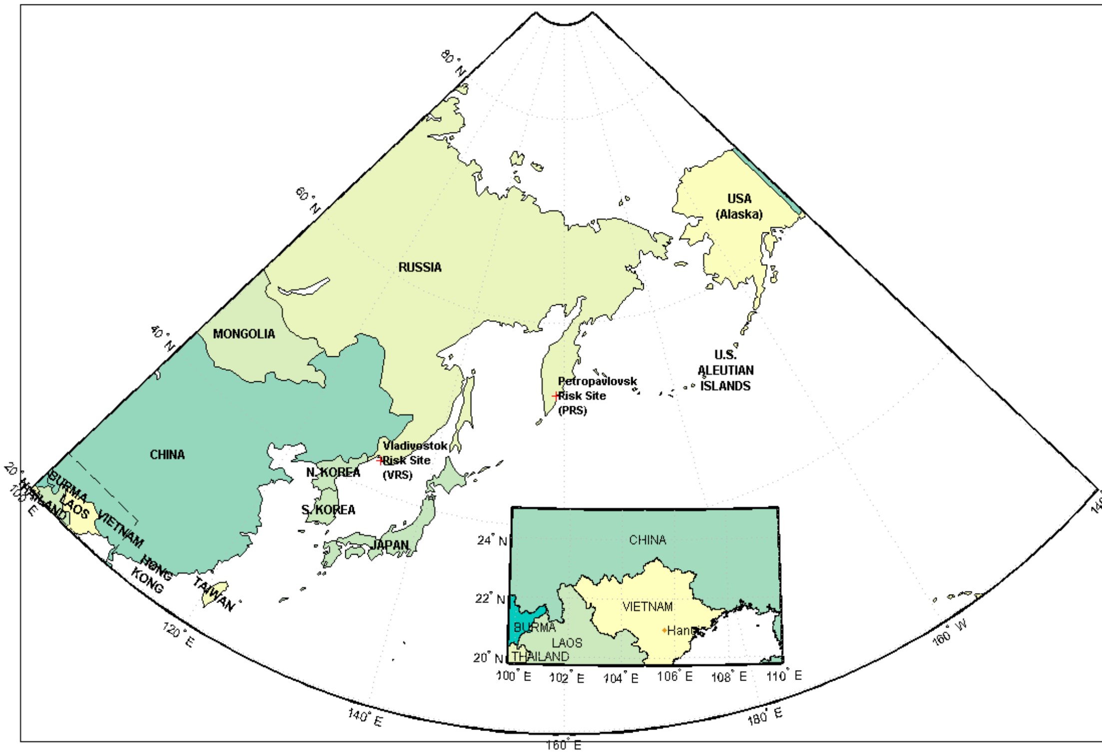


Figure 1. This figure represents the region of interest for this study. Both the Petropavlovsk (PRS) and Vladivostok (VRS) Nuclear Risk Sites are shown. The inset illustrates the lower left-hand corner of this region where the countries of Burma, Thailand, Laos, and Vietnam are located. A larger version of this figure is available as Figure A 1 in Appendix A.

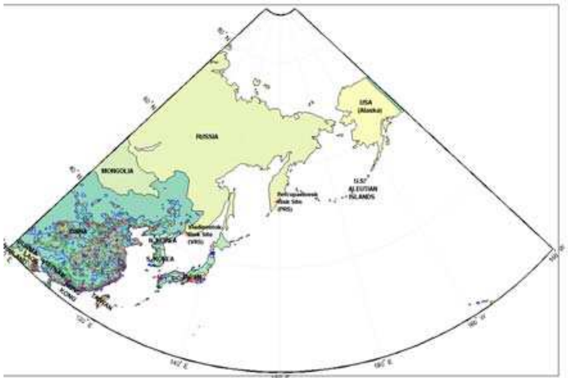
1.1 Population Information Used in this Study

Estimation of the dose commitment for a population in a given area impacted by a release from one of the NRS examined in this study requires an estimate of the population for that given area. Because the deposition information [6] was on the basis of a 0.5 by 0.5 degree grid (or 2 cells per degree) covering the area illustrated in Figure 1, it would be convenient if either the population information was available on the same "gridded" basis or if available information could be easily converted to the desired 0.5 by 0.5 degree basis. Fortunately a "gridded" representation of the world's population as of 1995 is available [7] on the Internet on a 0.083 by 0.083 degree (or 12 cells per degree) basis.

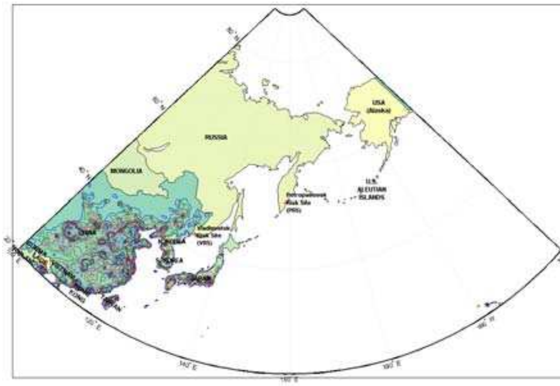
The population data was downloaded as a text file and loaded into MatLab [8]. A contour plot of the original data over the region of interest is provided in Figure 2a. MatLab® routines were then used to sum each 6 by 6 set of cells into a single cell to produce a matrix of the same dimensions representing the same geographic region as the original data [6]. The corresponding contour plot of the resulting 0.5 by 0.5 degree population data is shown in Figure 2b. It should also be noted that the total population for the matrices illustrated in Figure 2 both total 1.484×10^9 people.[1] The 2 cells per degree (or 0.5 by 0.5 degree) population data matrix thus obtained (as illustrated in Figure 2b) is used for all calculations in this memorandum. No attempt was made to forecast population changes since 1995 because there are just too many variables that are unknown; it is suggested that the variations introduced below in the parametric study will cover these population changes.

---

1 The maximum population in any cell are 1.286×10^6 and 1.192×10^7 people for the 12 cells per degree and 2 cells per degree grids, respectively. The contours for Figure 2a and Figure 2b are at 8572 and 158 944 persons each, respectively.



(a) Original data (12 cells per degree)
Contours every 8572 people



(b) Converted data (2 cells per degree)
Contours every 158 944 people

Figure 2. The above figures illustrate contour plots of the "gridded" population data used in this study. The original GPW data [7] are illustrated on the left (a) and the data converted to a 2 cells per degree grid are illustrated on the right (b). Larger views of Figure 2(a) and Figure 2(b) are provided in Appendix A as Figure A 2 and Figure A 3, respectively.

2 Deposition Data Analysis

Some description of the deposition data used as input to this study must be provided to make sense of the resulting dose estimates. The research tool used to generate the deposition results used in this study is a dispersion model. The Danish Meteorological Institute (DMI) long-range transport model – the Danish Emergency Response Model of the Atmosphere DERMA [9,10]—was employed to simulate 5-day atmospheric transport, dispersion, and deposition of Cs-137 for a series of one-day "unit hypothetical releases" (at the rate of 10^{10} Bq s^{-1} for a total release of (24 h d^{-1})(3600 s h^{-1})(10^{10} Bq s^{-1}) = 8.64×10^{14} Bq). Only the releases for Cs-137 were simulated for a single calendar year, 2000, to save computational resources. (It was recognized that a multi-year approach would have provided better data for statistical analysis; however, such a study was impracticable for the resources available [6]). The "unit hypothetical release" of 10^{10} Bq s^{-1} resulting in a total release over a 24-h period of 8.64×10^{14} Bq selected for the original data [6] is comparable to the radioactivity (i.e., 8×10^{14} Bq) of Cs-137 and Sr-90 in the spent nuclear fuels (in both reactors) at two years after the shutdown of a Russian nuclear submarine [11]. Thus it appears that any likely accident involving such a submarine would likely release significantly less activity to the atmosphere than considered in this study. The "unit hypothetical release" appears, therefore, a conservative one. How the "hypothetical unit release" compares to conceivable accident scenarios will be discussed in detail in the section concerning parameter variation below.

The meteorological data from the European Center for Medium-Range Weather Forecasts (ECMWF, Reading, UK) based on the ECMWF global model forecast and analysis were used as input data for the model simulation. Using the DERMA model, several important metrics were calculated for the region illustrated in Figure 1:

1) air concentration (Bq m^{-3}) of the radionuclide in the surface layer (surface air),
2) integrated in time air concentration (Bq h m^{-3}) of the radionuclide in the surface layer (integral concentration at surface or integrated concentration)
3) dry deposition (ddep) in Bq m^{-2} of the radionuclide on the underlying ground surface (dry deposition), and
4) wet deposition (wdep) in Bq m^{-2} of the radionuclide on the underlying ground surface (wet deposition).

The assumptions used in this study are discussed in Reference 6. Thus, for each initial day of release for each site, there are approximately 804 000 results for each of the four metrics listed above to examine for this study.[2]

Using the wet and dry deposition and integrated concentration data [6], the maximum dry, wet, and total depositions as well as integrated concentrations were computed (by day after release[3]) for each initial day of release for CY2000 having complete (i.e., 24x6 hours = 144 hours of) recorded data. These are the data from which the doses will be estimated. The results are discussed below.

2.1 Petropavlovsk Risk Site (PRS)

For the PRS releases, no depositions for the time periods (of up to six days after initial release) considered were found for the following countries:

- Burma
- Hong Kong
- Laos
- Taiwan
- Thailand
- Vietnam

for any day of CY2000. For the countries in which depositions were found resulting from the hypothetical "unit release" from the PRS of (24 h d^{-1})(3600 s h^{-1})(10^{10} Bq s^{-1}) = 8.64×10^{14} Bq, the maximum such release and other pertinent information are presented in Table 2 through Table 5 for Cs-137, which is the only radionuclide for which data are provided [6] for all available days of CY2000. The regional information is also presented. The maximum (non-zero) total deposition (tdep) values for Cs-137 from the PRS for CY2000 are provided in Exhibit 1.

Exhibit 1. Summary of Maximum Non-Zero Cs-137 Total Deposition (tdep) Values for the PRS Releases

Region	CY2000 Date	Maximum Deposition (Bq m^{-2})	Latitude	Longitude	Distance* (km)	Cell Area* (m^2)	Population
Regional	21-Mar	2.78E+04	52.50	157.50	87	1.89E+09	1944
Transboundary**	05-Nov	2.20E+04	52.50	159.00	65	1.89E+09	N/A
China	05-Jan	1.95E+02	52.50	126.00	2169	1.89E+09	7721
Japan	26-Apr	2.76E+02	43.50	142.50	1581	2.25E+09	155 808
Mongolia	04-Jan	1.09E+01	46.50	119.50	2855	2.13E+09	1835
N. Korea	07-Jan	5.42E+01	43.00	130.00	2372	2.26E+09	175 327
Russia	21-Mar	2.78E+04	52.50	157.50	87	1.89E+09	1944
S. Korea	05-Jan	4.09E+00	37.50	126.50	3001	2.45E+09	2 006 368

[2] The geographical region in Figure 1 was divided into a grid representing two cells per degree. Thus there were 241 columns by 139 rows of cells representing the geographical region of interest (20°N & 100°E to 90°N & 140°W). For each day of CY2000, the surface air concentration and integrated concentration as well as wet and dry depositions were computed every three hours [6] after the initial release; the total release lasted for 24 hours (with one release of 3600×10^{10} Bq every hour). The resulting data were then resampled every six hours after the initial release (up to a period of six days after the initial and five days after the final release) as input to this study. Thus the data set to be examined for each site on a given initial release date of CY2000 consisted of a file containing 241 columns by 139 rows by 24 records (i.e., 6 days by 24 hours per day = 144 hours by 1 record every six hours = 24 records) for a total of 803 976 results.

[3] It was decided to examine the available data on a daily basis instead of the monthly or seasonal basis used by Mahura [6] to capture as much of the variation in the data as possible. This appears appropriate when one is searching for maximum doses.

Region	CY2000 Date	Maximum Deposition (Bq m^{-2})	Latitude	Longitude	Distance* (km)	Cell Area* (m^2)	Population
Aleutian Islands (U.S.)	24-Jan	8.56E+02	52.50	185.50	1807	1.89E+09	63
Alaska (U.S.)	18-Feb	1.28E+03	58.50	198.00	2507	1.62E+09	22

* Distance and Cell Area represent the distance from the risk site to the maximum total deposition and area impacted by the maximum deposition, respectively.

** The transboundary region includes all areas, including ocean, outside of Russia. For this case, the maximum transboundary deposition was found in the ocean.

Because the deposition and integrated concentration information for Sr-90 and I-131 was not available for all days of CY2000 [6], it was initially determined whether reasonable estimates of these parameters could be made from the available Cs-137 information. The simplest approach was to determine whether there were definitive relationships between the unknown Sr-90 and I-131 values and those for the Cs-137 data. To do this, the Cs-137, Sr-90, and I-131 data [6] for releases from five specific days (i.e., the "specific case studies" for 05-Apr-2000, 26-Apr-2000, 05-Aug-2000, 10-Aug-2000, and 15-Nov-2000) were examined. These data are considered representative of the variation of the climactic conditions for the region for CY2000 [6]. These days were selected based upon the:

1) main direction of atmospheric transport,
2) possibility of precipitation during atmospheric transport,
3) relatively short travel time of the radioactive cloud from a given NRS location toward the region of interest,
4) relatively large coverage of the region of interest by the radioactive cloud during atmospheric transport, and
5) boundary layer height, which influences the stable boundary layer and velocity of atmospheric transport.

The simplest relationship between Sr-90 or I-131 and Cs-137 is a linear one. To see if such a relationship is reasonable for the data from the five chosen days, pair-wise correlations were computed using S-Plus, which is an application specially created for exploratory data analysis and statistics [12]. That is, if the pair-wise correlation between two parameters is unity, then a unique, linear relationship exists between them. The S-Plus results for the I-131 (for every day or 24-h period after initial release) versus Cs-137 (for every 6-h period after initial release) for dry deposition (on a Bq m^{-2} or "raw" basis) for the PRS are provided in Table 1. Note that the largest pair-wise correlations between the I-131 (at the desired or t_d time period in hours) and Cs-137 data primarily exist at the 42-h time period for Cs-137; the only exception is the I-131 24-h values, which are the largest using the Cs-137 values at the 24-h period. The results for all other I-131 data were similar; those for the Sr-90 versus Cs-137 manifested even higher pair-wise correlations. Therefore, it was decided to use simple, linear relationships to estimate the Sr-90 and I-131 deposition data from existing Cs-137 information.

The Sr-90 and I-131 values were predicted from the corresponding Cs-137 information (i.e., wdep or wet deposition, ddep or dry deposition, and integrated concentration) using the least-squares parameter, $A_{j,td}$, from the linear regression of the non-zero[4] data for the five specific release dates in relationships of the form:

Equation 1 $$X_j(t_d) = A_{j,td} Cs137_j(t_p)$$

where $X_j(t_d)$ is the value of the parameter represented by j (i.e., j = wdep, ddep, or integrated concentration) at the desired time, t_d, and $Cs137_j(t_p)$ is the value of the corresponding Cs-137 parameter at either the same or previous time (or $t_p \leq t_d$) that provides the best least-squares fit.

4 Thus only those data with at least one value for I-131 or Sr-90 and the corresponding Cs-137 value for the same location and times were used in the regression analyses.

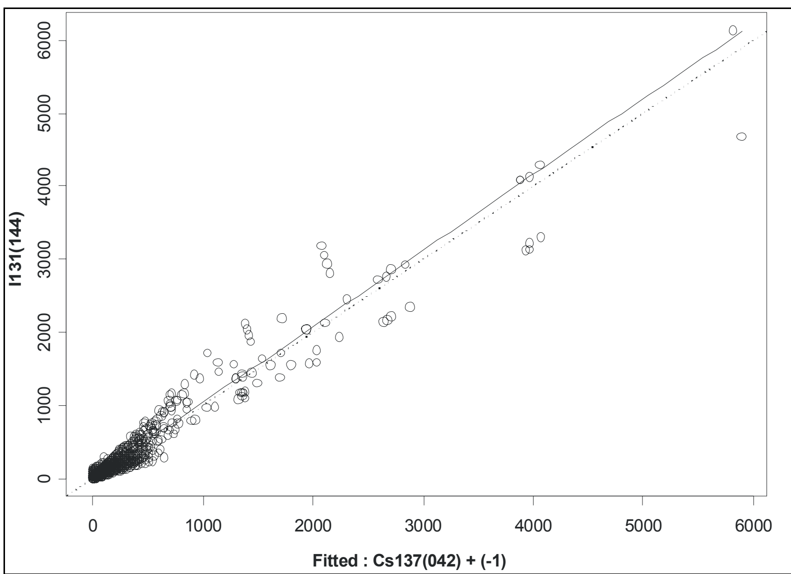
For example, the S-Plus [12] results for the PRS I-131 ddep data at t_d = 144 hours (or six days after initial release) versus the corresponding Cs-137 data at 42 hours are provided in Exhibit 3 below. The linear model was forced through the origin (i.e., no intercept) because there was no deposition at time zero. The breakdown of the contributions of data from the various days for the regression analysis presented in Exhibit 3 is provided in Exhibit 2.

Exhibit 2. Data Availability for Regression Analysis of Cs-137, Sr-90, and I-131 Total Depositions as Presented in Exhibit 3.

Release Date	Count	Percentage of Total
5-Apr-00	12532	31.4%
26-Apr-00	5869	14.7%
5-Aug-00	8110	20.3%
10-Aug-00	4771	11.9%
15-Nov-00	8650	21.7%
Total	39932	100.0%

Note that in this case (as illustrated in Exhibit 2), the data from each of the five days are well represented; the data from no single release date dominate the regression analysis. This is also true of the other regression analyses. The results of the fit in Exhibit 3 are amongst the poorest in this study—and these appear to represent the data reasonably well for the purpose of this study. In fact the simple, linear models used for I-131 describe more than 90% of the variation in the data. The Sr-90 relationships appear especially strong, that is, over 99% of the variation is described by the simple, linear models employed likely because the deposition velocities used in the Mahura study for Sr-90 and Cs-137 were very close [6]. Thus the results of the linear regression analyses were used without additional regard for prediction error or the like. The above analysis (as represented in Exhibit 3) was performed for both the Sr-90 and I-131 depositions and concentrations as functions of the corresponding Cs-137 information.

Exhibit 3. S-Plus Linear Regression Results for the PRS I-131 Dry Deposition (ddep) data at 144 hours versus the Cs-137 data at 42 hours. The necessary function call (i.e., `lm(formula = …)` and corresponding results for this case are provided in the right-hand side of the exhibit. Note that the relationship was forced through the origin using "… + `(-1)`" in the function call.




```
*** Linear Model ***

Call: lm(formula = I131(144) ~ Cs137(042) + (-1),
        data = I131.prs.ddepdata.144,
        na.action = na.exclude)

Residuals:
   Min     1Q    Median   3Q  Max
 -1209 0.000163 0.0342 0.87 1110

Coefficients:
             Value Std. Error t value Pr(>|t|)
Cs137(042)   1.440   0.002    827.920   0.000

Residual standard error: 25.4 on 39931 degrees of
freedom

Multiple R-Squared: 0.945

F-statistic: 685000 on 1 and 39931 degrees of
freedom, the p-value is 0
```

A summary of the fitted parameters (i.e., $A_{j,td}$ and t_d values in hours after initial release) for I-131 and Sr-90 are provided in Table 6 and Table 7, respectively. In these tables, "Raw" indicates the original value in Bq m^{-2} [6] and "Frac" indicates the value as a fraction of the total release—or the "raw" value in Bq m^{-2} times the area impacted normalized by the total release of 8.64×10^{14} Bq. The "Corr." and "R^2" represent the pair-wise correlation and multiple R^2 value for the fit (representing how much of the variation in the data is accounted for by the fit), respectively. In the results listed below, only the raw (or Bq m^{-2}) valued are used; however, the normalized values (in terms of fraction of the total released) could also have been used and are provided for completeness.

Using the "Raw" parameters from Table 6 and Table 7, the corresponding Sr-90 deposition values are computed and the results provided in Table 8 through Table 11. The maximum (non-zero) total deposition (tdep) values computed for Sr-90 from the PRS Cs-137 results for CY2000 are illustrated in Exhibit 4. Note how closely these Sr-90 values correspond to their respective Cs-137 values.

Exhibit 4. Summary of Maximum Non-Zero Sr-90 Total Deposition (tdep) Values for the PRS Releases

Region	CY2000 Date	Maximum Deposition (Bq m^{-2})	Latitude	Longitude	Distance* (km)	Area* (m^2)	Population
Regional	21-Mar	2.86E+04	52.50	157.50	87	1.89E+09	1944
Transboundary**	05-Nov	2.30E+04	52.50	159.00	65	1.89E+09	N/A
China	05-Jan	1.93E+02	52.50	126.00	2169	1.89E+09	7721
Japan	26-Apr	3.19E+02	43.50	142.50	1581	2.25E+09	155 808
Mongolia	04-Jan	1.11E+01	46.50	119.50	2855	2.13E+09	1835
N. Korea	07-Jan	6.04E+01	43.00	130.00	2372	2.26E+09	175 327
Russia	21-Mar	2.86E+04	52.50	157.50	87	1.89E+09	1944
S. Korea	05-Jan	2.14E+00	37.50	126.50	3001	2.45E+09	2 006 368
Aleutian Islands (U.S.)	24-Jan	8.51E+02	52.50	185.50	1807	1.89E+09	63
Alaska (U.S.)	18-Feb	1.36E+03	58.50	198.00	2507	1.62E+09	22

* Distance and Area represent the distance from the risk site to the maximum total deposition and area impacted by the maximum deposition, respectively.

** The transboundary region includes all areas, including ocean, outside of Russia. For this case, the maximum transboundary deposition was found in the ocean.

Those computed for I-131 are provided in Table 12 through Table 15. Note that the maximum value in Table 13 for the general region is located in the ocean (i.e., with zero population) and thus does not reside in Russia as do the other regional maximum values. The maximum (non-zero) total deposition (tdep) values computed for I-131 from the PRS Cs-137 results for CY2000 are provided in Exhibit 5.

Exhibit 5. Summary of Maximum Non-Zero I-131 Total Deposition (tdep) Values for the PRS Releases

Region	CY2000 Date	Maximum Deposition (Bq m^{-2})	Latitude	Longitude	Distance* (km)	Area* (m^2)	Population
Regional	12-Jun	4.65E+04	54.00	159.00	116	1.82E+09	1872
Transboundary**	07-Feb	3.09E+04	52.50	159.00	65	1.89E+09	N/A
China	04-Dec	6.19E-05	52.50	123.00	2365	1.89E+09	5976
Japan	03-Jan	3.83E+01	44.50	145.50	1338	2.21E+09	2136
Russia	12-Jun	4.65E+04	54.00	159.00	116	1.82E+09	1872
Aleutian Islands (U.S.)	18-Jan	5.06E+02	52.50	174.00	1043	1.89E+09	0
Alaska (U.S.)	20-Jan	3.41E+01	54.50	195.00	2379	1.80E+09	38

* Distance and Area represent the distance from the risk site to the maximum total deposition and area impacted by the maximum deposition, respectively.

** The transboundary region includes all areas, including ocean, outside of Russia. For this case, the maximum transboundary deposition was found in the ocean.

Furthermore, the Cs-137 data from the PRS, the maximum values for wet, dry, and total deposition (as well as the integrated concentration) are less than 90 km from the risk site. (All distances and areas in this report are computed using commands from the MatLab [8] Mapping Toolbox.) The 144-h and 48-h deposition maximum values are also provided to support the notion that the maximum values for Cs-137 are, in general, the same as those at the end of the time period considered and that most of the deposition has occurred in the first two days after the initial release.

In terms of the total deposition (which is what matters most in this assessment), the maximum value of 2.78×10^4 Bq m^{-2} for Cs-137 for the overall region (which resides in Russia) impacts "only" approximately 2000 people [7][5] (not that this impact would be insignificant to said 2000 people as it corresponds to an effective dose commitment of more than 4 mSv using the UNSCEAR 1993 Report methodology [13] described below). Figure 3 provides a histogram of the maximum total depositions for the overall region including Russia; note that 95% of the total depositions are less than 1.06×10^4 Bq m^{-2}.

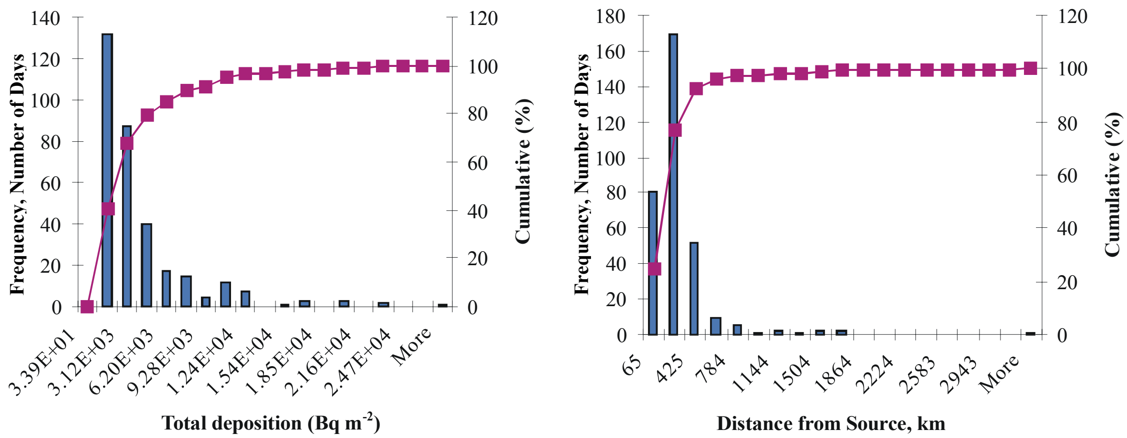


Figure 3. Frequency histogram and cumulative percentages for the PRS Cs-137 total deposition (tdep) maximum values (left) and corresponding distances from source in km (right).

Figure 4 illustrates the results for the transboundary (i.e., all areas, including the ocean, excluding Russia) depositions; note that the impact on the maximum values is small (because of the proximity of China to the PRS as illustrated in Figure 1). The transboundary region is important because it indicates the impact on countries (e.g., Japan, the United States, etc.) outside Russia where the releases may take place. Furthermore, it is likely that specialized models would be used for the areas near the risk sites; this study is more relevant for the areas outside Russia.

[5] All population estimates are obtained using the "Gridded Population of the World (GPW)" database [7], which was converted from a 0.083 by 0.083 degree cell size to a 0.5 by 0.5 degree cell size to conform to the original data [6]. The conversion was performed using MatLab [8] to sum each 36 (i.e., 6x6) set of GPW cells into the corresponding cell for the data in this study. The population information will be covered in more detail below.

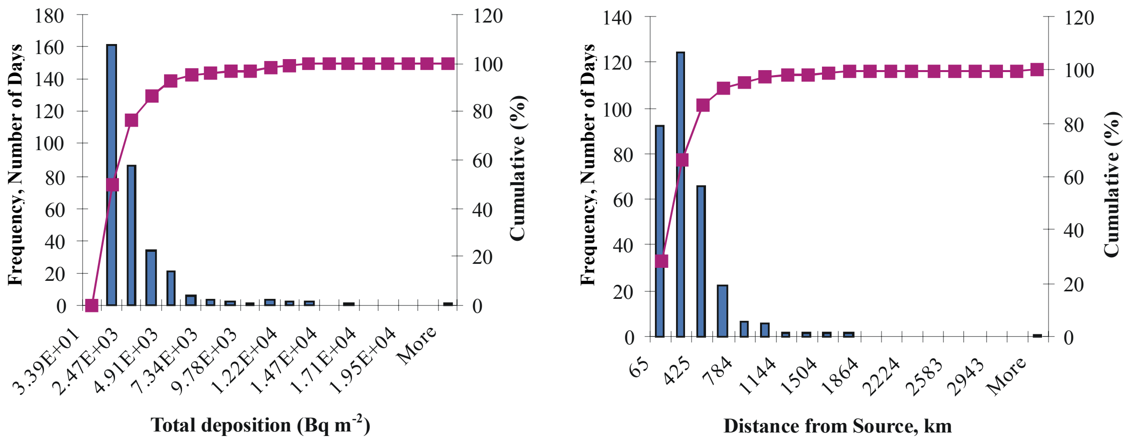


Figure 4. Transboundary frequency histogram and cumulative percentages for the PRS Cs-137 total deposition (tdep) maximum values (left) and corresponding distances from source in km (right).

The "large" populations (of over 2000 people) that are impacted by the maximum releases are in the countries of S. Korea, Japan, and N. Korea, and China (even though these depositions occur on 25% or fewer of the days considered). However, the most severely impacted countries (i.e., Alaska and the Aleutian Islands) in terms of the dose commitment are to the northeast of the PRS, or in the direction opposite to that of countries with large, impacted populations. The maximum total deposition for these countries (i.e., those with affected populations greater than 2000) ranges from 4.09 to 276 Bq m^{-2}. It is, therefore, possible that significant maximum and collective doses may be experienced from the PRS releases because there are large populations impacted by relatively small dose commitments (or less than 0.042 mSv per person) and larger dose commitments (albeit only approximately 0.2 mSv per person [13]) impacting much smaller populations. A parameter variation study will be performed below to determine whether the "worst-case" maximum dose commitments are radiologically significant to the impacted populations.

Finally, the Aleutian Islands were considered separately from the remainder of the United States territory (in the region of interest as indicated in Figure 1) to assure that any impact on the outlying islands would not bias the results of the analysis. It is interesting to note that the Cs-137 depositions from the PRS for the mainland United States territory are often larger than those for the Aleutian Islands, which are more proximate to the risk site. Not surprisingly (and to compound the impact), many more people are impacted on the mainland than on the Aleutian Islands.

Because of the manner in which the results for the Sr-90 depositions are computed from the Cs-137 results, the maximum values necessarily follow those for Cs-137. There are no results that differ significantly from those presented for Cs-137 above except that the maximum total deposition is 2.86×10^4 Bq m^{-2} (which impacts, again, approximately 2000 persons with an effective dose commitment of 1.6 mSv [13]). Figure 5 provides a histogram of the maximum total Sr-90 depositions for the overall region; note that 95% of the total depositions are less than 1.27×10^4 Bq m^{-2}. The depositions for S. Korea, Japan, and N. Korea, and China range from 2.14 to 319 Bq m^{-2}. Figure 6 illustrates the maximum depositions for the transboundary conditions; again note the small impact on the maximum deposition.

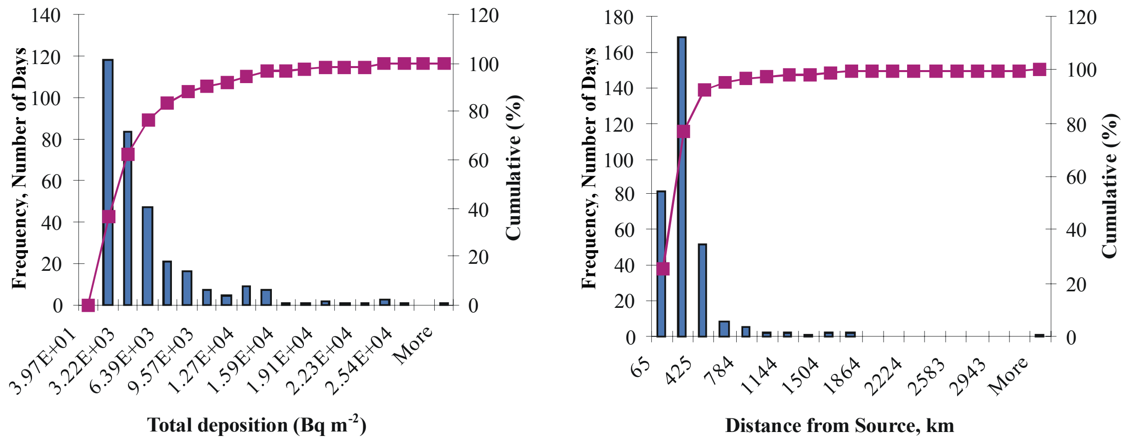


Figure 5. Frequency histogram and cumulative percentages for the PRS Sr-90 total deposition (tdep) maximum values (left) and corresponding distances from source in km (right).

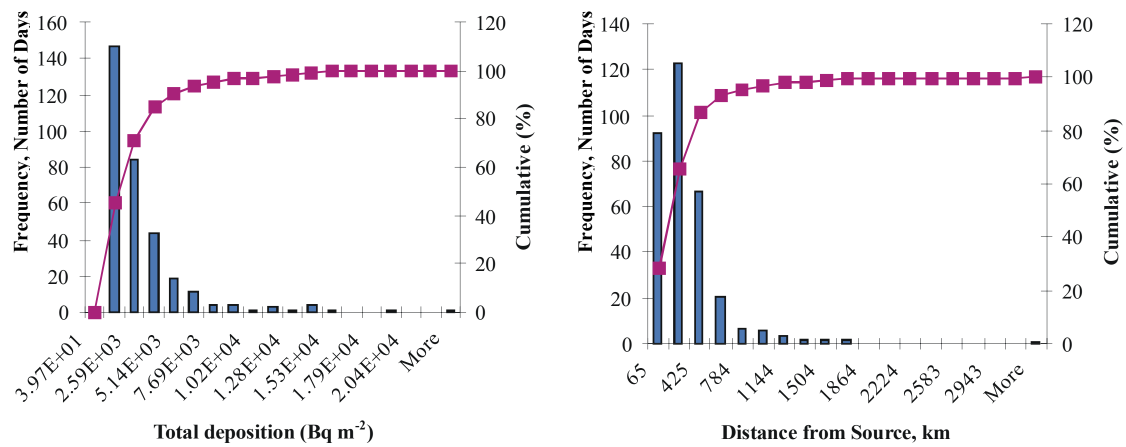


Figure 6. Transboundary frequency histogram and cumulative percentages for the PRS Sr-90 total deposition (tdep) maximum values (left) and corresponding distances from source in km (right).

However, the I-131 results do appear to be significantly different from those for Cs-137 (and thus Sr-90); these results are not surprising considering the differences in the deposition velocities[6] used to produce the results (for the five specific days studied above) [6]. The maximum total I-131 deposition is $4.65\text{x}10^4$ Bq m^{-2}, which impacts almost 1900 people (in Russia) and is more than 60% higher than either the corresponding Cs-137 or Sr-90 depositions; however, the effective dose commitment using the UNSCEAR 1993 Report methodology [13] would be less than 0.18 mSv per person. This result appears reasonable because the I-131 deposition velocity used to generate the results is 3 to 4 times higher than that for either Sr-90 or Cs-137, respectively. Figure 7 provides a histogram of the maximum total I-131 depositions for the overall region; note that 95% of the total depositions are less than $2.33\text{x}10^4$ Bq m^{-2}. Figure 8 illustrates the distribution of the maximum I-131 depositions for the transboundary conditions; note again the small impact of this condition on the maximum deposition. This is again due to the proximity of China to the PRS as illustrated in Figure 1.

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[6] The deposition values given in Ref. 6 are 0.0015, 0.002, and 0.006 m s^{-1} for Cs-137, Sr-90, and I-131, respectively.

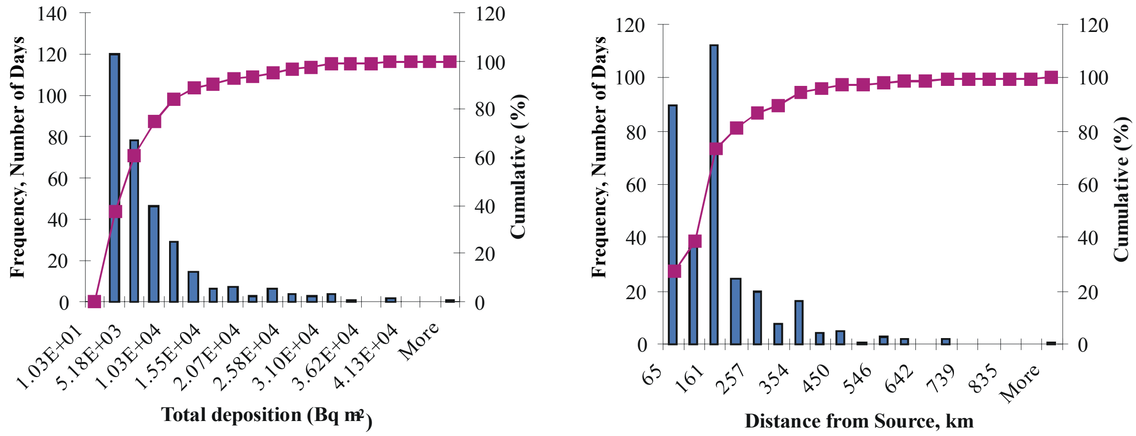


Figure 7. Frequency histogram and cumulative percentages for the PRS I-131 total deposition (tdep) maximum values (left) and corresponding distances from source in km (right).

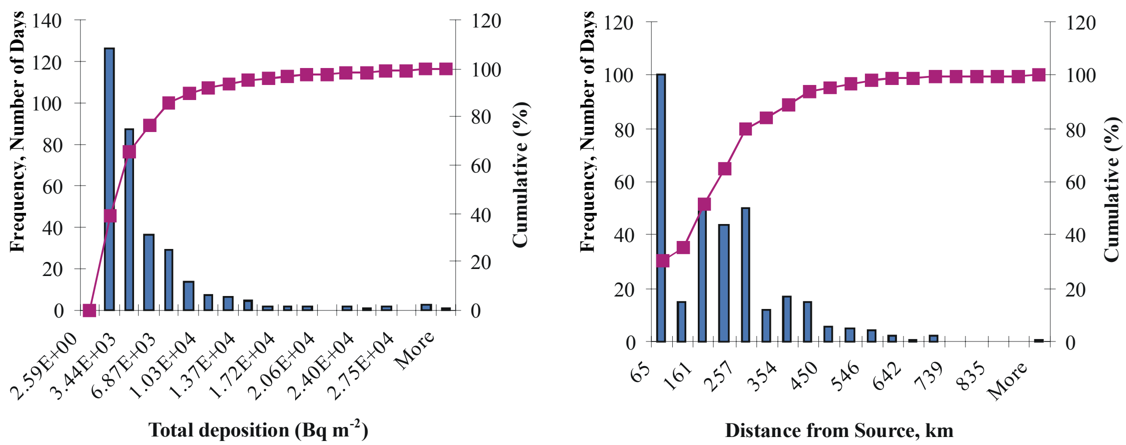


Figure 8. Transboundary frequency histogram and cumulative percentages for the PRS I-131 total deposition (tdep) maximum values (left) and corresponding distances from source in km (right).

For I-131, an additional three countries (i.e., Mongolia, N. Korea, and S. Korea for a total of seven) are not predicted to have depositions during CY2000. Furthermore, those countries, with the exception of Russia, that have predicted depositions tend to have many fewer days during the year with depositions of I-131 (as illustrated in the appropriate N(%) columns in Table 12 through Table 15) than either Cs-137 or Sr-90. Furthermore, none of the maximum total depositions impact more than 6000 people, which is in China where the maximum total deposition of 6.19×10^{-5} Bq m^{-2} is negligible because it translates into an effective dose commitment of 3×10^{-10} mSv per person (as indicated below).

2.1.1 Specific Case Examples: Japan and U.S. Depositions from the PRS

Because it is apparent that air masses from the Asian continent can move rapidly and only slightly diluted across the Pacific Ocean [14,15], it has been decided to examine these specific areas for possible impacts from the nuclear risk sites in this report. The importance of this examination is highlighted in Table 4, Table 10, and Table 14 by the fact that the maximum Cs-137, Sr-90, and I-131 depositions, respectively, to any country other that Russia and China, which are both proximate to the nuclear risk sites, are to either Japan or the U.S. territories. Furthermore, because the Sr-90 depositions necessarily follow those for Cs-137 and the I-131 depositions are smaller and will have significantly less impact on the transboundary region (which includes both Japan and the U.S.), it was decided to examine only Cs-137 for the specific examples.

The histograms showing the Cs-137 depositions and distances from the PRS for Japan are provided in Figure 9. As indicated in Table 4, there are no depositions in Japan on approximately 75% of all CY2000 days. Furthermore, the maximum depositions will be less than 15 Bq m^{-2} on approximately 95% of all CY2000 days. The maximum deposition of 276 Bq m^{-2} appears to be an isolated case.

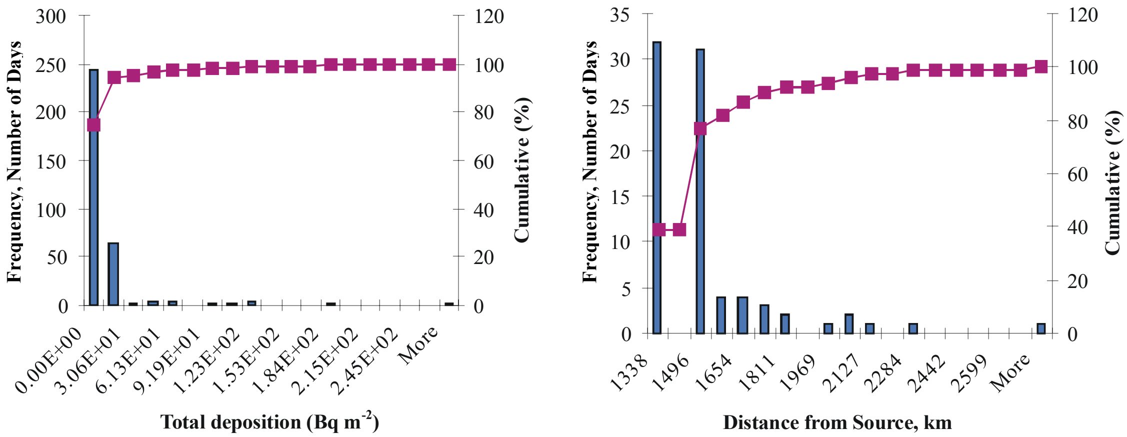
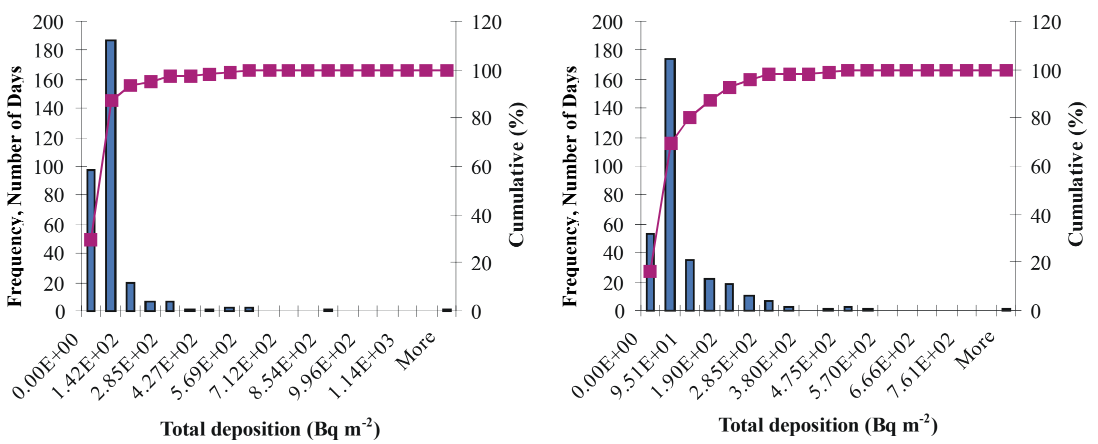


Figure 9. Japan Results: Frequency histogram and cumulative percentages for the PRS Cs-137 total deposition (tdep) maximum values (left) and corresponding distances from source in km (right).

The histograms for the U.S. territory considered in this study are provided in Figure 10. Note that the depositions are normally about an order of magnitude higher than those in Japan (as illustrated in Figure 9). There is also a much higher frequency of deposition from the PRS for both Alaska in Figure 10(a) and the Aleutian Islands in Figure 10(b) than in Japan. Again the maximum total depositions of 1280 and 856 Bq m^{-2} for Alaska and the Aleutian Islands, respectively, appear to be isolated cases that occur within three weeks of each other early in the year (i.e., before 18-Feb-2000). As a point of comparison, the maximum deposition for Japan occurred in late April. This is not surprising considering the relative distances and orientations of these areas from the PRS as shown in Figure 1.



(a) Alaska (U.S.) (b) Aleutian Islands (U.S.)

Figure 10. U.S. Results: Frequency histogram and cumulative percentages for the PRS Cs-137 total deposition (tdep) maximum values for Alaska (left) and Aleutian Islands (right).

2.2 Vladivostok Risk Site (VRS)

For releases from the VRS (which is shown in Figure 1), no depositions for the time periods (of up to six days after initial release) considered were found for the following countries:

- Burma
- Laos
- Thailand

For the countries in which depositions were found resulting from the hypothetical "unit release" from the VRS of (24 h d^{-1})(3600 s h^{-1})(10^{10} Bq s^{-1}) = 8.64×10^{14} Bq, the maximum such release and other pertinent information are presented in Table 16 through Table 19 for Cs-137, which is the only radionuclide for which data are provided [6] for all days of CY2000. The regional information is also presented. The maximum (non-zero) total deposition (tdep) values for Cs-137 from the VRS for CY2000 are presented in Exhibit 6.

Exhibit 6. Summary of Maximum (Non-Zero) Cs-137 Total Depositions (tdep) for the VRS Releases

Region	CY2000 Date	Maximum Deposition (Bq m^{-2})	Latitude	Longitude	Distance* (km)	Area* (m^2)	Population
Regional	02-Aug	2.64E+04	43.50	133.50	134	2.25E+09	34 008
Transboundary**	18-Nov	9.06E+03	42.00	133.50	166	2.30E+09	N/A
China	07-Jun	6.93E+03	43.50	131.50	69	2.25E+09	42 463
Hong Kong	12-Sep	5.57E+00	22.50	114.50	2794	2.85E+09	125 994
Japan	16-Dec	3.85E+03	40.50	141.00	796	2.35E+09	358 298
Mongolia	10-May	6.70E+01	47.00	120.00	1042	2.11E+09	33 341
N. Korea	20-Aug	4.26E+03	42.00	129.00	270	2.30E+09	200 822
Russia	02-Aug	2.64E+04	43.50	133.50	134	2.25E+09	34 008
S. Korea	11-Jan	1.03E+03	38.50	127.50	628	2.42E+09	292 252
Taiwan	29-Nov	1.91E+02	24.00	121.50	2322	2.82E+09	152 461
Aleutian Islands (U.S.)	23-Apr	5.86E+01	52.00	177.00	3464	1.91E+09	0
Alaska (U.S.)	24-Mar	1.12E+02	60.00	210.00	5359	1.55E+09	1314
Vietnam	29-Nov	2.88E-06	20.50	107.00	3416	2.89E+09	13 869

* Distance and Area represent the distance from the risk site to the maximum total deposition and area impacted by the maximum deposition, respectively.

** The transboundary region includes all areas, including ocean, outside of Russia. For this case, the maximum transboundary deposition was found in the ocean.

The Sr-90 and I-131 data corresponding to that in Exhibit 6 from the VRS were estimated using simple relationships (i.e., of the form presented in Equation 1) derived from the Cs-137, Sr-90, and I-131 data [6] for releases from five specific days (i.e., 05-Apr-2000, 26-Apr-2000, 05-Aug-2000, 10-Aug-2000, and 15-Nov-2000). The necessary fitted parameters for I-131 and Sr-90 are provided in Table 6 and Table 7. Using the appropriate parameters and Equation 1, the corresponding Sr-90 deposition values are provided in Table 20 through Table 23. The maximum (non-zero) total deposition (tdep) values computed for Sr-90 from the VRS Cs-137 results for CY2000 are provided in Exhibit 7.

Exhibit 7. Summary of Maximum (Non-Zero) Sr-90 Total Depositions (tdep) for the VRS Releases

Region	CY2000 Date	Maximum Deposition (Bq m^{-2})	Latitude	Longitude	Distance* (km)	Area* (m^2)	Population
Regional	02-Aug	3.26E+04	43.50	133.50	134	2.25E+09	34 008
Transboundary**	02-Aug	1.09E+04	42.50	133.50	135	2.28E+09	717
China	07-Jun	7.87E+03	43.50	131.50	69	2.25E+09	42 463

Region	CY2000 Date	Maximum Deposition (Bq m^{-2})	Latitude	Longitude	Distance* (km)	Area* (m^2)	Population
Hong Kong	29-Nov	2.26E-03	22.50	114.50	2794	2.85E+09	125 994
Japan	16-Dec	4.40E+03	40.50	141.00	796	2.35E+09	358 298
Mongolia	10-May	7.52E+01	47.00	120.00	1042	2.11E+09	33 341
N. Korea	20-Aug	5.16E+03	42.00	129.00	270	2.30E+09	200 822
Russia	02-Aug	3.26E+04	43.50	133.50	134	2.25E+09	34 008
S. Korea	11-Jan	1.19E+03	38.50	127.50	628	2.42E+09	292 252
Taiwan	29-Nov	2.17E+02	24.00	121.50	2322	2.82E+09	152 461
Aleutian Islands (U.S.)	23-Apr	6.05E+01	52.00	177.00	3464	1.91E+09	0
Alaska (U.S.)	25-Mar	4.17E+01	58.50	202.50	4986	1.62E+09	15
Vietnam	29-Nov	4.41E-10	20.50	107.00	3416	2.89E+09	13 869

* Distance and Area represent the distance from the risk site to the maximum total deposition and area impacted by the maximum deposition, respectively.

** The transboundary region includes all areas, including ocean, outside of Russia.

Note again how closely these Sr-90 values correspond to their respective Cs-137 values. Those computed for I-131 are provided in Table 24 through Table 27. The maximum (non-zero) total deposition (tdep) values computed for I-131 from the VRS Cs-137 results for CY2000 are presented in Exhibit 8.

Exhibit 8. Summary of Maximum (Non-Zero) I-131 Total Depositions (tdep) for the VRS Releases

Region	CY2000 Date	Maximum Deposition (Bq m^{-2})	Latitude	Longitude	Distance* (km)	Area* (m^2)	Population
Regional	12-Jun	5.28E+04	43.50	133.50	134	2.25E+09	34 008
Transboundary**	12-Jun	1.76E+04	42.50	133.50	135	2.28E+09	717
China	07-Jun	1.64E+04	43.50	131.50	69	2.25E+09	42 463
Japan	20-Nov	2.61E+03	36.00	138.00	933	2.50E+09	405 254
Mongolia	21-Apr	5.86E-04	47.00	120.00	1042	2.11E+09	33 341
N. Korea	20-Aug	9.86E+03	42.00	129.00	270	2.30E+09	200 822
Russia	12-Jun	5.28E+04	43.50	133.50	134	2.25E+09	34 008
S. Korea	11-Jan	1.14E+03	37.50	129.00	662	2.45E+09	155 901
Aleutian Islands (U.S.)	07-Mar	6.59E+00	52.00	177.00	3464	1.91E+09	0
Alaska (U.S.)	14-Nov	5.36E-12	55.00	198.00	4801	1.78E+09	46

* Distance and Area represent the distance from the risk site to the maximum total deposition and area impacted by the maximum deposition, respectively.

** The transboundary region includes all areas, including ocean, outside of Russia.

Note that for the Cs-137 data from the VRS, the maximum values for dry and total deposition (as well as the integrated concentration) are 134 km from the risk site, which are similar to the results mentioned above for the PRS. In terms of the total deposition (which is of primary importance in this assessment), the maximum value of 2.64×10^4 Bq m^{-2} for the overall region (which resides again in Russia and translates into an effective dose commitment of approximately 4 mSv per person using the UNSCEAR 1993 Report methodology [13]) impacts over 34 000 people, which is many more than for the releases from the PRS. Figure 11 provides a histogram of the maximum total depositions for the overall region; note that 95% of the maximum total depositions are less than 8850 Bq m^{-2}. Figure 12 illustrates the depositions for the transboundary (i.e., excluding Russia) conditions; note again the small impact (i.e., by approximately a factor of three lower) on the maximum deposition value. The appearance of the distance histogram in Figure 12 is explained by the fact that many of the maximum depositions described by this figure are found in the ocean around the VRS. This will not be the case when doses are computed below.

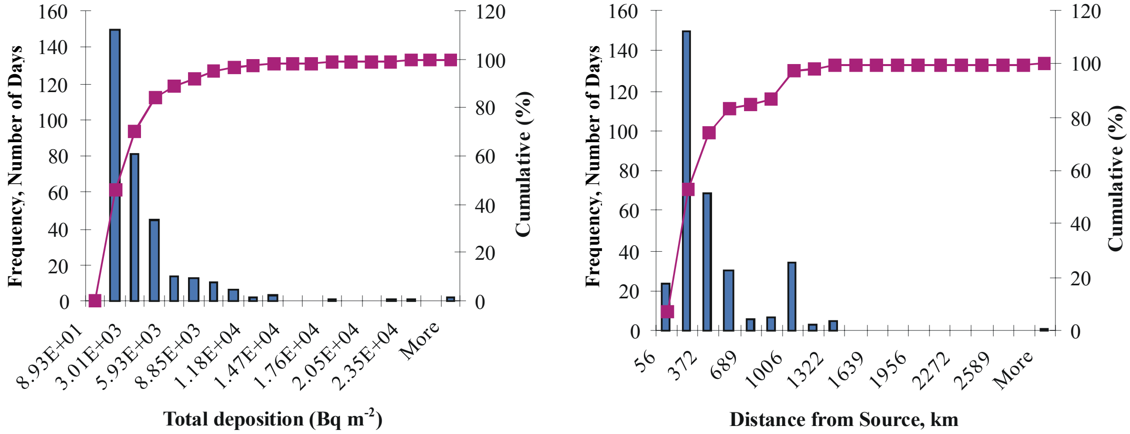


Figure 11. Frequency histogram and cumulative percentages for the VRS Cs-137 total deposition (tdep) maximum values (left) and corresponding distances from source in km (right).

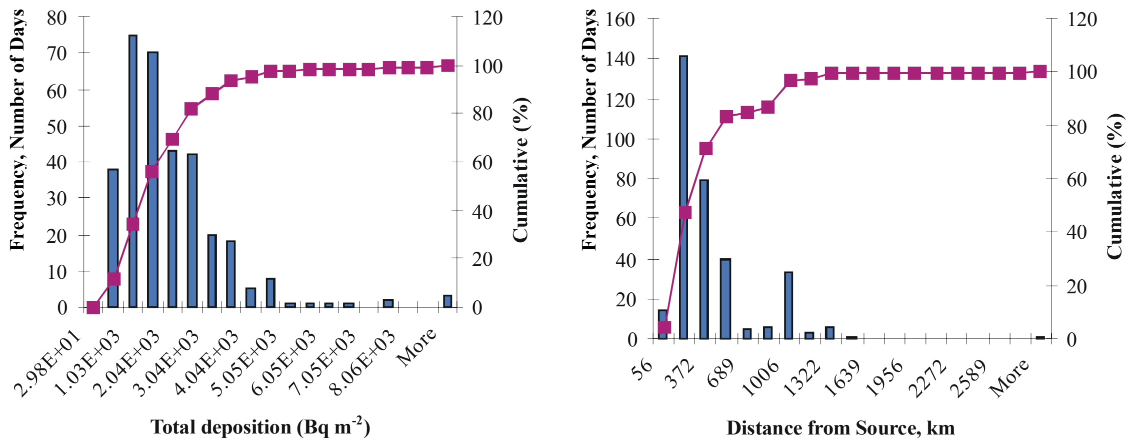


Figure 12. Transboundary frequency histogram and cumulative percentages for the VRS Cs-137 total deposition (tdep) maximum values (left) and corresponding distances from source in km (right).

Also unlike the PRS, there are seven countries with maximum depositions of 5.6 to 6930 Bq m^{-2} from the VRS releases that impact between 33 000 and 358 000 people. Only the depositions for the Aleutian Islands, Alaska, and Vietnam impact significantly fewer (i.e., fewer than 14 000) people. Therefore, larger maximum individual and collective doses will be experienced from the VRS depositions than those from the PRS; these are evaluated below.

Because of the manner in which the results for the Sr-90 depositions are computed from the Cs-137 results, the maximum values necessarily follow those for Cs-137. There are no results that differ significantly from those presented for Cs-137 above except that the maximum total deposition is 3.26×10^4 Bq m^{-2} (which impacts, again, more than 34 000 persons). Figure 13 provides a histogram of the maximum total Sr-90 depositions for the overall region; note that 95% of the total depositions are less than 1.09×10^4 Bq m^{-2}. The depositions for those countries (other than Russia) in which the maximum total deposition impacts over 30 000 people range from 2.26×10^{-3} to 7870 Bq m^{-2}. Figure 14 illustrates the distribution of maximum total depositions for transboundary conditions. Note again the small impact on the maximum deposition value. The appearance of the distance histogram is explained by the fact that many of the maximum depositions are found in the ocean around the VRS.

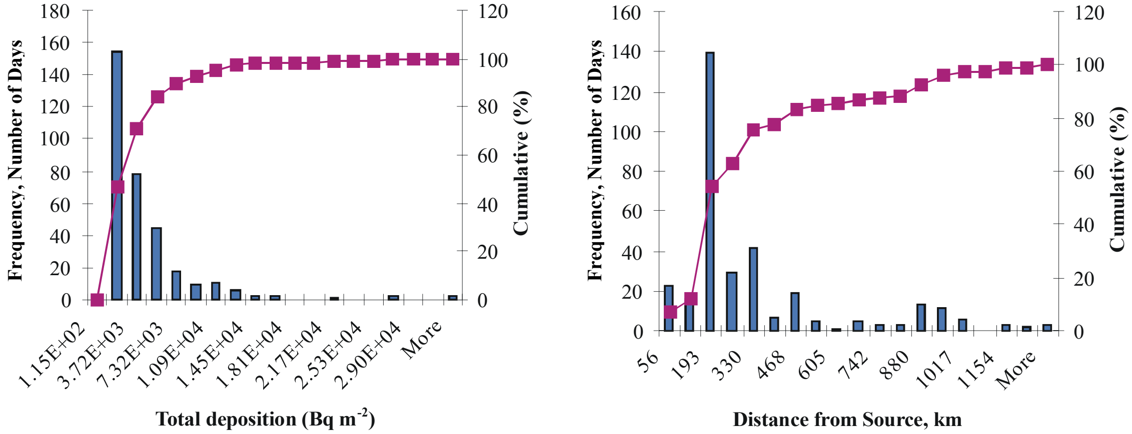


Figure 13. Frequency histogram and cumulative percentages for the VRS Sr-90 total deposition (tdep) maximum values (left) and corresponding distances from source in km (right).

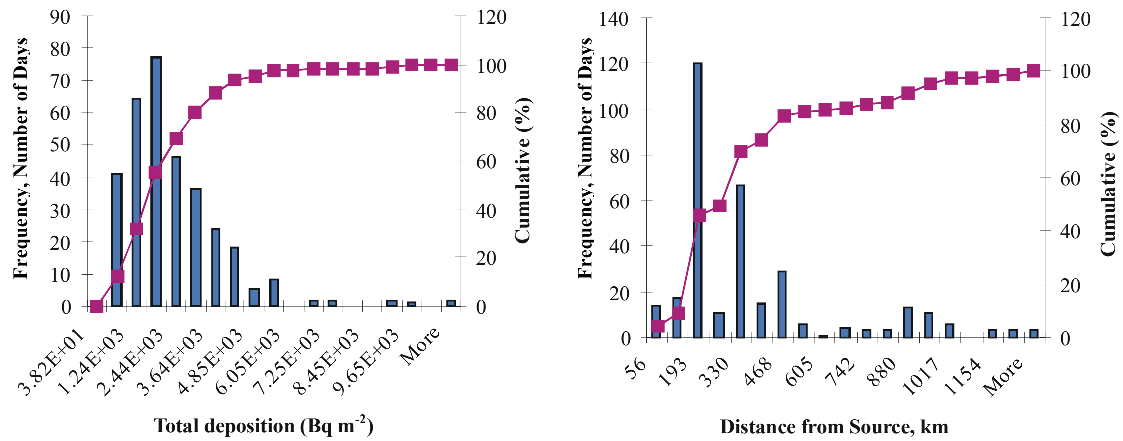


Figure 14. Transboundary frequency histogram and cumulative percentages for the VRS Sr-90 total deposition (tdep) maximum values (left) and corresponding distances from source in km (right).

However, the I-131 results are again significantly different from those for Cs-137 (and thus Sr-90). The maximum total I-131 deposition is 5.28×10^4 Bq m^{-2}, which again impacts over 34 000 people (in Russia), but is more than 60% and 100% higher than either the corresponding Sr-90 or Cs-137 deposition, respectively. This result appears reasonable because the I-131 deposition velocity used to generate these results is 3 to 4 times higher than that for either Sr-90 or Cs-137, respectively. However, the effective dose commitment for this deposition value is 0.25 mSv per person [13] or approximately two orders of magnitude lower than the corresponding maximum Cs-137 dose commitment.

Figure 15 provides a histogram of the maximum total I-131 depositions for the overall region; note that 95% of the total depositions are less than 1.78×10^4 Bq m^{-2}. Figure 16 illustrates the distribution of maximum total depositions for transboundary conditions. Note again the small impact on the maximum deposition value. The appearance of the distance histogram is explained by the fact that many of the maximum depositions are found in the ocean around the VRS.

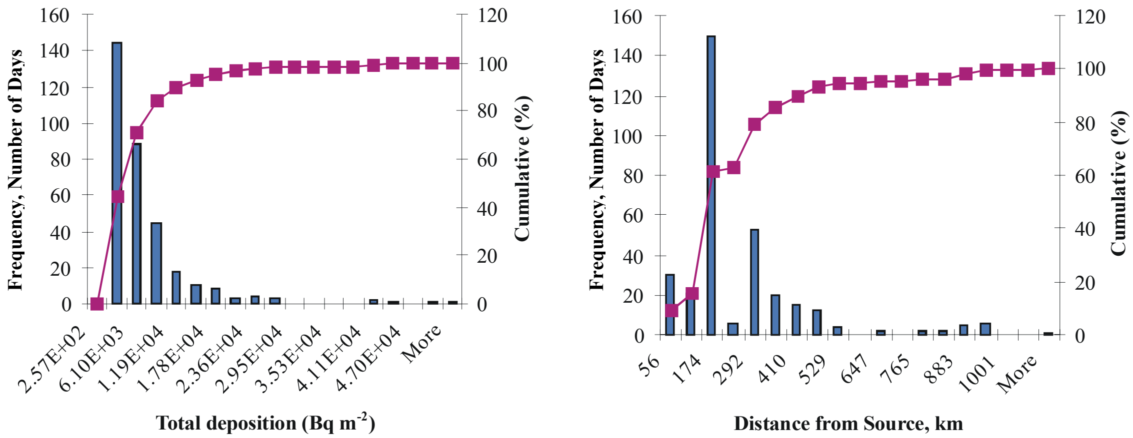


Figure 15. Frequency histogram and cumulative percentages for the VRS I-131 total deposition (tdep) maximum values (left) and corresponding distances from source in km (right).

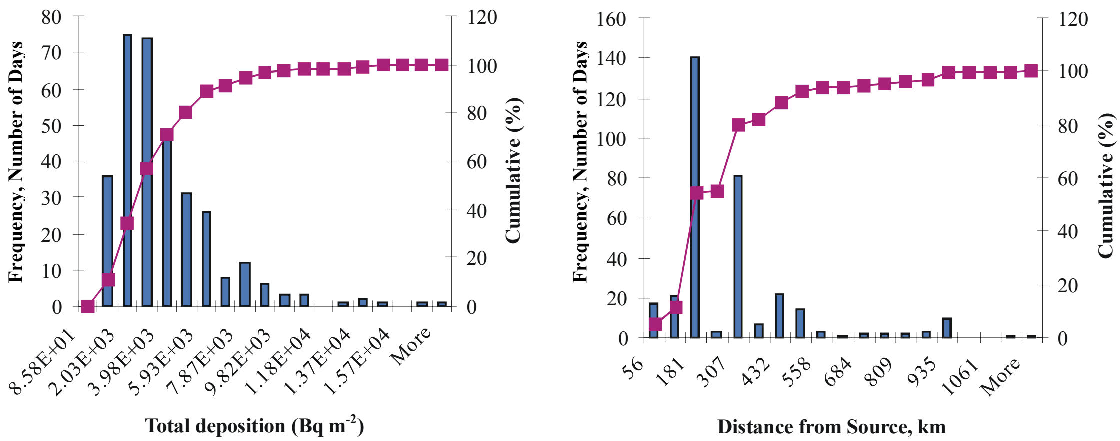


Figure 16. Transboundary frequency histogram and cumulative percentages for the VRS I-131 total deposition (tdep) maximum values (left) and corresponding distances from source in km (right).

An additional three countries (i.e., Hong Kong, Taiwan, and Vietnam for a total of four) are predicted to not have I-131 depositions from the VRS releases for any day during CY2000. Furthermore, those countries, with the exception of Russia, that have predicted depositions tend to have many fewer days during the year with depositions of I-131 (as illustrated in the appropriate N(%) columns in Table 24 through Table 27) than either Cs-137 or Sr-90. Furthermore, most of the maximum total depositions impact more than 33 000 people. Therefore, the VRS I-131 depositions impact many more people than those from the PRS; however, the dose commitments themselves were small in either case as illustrated above.

2.2.1 Specific Case Examples: Japan and U.S. Depositions from the VRS

The histograms showing the Cs-137 depositions and distances from the VRS for Japan are provided in Figure 17. As indicated in Table 18, the deposition frequency and magnitudes for the VRS are very different than those for the PRS releases. There are depositions on more than 96% of CY2000 days and the maximum deposition of 3850 Bq m^{-2} in December is well over an order of magnitude higher than that from the PRS. Also there are maximum depositions over 1000 Bq m^{-2} on approximately 10%

of all CY2000 days. Therefore the impact from the VRS on Japan is likely to be much more profound than that from the PRS.

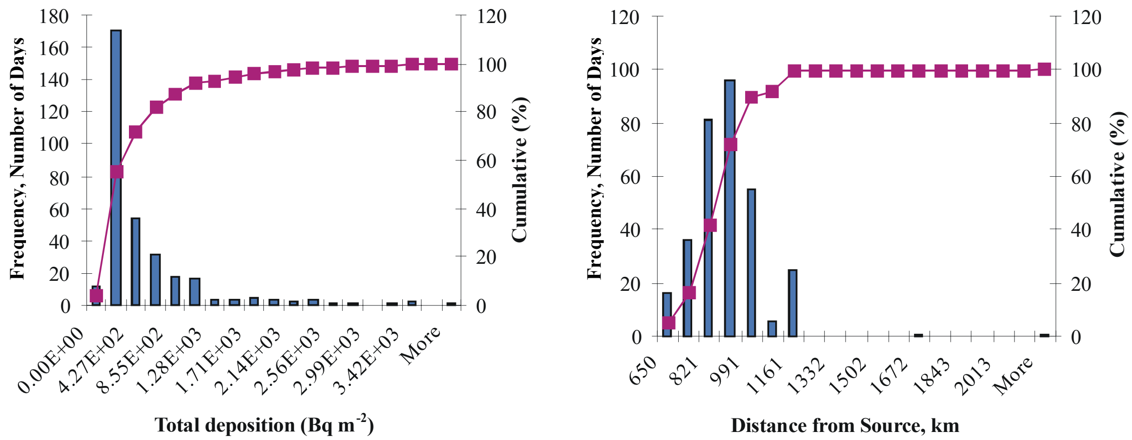
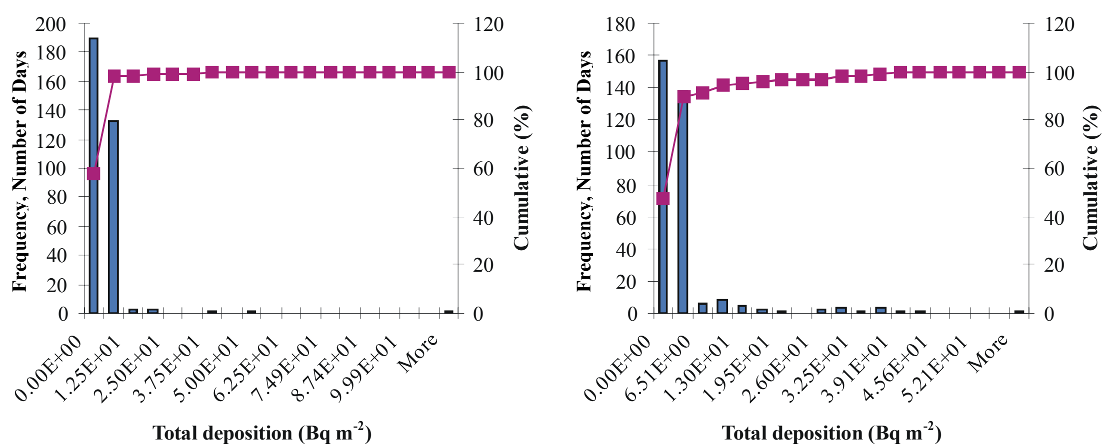


Figure 17. Japan Results: Frequency histogram and cumulative percentages for the VRS Cs-137 total deposition (tdep) maximum values (left) and corresponding distances from source in km (right).

The histograms for the U.S. territory considered in this study are provided in Figure 18. Note that the depositions are normally about an order of magnitude less than those in Japan (as illustrated in Figure 17). There is also a much lower frequency of deposition from the VRS for both Alaska (in Figure 18a) and the Aleutian Islands (in Figure 18b) than in Japan. Again the maximum depositions of 112 and 59 Bq m^{-2} for Alaska and the Aleutian Islands, respectively, appear to be isolated cases and occur within approximately one month of each other. The maximum deposition in Japan, on the other hand, occurred in December 2000.



(a) Alaska (U.S.) (b) Aleutian Islands (U.S.)

Figure 18. U.S. Results: Frequency histogram and cumulative percentages for the VRS Cs-137 total deposition (tdep) maximum values for Alaska (left) and the Aleutian Islands (right).

3 Dose Calculations

The purpose of this study is to estimate doses for the deposition results provided by Mahura [6]. It was decided to estimate the effective dose commitments for both the maximum exposed individual (which will be described below) and adults corresponding to the depositions. The basis selected for the dose estimation methodology is that provided in the UNSCEAR 1993 Report [13]. It is recognized that this methodology is not the only acceptable manner in which to estimate such doses. The UNSCEAR methodology was selected because it is independent, defensible, and lends itself to a facile examination of variation (which will be described below). To wit [13],

> "Although the terminology was developed for evaluations of doses from radionuclides produced during atmospheric nuclear testing, *the methodology is generally applicable to any source of release of radionuclides to the air or terrestrial environment*." [Italics are the author's.]

3.1 UNSCEAR Effective Dose Commitment Estimates

In the UNSCEAR 1993 Report, the effective dose commitments for an adult individual were computed for Cs-137 and Sr-90 and that for an age-weighted individual was computed for I-131. The effective dose commitment is is the sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose to these organs or tissues; the committed dose is the dose to organs or tissues of reference that will be received from an intake of radioactive material by an individual during the 50-year period following the intake (or a 70-year period for infants). The effective dose commitment, D_c, for a specific radionuclide due to an environmental input, A_0, is given in the UNSCEAR 1993 Report by [13]:

Equation 2

$$D_c = P_{01}[\underbrace{P_{12}P_{23}P_{34}P_{45}}_{\text{ingestion}} + \underbrace{P_{14}P_{45}}_{\text{inhalation}} + \underbrace{P_{15}}_{\text{cloud gamma}} + \underbrace{P_{12}P_{25}}_{\text{external ground}}]A_0$$

where P_{01} is the integrated concentration of a radionuclide in the air[7] at a given location or averaged for a broader region divided by the amount released, A_0; the other parameters will be defined in detail subsequently. The first term in the equation above relates deposition to dose via the ingestion pathway, the second term via the inhalation pathway, the third term accounts for direct (cloud gamma) irradiation from the nuclide in air, and the fourth term accounts for the component of external irradiation from the radionuclides deposited on the ground.

A set of effective ingestion, inhalation, and external exposure transfer coefficients, each referred to as P_{25} in the UNSCEAR 1993 Report, from deposition to dose in units of nSv per Bq m^{-2} was defined using average or nominal values of the appropriate input parameters. However, because the ways in which the P_{25} coefficients are derived differ from pathway to pathway, the individual deposition-to-dose coefficients will be referred to using the nomenclature set forth in the 2000 UNSCEAR Report [16]. This will be described in detail below. Using the depositions [6] as summarized above, these transfer coefficients are then used to compute the

1) corresponding maximum effective dose commitments to determine the potential impact of the releases relative to a number of reference levels (e.g., 0.15, 1.0, and 10.0 mSv per year[8]

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7 Note that this equation involves the integrated air concentration even though the deposition data presented earlier involves deposition to ground. Each part of the equation relating deposition to dose will be translated below into the correct form incorporating the original deposition values [6].

8 "In respect of CERCLA, US EPA has proposed a 15 mrem [or 0.15 mSv] per annum dose limit, as compared with the international reference level of 100 mrem (1 mSv) and the proposed level of 1000 mrem (10 mSv) below which intervention is rarely justified." [17] The same reference indicates that "… in practice, [1000 mrem or] 10 mSv represents a more realistic generic reference level below which interventions are rarely justifiable and [10 000 mrem or] 100 mSv represents a more realistic generic level above which interventions

[17,18]) for practices and interventions[9] [19] as well as to the average natural background radiation level of 2.4 mSv per year [13,16] and

2) collective (or population) effective dose commitments for a series of hypothetical threshold values (i.e., 0 or no threshold, 0.1, 0.15, 1.0, and 10.0 mSv) to study the impact of such thresholds on collective dose commitments—this is not meant to support or refute the use of such thresholds, merely to examine their impact. The threshold levels used in this report were selected to be relatively small; they correspond to the conservative reference levels described above (because they will be applied to committed—not annual—doses).

However, to illustrate the methodology, each transfer coefficient will be discussed briefly before the dose commitments are computed.

3.1.1 UNSCEAR Ingestion Pathway

As indicated in Equation 2, the UNSCEAR transfer coefficients for ingestion are computed using the following form:

Equation 3 $$P_{2345} \equiv P_{23} P_{34} P_{45}$$

where P_{23} represents the transfer from deposition to diet, P_{34} links the concentrations of radionuclides in diet to those in the body, and P_{45} the concentrations in body to dose. Note that P_{12} represents the ground deposition and, therefore, the resulting P_{2345} coefficient is what is necessary to relate the ground deposition to dose. The transfer, represented by the coefficient P_{23} in units of mBq a kg^{-1} per Bq m^{-2} (where the "a" represents annum or year per the UNSCEAR 1993 Report), of Sr-90 and Cs-137 from deposition to diet was modeled using a three-component model considering transfer in the first year from mainly direct deposition, transfer in the second year from lagged use of stored foods and uptake from the surface deposits, and transfer via root uptake from the accumulated deposits. (The manner in which P_{23} values were obtained for I-131 will be discussed below.) The parameters provided in the UNSCEAR 1993 Report for Sr-90 and Cs-137 were obtained from regression analysis for data from Argentina, Denmark, and the United States; the fact that only the United States is from the region of interest will be discussed below in the section concerning sensitivities to parameter variation. The P_{23} ranges are provided in Table 28 (although the reason for differences for Sr-90 and Cs-137 is not readily apparent to the author even though it may have to do with fitting data from different regions of the U.S.).

The UNSCEAR values for the P_{34} transfer coefficient, which relates the concentrations of radionuclides in the diet to those in the body, is, in effect, the consumption rate of the five food groups listed in Table 28. The fractional consumptions by weight provided in the report (based again upon Argentina, Denmark, and the United States) were used assuming an average food consumption rate of 500 kg a^{-1} [13]. These values are provided in Table 29.

The UNSCEAR P_{45} transfer coefficients represent the effective committed dose per unit intake for the ingestion of, in this case Sr-90 and Cs-137, and were given as 28 and 13 nSv Bq^{-1} [13,20],

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are almost always justifiable." Note that because committed doses are estimated in this report, comparison to the above annual limits will be conservative. The ICRP also recommended permanent resettlement following an accident at an averted dose of 1000 mSv in a lifetime, corresponding to an average annual dose of 15-20 mSv [18].

9 The concepts of practices and interventions were introduced by the ICRP in Publication 60 [19], as "human activities [that] increase the overall exposure to radiation…" and "human activities [that] can decrease the overall exposure…", respectively. "The clearest distinction between practices and interventions is the ability to choose a priori whether to accept beneficial sources and the consequent exposures. If a choice is still available, the exposure can usually be said to be due to a practice…. Subsequent steps to reduce the annual doses attributable to the practice are improvements in the practice and not necessarily an intervention. If there is no choice, because the sources already exist, any action taken to reduce exposures is an intervention." [19]

respectively. The Sr-90 and Cs-137 P_{45} values represent the committed equivalent doses for a period of 50 years after intake for adults.

Therefore, the UNSCEAR P_{2345} transfer coefficients for Cs-137 and Sr-90 can be obtained by multiplication of the appropriate parameters as indicated in Equation 3:

$$\begin{aligned} P_{2345} &= P_{23}P_{34}P_{45} \\ &= \left(8.4\text{x}10^{-3}\text{ Bq a kg}^{-1}\text{ per Bq m}^{-2}\right)\left(500\text{ kg a}^{-1}\right)\left(13\text{ nSv Bq}^{-1}\right) \\ &= 55\text{ nSv per Bq m}^{-2}\text{ for }{}^{137}\text{Cs} \end{aligned}$$

$$\begin{aligned} P_{2345} &= P_{23}P_{34}P_{45} \\ &= \left(3.6\text{x}10^{-3}\text{ Bq a kg}^{-1}\text{ per Bq m}^{-2}\right)\left(500\text{ kg a}^{-1}\right)\left(28\text{ nSv Bq}^{-1}\right) \\ &= 50\text{ nSv per Bq m}^{-2}\text{ for }{}^{90}\text{Sr} \end{aligned}$$

or upon separating the P_{23} and P_{34} coefficients into those for the individual food groups:

Equation 4

$$\begin{aligned} P_{2345} &= \left[\Sigma_5\left(P_{23}P_{34}\right)_i\right]P_{45} \\ &= \Big[\left(6.8\text{x}10^{-3}\text{ Bq a kg}^{-1}\text{ per Bq m}^{-2}\right)\left(156.7\text{ kg}^{-1}\right) \\ &\quad+\left(15.7\text{x}10^{-3}\text{ Bq a kg}^{-1}\text{ per Bq m}^{-2}\right)\left(83.3\text{ kg}^{-1}\right) \\ &\quad+\left(3.2\text{x}10^{-3}\text{ Bq a kg}^{-1}\text{ per Bq m}^{-2}\right)\left(123.3\text{ kg}^{-1}\right) \\ &\quad+\left(3.3\text{x}10^{-3}\text{ Bq a kg}^{-1}\text{ per Bq m}^{-2}\right)\left(71.7\text{ kg}^{-1}\right) \\ &\quad+\left(20.1\text{x}10^{-3}\text{ Bq a kg}^{-1}\text{ per Bq m}^{-2}\right)\left(66.7\text{ kg}^{-1}\right)\Big]\left(13\text{ nSv Bq}^{-1}\right) \\ &= 56\text{ nSv per Bq m}^{-2}\text{ for }{}^{137}\text{Cs} \end{aligned}$$

$$\begin{aligned} P_{2345} &= \left[\Sigma_5\left(P_{23}P_{34}\right)_i\right]P_{45} \\ &= \Big[\left(3.7\text{x}10^{-3}\text{ Bq a kg}^{-1}\text{ per Bq m}^{-2}\right)\left(153.3\text{ kg}^{-1}\right) \\ &\quad+\left(9.1\text{x}10^{-3}\text{ Bq a kg}^{-1}\text{ per Bq m}^{-2}\right)\left(85.0\text{ kg}^{-1}\right) \\ &\quad+\left(2.5\text{x}10^{-3}\text{ Bq a kg}^{-1}\text{ per Bq m}^{-2}\right)\left(111.7\text{ kg}^{-1}\right) \\ &\quad+\left(1.8\text{x}10^{-3}\text{ Bq a kg}^{-1}\text{ per Bq m}^{-2}\right)\left(75.0\text{ kg}^{-1}\right) \\ &\quad+\left(1.4\text{x}10^{-3}\text{ Bq a kg}^{-1}\text{ per Bq m}^{-2}\right)\left(70.0\text{ kg}^{-1}\right)\Big]\left(28\text{ nSv Bq}^{-1}\right) \\ &= 52\text{ nSv per Bq m}^{-2}\text{ for }{}^{90}\text{Sr} \end{aligned}$$

where values of 55 and 52 nSv per Bq m^{-2} are provided in Reference 13 (and any differences are due to round-off errors). The above transfer factors can also be defined in terms of their percent contributions as illustrated in Table 30.

3.1.2 I-131 Ingestion Pathway

For I-131, only the milk pathway was assumed significant in the UNSCEAR 1993 Report (which appears a reasonable assumption). The P_{23} value used for I-131 is 0.63 mBq a L^{-1} per Bq m^{-2} [21]. For an average milk consumption rate, P_{34}, of 0.3 L d^{-1} (or 109.5 L a^{-1}), this would give a $P_{234} = P_{23}P_{34}$ coefficient for I-131 of

Equation 5

$$\begin{aligned} P_{234} &\equiv P_{23}P_{34} \\ &= \left[\left(0.63\text{ mBq a L}^{-1}\text{ per Bq m}^{-2}\right)\left(10^{-3}\text{ Bq per mBq}\right)\right]\left(109.5\text{ L a}^{-1}\right) \\ &= 0.07\text{ Bq per Bq m}^{-2}\text{ for }{}^{131}\text{I} \end{aligned}$$

However, age-dependent factors were considered in the UNSCEAR 1993 Report. Milk consumption rates (i.e., age-specific P_{34} values) for age groups of 0-1 year, 1-9 years, 9-19 years, and adult were 330, 180, 150, and 90 L a^{-1}, respectively. However, the P_{34} parameter used in the UNSCEAR 1993 Report to derive the P_{45} coefficient was the average, 109.5 L a^{-1} [13]. This will be explained below.

The population distribution for the same age groups was assumed to be 2, 16, 20, and 62%, respectively, in the UNSCEAR 1993 Report. (The potential differences in population distribution for the countries studied will be discussed during the parameter variation study below.) The individual P_{45} coefficients for the same age groups were 210, 110, 29, and 22 nSv Bq^{-1}, respectively, where the 0-1 age group coefficient used in the UNSCEAR 1993 Report [13] was the average (i.e., 210 nSv Bq^{-1}) of the values for 3 months (240 nSv Bq^{-1}) and 1 year (180 nSv Bq^{-1}) as given in Reference 20. The P_{2345} computed from this information would, therefore, be:

Equation 6

$$\begin{aligned} P_{2345} &= P_{23} \sum_4 (pP_{34} P_{45})_i \\ &= \left(0.63\text{x}10^{-3} \text{ Bq a L}^{-1} \text{ per Bq m}^{-2}\right)\Big[(0.02)\left(330 \text{ L a}^{-1}\right)\left(210 \text{ nSv Bq}^{-1}\right) \text{for 0-1 year} \\ &\qquad + (0.16)\left(180 \text{ L a}^{-1}\right)\left(110 \text{ nSv Bq}^{-1}\right) \text{for 1-9 years} \\ &\qquad + (0.20)\left(150 \text{ L a}^{-1}\right)\left(29 \text{ nSv Bq}^{-1}\right) \text{for 9-19 years} \\ &\qquad + (0.62)\left(90 \text{ L a}^{-1}\right)\left(22 \text{ nSv Bq}^{-1}\right) \text{for adults}\Big] \\ &= 4.2 \text{ nSv per Bq m}^{-2} \text{ for } ^{131}\text{I} \end{aligned}$$

where p_i is the fraction of the population in the specific age group. If an average milk consumption rate of 109.5 L a^{-1} is to be used (to obtained the same P_{25} value of 4.2 nSv per Bq m^{-2} as above), then the necessary P_{45} value would be 60.7 nSv Bq^{-1} [21], which is nominally the same as that, 61 nSv Bq^{-1}, provided in the UNSCEAR 1993 Report. Thus the overall UNSCEAR P_{2345} coefficient for I-131 is given by:

Equation 7

$$\begin{aligned} P_{2345} &= P_{23} P_{34} P_{45} = \left(0.63\text{x}10^{-3} \text{ Bq a L}^{-1} \text{ per Bq m}^{-2}\right)\left(109.5 \text{ L a}^{-1}\right)\left(61 \text{ nSv Bq}^{-1}\right) \\ &= 4.3 \text{ nSv per Bq m}^{-2} \text{ for } ^{131}\text{I}, \end{aligned}$$

which agrees reasonably with the value of 4.2 nSv per Bq m^{-2} given in Reference 13. The above detailed calculations are provided because they are important when deriving new parameters in the parameter variation study below. An alternative development of this ingestion coefficient is also provided in Appendix B.

3.1.3 UNSCEAR Inhalation Pathway

Per the UNSCEAR 1993 Report [13], the transfer coefficient, P_{245}, relating deposition to dose for the inhalation pathway is computed using the following information:

Equation 8

$$\begin{aligned} P_{12} P_{245} &= P_{14} P_{45} \\ P_{245} &= \frac{P_{14} P_{45}}{P_{12}} \end{aligned}$$

where P_{14} is the average breathing rate (i.e., 7300 m^3 a^{-1} [13]), P_{45} is the appropriate dose per unit intake factor in nSv Bq^{-1} for an adult,[10] and P_{12} is the deposition velocity (i.e., assumed to be 1.76 cm

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[10] The text on page 98 of the UNSCEAR 1993 Report [13], which indicates that the inhalation coefficients are in terms of nGy Bq^{-1}, is in disagreement with the values provided in Table 7 in said report, which indicate that these coefficients are in terms of nSv Bq^{-1}. The fact that the normal quality factor, which relates Gy to

s^{-1} or $5.56x10^5$ m a^{-1} for all radionuclides [13]). Using the P_{45} values for inhalation of 8.5, 350, and 13 nSv Bq^{-1} for Cs-137, Sr-90, and I-131, respectively, [13] Equation 8 provides the following transfer coefficients:

$$P_{245} = \frac{P_{14} P_{45}}{P_{12}} = \frac{\left(7300\ \text{m}^3\ \text{a}^{-1}\right)\left(8.5\ \text{nSv Bq}^{-1}\right)}{\left(5.56\text{x}10^5\ \text{m a}^{-1}\right)} = 0.11\ \text{nSv per Bq m}^{-2}\ \text{for}\ ^{137}\text{Cs}$$

$$P_{245} = \frac{P_{14} P_{45}}{P_{12}} = \frac{\left(7300\ \text{m}^3\ \text{a}^{-1}\right)\left(350\ \text{nSv Bq}^{-1}\right)}{\left(5.56\text{x}10^5\ \text{m a}^{-1}\right)} = 4.6\ \text{nSv per Bq m}^{-2}\ \text{for}\ ^{90}\text{Sr}$$

$$P_{245} = \frac{P_{14} P_{45}}{P_{12}} = \frac{\left(7300\ \text{m}^3\ \text{a}^{-1}\right)\left(13\ \text{nSv Bq}^{-1}\right)}{\left(5.56\text{x}10^5\ \text{m a}^{-1}\right)} = 0.17\ \text{nSv per Bq m}^{-2}\ \text{for}\ ^{131}\text{I}$$

which agree with the values in the UNSCEAR 1993 Report. Note that the UNSCEAR 1993 Report absorption assumptions for the inhalation pathway are Class D (days) for I-131 and Cs-137 and Class Y (years) for Sr-90. These classifications changed after the UNSCEAR 1993 Report was issued; however, the older nomenclature is used so it will be consistent with the information from the 1993 Report.

3.1.4 UNSCEAR External Irradiation

In addition to internal radiation from inhaled or ingested radionuclides, people are also irradiated externally from gamma-emitting nuclides dispersed in air and on the ground. As the contamination normally spends much more time on the ground than in the air, the external dose due to irradiation from the earth's surface is normally significantly higher[11] than the dose due to irradiation while the cloud of contamination passes [13]. Therefore, the external exposure due to radioactive cloud passage will be assumed negligible for the purpose of this study (as it was in the UNSCEAR 1993 Report [13]).

In the UNSCEAR 1993 Report [13], the P_{25} transfer coefficients for external irradiation due to ground contamination were computed by multiplying the appropriate exposure rate [22] by the mean lifetime of the radionuclide (i.e., half-life divided by ln(2)) and then by an average factor assuming 80% indoor occupancy with a shielding factor of 0.2. The latter factor also incorporates a factor of 0.7 Sv per Gy accounting for the equivalent dose rate in the body per unit absorbed dose rate in air [13]). For I-131, the dose rate conversion factor applying to an infinite plane source [22] is $7.30x10^{-3}$ mR h^{-1} per mCi km^{-2}, which is converted to the units used in this report via:

Equation 9

$$\begin{aligned}
&\left(7.30\text{x}10^{-3}\ \mu\text{R h}^{-1}\ \text{per mCi km}^{-2}\right)\left(1\ \text{R per}\ 10^6\ \mu\text{R}\right)\left(0.876\ \text{rad per R}\right)\\
&\quad \text{x}\left(1\ \text{Gy per 100 rad}\right)\left(10^9\ \text{nGy per Gy}\right)\left(1\ \text{h per}\ 60^2\ \text{s}^{-1}\right)\left(1000\ \text{mCi per Ci}\right)\\
&\quad \text{x}\left(2.703\text{x}10^{-11}\ \text{Ci per Bq}\right)\left(1000^2\ \text{m}^2\ \text{per km}^2\right)\\
&= 4.8\text{x}10^{-7}\ \text{nGy s}^{-1}\ \text{per Bq m}^{-2}\ \text{for}\ ^{131}\text{I}
\end{aligned}$$

Sv, is unity for the types of radiation involved means that these coefficients should be interchangeable for the radionuclides considered; however, this issue will arise below when external radiation is considered.

11 "The average ratio of the absorbed dose from ground surface contamination to that from immersion is proportional to the half-life of the radionuclide and is, for example, of the order of 100 for short-lived ^{140}Ba [with a half-life of 12.75 days] and 1,000,000 for long-lived ^{137}Cs [with a half-life of 31.14 years] [13]." Thus the ratio will be somewhat less than 100 for the short-lived ^{131}I, but still not likely to be significant.

where the value of 0.876 rad per R [23] is based upon 33.97 eV per ion pair[12]. Using the mean lifetime of I-131 (with half-life, $t_{1/2}$, of $6.95x10^5$ s [6]); indoor occupancy rate, R_i, of 80% (or 0.80 fraction); shielding factor, S_h, of 0.2; and conversion from nGy to nSv of 0.7 provides the following P_{25} transfer factor for I-131:

Equation 10

$$\begin{aligned} P_{25} &= (0.7 \text{ nSv per nGy})(4.8x10^{-7} \text{ nGy s}^{-1} \text{ per Bq m}^{-2})\left(\frac{t_{1/2}}{\ln(2)} s\right)[(1-R_i)+R_iS_h] \\ &= (0.7 \text{ nSv per nGy})(4.8x10^{-7} \text{ nGy s}^{-1} \text{ per Bq m}^{-2})\left(\frac{6.95x10^5}{\ln(2)} s\right)[(1-0.8)+(0.8)(0.2)] \\ &= 0.12 \text{ nSv per Bq m}^{-2} \text{ for } {}^{131}\text{I} \end{aligned}$$

which agrees with the value in the UNSCEAR 1993 Report [13]. No value was given for Sr-90 (likely because Sr-90 is a pure beta emitter).

For Cs-137, the exposure rate of $4.32x10^{-3}$ mR h^{-1} per mCi km^{-2} applying to an exponential concentration profile in the ground with mean depth 3 cm was used[13]. This is converted to the units used in this report via:

Equation 11

$$\begin{aligned} &(4.32x10^{-3} \ \mu\text{R h}^{-1} \text{ per mCi km}^{-2})(1 \text{ R per } 10^6 \ \mu\text{R})(0.876 \text{ rad per R}) \\ &\quad x(1 \text{ Gy per 100 rad})(10^9 \text{ nGy per Gy})(1 \text{ h per } 60^2 \text{ s}^{-1})(1000 \text{ mCi per Ci}) \\ &\quad x(2.703x10^{-11} \text{ Ci per Bq})(1000^2 \text{ m}^2 \text{ per km}^2) \\ &= 2.84x10^{-7} \text{ nGy s}^{-1} \text{ per Bq m}^{-2} \text{ for } {}^{137}\text{Cs} \end{aligned}$$

Using the mean lifetime of Cs-137 (with half-life, $t_{1/2}$, of $9.50x10^8$ s [6]); indoor occupancy rate, R_i, of 80% (or 0.80 fraction); shielding factor, S_h, of 0.2; and conversion from nGy to nSv of 0.7 provides the following P_{25} transfer factor for Cs-137:

Equation 12

$$\begin{aligned} P_{25} &= (0.7 \text{ nSv per nGy})(2.84x10^{-7} \text{ nGy s}^{-1} \text{ per Bq m}^{-2})\left(\frac{t_{1/2}}{\ln(2)} s\right)[(1-R_i)+R_iS_h] \\ &= (0.7 \text{ nSv per nGy})(2.84x10^{-7} \text{ nGy s}^{-1} \text{ per Bq m}^{-2})\left(\frac{9.50x10^5}{\ln(2)} s\right)[(1-0.8)+(0.8)(0.2)] \\ &= 98 \text{ nSv per Bq m}^{-2} \text{ for } {}^{137}\text{Cs} \end{aligned}$$

which agrees well with the value in the UNSCEAR 1993 Report of 97 nSv per Bq m^{-2}. The above derivations are provided because they are necessary to derive new coefficients for the parameter variation study below.

To summarize, the UNSCEAR values for the external exposure P_{25} coefficients for Cs-137, I-131, and Sr-90 were 97, 0.12, and 0 nSv per Bq m^{-2}, respectively, which compare well to those computed in this report as a check on the methodology (and will subsequently be used to examine the sensitivity to variations in the various parameters used to compute the aforementioned values). Thus the deposition-to-dose transfer coefficients needed to estimate dose commitments for the deposition values summarized in Table 4, Table 10, Table 14 for PRS and Table 18, Table 22, and Table 26 for the VRS.

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12 In these calculations and the ones to follow, the small fraction of photon energy that is converted to electrons and then not absorbed due to bremmstrahlung production by electrons is assumed negligible.

13 In Reference 22, the exposure rate for Cs-137 at a relaxation length of 4.8 g cm^{-2} in soil is given as $4.32x10^{-3}$ mR h^{-1} per mCi km^{-2}. The soil density is not provided in Reference 13, thus it is assumed to be 1.6 g cm^{-3} giving the corresponding exposure rate at a depth of 3 cm.

3.1.5 UNSCEAR Deposition-to-Dose Transfer Coefficient Summary

The various transfer coefficients needed to translate from deposition to effective dose commitments are summarized in Table 31. The Cs-137 dose commitments are dominated by the external exposure pathway with a significant contribution from ingestion; the inhalation pathway plays little part in the dose commitment. For Sr-90 and I-131, the ingestion pathway dominates with little contribution from either inhalation or external exposure.

3.2 UNSCEAR Maximum Effective Dose Commitment Estimates

Using Equation 8 and the assumption that the irradiation due to cloud passage can be assumed negligible, Equation 2 can be rewritten as

Equation 13

$$\begin{aligned} D_c &= (P_{01}P_{12}A_0)[\underset{\text{ingestion}}{P_{2345}} + \underset{\text{inhalation}}{P_{245}} + \underset{\text{external ground}}{P_{25}}] \\ &= (P_{01}P_{12}A_0)[\underset{\text{ingestion}}{\Sigma_5 (P_{23}P_{34})P_{45}} + \underset{\text{inhalation}}{(P_{14}P_{45})/P_{12}} + \underset{\text{external ground}}{P_{25}}] \end{aligned}$$

where the term, $P_{01}P_{12}A_0$, in the parentheses is the total deposition of the radionuclide in question for a given area and each of the terms in the brackets represent the corresponding UNSCEAR deposition-to-dose transfer factor identified above (where the ingestion pathway is limited to five food groups). As an example of how to use these factors, the maximum total Cs-137 deposition for the PRS (on a regional basis) is given in Table 4 as $2.78\text{x}10^4$ Bq m^{-2}. To convert this deposition to dose, the UNSCEAR 1993 transfer factors for Cs-137 defined above can be used:

Equation 14

$$\begin{aligned} D_c &= (P_{01}P_{12}A_0)[\underset{\text{ingestion}}{P_{2345}} + \underset{\text{inhalation}}{P_{245}} + \underset{\text{external ground}}{P_{25}}] \\ &= (2.78\text{x}10^4 \text{ Bq m}^{-2})\left[\underset{\text{ingestion}}{55 \text{ nSv per Bq m}^{-2}} + \underset{\text{inhalation}}{0.11 \text{ nSv per Bq m}^{-2}} + \underset{\text{external ground}}{97 \text{ nSv per Bq m}^{-2}}\right] \\ &\quad \text{x } (1000 \text{ mSv per } 10^{-9} \text{ nSv}) \\ &= 4.22 \text{ mSv per person for } {}^{137}\text{Cs.} \end{aligned}$$

Thus for the PRS, the maximum dose commitment to an adult individual is approximately 4 mSv (or 0.4 rem), which is less than twice the average annual background radiation dose (2.4 mSv) for the area under study [13]. The maximum total Cs-137 deposition for the VRS is $2.64\text{x}10^4$ Bq m^{-2} from Table 18. This translates into an effective, committed dose of 4.01 mSv (or 0.4 rem) per person using a computation similar to that provided in Equation 14. The proximity of these maximum values may be surprising; however, these maximum values are both found in Russia near the risk site, which explains why these values can be approximately the same. On the other hand, the maximum effective Cs-137 dose commitment for the VRS transboundary area is approximately five times that for the PRS because the effected populations are at greater distances from the source of the release.

Transboundary effects will also be considered below. Unlike those for the depositions above (where the ocean outside of Russia was examined), the transboundary dose commitments will only be computed for those areas on land. It makes little or no sense to compute a dose commitment from the ingestion pathway on areas of the ocean. Furthermore, even those ocean areas where fisherman may be impacted are excluded because there is little chance that the fishermen will spend enough time at sea to have the long-term dose commitments computed in this report. If desired, the depositions presented earlier can be used to examine the impact of acute doses of radiation; however, that is not the purpose of this study nor is it likely that the values determined in this report would lead to significant acute doses. It is outside the scope of this report to examine the deposition on the oceans, uptake by fish, and subsequent doses to consumers; however, this could be done with the deposition values provided in this report.

3.2.1 UNSCEAR Maximum Effective Dose Commitments for the PRS

Using the transfer factors described above, the effective dose commitments for the maximum total depositions for Cs-137, Sr-90, and I-131 corresponding to the values in Table 4, Table 10, and Table 14, respectively, were computed for the PRS. For Cs-137, Table 32 provides the total, maximum effective dose commitment for the region and each country as well as the components of the total by type (i.e., ingestion, inhalation, and external exposure).

On the basis of individual countries, the maximum, non-zero dose commitments in Table 32 for Cs-137 releases from the PRS can be summarized by the following rank ordering:

PRS Cs-137: Regional = Russia >> Alaska (U.S.) > Aleutians (U.S.) > Japan > China > N. Korea > Mongolia > S. Korea.

In other words, the maximum dose commitment is found in Russia (as expected), which is almost two orders of magnitude higher than that for any country. However, despite its proximity to the PRS, China will be impacted by smaller doses than either the U.S. territories or Japan, which shows the importance of wind circulation patterns. It can be noted that separating the Aleutian Islands from the remainder of the U.S. territory (namely Alaska) considered in this study had little impact on the results.

Figure 19 illustrates the frequency and cumulative percentages for the Cs-137 maximum effective dose commitments for the land areas in the region of study. As described above, the maximum total Cs-137 deposition translates into a committed dose of approximately 4 mSv (or 0.4 rem) per person, which can be considered a reasonably low dose commitment. It should also be noted that 95% of the maximum dose commitments are less than 1.6 mSv (or 0.16 rem) per person, which indicates that most of the dose commitments are much less than the maximum (as illustrated in Figure 19). Furthermore, 85% of the maximum dose commitments are less than 0.94 mSv or 0.09 rem per person. Finally, almost 98% of all the maximum dose commitments for CY2000 are less than the average annual background radiation dose of 2.4 mSv [13], and the maximum UNSCEAR dose commitment of 4.22 mSv is less than twice that from background radiation. Thus the maximum Cs-137 dose commitments from the PRS releases appear to be relatively low and within the variation expected in background radiation doses for the area under study [13].

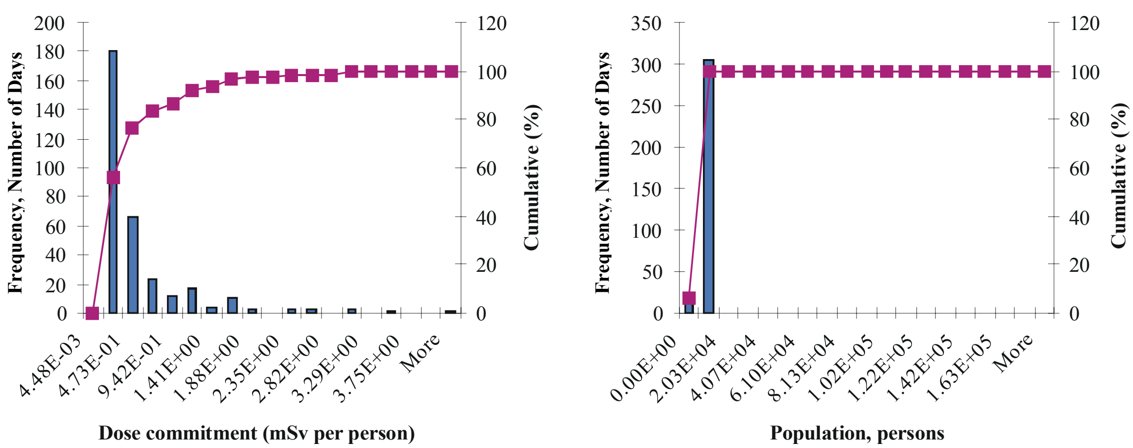


Figure 19. Frequency histogram and cumulative percentages for the PRS Cs-137 maximum effective dose commitments (left) and corresponding populations (right).

Figure 20 illustrates the results for the transboundary conditions provided in Table 32. There is a significant impact on the maximum dose commitment (where the maximum transboundary dose commitment of 0.2 mSv per person in Alaska) is more than an order of magnitude less than that for Russia. It is also interesting to note that the numbers of people impacted by the transboundary doses appear to be much higher than that in Russia. However, the maximum transboundary dose commitment (of approximately 0.2 mSv) is negligible when compared to the annual average background radiation (of 2.4 mSv) in the area of study.

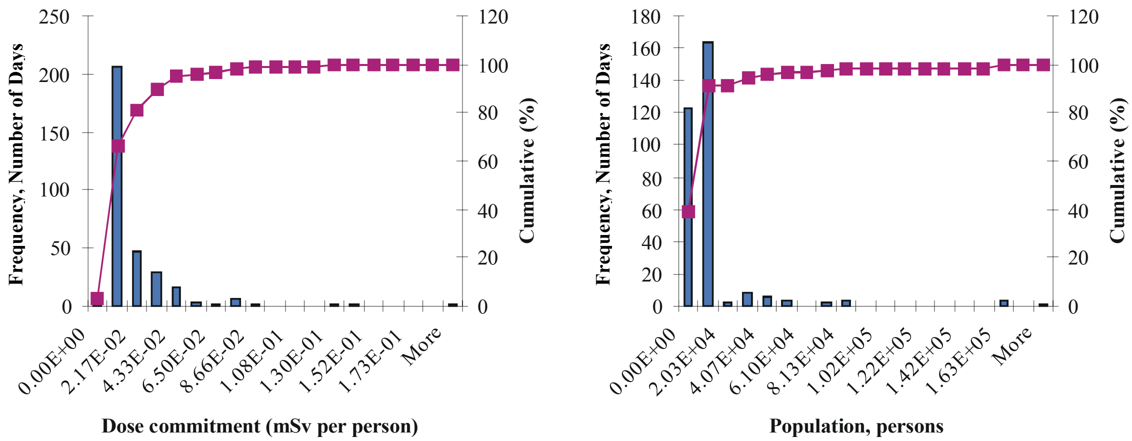


Figure 20. Transboundary frequency histogram and cumulative percentages for the PRS Cs-137 maximum effective dose commitments (left) and corresponding populations (right).

For the Sr-90 values computed from the PRS Cs-137 results as described above, Table 33 provides the total, maximum effective dose commitment for the region and each country as well as the components of the total by type (i.e., ingestion, inhalation, and external exposure which is zero for Sr-90). Note that these follow the same general patterns as the PRS Cs-137 dose commitments described above.

Figure 21 illustrates the frequency and cumulative percentages for the Sr-90 maximum effective dose commitments for the region of study. The maximum total Sr-90 deposition of 2.86×10^4 Bq m^{-2} from Table 10 translates into a maximum, committed dose of 1.6 mSv (or 0.16 rem) per person, which is only approximately two-thirds that of the average annual background radiation dose (2.4 mSv). It should be noted that 95% of the maximum dose commitments are less than 0.70 mSv (or 0.07) rem per person and 85% of the maximum dose commitments are less than 0.36 mSv (or 0.04) rem per person. This indicates that the majority of dose commitments are much less than the maximum (as illustrated in Figure 21). Furthermore, all the maximum dose commitments are less than the average annual background radiation dose (2.4 mSv).

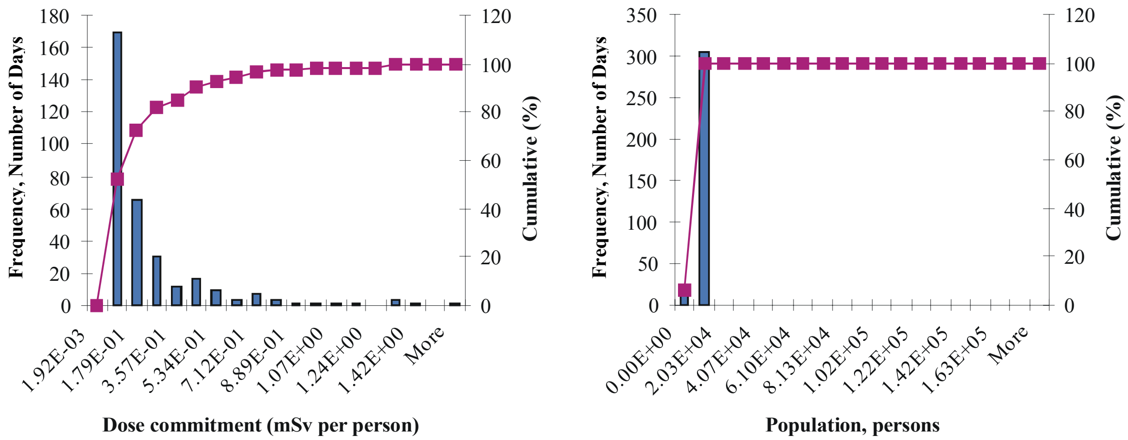


Figure 21. **Frequency histogram and cumulative percentages for the PRS Sr-90 maximum effective dose commitments (left) and corresponding populations (right).**

Figure 22 illustrates the results for the transboundary conditions; all the maximum dose commitments are less than the average annual background dose. Note that the results are necessarily similar to those for Cs-137.

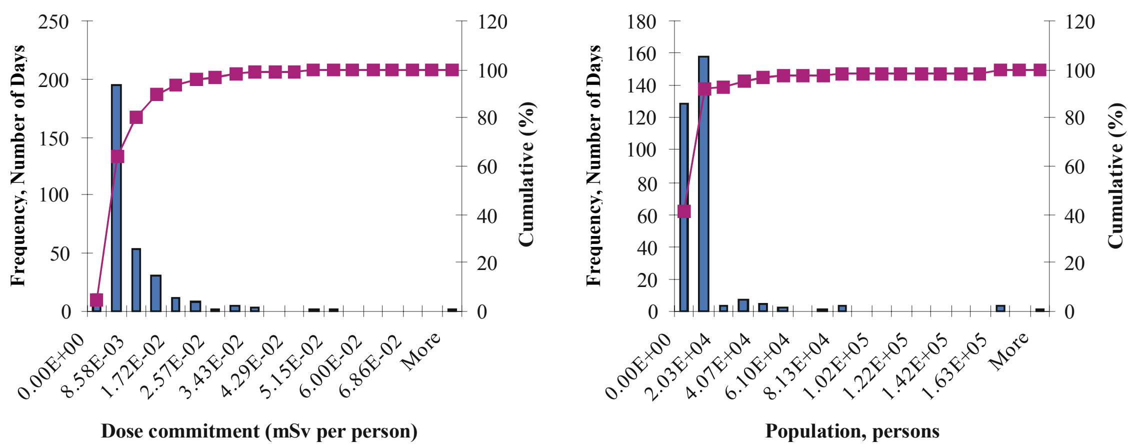


Figure 22. **Transboundary frequency histogram and cumulative percentages for the PRS Sr-90 maximum effective dose commitments (left) and corresponding populations (right).**

For the I-131 values computed from the PRS Cs-137 results as described above, Table 34 provides the total, maximum effective dose commitment for the region and each country as well as the components of the total by type (i.e., ingestion, inhalation, and external exposure). The maximum total dose commitment again resides within Russia, and the maximum dose commitments for all other countries are lower by almost two orders of magnitude.

Figure 23 illustrates the frequency and cumulative percentages for the I-131 maximum effective dose commitments for the region of study. The maximum total deposition of 4.65×10^{4} Bq m^{-2} from Table 14 translates into a committed dose of 0.18 mSv (or 0.02 rem) per person as illustrated in Table 34, which is less than one-tenth that of the average annual background dose [13]. It should be noted that 95% of the maximum dose commitments are less than 0.08 mSv or 0.01 rem per person (and 85% are less than 0.04 mSv per person). As illustrated in Figure 23, this indicates that many of the dose commitments from I-131 are significantly lower than the maximum as would be expected.

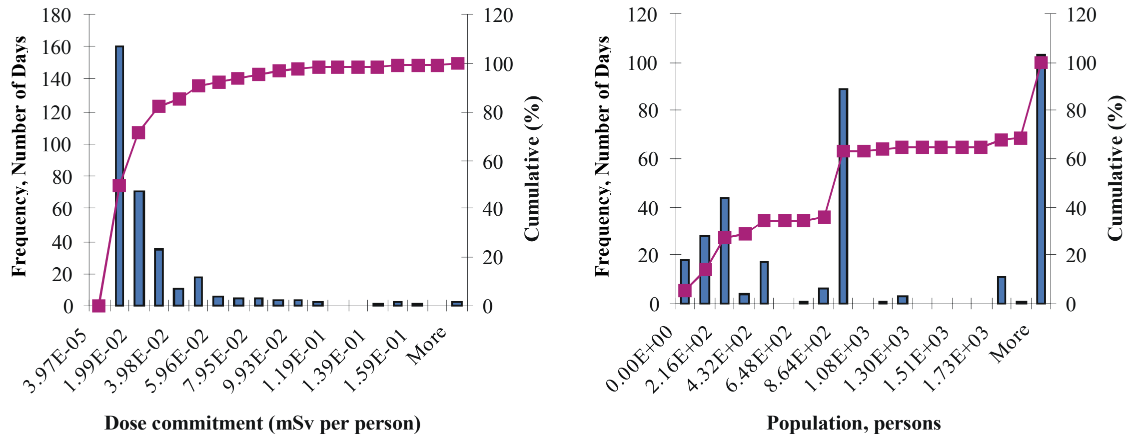


Figure 23. Frequency histogram and cumulative percentages for the PRS I-131 maximum effective dose commitments (left) and corresponding populations (right).

Figure 24 illustrates the results for the transboundary conditions. Note the maximum I-131 dose of 2.4×10^{-3} mSv per person outside of Russia is almost two orders of magnitude less than within. This illustrates that the impacts of I-131 will be most significant in the areas near the risk sites for the conditions considered in this study.

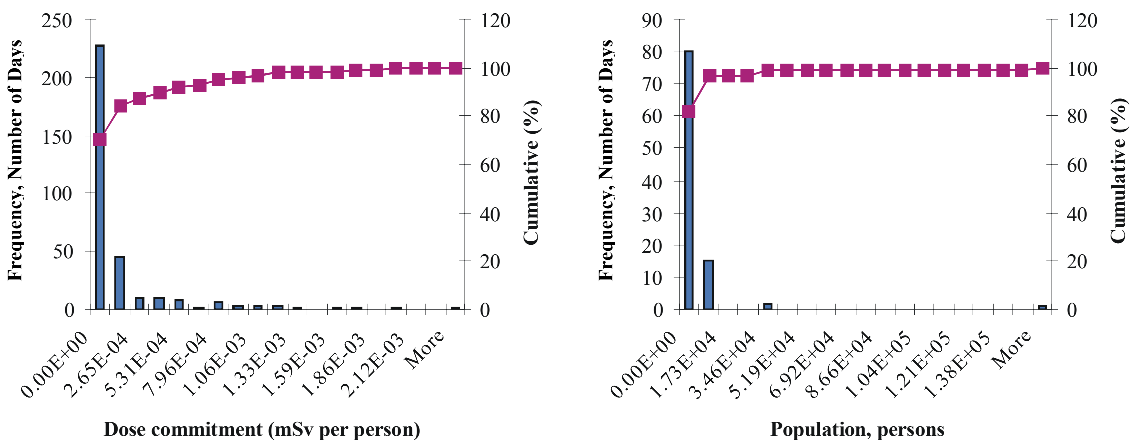


Figure 24. Transboundary frequency histogram and cumulative percentages for the PRS I-131 maximum effective dose commitments (left) and corresponding populations (right).

3.2.1.1 Specific Case Examples: Japan and U.S. Dose Commitments from the PRS

As explained above, the Cs-137 results for Japan and the U.S. territories considered in this study are provided. Figure 25 illustrates the maximum dose commitments from the PRS for Japan. (Note the similarity of appearance with Figure 9 above.) Note that there are doses on only approximately 25% of CY2000 days and that the maximum dose commitment of 4×10^{-2} mSv per person appears to be an isolated event. The maximum dose commitments will be less than 2×10^{-3} mSv per person on approximately 95% of CY2000 days for Japan. All such dose commitments are negligible when compared to the average annual background dose of 2.4 mSv.

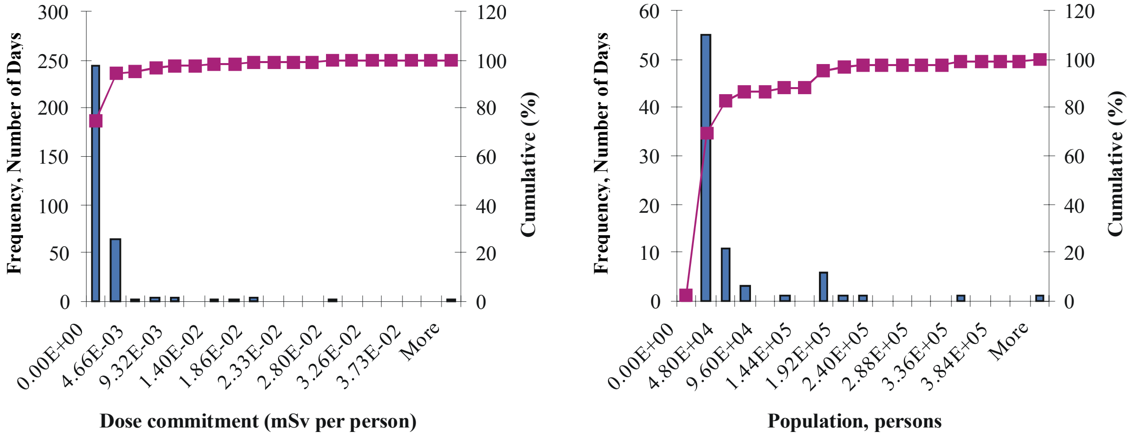
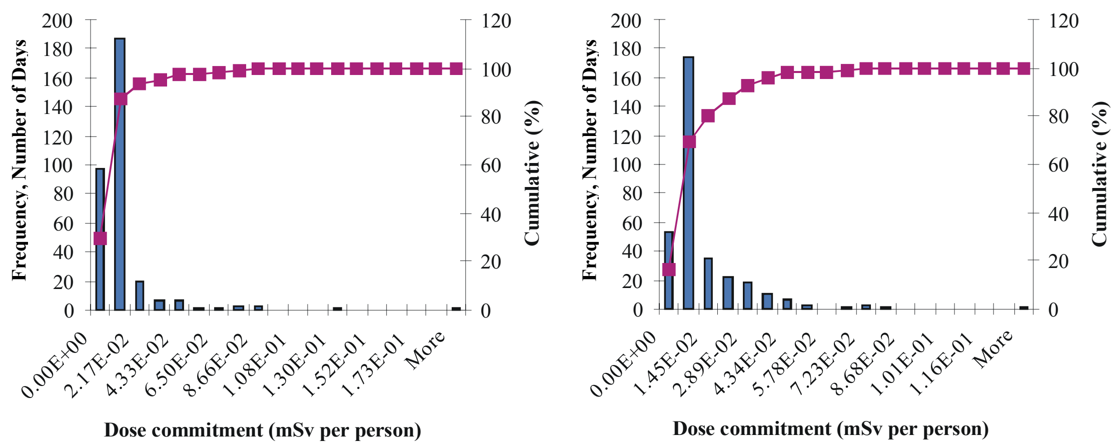


Figure 25. Japan Results: Frequency histogram and cumulative percentages for the PRS Cs-137 maximum effective dose commitments (left) and corresponding populations (right).

The histograms illustrating the dose commitments for the U.S. territories considered in this study are provided in Figure 26. Note that the dose commitments are approximately an order of magnitude higher than those in Japan (as illustrated in Figure 25). There is also a much higher frequency of deposition from the PRS for both Alaska (in Figure 26a) and the Aleutian Islands (in Figure 26b) than in Japan. Again the maximum dose commitments of 0.20 and 0.13 mSv per person for Alaska and the Aleutian Islands, respectively, appear to be isolated cases and occur within approximately three weeks of each other early in the year (i.e., before 18-Feb-2000) resulting from the winter winds. The maximum deposition in Japan, on the other hand, occurred late in April (i.e., during the shoulder season). Again all such maximum dose commitments are negligible when compared to the average annual background dose.



(a) Alaska (U.S.)

(b) Aleutian Islands (U.S.)

Figure 26. U.S. Results: Frequency histogram and cumulative percentages for the PRS Cs-137 maximum effective dose commitments for Alaska (left) and the Aleutian Islands (right).

3.2.2 Verifying the PRS Dose Commitment Estimates Using RESRAD

The UNSCEAR-based dose commitments are checked using the RESRAD 6 [24] code. Argonne National Laboratory (ANL) developed the RESRAD code in support of U.S. Department of Energy (DOE) order (DOE Order 5400.5) establishing guidelines for residual radioactive material [25]. The DOE and other U.S. agencies including Environmental Protection Agency (EPA), Army Corps of

Engineers, Nuclear Regulatory Commission (NRC) have used RESRAD to derive cleanup criteria and dose calculations. The doses computed by RESRAD are the effective dose equivalent from external radiation (using the Federal Guidance Report No. 12, FGR-12, [26] information as default) and the committed effective dose equivalent from internal radiation [24]. All important exposure pathways for the critical population group must be considered in deriving soil guidelines. These pathways include the following:

- Direct exposure to external radiation from the contaminated soil material;
- Internal dose from inhalation of airborne radionuclides, including radon progeny, which are not considered in this study; and
- Internal dose from ingestion of
    - Plant foods grown in the contaminated soil and irrigated with contaminated water,
    - Meat and milk from livestock fed with contaminated fodder and water,
    - Drinking water from a contaminated well or pond,
    - Fish from a contaminated pond, and
    - Contaminated soil.

These exposure pathways are considered in RESRAD and, therefore, this code appears an appropriate choice for verifying the dose commitments estimated using the methodology in the UNSCEAR 1993 Report.

To verify the doses estimated in this report using RESRAD, a number of RESRAD default values were modified to be consistent with those of the UNSCEAR 1993 Report [13]. An example set of the input data of interest for running RESRAD is provided in Table 35 for 01-JAN-2000. For a given cell with total predicted deposition [6], the area, `AREA`, of the contaminated zone is set to be the size of the area of the cell as computed by MatLab [8]. The thickness, `THICK0`, of the contaminated zone is set to the same depth, 3 cm or $3x10^{-2}$ m, used in the UNSCEAR calculations for Cs-137 external exposure [13]. The initial radionuclide concentration, `S1(1)`, for RESRAD was computed using the initial maximum deposition, in this example 4260 Bq m^{-2}, using the following relationship:

Equation 15

$$\begin{aligned}\texttt{S1(1)} &= \frac{\left(4.26\text{x}10^{3}\ \text{Bq m}^{-2}\right)}{\left(\texttt{DENSCZ}\,\text{g cm}^{-3}\right)\left(100^{3}\ \text{cm}^{3}\ \text{m}^{-3}\right)\left(\texttt{THICK0}\,\text{m}\right)} \\ &= \frac{\left(4.26\text{x}10^{3}\ \text{Bq m}^{-2}\right)}{\left(1.5\ \text{g cm}^{-3}\right)\left(100^{3}\ \text{cm}^{3}\ \text{m}^{-3}\right)\left(3\text{x}10^{-2}\ \text{m}\right)} \\ &= 9.47\text{x}10^{-2}\ \text{Bq g}^{-1}\end{aligned}$$

which is the value provided in Table 35. The values in Table 35 are provided to RESRAD 6 and the corresponding doses obtained. A system was developed using the Microsoft® Word 2000 MailMerge tool (e.g., see Listing 1 in Appendix C) with a Microsoft® Excel 2000 input file (as shown in Listing 2 in Appendix C) to generate two sets of 326 input files (or one for each day for each radionuclide) for the maximum total Cs-137 and Sr-90 depositions for the PRS.[14] Then MatLab [8] was used as a shell program to process the files in RESRAD 6 (as illustrated in Listing 3 in Appendix C),[15] and the results for Cs-137 and Sr-90 parsed into two final sets of 326 different combinations of doses (as computed in RESRAD 6) on a mSv per year basis. The MatLab files used to parse the RESRAD dose information are provided in Listings 4 and 5 in Appendix C. The resulting doses were multiplied by the 50-y exposure period used to make them comparable to the values computed using the UNSCEAR 1993 Report methodology.

The total doses from RESRAD 6 for Cs-137 and Sr-90 are compared to those obtained from the UNSCEAR 1993 Report methodology in Figure 27 and Figure 28, respectively. Note that although the values from the individual pathways vary somewhat, the total dose commitments for Cs-137 are

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14 Note that because of its very short half-life (i.e., 8 days), I-131 is not available in RESRAD 6 and could not be checked for this report.

15 The executable file, `RESCALC.exe`, from RESRAD 6 was used to perform the calculations for this report.

virtually the same and those for Sr-90 are within 56% of each other throughout the range of data. Much of the difference in the Sr-90 values can be explained using the following rationale. The Sr-90 dose commitments are dominated by ingestion. As described above, the ingestion P_{45} transfer factor used in the UNSCEAR 1993 Report is 28 nSv Bq^{-1} for Sr-90. The default factor used in RESRAD 6 [25] is 38.5 nSv Bq^{-1} from Federal Guidance Report No. 11 or FGR-11 [27]. This accounts for most of the difference in the dose commitments. It should be further noted that the ingestion P_{45} transfer coefficient for Cs-137 used in the UNSCEAR 1993 Report (i.e., 13 nSv Bq^{-1} [13]) and RESRAD 6 (i.e., 13.5 nSv Bq^{-1} from [27]) are very close. Furthermore, the Cs-137 dose is dominated by external exposure; it is expected that these values should change little from the time of the UNSCEAR 1993 Report and the basis [26] for the RESRAD 6 computations.

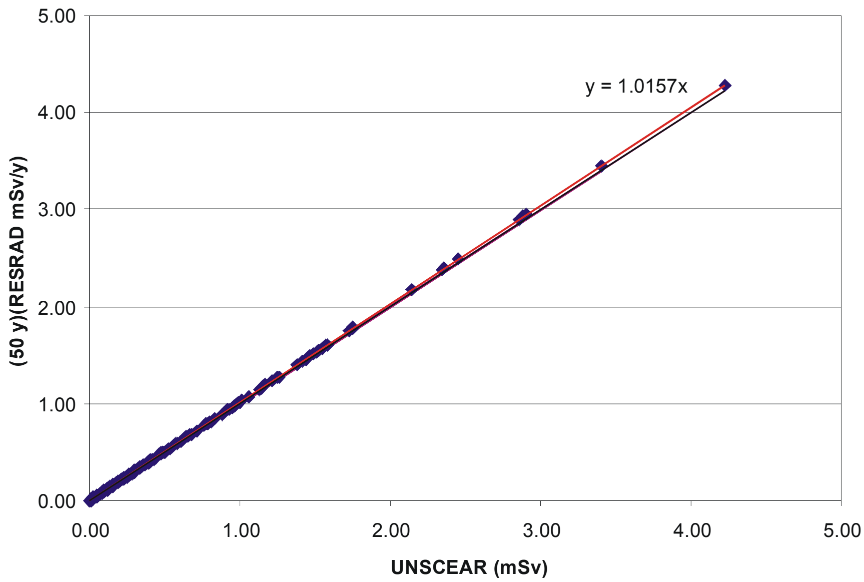


Figure 27. Comparison of RESRAD 6 Cs-137 Results (after multiplication by a 50-y exposure period) to those from the UNSCEAR 1993 Report. Values are total dose commitments in mSv $person^{-1}$.

Because of the proportional nature between the doses computed using RESRAD 6 and the UNSCEAR 1993 Report methodology, this verification will not be repeated for subsequent dose commitment calculations. However, information from FGR-11 [27] will be considered below in the parameter variation study to assure that the dose commitments cited in this report consider all relevant sources of information.

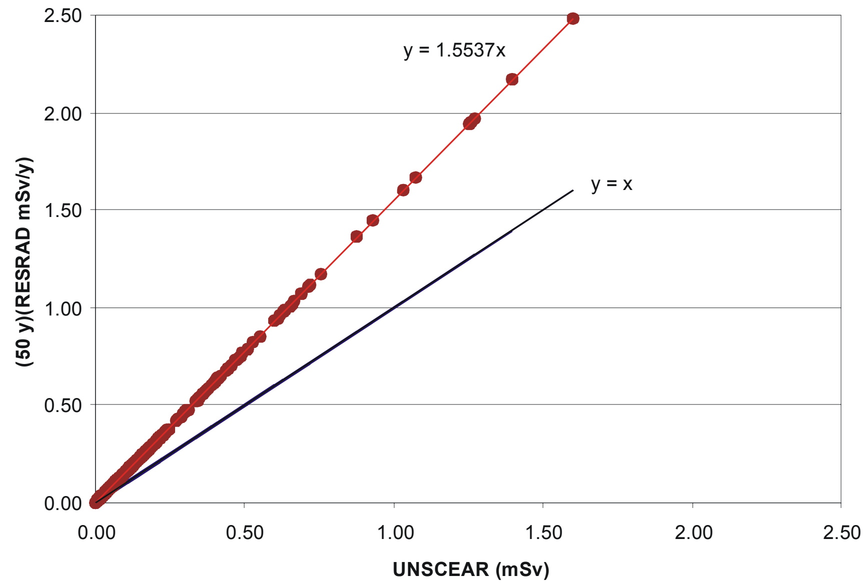


Figure 28. Comparison of RESRAD 6 Sr-90 Results (after multiplication by a 50-y exposure period) to those from the UNSCEAR 1993 Report. Values are total dose commitments in mSv person^{-1}.

3.2.3 Maximum Effective Dose Commitments for the VRS

Using the transfer factors described above, the effective dose commitments for the maximum total depositions for Cs-137, Sr-90, and I-131 corresponding to the values in Table 18, Table 22, and Table 26, respectively, were computed for the VRS. For Cs-137, Table 36 provides the total, maximum effective dose commitment for the region and each country as well as the components of the total by type (i.e., ingestion, inhalation, and external exposure). Note that the maximum, non-zero total dose commitments for the VRS are ordered as follows:

VRS Cs-137: Region = Russia > China > N. Korea > Japan > Taiwan > Alaska (U.S.) > Mongolia > Aleutians (U.S.) > Hong Kong > Vietnam

Therefore, even though the maximum dose commitment resides in Russia (as found for the PRS results), the values for other surrounding countries (e.g., China, N. Korea, and Japan) are not orders of magnitude lower than that for Russia, but approximately four to eight times lower. This will be significant if the dose commitments are large enough to be of concern.

Figure 29 illustrates the frequency and cumulative percentages for the Cs-137 maximum effective dose commitments for the region of study. The maximum total Cs-137 deposition of 2.64×10^4 Bq m^{-2} from Table 18 translates into an effective dose commitment of approximately 4 mSv (or 0.4 rem) per person as indicated in Table 36, which is less than twice the average annual background dose of 2.4 mSv [13] and thus within what could be considered normal variation of the background dose. It should also be noted that 95% of the maximum dose commitments are less than 1.35 mSv or 0.13 rem per person, which indicate that most of the dose commitments are much less than the maximum (as illustrated in Figure 29). Furthermore, 85% of the maximum dose commitments are less than 0.68 mSv (or 0.07 rem) per person. Finally, over 98% of all maximum dose commitments for CY2000 are less than the average annual background dose.

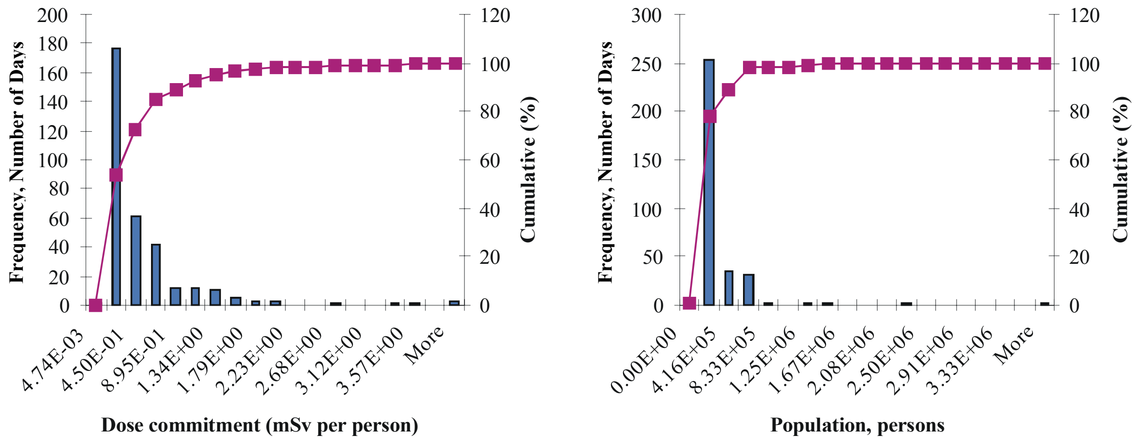


Figure 29. Frequency histogram and cumulative percentages for the VRS Cs-137 maximum effective dose commitments (left) and corresponding populations (right).

Figure 30 illustrates the results for the transboundary conditions provided in Table 36. There are less significant impacts on the maximum dose commitment (i.e., by about a factor of four) or population than for the PRS. This is because of the proximity of China to the VRS as illustrated in Figure 1. For these conditions, N. Korea will have the next highest (to China) dose commitment of 0.65 mSv per person, which is considerably smaller than the average annual background dose.

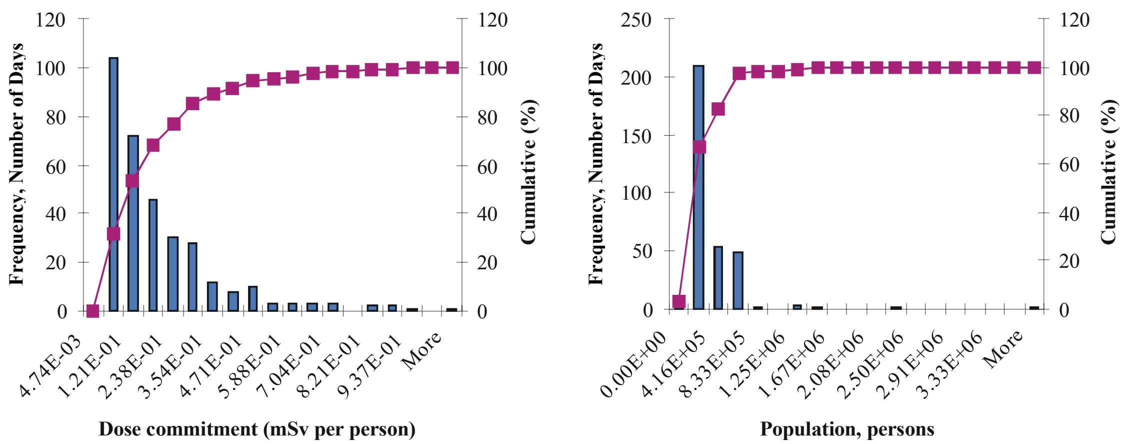


Figure 30. Transboundary frequency histogram and cumulative percentages for the VRS Cs-137 maximum effective dose commitments (left) and corresponding populations (right).

For the Sr-90 values computed from the VRS Cs-137 results as described above, Table 37 provides the total, maximum effective dose commitment for the region and each country as well as the components of the total by type (i.e., ingestion, inhalation, and external exposure which are zero for Sr-90). Note that the dose commitment ordering is the same as that for the VRS Cs-137 results.

Figure 31 illustrates the frequency and cumulative percentages for the Sr-90 maximum effective dose commitments for the region of study. The maximum total Sr-90 deposition of 3.26×10^4 Bq m^{-2} from Table 22 translates into a maximum, committed dose of 1.69 mSv (or 0.17 rem) per person (as indicated in Table 37), which is significantly less than the average annual background dose of 2.4 mSv. It should be noted that 95% of the maximum dose commitments are less than 0.57 mSv (or 0.06 rem) per person and 85% of the maximum dose commitments are less than 0.29 mSv (or 0.03 rem) per person. This indicates that the majority of dose commitments are much less than the maximum (as illustrated in Figure 31). Figure 32 illustrates the transboundary results, which necessarily follow those for Cs-137 above.

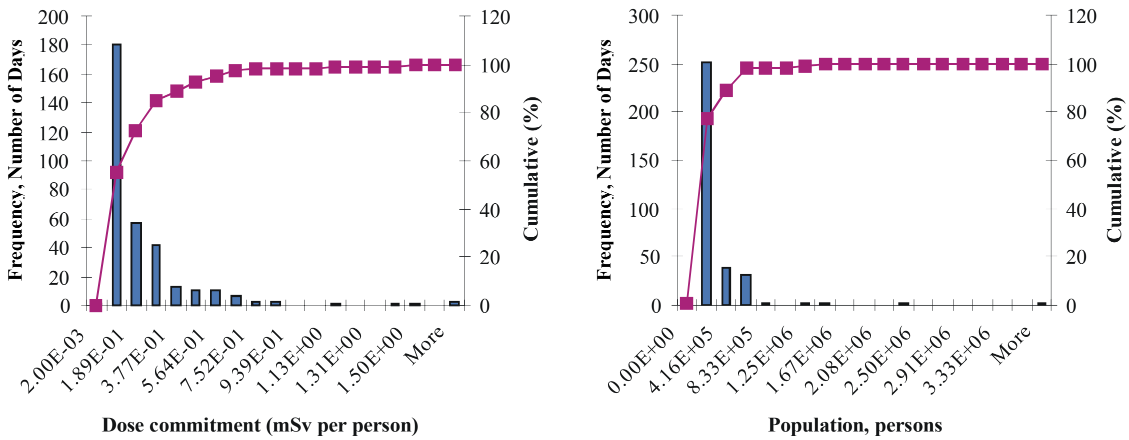


Figure 31. Frequency histogram and cumulative percentages for the VRS Sr-90 maximum effective dose commitments (left) and corresponding populations (right).

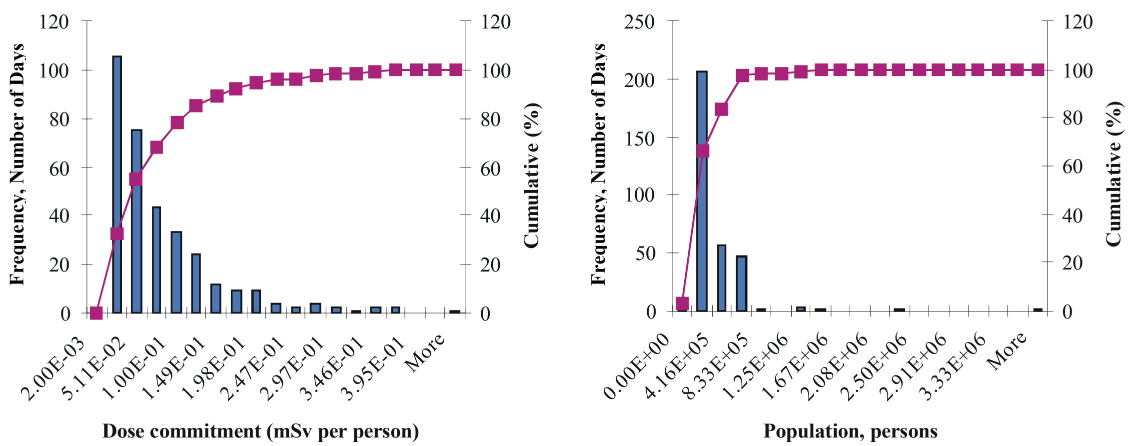


Figure 32. Transboundary frequency histogram and cumulative percentages for the VRS Sr-90 maximum effective dose commitments (left) and corresponding populations (right).

For the I-131 values computed from the VRS Cs-137 results as described above, Table 38 provides the total, maximum effective dose commitment for the region and each country as well as the components of the total by type (i.e., ingestion, inhalation, and external exposure). The ordering of the VRS I-131 results generally agrees with that for the Cs-137 and Sr-90 except for those additional countries that have no dose commitments.

Figure 33 illustrates the frequency and cumulative percentages for the I-131 maximum effective dose commitments for the region of study. The maximum total deposition of 5.28×10^4 Bq m^{-2} from Table 26 translates into a committed dose of 0.25 mSv (or 0.03 rem) per person as illustrated in Table 38, which is almost an order of magnitude lower than the average annual background dose of 2.4 mSv [13]. It should be noted that 95% of the maximum dose commitments are less than 0.08 mSv (or 0.01 rem) per person. As illustrated in Figure 33, this indicates that many of the dose commitments from I-131 are significantly lower than the maximum. Figure 34 illustrates the transboundary results for I-131 from the VRS. These results again illustrate that the impact on the transboundary region for releases from the VRS are smaller than those from the PRS.

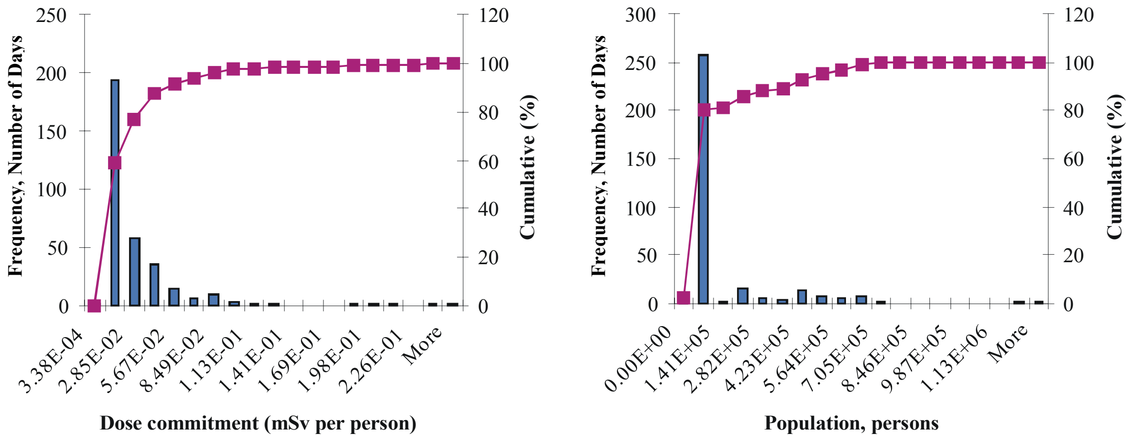


Figure 33. Frequency histogram and cumulative percentages for the VRS I-131 maximum effective dose commitments (left) and corresponding populations (right).

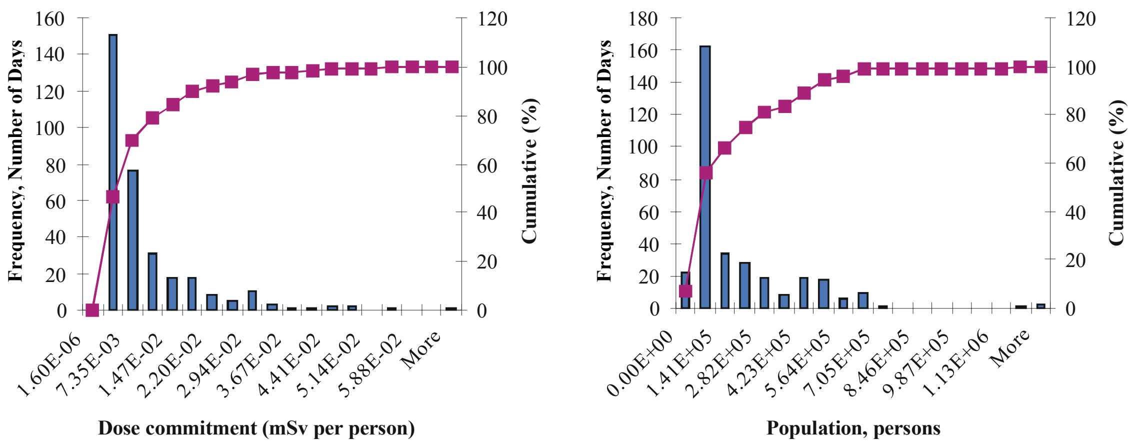


Figure 34. Transboundary frequency histogram and cumulative percentages for the VRS I-131 maximum effective dose commitments (left) and corresponding populations (right).

3.2.3.1 Specific Case Examples: Japan and U.S. Dose Commitments from the VRS

As explained above, the Cs-137 results for Japan and the U.S. territories considered in this study are provided. Figure 35 illustrates the maximum dose commitments from the VRS for Japan. The dose commitment frequency and magnitudes for the VRS are very different than those from the PRS. There are dose commitments on more than 96% of CY2000 days and the maximum dose of 0.6 mSv per person in December 2000 is more than an order of magnitude higher than that from the PRS. Also there are maximum dose commitments over 0.15 mSv per person on approximately 10% of all CY2000 days. Therefore, the impact from the VRS on Japan is greater than that from the PRS; however, all such dose commitments are significantly less than the average annual background dose of 2.4 mSv [13].

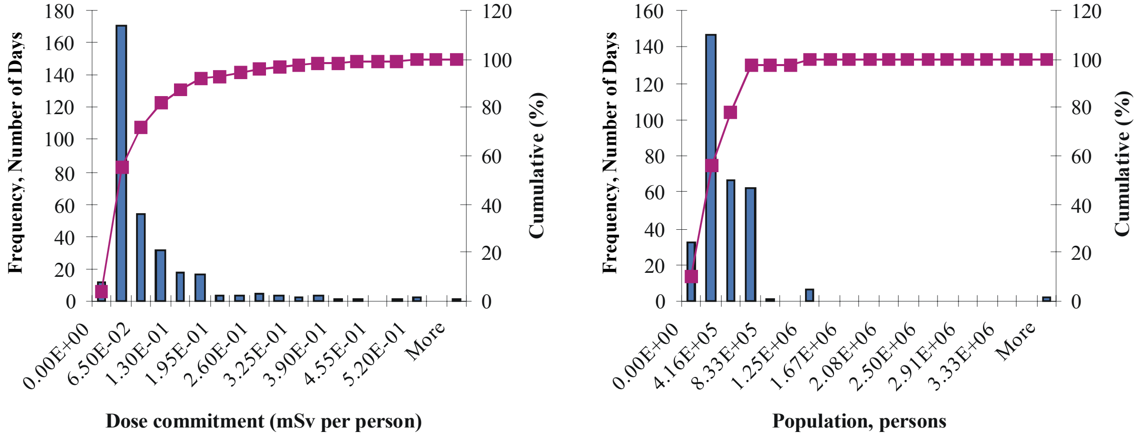
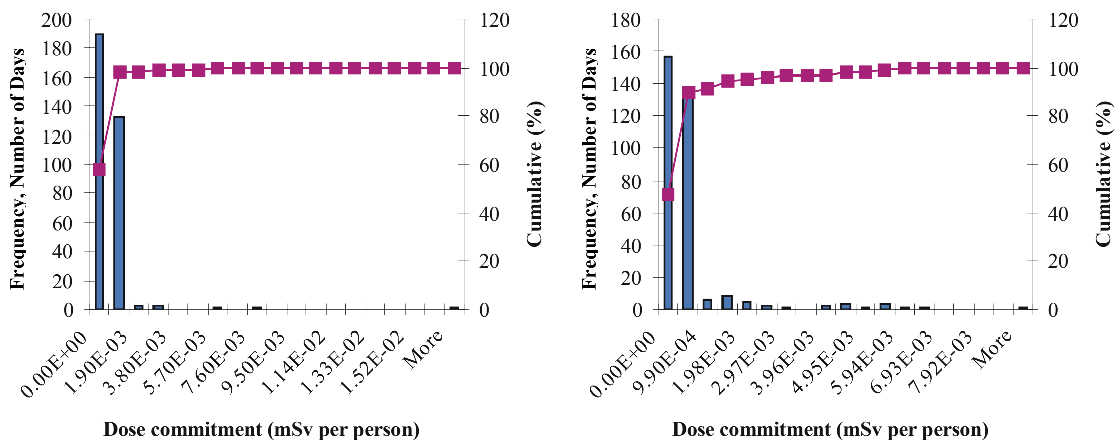


Figure 35. Japan Results: Frequency histogram and cumulative percentages for the VRS Cs-137 maximum effective dose commitments (left) and corresponding populations (right).

The dose commitment histograms for the U.S. territories considered in this study are provided in Figure 36. Note that the dose commitments are approximately an order of magnitude less than those in Japan. There is also a much lower frequency of dose commitments from the VRS for both Alaska in Figure 36(a) and the Aleutian Islands in Figure 36(b) than in Japan. Again the maximum doses of 2×10^{-2} and 9×10^{-3} mSv per person for Alaska and the Aleutian Islands, respectively, appear to be isolated cases and occur within approximately one month of each other. The maximum deposition in Japan, on the other hand, occurred in December 2000. All such dose commitments are within the normal variation for the background dose.



(a) Alaska (U.S.) (b) Aleutian Islands (U.S.)

Figure 36. U.S. Results: Frequency histogram and cumulative percentages for the VRS Cs-137 maximum effective dose commitments for Alaska (left) and the Aleutian Islands (right).

3.2.4 Maximum Effective Dose Commitments Summarized and Compared to Reference Limits

A summary of the (non-zero) maximum effective dose commitments (incorporating the ingestion, inhalation, and external exposure pathways, where applicable) for the hypothetical "unit releases" from the PRS and VRS is presented in Exhibit 9. Note that on a regional basis that the maximum effective dose commitments are comparable (because these maximum values reside in Russia). However, the impact outside of Russia is more profound from the VRS than from the PRS.

Furthermore, the effects from Cs-137 releases (from either site) appear to be of more concern than those (for the same releases) from either Sr-90 or I-131. For example, the external exposure pathway for Sr-90 is negligible and only the ingestion (i.e., milk) pathway is considered for I-131. Furthermore, I-131 has a very short half-life and is only effective for a few weeks.

Exhibit 9. Summary of the Maximum (Non-Zero) Effective Dose Commitments Using the UNSCEAR 1993 Report Methodology

PRS

	Maximum Effective Dose Commitment (mSv)*		
Region	**Cs-137**	**Sr-90**	**I-131**
Regional	4.22E+00	1.60E+00	1.79E-01
Transboundary**	1.95E-01	7.72E-02	2.39E-03
China	2.96E-02	1.09E-02	2.92E-10
Hong Kong			
Japan	4.20E-02	1.81E-02	1.81E-04
Mongolia	1.65E-03	6.29E-04	
N. Korea	8.25E-03	3.42E-03	
Russia	4.22E+00	1.60E+00	1.79E-01
S. Korea	6.22E-04	1.21E-04	
Taiwan			
Aleutians (U.S.)	1.30E-01	4.81E-02	2.39E-03
Alaska (U.S.)	1.95E-01	7.72E-02	1.61E-04
Vietnam			

VRS

	Maximum Effective Dose Commitment (mSv)*		
Region	**Cs-137**	**Sr-90**	**I-131**
Regional	4.01E+00	1.69E+00	2.54E-01
Transboundary**	1.05E+00	4.44E-01	6.61E-02
China	1.05E+00	4.44E-01	6.61E-02
Hong Kong	8.48E-04	1.28E-07	
Japan	5.85E-01	2.45E-01	1.26E-02
Mongolia	1.02E-02	4.26E-03	2.82E-09
N. Korea	6.48E-01	2.68E-01	4.24E-02
Russia	4.01E+00	1.69E+00	2.54E-01
S. Korea	1.57E-01	6.57E-02	5.94E-03
Taiwan	2.91E-02	1.23E-02	
Aleutians (U.S.)	8.91E-03	3.43E-03	3.57E-05
Alaska (U.S.)	1.71E-02	2.36E-03	2.90E-17
Vietnam	4.38E-10	2.50E-14	

* The effective dose commitments are comprised of the following components (based upon the UNSCEAR 1993 Report [13] methodology):
Cs-137: Ingestion 36.2%, Inhalation 0.1%, External Exposure 63.8%
Sr-90: Ingestion 91.9%, Inhalation 8.1%, External Exposure 0%
I-131: Ingestion 93.5%, Inhalation 3.8%, External Exposure 2.7%.

** The transboundary region includes only land areas outside of Russia.

Table 39 illustrates the manner in which the maximum, regional dose commitments (on a daily basis computed using the UNSCEAR methodology) for the PRS and VRS compare to various annual reference limits.[16] Note the similarities amongst the various numbers of dose commitments relative to reference limits for the two sites. As indicated above, the main difference appears to be the numbers of people impacted by the VRS releases relative to those from the PRS. The information in Table 39 indicates that all dose commitments (regardless of the radionuclide) from the two sites are below the 10-mSv annual limit in which intervention is rarely justified [17]; approximately 98% of all maximum daily dose commitments are below the average annual background dose of 2.4 mSv. However, it is true that the majority of the Cs-137 dose commitments exceed the annual 0.15 mSv (or 15 mrem) per person limit proposed by the US EPA; the dose commitments for Sr-90 and I-131 are generally lower that those for Cs-137 for the conditions of this study. Table 40 illustrates the same information for the transboundary region; note that the dose commitments are significantly lower for these conditions.

3.3 Effective UNSCEAR Collective Dose Commitments

The final examination of the UNSCEAR dose commitment estimates is what impact might there be on those persons that would be exposed to the various releases described above. That is, the collective dose commitments will be computed for the corresponding maximum dose commitments described

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[16] It is understood that dose commitments are compared to annual dose limits; this application should be conservative because the dose commitments are computed for periods of 70 years for infants and 50 years for adults in the UNSCEAR 1993 Report [13] although they could be computed for each year. However, because they are used for prevention, they should not be used alone for conditions following an accident.

above. Furthermore, from the information above, it is apparent that many people would be exposed to very small doses of radiation. In the words of ICRP 82 [18]:

> "The unlimited aggregation of collective dose over time and space into a single value is unhelpful because it deprives the decision maker of much necessary information. The levels of individual dose and the time distribution of collective dose may be significant factors in making decisions."

To examine the impact that relatively small doses have on the collective dose commitments computed in this study, a series of threshold values (i.e., 0.1, 0.15,1.0, and 10.0 mSv per person) were selected. In effect, if the dose commitment at a given location does not exceed the threshold, then the dose commitment is ignored to compute the collective dose and to examine the resulting impact on the assessment. This is meant in no way to be an endorsement of the "threshold concept," it merely allows assessment of the impact of small doses on collective dose assessment in keeping with the inferred meaning of ICRP 82 [18].

3.3.1 Effective UNSCEAR Collective Dose Commitments for the PRS

The effective, maximum collective dose commitments corresponding to the total depositions for Cs-137, Sr-90, and I-131 in Table 4, Table 10, and Table 14, respectively, were computed for the PRS. For Cs-137, Figure 37 illustrates the frequency and cumulative percentages for the maximum collective dose commitments for the region of study assuming no threshold. Table 41 and Table 42 provide the maximum collective dose commitment for the region as well as each country in the region for each of the threshold levels described above. (The collective dose commitments are also broken down by pathway for information purposes.) Note that the maximum collective PRS dose commitments (for the no threshold hypothesis) are rank-ordered as follows:[17]

PRS Cs-137: Regional > Japan > Russia > China > Alaska (U.S.) > S. Korea > N. Korea > Aleutians (U.S.) > Mongolia

Therefore, even though the maximum Cs-137 dose commitment was found in Russia (as indicated in Table 32), the maximum collective dose is found in Japan (which is not surprising based upon its high population density and relative proximity to the PRS in comparison to the low population density in Russia near the PRS). Using a mortality risk factor of $5x10^{-5}$ per mSv for all ages [19], these results would indicate that there might be up to 15 additional, eventual mortalities in the region based upon the "no threshold" results in Table 41; Japan might have as many as 14 additional mortalities while Russia and China might have as many as four and three, respectively.[18] However, none of these collective dose commitments from the PRS translate into a single mortality per 100 000 persons. Figure 38 illustrates the results for the transboundary conditions; note there is a significant impact on the magnitudes of the largest maximum collective dose commitments versus those for the overall region in Figure 37. In other words, the total number of collective dose commitments greater than, for example, 40 person-Sv is much lower for the transboundary region than the overall region.

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[17] In this assessment, the regional value corresponds to the maximum collective dose over the whole region on any given day in CY2000, and thus does not correspond to either the maximum for any country or the sum of the maximum values for the countries.

[18] All mortality-related results in this report are based upon a value of $5x10^{-5}$ additional mortalities per mSv for persons of all ages [19] (which translates to $5x10^{-2}$ mortalities per person-Sv). The regional maximum of 299 person-Sv from Table 41 gives a maximum value of 15 additional mortalities for the region.

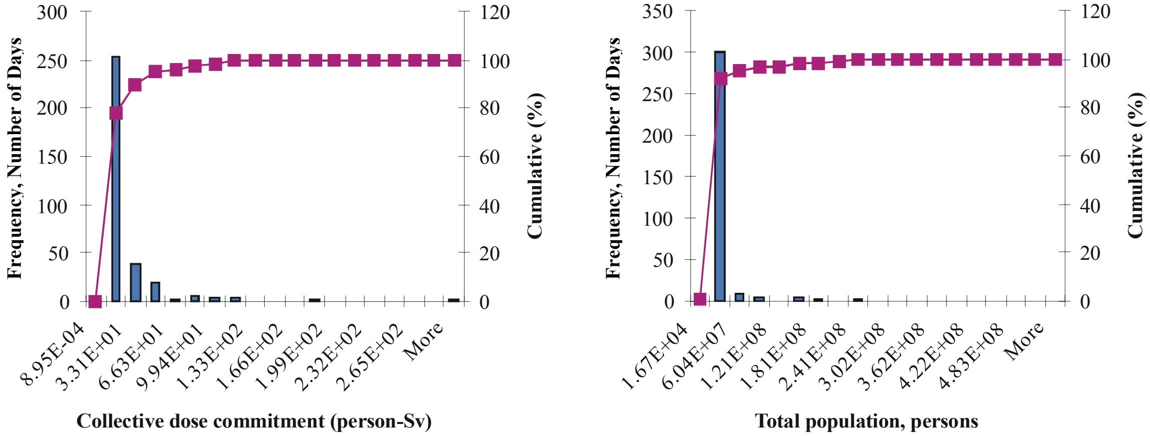

Figure 37. Frequency histogram and cumulative percentages for the PRS Cs-137 effective population dose commitments (left) and corresponding populations (right) for CY2000. No Threshold Basis.

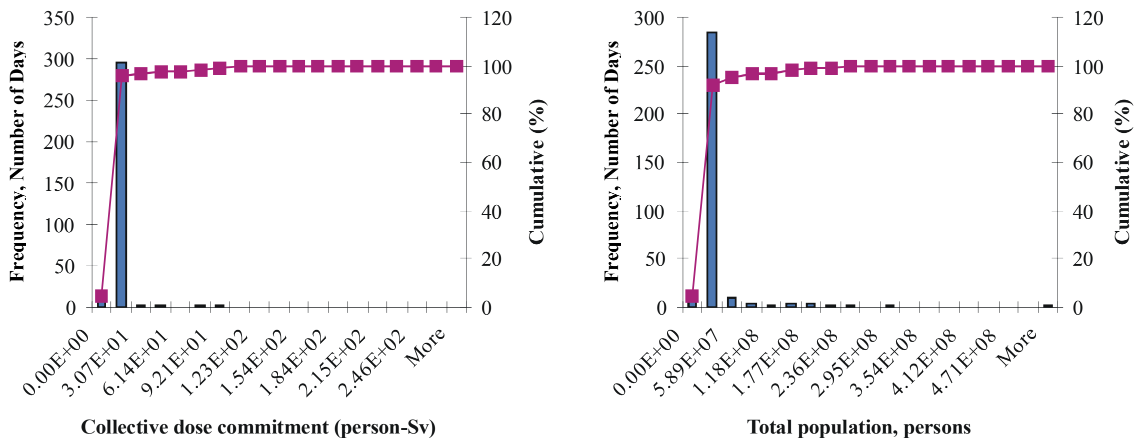

Figure 38. Transboundary frequency histogram and cumulative percentages for the PRS Cs-137 effective population dose commitments (left) and corresponding populations (right) for CY2000. No Threshold Basis.

However, the above analysis ignores the inferred ICRP 82 [18] intent that collective dose estimates should not be made over large regions. To wit, Table 41 and Table 42 can be used to evaluate the impact that small doses in concert with large populations have on the collective dose estimates in this study. If a value of 0.1 mSv (or 10 mrem) per person is used as a threshold for the collective dose computation, then Japan, which had the highest collective dose commitment (and a possibility of up to 14 additional mortalities), has a collective dose of zero. On the other hand, the collective dose commitment for Russia is not impacted significantly, as the individual dose commitments, in general, are much higher than the hypothetical 0.10 mSv per person threshold. The results using the larger threshold values do not add much additional information except to highlight the obvious fact that Russia will bear the brunt of any release of the type studied in this report.

For Sr-90, Figure 39 illustrates the frequency and cumulative percentages for the maximum collective dose commitments for the region of study assuming no threshold. Table 43 and Table 44 provide the maximum collective dose commitment for the region as well as each country in the region as a function of the assumed threshold level. Note that the maximum collective PRS dose commitments (for the no threshold hypothesis) have the same ordering as those for the Cs-137, but are less than one-half of the corresponding values for Cs-137. Again, even though the maximum dose commitment was found in Russia (as indicated in Table 33), the maximum collective dose is found in Japan. (This collective dose translates into six additional mortalities [19]; however, none of the collective dose commitments translate into a single, additional mortality per 100 000 persons.)

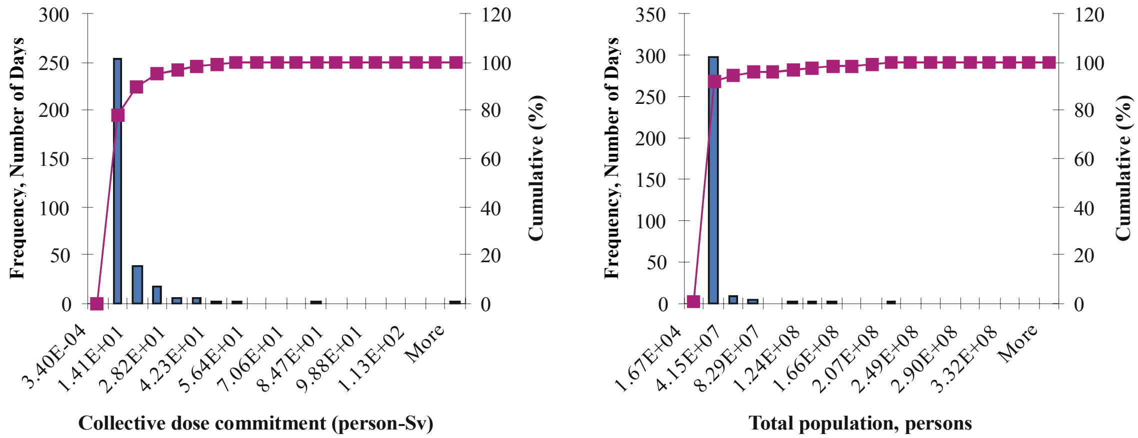

Figure 39. Frequency histogram and cumulative percentages for the PRS Sr-90 effective collective dose commitments (left) and corresponding populations (right) for CY2000. No Threshold Basis.

The results in Table 43 and Table 44 confirm the potential impacts of small doses in concert with large populations on the collective dose estimates discussed above for Cs-137. With even a relatively low threshold of 0.1 mSv (or 0.01 rem), the collective dose commitment and potential additional mortalities in Japan, which had the largest collective dose commitment under the no threshold condition, would be zero. Figure 40 illustrates the transboundary results for the PRS Sr-90 collective dose commitments; note that these results are necessarily consistent with those for Cs-137 above. This is a direct result of the assumed linear relationship between their depositions.

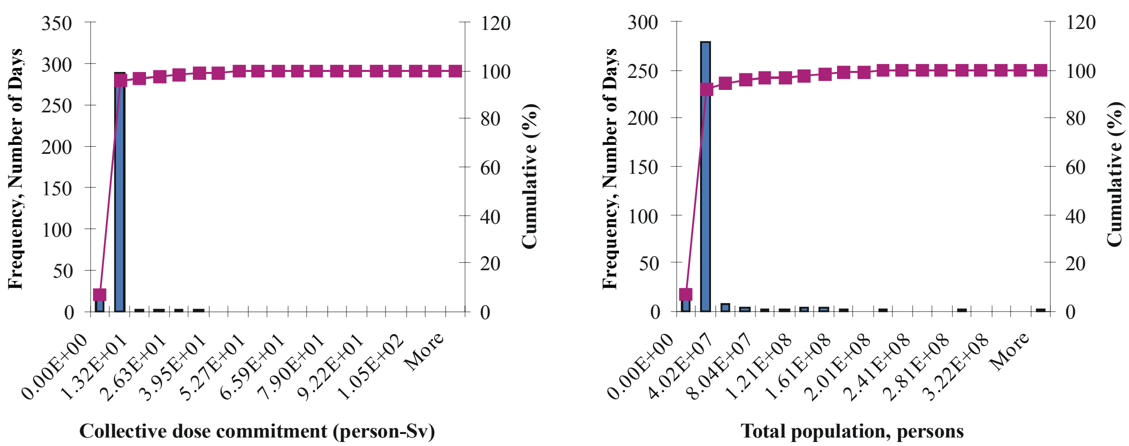

Figure 40. Transboundary frequency histogram and cumulative percentages for the PRS Sr-90 effective collective dose commitments (left) and corresponding populations (right) for CY2000. No Threshold Basis.

For I-131, Figure 41 illustrates the frequency and cumulative percentages for the maximum collective dose commitments for the region of study assuming no threshold. Table 45 and Table 46 provide the maximum collective dose commitment for the region as well as each country in the region as a function of the assumed threshold level. Note that the maximum collective PRS dose commitments (for the no threshold hypothesis) are rank-ordered as follows:

PRS I-131: Regional > Russia > Japan > Aleutians (U.S.) > Alaska (U.S.) > China

Thus for I-131, the maximum dose commitment and collective dose are found in Russia (which is unlike the results for Cs-137 and Sr-90). This is not surprising based upon the higher deposition velocity of I-131 and the low dose commitments found in Japan. As a matter of fact, the results in Table 45 and Table 46 indicate that little I-131 from PRS impacts any countries other than Russia. (Even in Russia, there is not enough of a collective dose to translate into a single, additional mortality and none of the collective dose commitments translate into a single additional mortality per 1 000 000 persons.) Furthermore, the impact is much smaller than that for either Cs-137 or Sr-90 releases from the PRS. Figure 42 illustrates the transboundary results for I-131 from the PRS. Note that there is a profound impact on the magnitudes of the collective dose commitments.

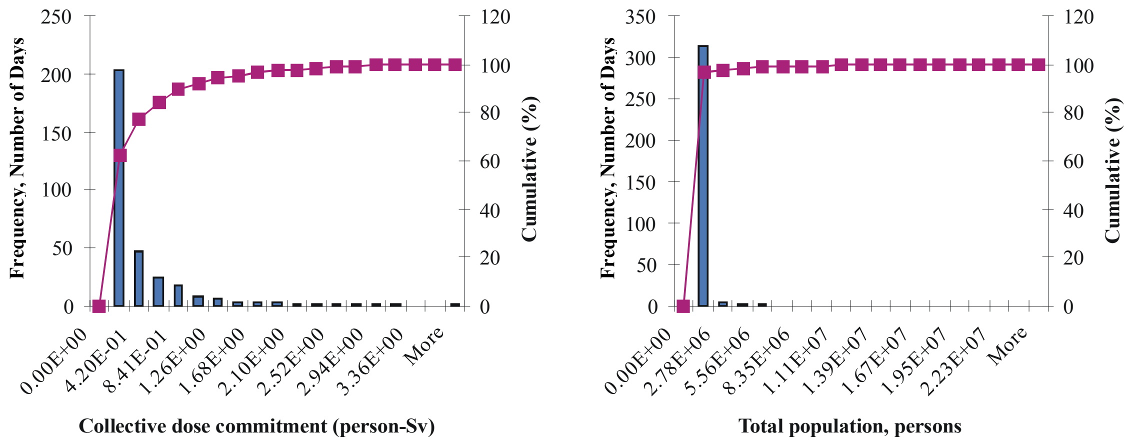

Figure 41. Frequency histogram and cumulative percentages for the PRS I-131 effective collective dose commitments (left) and corresponding populations (right) for CY2000. No Threshold Basis.

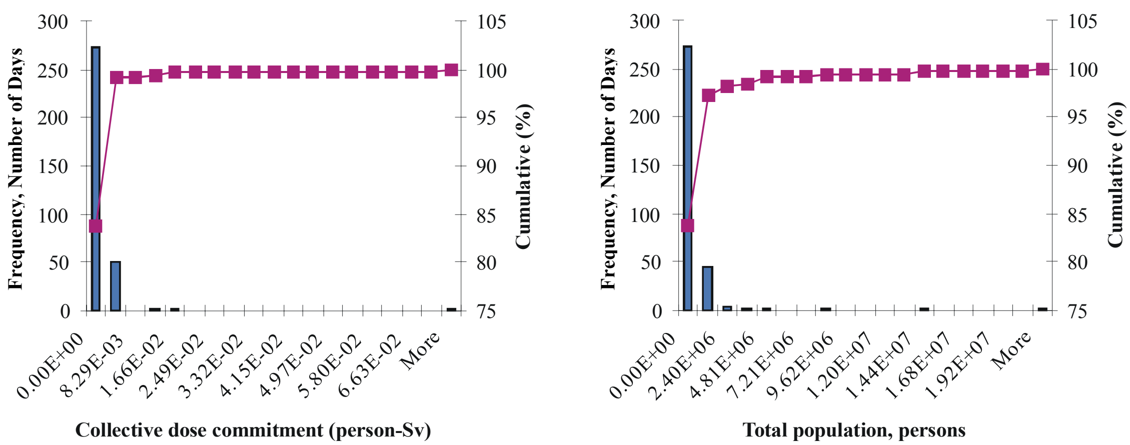

Figure 42. Transboundary frequency histogram and cumulative percentages for the PRS I-131 effective collective dose commitments (left) and corresponding populations (right) for CY2000. No Threshold Basis.

3.3.1.1 *Specific Case Examples: Japan and U.S. Collective Dose Commitments from the PRS*

Because it is apparent that air masses from the Asian continent can move rapidly and only slightly diluted across the Pacific Ocean [14,15], it has been decided to examine these areas for possible impacts from the nuclear risk sites. Furthermore, because the Sr-90 depositions necessarily follow those for Cs-137 and the I-131 depositions are smaller and will have significantly less impact on the transboundary region (which includes both Japan and the U.S.), it was decided to examine only Cs-137 for these specific examples.

Figure 43 illustrates the collective dose results for Japan from the PRS releases for CY2000. Using a mortality risk factor of $5x10^{-5}$ per mSv for all ages [19], almost 97% of all maximum collective dose commitments will result in less than one additional, eventual mortality from the PRS releases. As mentioned above, the maximum collective dose commitment of 276 person-Sv, which appears from Figure 43 to be an isolated case, could result in as many as 14 additional mortalities.

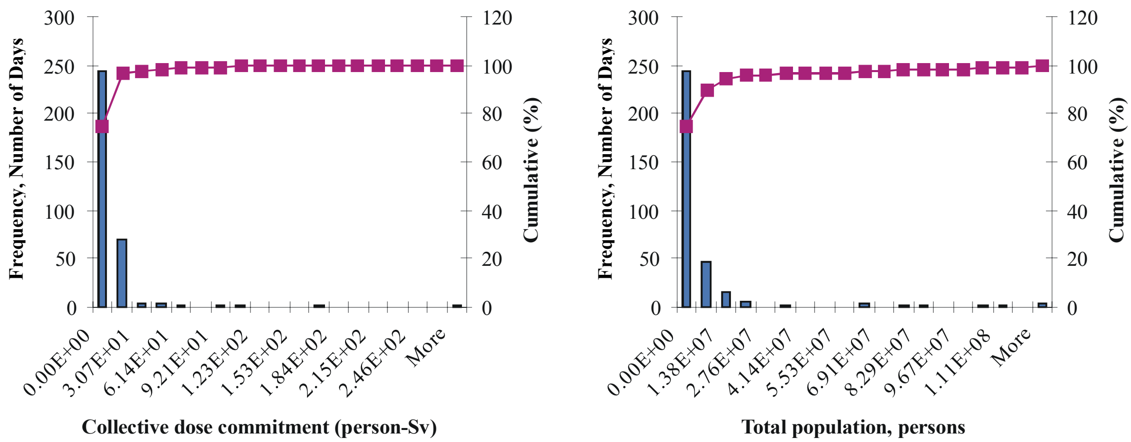

Figure 43. Japan Results: Frequency histogram and cumulative percentages for the PRS Cs-137 effective collective dose commitments (left) and corresponding populations (right) for CY2000. No Threshold Basis.

The results for the collective dose commitments from the PRS for the U.S. territories considered in this report are illustrated in Figure 44 and Figure 45. Note that, when a mortality risk factor of $5x10^{-5}$ per mSv for all ages [19] is employed, none of the collective dose commitments shown in these figures translate into a single, additional mortality from the PRS releases for CY2000.

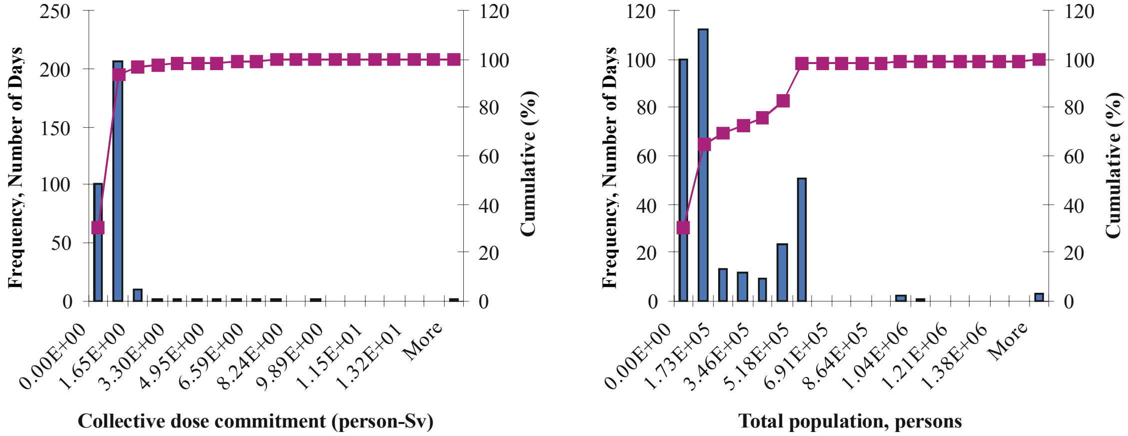

Figure 44. Alaska (U.S.) Results: Frequency histogram and cumulative percentages for the PRS Cs-137 effective collective dose commitments (left) and corresponding populations (right) for CY2000. No Threshold Basis.

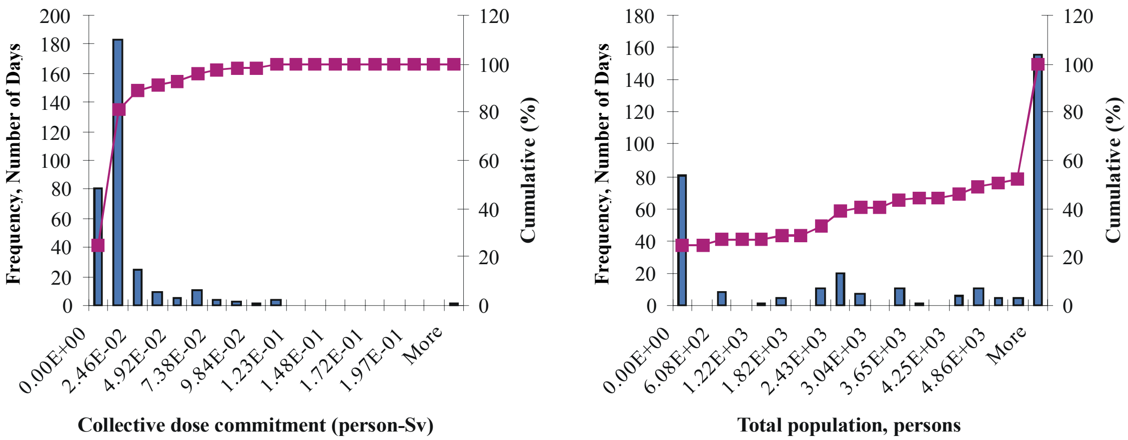

Figure 45. Aleutian Islands (U.S.) Results: Frequency histogram and cumulative percentages for the PRS Cs-137 effective collective dose commitments (left) and corresponding populations (right) for CY2000. No Threshold Basis.

3.3.2 Effective UNSCEAR Collective Dose Commitments for the VRS

The effective, maximum collective dose commitments corresponding to the total depositions for Cs-137, Sr-90, and I-131 in Table 18, Table 22, and Table 26, respectively, were computed for the VRS. For Cs-137, Figure 46 and Figure 47 illustrate the frequency and cumulative percentages for the maximum collective dose commitments for the overall and transboundary region, respectively, assuming no threshold. Table 47 and Table 48 provide the maximum collective dose commitment for the region as well as each country in the region as a function of the assumed threshold level. (The collective dose commitments are also broken down by pathway for information purposes.) Note that the maximum collective VRS dose commitments (for the no threshold hypothesis) are rank-ordered as follows:[19]

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[19] In this assessment, the regional value corresponds to the maximum collective dose over the whole region on any given day in CY2000, and thus does not correspond to either the maximum for any country or the sum of the maximum values for the countries.

VRS Cs-137: Regional > Japan > China > N. Korea > S. Korea > Russia > Taiwan > Hong Kong > Alaska (U.S.) > Mongolia > Aleutians (U.S.) > Vietnam

Therefore, even though the maximum dose commitment was found in Russia (as indicated in Table 36), the maximum collective dose is again found in Japan (which is not surprising based upon its high population density and relative proximity to the VRS). However unlike the PRS results, many countries have collective dose commitments within an order of magnitude of that for Japan.

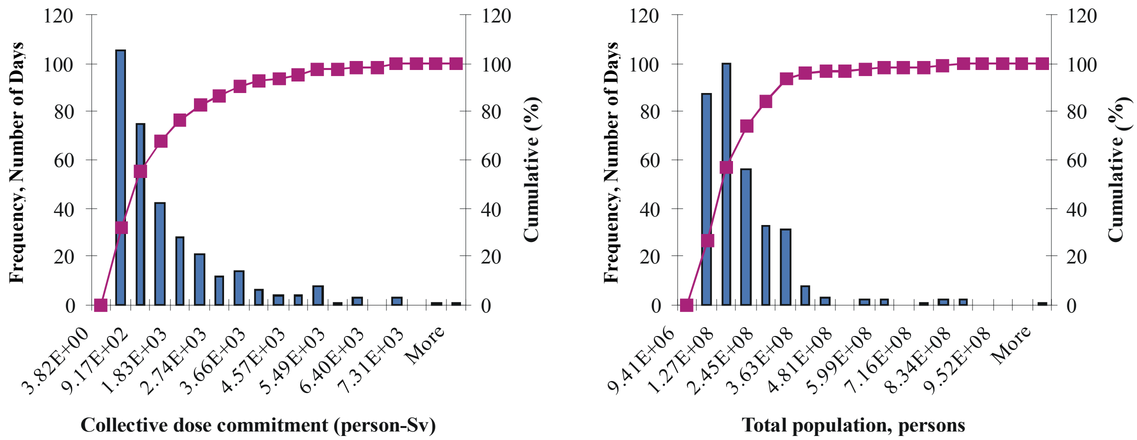


Figure 46. Frequency histogram and cumulative percentages for the VRS Cs-137 effective collective dose commitments (left) and corresponding populations (right) for CY2000. No Threshold Basis.

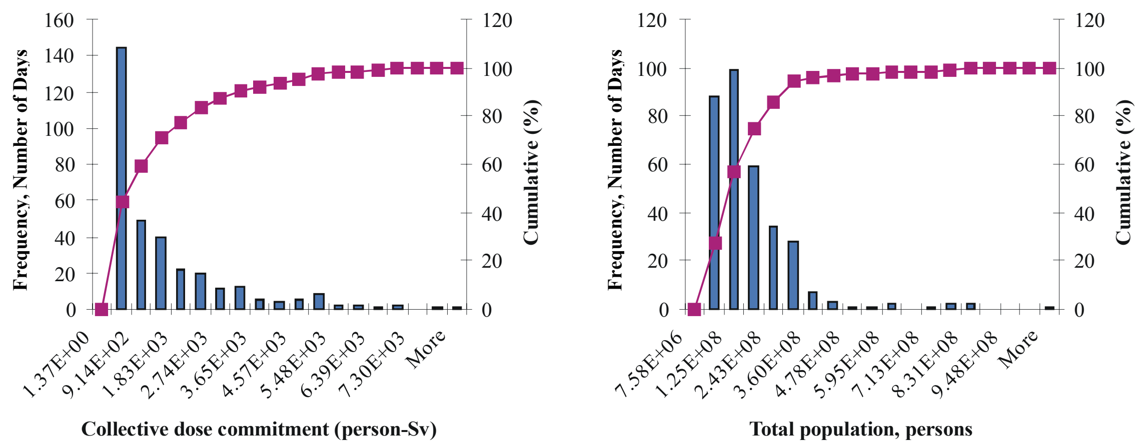
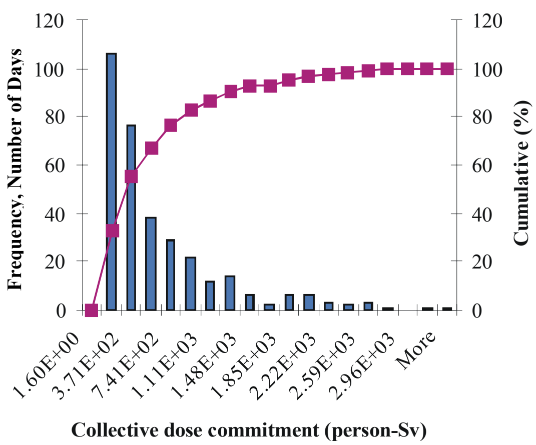


Figure 47. Transboundary frequency histogram and cumulative percentages for the VRS Cs-137 effective collective dose commitments (left) and corresponding populations (right) for CY2000. No Threshold Basis.

The effects of the VRS releases are potentially greater than those from the PRS. For example, the maximum collective dose commitments in Table 41 correspond to up to an additional 411 mortalities [19] over the entire region when a mortality risk factor of $5x10^{-5}$ per mSv for all ages [19] is used. The additional mortalities from the maximum collective dose commitments for Japan, China, N. Korea, S. Korea, Russia, and Taiwan are approximately 399, 360, 104, 102, 68, and 13, respectively. Therefore, even the impact on Taiwan, a country not proximate to the VRS, could be considered significant. However, again none of the collective dose commitments translate into a single mortality per 100 000 persons.

Also unlike the results for the PRS analysis, Table 47 and Table 48 indicate that there is much less of an impact of magnitudes of the dose commitments in concert with large populations on the collective VRS dose estimates. That is, the collective dose commitments for the countries (e.g., Japan, China, N. Korea, S. Korea, and Russia) in the vicinity of the VRS appear relatively insensitive to the introduction of thresholds into the collective dose commitment computation. Furthermore, even the results after imposing a threshold of 0.1 mSv (or 0.01 rem) translate into 270 additional mortalities in Japan and significant numbers in other countries of interest. This is a result of much higher dose commitments in these countries resulting from the VRS releases. Only when a relatively large threshold (e.g., 1.0 mSv) is imposed do the releases not significantly impact countries outside of Russia.

For Sr-90, Figure 48 and Figure 49 illustrate the frequency and cumulative percentages for the maximum collective dose commitments for the overall and transboundary region, respectively, assuming no threshold. Table 49 and Table 50 provide the maximum collective dose commitment for the region as well as each country in the region as a function of the assumed threshold level. Note that the maximum collective VRS dose commitments (for the no threshold hypothesis) have the same ordering as those for the Cs-137. Again, even though the maximum dose commitment was found in Russia (as indicated in Table 37), the maximum collective dose is found in Japan. The number of additional mortalities can be as high as 166 for the region and 146 and 164 for China and Japan, respectively, or less than one-half those from the VRS Cs-137 releases. The results in Table 49 and Table 50 confirm the insensitivity of the collective dose estimates to the imposition of thresholds because the relative magnitudes of the dose commitments as indicated above for Cs-137.



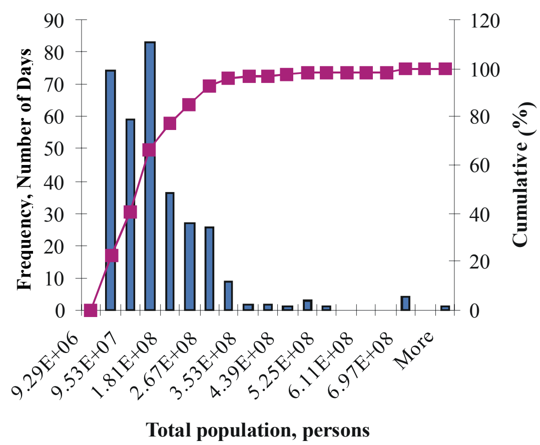


Figure 48. Frequency histogram and cumulative percentages for the VRS Sr-90 effective collective dose commitments (left) and corresponding populations (right) for CY2000. No Threshold Basis.

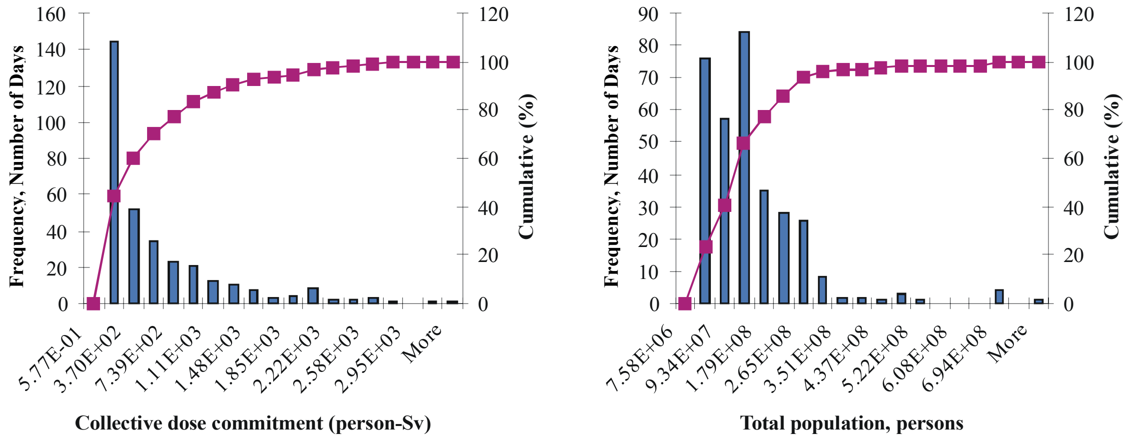


Figure 49. Transboundary frequency histogram and cumulative percentages for the VRS Sr-90 effective collective dose commitments (left) and corresponding populations (right) for CY2000. No Threshold Basis.

For I-131, Figure 50 and Figure 51 illustrate the frequency and cumulative percentages for the maximum collective dose commitments for the overall and transboundary region, respectively, assuming no threshold. Table 51 and Table 52 provide the maximum collective dose commitment for the region as well as each country in the region as a function of the assumed threshold level. Note that the maximum collective PRS dose commitments (for the no threshold hypothesis) are rank-ordered as follows:

VRS I-131: Regional > Japan > China > S. Korea > N. Korea > Russia > Aleutians (U.S.) > Mongolia > Alaska (U.S.)

Thus for I-131, the maximum collective VRS dose commitment is found in Japan (which is unlike the results found for the corresponding PRS releases). Unlike the Cs-137 and Sr-90 results, the I-131 releases translate into ten or fewer additional mortalities. Also unlike the VRS results for Cs-137 and Sr-90, the collective doses are relatively sensitive to the imposition of a threshold (because of the much smaller dose commitments for I-131 in countries other than Russia). This is not surprising based upon the higher deposition velocity of I-131. Again, the results in Table 51 and Table 52 indicate that little I-131 from the VRS releases impacts any countries other than Russia. Furthermore, the impact is much smaller than that for either Cs-137 or Sr-90 releases from the PRS. None of the collective dose commitments translate into a single mortality per 1 000 000 persons.

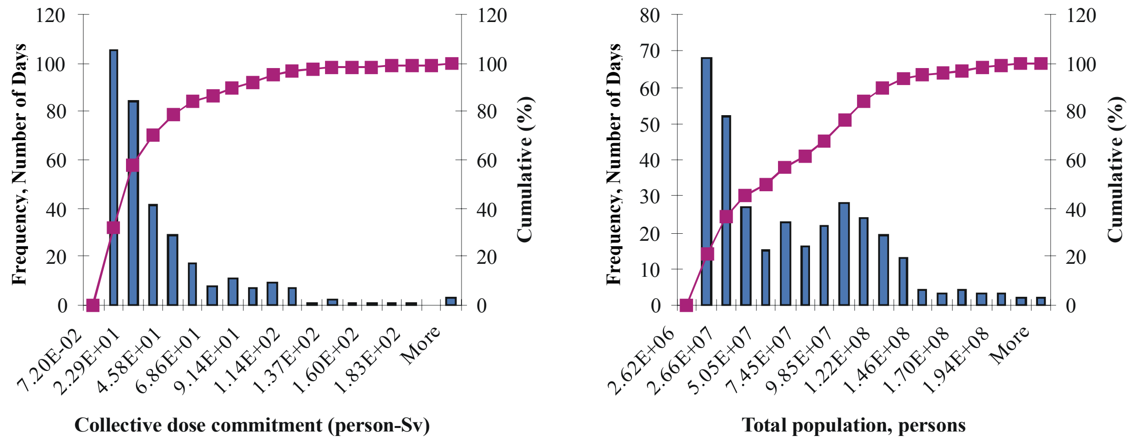


Figure 50. Frequency histogram and cumulative percentages for the VRS I-131 effective collective dose commitments (left) and corresponding populations (right) for CY2000. No Threshold Basis.

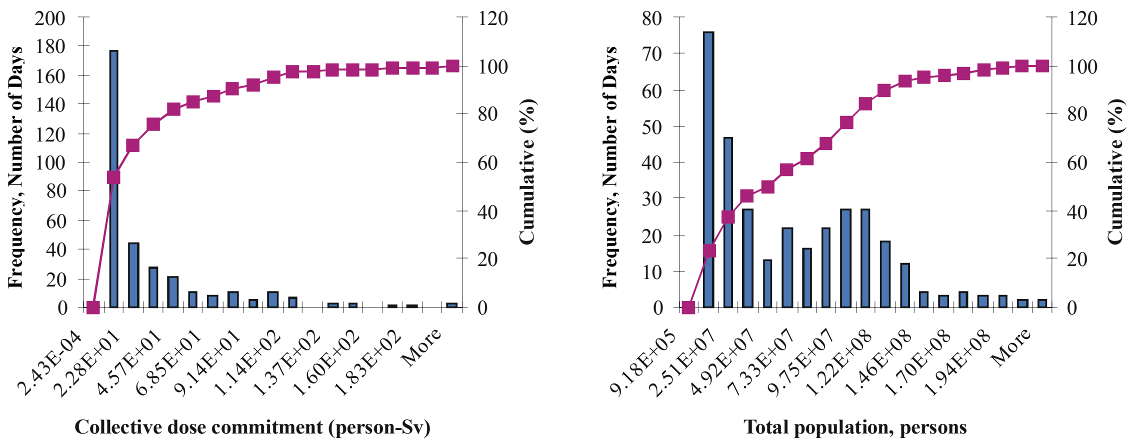


Figure 51. Transboundary frequency histogram and cumulative percentages for the VRS I-131 effective collective dose commitments (left) and corresponding populations (right) for CY2000. No Threshold Basis.

3.3.2.1 Specific Case Examples: Japan and U.S. Collective Dose Commitments from the VRS

Figure 52 illustrates the collective dose results for Japan from the VRS releases for CY2000. Using a mortality risk factor of $5x10^{-5}$ per mSv for all ages [19], the maximum collective dose commitment of 7990 person-Sv would translate into almost 400 additional mortalities or 3.2 additional mortalities per 1 000 000 persons. However, the information in Figure 52 indicates that this would be a low-probability event for CY2000. Over 60% of the maximum collective dose commitments are less than 420 person-Sv, which would translate into 22 additional mortalities.

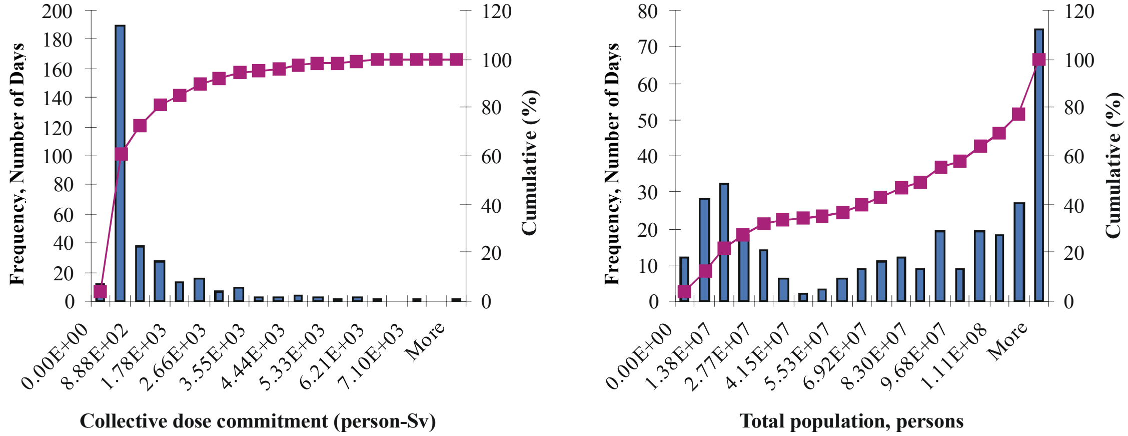


Figure 52. Japan Results: Frequency histogram and cumulative percentages for the VRS Cs-137 effective collective dose commitments (left) and corresponding populations (right) for CY2000. No Threshold Basis.

The results for the collective dose commitments from the VRS for the U.S. territories considered in this report are illustrated in Figure 53 and Figure 54. Note that, when a mortality risk factor of $5x10^{-5}$ per mSv for all ages [19] is employed, none of the collective dose commitments shown in these figures translate into a single, additional mortality from the VRS releases for CY2000. Furthermore, none of the collective dose commitments translate into a single additional mortality per 1 000 000 persons.

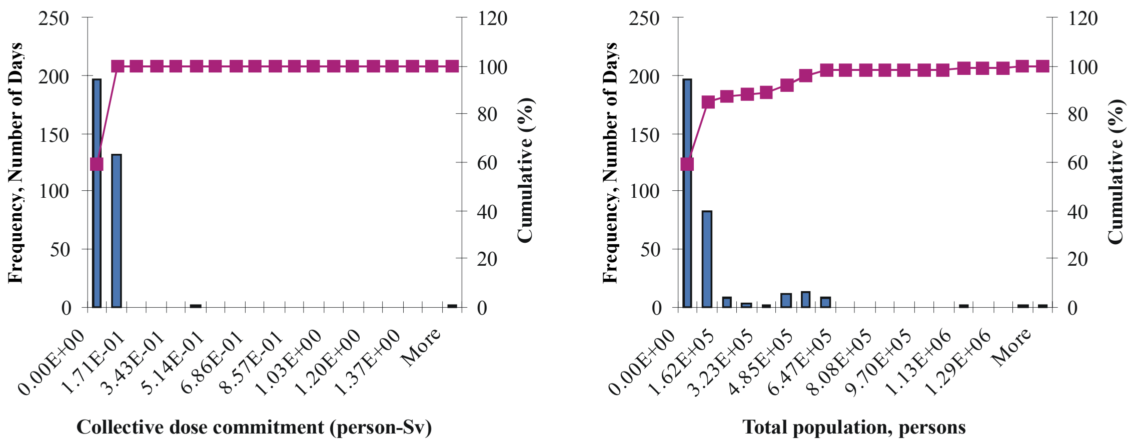


Figure 53. Alaska (U.S.) Results: Frequency histogram and cumulative percentages for the VRS Cs-137 effective collective dose commitments (left) and corresponding populations (right) for CY2000. No Threshold Basis.

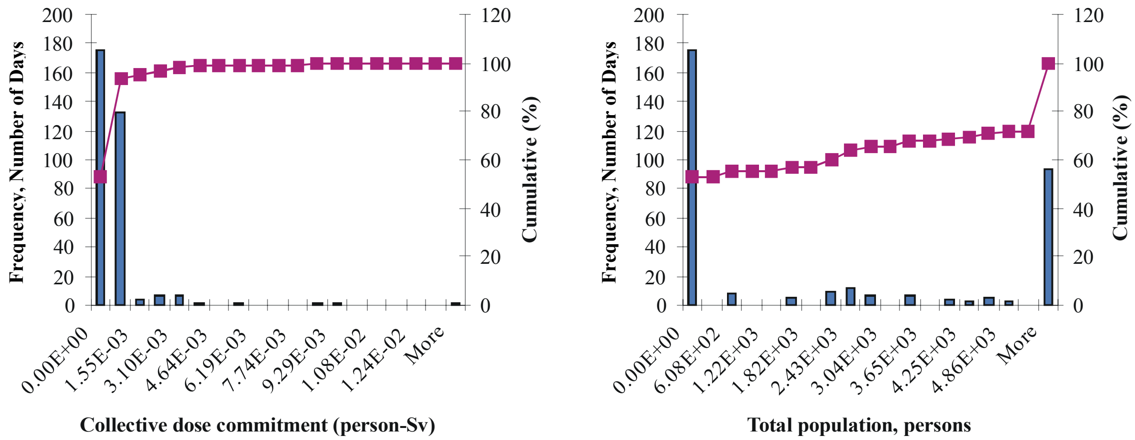


Figure 54. Aleutian Islands (U.S.) Results: Frequency histogram and cumulative percentages for the VRS Cs-137 effective collective dose commitments (left) and corresponding populations (right) for CY2000. No Threshold Basis.

3.3.3 Summary of the Effective UNSCEAR Collective Dose Commitments

A summary of the (non-zero) maximum effective collective dose commitments (based upon the UNSCEAR 1993 Report methodology and assuming no threshold) for both the PRS and VRS is presented in Exhibit 10. Therefore, even though the maximum effective dose commitments from the PRS and VRS were reasonably similar (as illustrated above), the higher populations impacted from the VRS releases generally resulted in significantly larger collective dose commitments. It also appears that the Cs-137 dose commitments will be of primary concern for either site.

Exhibit 10. Summary of Maximum (Non-Zero) Effective Collective Dose Commitments Using the UNSCEAR 1993 Report Methodology

PRS

	Maximum Effective Collective Dose Commitment (person-Sv)*		
Region	**Cs-137**	**Sr-90**	**I-131**
Regional	2.98E+02	1.27E+02	3.78E+00
Transboundary**	2.76E+02	1.19E+02	7.46E-02
China	6.96E+01	2.78E+01	4.08E-08
Hong Kong			
Japan	2.76E+02	1.19E+02	7.46E-02
Mongolia	1.59E-01	5.98E-02	
N. Korea	8.47E+00	3.38E+00	
Russia	8.63E+01	3.76E+01	3.78E+00
S. Korea	9.75E+00	1.78E+00	
Taiwan			
Aleutians (U.S.)	2.21E-01	8.15E-02	2.49E-03
Alaska (U.S.)	1.48E+01	5.20E+00	7.10E-05
Vietnam			

VRS

	Maximum Effective Collective Dose Commitment (person-Sv)*		
Region	**Cs-137**	**Sr-90**	**I-131**
Regional	8.23E+03	3.33E+03	2.06E+02
Transboundary**	8.22E+03	3.32E+03	2.06E+02
China	7.21E+03	2.93E+03	1.76E+02
Hong Kong	1.59E+00	3.72E-04	
Japan	7.99E+03	3.28E+03	2.06E+02
Mongolia	1.35E+00	4.74E-01	1.13E-07
N. Korea	2.09E+03	8.68E+02	9.12E+01
Russia	1.36E+03	5.63E+02	6.68E+01
S. Korea	2.05E+03	8.53E+02	9.82E+01
Taiwan	2.67E+02	1.13E+02	
Aleutians (U.S.)	1.39E-02	3.29E-03	4.74E-07
Alaska (U.S.)	1.54E+00	8.66E-02	4.95E-18
Vietnam	6.07E-09	3.46E-13	

* The effective collective dose commitments are comprised of the following components (based upon the UNSCEAR 1993 Report [13] methodology):
Cs-137: Ingestion 36.2%, Inhalation 0.1%, External Exposure 63.8%
Sr-90: Ingestion 91.9%, Inhalation 8.1%, External Exposure 0%
I-131: Ingestion 93.5%, Inhalation 3.8%, External Exposure 2.7%.

** The transboundary region includes only land areas outside of Russia.

A study of the impact of imposing threshold values on the various collective dose commitments was also undertaken. Figure 55 illustrates the impact of such thresholds on the maximum collective Cs-137 dose commitments for those areas where the impact would be at least one additional mortality (using a mortality risk factor of $5x10^{-5}$ per mSv for all ages [19]). Note that only the collective doses for the entire region and Russia do not fall to zero using a threshold value of 0.10 mSv per person. Therefore, there would be a significant impact on collective doses if even a relatively small threshold (i.e., 0.10 mSv) were imposed on the calculation.

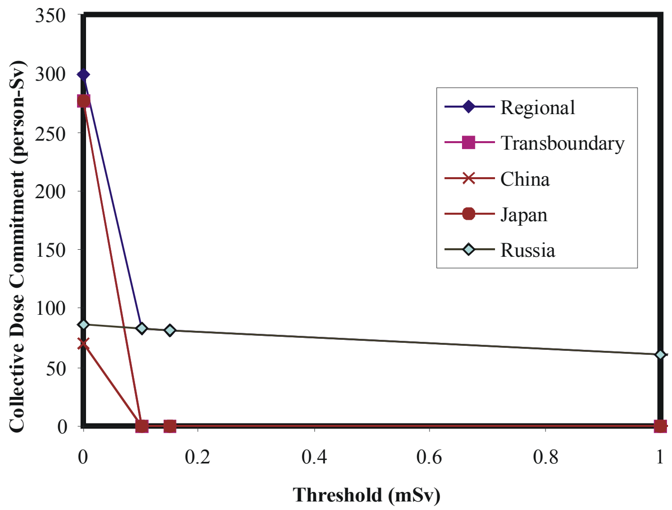


Figure 55. Impact of Imposing Hypothetical Threshold Values on the UNSCEAR Maximum Effective Collective Cs-137 Dose Commitments for the PRS. Only those values are shown where at least one additional mortality would result for the no threshold case.

The corresponding relationship between the maximum collective dose commitments and threshold for the VRS is provided in Figure 56. Notice that the impact of thresholds on the VRS collective dose commitments is much smaller than that for the corresponding PRS doses; however, they still appear to be significant for most countries impacted by the PRS releases.

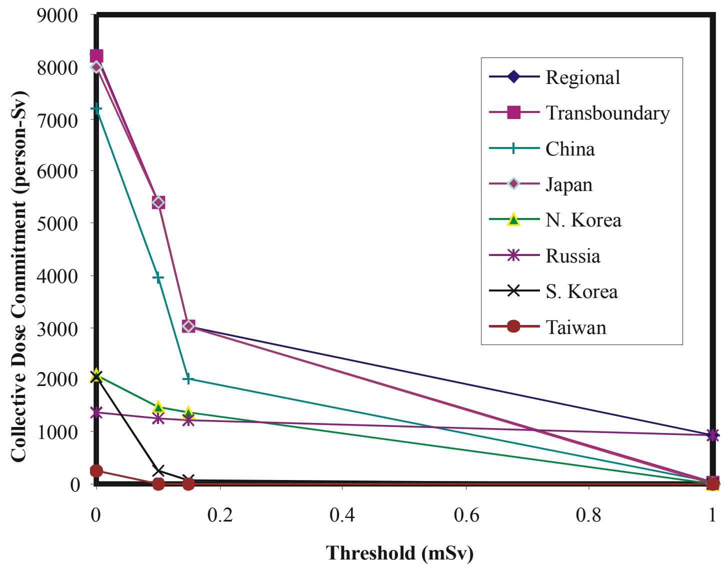


Figure 56. Impact of Imposing Hypothetical Threshold Values on the UNSCEAR Maximum Effective Collective Cs-137 Dose Commitments for the VRS. Only those values are shown where at least one additional mortality would result for the no threshold case.

4 Parameter Variation Study

There are three major sources of potential "error" or uncertainty in the dose calculations provided in this report. The first is the deposition values [6] provided as the input to said calculations. The deposition data provided are based upon data for approximately 90% of the days in a single calendar year (i.e., CY2000) and, as was stated by Mahura [6], a multi-year approach would be best for statistical analysis of the deposition data. Furthermore, because wet deposition is related to rainfall, these deposition data can be highly variable as are the dry deposition velocities (whose effects were indicated by the differences found between Cs-137, Sr-90, and I-131 depositions for the five specific case studies used to generate the relationship between Cs-137 and the other radionuclides of interest). Thus the possible input data to this study would have had a great deal more variation if the resources were available to examine the possible effects such as year-to-year variation or variation in deposition velocities. It is thought that by examining the range of conceivable release values (as they compare to the "unit hypothetical release" of $8.64x10^{14}$ Bq used to generate the data [6]) and the maximum values on a day-to-day basis for the given time-slice represented by the CY2000 results, that a reasonable set of conclusions can be drawn concerning future releases from the two risk sites studied in this report.

A second source of potential variation present in the dose calculations in this report are the UNSCEAR 1993 Report deposition-to-dose transfer factors (i.e., P_{2345}, P_{245}, and P_{25}) described above. Given a total deposition at a specific location, these provide an estimate of the dose commitment that would be imparted to an adult (except for the case of I-131 where a weighted value is instead used) under average or nominal conditions using information that is often decades old and not necessarily concerning the region of interest. The UNSCEAR methodology is sound; however, little account was taken for the countries of interest in this study. In this section, the parameters that constitute the various deposition-to-dose transfer factors will be examined to provide a more reasonable range of values for the region of interest.

The third source of error applies to computing collective doses, and that is the population data used in this study. These data are from 1995 [7] and, therefore, are somewhat out of date. However, these data are used "as-is" as any adjustment of the data would be arbitrary and likely to introduce more error than warranted especially when considering the other sources of error that are examined below.

There are a number of different techniques that can be used to examine such variations in the factors comprising the deposition-to-dose coefficients defined above. One could set up a number of scenarios where the doses will be computed for each individual (i.e., infant, child, adult, etc.) of interest for each of the 13 countries represented in the region of interest. This would also entail defining the various parameters for ingestion, inhalation, and external exposure representing each selected region and individual. However, such a technique appears unwarranted when considering the variation inherent in the input data. The approach taken in this study is to define reasonable ranges for the source term and the various parameters used in computing the deposition-to-dose coefficients and then, using said ranges, compute the resulting ranges of the transfer factors and the resulting maximum dose commitments for both the maximum individual and adult cases. These results will be analyzed to determine whether accounting for reasonable variation in the source term and the parameters used to develop the deposition-to-dose transfer coefficients would alter the conclusions drawn from examination of the dose commitments computed using the UNSCEAR values for the "unit hypothetical release."

4.1 Environmental Releases from Typical Accident Scenarios

The total release, A_0, in this study consisted of a series of one-day "unit hypothetical releases" at the rate of 1×10^{10} Bq s^{-1} for a total release of (24 h d^{-1})(3600 s h^{-1})(10^{10} Bq s^{-1}) = 8.64×10^{14} Bq each for Cs-137, Sr-90, and I-131. It will be shown how this release compares to the releases from possible accident scenarios of the Russian Far East nuclear risk sites. Then noting that because the depositions and dose commitments are proportional to the initial total release, A_0, the doses that would result from the various accident scenarios will be considered both in light of the original UNSCEAR approach and then as part of the parameter variation study that takes into account the various dose pathways discussed above.

The Cs-137 and Sr-90 isotopic inventories for the nuclear submarines (NS) and other facilities pertinent to the Russian Far East nuclear risk sites (i.e., PRS and VRS) are presented in Table 53 [28,29,30,31,32,33,34]. However, it is implausible to consider an accident scenario consisting of both reactors on board a first or second generation nuclear submarine (NS) or every storage or transport cask in a building being involved in even the worst-case accident scenario. Therefore, the information in Table 53 has been summarized based upon the spent fuel assemblies (SFA's) either in or hypothesized to be in (using a nominal value of 287 SFA's per core [32]) the various reactor cores and storage facilities described in Table 53. These values are summarized in Table 54.

Table 55 indicates the various configurations assumed in this study for nuclear submarines and transport casks whose inventories are described in Table 53 and Table 54. Note that the maximum Cs-137 and Sr-90 inventories for the conditions assumed for this study for the PRS and VRS are 5.67 and 4.80 times higher, respectively, than the "unit hypothetical release" used [6] to generate the deposition data for this study.

The inventory for I-131 is somewhat more straightforward as it primarily depends on the fission yield of the accident. Using a total number of fissions of 5.0×10^{18} to represent the Chazhma Bay accident [35], the inventory of I-131 was estimated to be 1.45×10^{11} Bq. A NATO report [34] concerning two defense-related cross-border problems examined a hypothetical criticality accident involving 1×10^{20} fissions (considered bounding [36]) in which the I-131 inventory is between 1.3×10^{10} Bq (at the time of the accident) and 4.3×10^{12} Bq (one day after the accident corresponding to the end of the releases modeled in this study). This information is also found in Table 55; note that even the maximum I-131 inventory in this table is more than 200 times lower than the "unit hypothetical release" of 8.64×10^{14} Bq used to generate the data for this study.

However, the release fraction (i.e., the fraction of the inventory that is released into the atmosphere) for a given accident scenario also determines the environmental release, A_0. Table 56 provides a summary of the release fractions for a series of accident scenarios [36,37,38,39,40,41]. Note that the release fractions for each element considered in this study can vary over several orders of magnitude depending upon the severity of the accident scenario. Also note that, depending upon the accident scenario, almost all the Cs-137 or I-131 can be released into the atmosphere, whereas the Sr-90 tends to stay within the fuel assemblies even during the most severe accident scenarios.

By combining the various values from the inventories in Table 55 and the release fractions in Table 56, the potential environmental source terms pertinent to this study can be estimated. These are provided in Table 57. Note that the "unit hypothetical release" used to generate the deposition data used in this report is significantly greater than the median values examined but less than the maximum values for Cs-137, greater than the maximum values for Sr-90, and more than 250 times greater than the maximum value for I-131. Therefore, the choice of a "unit hypothetical release" of 8.64×10^{14} Bq used in this study appears to be representative for Cs-137, conservative for Sr-90, and grossly conservative for I-131. This information will be factored into the parameter variation study below.

4.2 Ingestion Transfer Coefficients

As stated above, the UNSCEAR P_{25} transfer coefficient is computed using Equation 3: $P_{2345} = P_{23}P_{34}P_{45}$ where P_{23} represents the deposition to diet transfer, P_{34} links the concentrations of radionuclides in diet to those in the body, and P_{45} the concentrations in body to dose. This will be the basis for the ingestion "design" for Sr-90 and Cs-137. The P_{2345} transfer factor for I-131 will be discussed below as only the milk pathway is considered.

The transfer, represented by the coefficient P_{23} in units mBq a kg^{-1} per Bq m^{-2}, of Sr-90 and Cs-137 from deposition to diet was modeled in the 1993 UNSCEAR Report using a three-component model considering transfer in the first year from mainly direct deposition, transfer in the second year from lagged use of stored foods and uptake from the surface deposits, and transfer via root uptake from the accumulated deposits [13]. The data provided in the UNSCEAR report were obtained from regression analysis for data from Argentina, Denmark, and the United States. These values appear to have not changed in the 2000 UNSCEAR Report [16]. No comparable data were discovered for the countries considered in our study so the range of results for these three countries will be used to represent the range of values for our study after adjusting by an arbitrary 10% on either side to provide some degree of safety margin and variability. Said P_{23} ranges are provided in Table 58.

To derive values for the UNSCEAR P_{34} transfer coefficient, the fractional amounts by weight consumed provided in the report (based again upon Argentina, Denmark, and the United States) were used assuming an average food consumption rate of 500 kg a^{-1} [13]. These values are provided in Table 59. However, because the region of interest in our study is not well-covered by the three countries considered in the UNSCEAR 1993 Report, it was decided to include other dietary data in defining the P_{34} range as opposed to adjusting the ranges presented in Table 59 by some arbitrary factor as was found necessary for the P_{23} coefficient. Note that Table 59 provides information (i.e., minimum and maximum values) that was not provided in Table 29.

Additional consumption rate values were taken from a number of sources including:

- the values of milk consumption provided on a "by age" basis in the UNSCEAR 1993 Report [13],
- a 1982 UNSCEAR report [42] on the effects of atomic radiation,
- a study [43] concerned with diet and disease in Asia,
- the UNFAO food balance sheets [44],
- a United Nations report [45] on the effects of ionizing radiation, and
- the NRC 1.109 [46] values for the "maximum exposed individual."

The following milk consumptions: 330, 180, 150, and 90 L a^{-1} for age groups 0-1, 1-9, 9-19, and adult, respectively, were provided in the UNSCEAR 1993 Report [13]. When converted to a kg a^{-1} basis (using a milk specific gravity of 1.03), they correspond to 339.9, 185.4, 154.5, and 92.7 kg a^{-1}, respectively. Note that these values do not appear to be represented by the corresponding values in Table 59, which are not age-dependent in nature, and thus the age-dependent values will be considered below for the milk pathway where applicable.

The values provided in the 1982 UNSCEAR report [42] for age-dependent dietary intakes are provided in Table 60. (Note the total is 500 kg a^{-1} per adult as in Table 59; however, the age-dependent 1982 UNSCEAR Report values for milk consumption are again different from those used in the UNSCEAR 1993 Report.) The Asian dietary report [43] gave a breakdown of food available for consumption (which is considered a limit for the purposes of this study) per income level. The P_{34} values derived from these data are provided in Table 61. Similar values derived from the UNFAO food balance sheets database [44] are provided in Table 62.

Another source considered for consumption rates was provided in the United Nations report [45] on the effects of ionizing radiation; these values are presented in Table 63. However, two of the values were cited as being unusually high or low [45] and, therefore, were not used to define the design space for the consumption parameters although it would have little impact on the worst-case results that will be presented below. So, in effect, the only value from this source that was used was the United States meat consumption rate. (Also note that the vegetable and fruit categories were grouped differently than in the other tables.) Note this report is the source of the consumption information used in the 2000 UNSCEAR Report and, therefore, no additional reference pertaining to the consumption rates used in the 2000 UNSCEAR Report will be made.

The final source of consumption information considered was NRC 1.109 [46]. The data for the average individual and the "maximum exposed individual"[20] are provided in Table 64 and Table 65, respectively. The ranges for all pathways considered using the information in Table 58 through Table 65 are summarized in Table 66.

Therefore, for the consumption data gathered for this study, there are data (i.e., those in Table 59, Table 62, and Table 63) that represent average consumption values, there are also data (i.e., the UNSCEAR 1993 Report [13] milk consumption values, Table 60, Table 64, and Table 65) that are characterized by age, and even data that are characterized by income level for the region of interest. The age-dependent extreme values, as they relate to the adult consumption values, are summarized in Table 67. Furthermore, it will be assumed that for the purposes of this study that the non-age-specific consumption rates provided elsewhere can be considered adult consumption rates.[21] The range of these "adult" consumption rates and those obtained using the age-specific factors in Table 67 are provided in Table 68.

Note the minimum and maximum totals in Table 68 are between less than one-tenth and three and one-half times that of the average annual consumption (i.e., assumed to be 500 kg a^{-1}) in the UNSCEAR 1993 Report. It was decided to follow the example set by the NRC 1.109 "maximum exposed individual" [46] where the totals of the consumption values ranged between 339.9 and 1149 kg a^{-1} (or between 68% and 230% of the assumed average value of 500 kg a^{-1}). Furthermore, representing the consumption rates in this manner allows the unit-sum type constraint[22] that would otherwise be on this parameter to be omitted making the design study to be executed in a much more straightforward manner. Furthermore, a constrained design tends to decrease variation (i.e., a constraint is imposed) in the resulting parameters, which is not desirable when attempting to examine the worst-case scenario. Thus the ranges in Table 68 are considered to be broad enough to not warrant any additional safety margin or more complex design structure.

As described above, the UNSCEAR P_{45} transfer coefficients representing the effective committed dose per unit intake (in nSv Bq^{-1}) for the ingestion of Sr-90 and Cs-137 were given as 28 and 13, respectively [13]. (These values are for the committed equivalent doses for a period of 50 years after intake for adults). However, not all the people that will be exposed will be adults; this can be

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[20] Such individuals are "characterized with regard to food consumption, occupancy, and other usage of the region in the vicinity of the plant site and as such represent individuals with habits representing reasonable deviations from the average for the population in general." [46]

[21] From inspection of the available population distribution information, the majority of the impacted persons will be adults. Furthermore, it is likely that any bias resulting from this assumption will be more than compensated for by the wide range of consumption rates considered.

[22] A unit-sum type constraint is one where the sum of the proportions (e.g., the fractions of an average consumption rate) must equal one and are thus constrained.

accommodated by computing the P_{2345} transfer coefficient for ingestion in the same manner as was done for I-131 in Equation 6. The ingestion P_{45} transfer coefficients considered in this study are provided in Table 69 [27,46,47].

Note that the NRC 1.109 [46] values for Sr-90 in Table 69 are more than an order of magnitude higher than any of the others. The values in the NRC 1.109 guide are based upon ICRP-2 [48] models; whereas, the other values are based upon models using assumptions in ICRP-26 [49] and later. The ICRP-2 models used the assumption that a single organ could be considered critical and doses were limited to a specified annual dose to said critical organ. The other three sets of P_{45} values (i.e., NRPB [20] used in the UNSCEAR 1993 Report [13], FGR-11 [27], and ICRP-72 [47]) in Table 69 involve the concept of tissue weighting factors, which represent the ratio of the risk for the effect in an organ to the risk for whole body upon irradiation. Because the NRC 1.109 P_{45} coefficients are based upon an older (and, in a great many cases, superceded) model for dose effects, these coefficients (for both ingestion and, later, inhalation) will not be considered for this study. However, they have been presented for completeness.

Population information was used above to weight the I-131 ingestion values found in the UNSCEAR 1993 Report [13]; however, the population information is not strictly applicable to the region of interest in this study. Additional, and more pertinent, population information from the United States 2000 Census for Alaska [50], the Japanese Ministry of Public Management, Home Affairs, Posts and Telecommunications [51], and the Republic of Korea National Statistical Office [52] is provided in Table 70. This is considered a reasonable coverage for the region of interest. These population data have a constraint upon them; that is, they must sum to 100% (or their corresponding fractions must sum to unity). To better represent the possible values, the lower and upper ranges representing the values in Table 70 were used to define an extreme vertex design; the ten vertices representing the design and the centroid are provided in Table 71. The extreme vertices will be considered in any calculation using the population data to assure that representative variation has been included.

If the resources and time were available, it would be possible to generate a very large design space covering all the various parameters that comprise the P_{23}, P_{34}, and P_{45} transfer coefficients for the ingestion pathways. However such resources are not available and not warranted because of the nature and uncertainties inherent in the input data. Therefore, for the purposes of this study, it will be considered to be of equivalent value to generate reasonable ranges for the P_{2345} coefficients for each of the five ingestion pathways considered using the ranges of the P_{23}, P_{34}, and P_{45} factors and populations described above. Considering the variations involved, a defensible case can be made that the resulting design in P_{2345} space will provide the appropriate information because the results can be transformed back into the component parameters important to each pathway.

An age-weighted P_{2345} transfer coefficient accounting for the five pathways noted above is computed using the following relationship (where $p_{i,j}$ is again the population fraction for the i^{th} pathway and j^{th} age group):

Equation 16 $$P_{2345} = \Sigma_5 \left[P_{23} \Sigma_4 \left(pP_{34} P_{45}\right)_i\right]_j \quad \text{for } j = 1,\ldots,5 \text{ pathways and } i = 1,\ldots,4 \text{ age groups,}$$

which is analogous to that used to compute the I-131 ingestion P_{2345} transfer coefficient in Equation 6, in which only the milk pathway was considered. For example, using the UNSCEAR 1993 Report values (instead including the age-specific P_{45} transfer factors from Reference 20), the Cs-137 P_{25} transfer coefficient would be:

Equation 17 $P_{2345} = \Sigma_5 \left[P_{23} \Sigma_4 \left(pP_{34} P_{45}\right)_i\right]_j$

$$
\begin{aligned}
P_{2345} = \{ & \left(6.8\text{x}10^{-3} \text{ Bq a kg}^{-1} \text{ per Bq m}^{-2}\right)\left[(0.02)\left(156.7 \text{ kg a}^{-1}\right)\left(15.5 \text{ nSv Bq}^{-1}\right) \text{ for 0 - 1 year} \right. \\
& + (0.16)\left(156.7 \text{ kg a}^{-1}\right)\left(10 \text{ nSv Bq}^{-1}\right) \text{ for 1 - 9 years} \\
& + (0.20)\left(156.7 \text{ kg a}^{-1}\right)\left(13 \text{ nSv Bq}^{-1}\right) \text{ for 9 - 19 years} \\
& \left. + (0.62)\left(156.7 \text{ kg a}^{-1}\right)\left(13 \text{ nSv Bq}^{-1}\right) \text{ for adults}\right] \text{ for milk} \\
& + \left(15.7\text{x}10^{-3} \text{ Bq a kg}^{-1} \text{ per Bq m}^{-2}\right)\left[(0.02)\left(83.3 \text{ kg a}^{-1}\right)\left(15.5 \text{ nSv Bq}^{-1}\right) \text{ for 0 - 1 year} \right. \\
& + (0.16)\left(83.3 \text{ kg a}^{-1}\right)\left(10 \text{ nSv Bq}^{-1}\right) \text{ for 1 - 9 years} \\
& + (0.20)\left(83.3 \text{ kg a}^{-1}\right)\left(13 \text{ nSv Bq}^{-1}\right) \text{ for 9 - 19 years} \\
& \left. + (0.62)\left(83.3 \text{ kg a}^{-1}\right)\left(13 \text{ nSv Bq}^{-1}\right) \text{ for adults}\right] \text{ for grains} \\
& + \left(3.2\text{x}10^{-3} \text{ Bq a kg}^{-1} \text{ per Bq m}^{-2}\right)\left[(0.02)\left(123.3 \text{ kg a}^{-1}\right)\left(15.5 \text{ nSv Bq}^{-1}\right) \text{ for 0 - 1 year} \right. \\
& + (0.16)\left(123.3 \text{ kg a}^{-1}\right)\left(10 \text{ nSv Bq}^{-1}\right) \text{ for 1 - 9 years} \\
& + (0.20)\left(123.3 \text{ kg a}^{-1}\right)\left(13 \text{ nSv Bq}^{-1}\right) \text{ for 9 - 19 years} \\
& \left. + (0.62)\left(123.3 \text{ kg a}^{-1}\right)\left(13 \text{ nSv Bq}^{-1}\right) \text{ for adults}\right] \text{ for vegetables} \\
& + \left(3.3\text{x}10^{-3} \text{ Bq a kg}^{-1} \text{ per Bq m}^{-2}\right)\left[(0.02)\left(71.1 \text{ kg a}^{-1}\right)\left(15.5 \text{ nSv Bq}^{-1}\right) \text{ for 0 - 1 year} \right. \\
& + (0.16)\left(71.1 \text{ kg a}^{-1}\right)\left(10 \text{ nSv Bq}^{-1}\right) \text{ for 1 - 9 years} \\
& + (0.20)\left(71.7 \text{ kg a}^{-1}\right)\left(13 \text{ nSv Bq}^{-1}\right) \text{ for 9 - 19 years} \\
& \left. + (0.62)\left(71.7 \text{ kg a}^{-1}\right)\left(13 \text{ nSv Bq}^{-1}\right) \text{ for adults}\right] \text{ for fruit} \\
& + \left(20.1\text{x}10^{-3} \text{ Bq a kg}^{-1} \text{ per Bq m}^{-2}\right)\left[(0.02)\left(66.7 \text{ kg a}^{-1}\right)\left(15.5 \text{ nSv Bq}^{-1}\right) \text{ for 0 - 1 year} \right. \\
& + (0.16)\left(66.7 \text{ kg a}^{-1}\right)\left(10 \text{ nSv Bq}^{-1}\right) \text{ for 1 - 9 years} \\
& + (0.20)\left(66.7 \text{ kg a}^{-1}\right)\left(13 \text{ nSv Bq}^{-1}\right) \text{ for 9 - 19 years} \\
& \left. + (0.62)\left(66.7 \text{ kg a}^{-1}\right)\left(13 \text{ nSv Bq}^{-1}\right) \text{ for adults}\right] \text{ for meat} \}
\end{aligned}
$$

$$
\begin{aligned}
P_{2345} = \{ & 13.4 \text{ nSv per Bq m}^{-2} \text{ for milk} \\
& + 16.4 \text{ nSv per Bq m}^{-2} \text{ for grains} \\
& + 5.0 \text{ nSv per Bq m}^{-2} \text{ for vegetables} \\
& + 3.0 \text{ nSv per Bq m}^{-2} \text{ for fruit} \\
& + 16.9 \text{ nSv per Bq m}^{-2} \text{ for meat} \} \\
= & \ 55 \text{ nSv per Bq m}^{-2} \text{ for } {}^{137}\text{Cs}
\end{aligned}
$$

versus a value of 56 nSv per Bq m^{-2} computed previously in Equation 4 or the value of 55 nSv per Bq m^{-2} provided in the UNSCEAR 1993 Report [13] (and also computed using Equation 3 in Section 3.1.1). Therefore, the age-specific P_{45} values have very little impact on the calculation for this specific case where the P_{45} values vary between 10 and 15.5 nSv Bq^{-1}.

A very large set of possible P_{2345} transfer coefficients for Cs-137 and Sr-90 can be obtained by substituting the various possible values of P_{23}, p, P_{34}, and P_{45} into Equation 17. The ranges describing the possible transfer coefficients by both age[23] and pathway (including the weighted values obtained using Equation 17) are provided in Table 72 and Table 73 for Cs-137 and Sr-90, respectively. The corresponding values from the UNSCEAR 1993 Report [13] are 55 and 52 nSv Bq^{-1} for Cs-137 and Sr-90, respectively; therefore, there is the possibility of very different dose estimates from those

[23] In estimating the values for Table 72 and Table 73, if only adult values are provided (e.g., the UNSCEAR 1993 Report consumption values for pathways other than milk and the FGR-11 [27] P_{45} coefficients), then the adult values are substituted for the missing values. This will provide conservative minimum and maximum values for the coefficients desired in this study.

obtained using the UNSCEAR 1993 Report values. The Cs-137 and Sr-90 P_{2345} coefficients for adults, which were the values computed in the UNSCEAR 1993 Report [13], are between 0.13 and 4.6 times and 0.12 to 7.4 times, respectively, the values provided in the UNSCEAR 1993 Report. For the "maximum individual"[24], or that age group with the highest deposition-to-dose P_{2345} ingestion coefficient, the values in Table 72 and Table 73 for Cs-137 (for teens) and Sr-90 (for infants) are between 0.13 and 6.0 times and between 0.014 and 34.3 times, respectively, the values provided in the UNSCEAR 1993 Report.

4.2.1 I-131 Ingestion Design Space Definition

For I-131, only the milk pathway was assumed significant in the UNSCEAR 1993 Report (which appears a reasonable assumption). The P_{23} value used for I-131 is 0.63 mBq a L^{-1} per Bq m^{-2} [21], which was derived for an average milk consumption rate of 0.3 L d^{-1} (or 109.5 L a^{-1}). Use of these values provides a nominal $P_{234} = P_{23}P_{34}$ coefficient for I-131 of 0.07 Bq per Bq m^{-2}. As illustrated in Equation 6, the population information in Table 70 was used with the following milk consumptions: 330, 180, 150, and 90 L a^{-1} for age groups 0-1, 1-9, 9-19, and adult, respectively, to derive an overall P_{2345} coefficient for I-131 of 4.2 nSv per Bq m^{-2}.

Defining a design space for the I-131 P_{25} coefficients requires information concerning the ranges for the P_{23}, P_{34}, and P_{45} parameters resulting from site specific criteria, updated information, etc. As in the case of the P_{23} parameters for Sr-90 and Cs-137, the basic information as to how this value used was obtained is not available; therefore, an arbitrary factor of 10% on either side of the UNSCEAR P_{23} value was employed. The P_{34} design range from Table 68 for milk converted to a L a^{-1} basis will be used. The P_{45} coefficients for I-131 are provided in Table 69 (where a value of 61 nSv Bq-1 will be examined as this is the age-weighted value used in the UNSCEAR 1993 Report [13]). As above, the NRC 1.109 values were not used as they are based upon a different assumption than the other three sets of information. Using the aforementioned information, the ranges describing the resulting I-131 P_{2345} coefficients for ingestion are provided in Table 74; the value used in the UNSCEAR 1993 Report is 4.2 nSv per Bq m^{-2}. Note that the weighted values, which are analogous to those computed in the UNSCEAR 1993 Report, are between 0.008 and 4.4 times the value provided in the UNSCEAR 1993 Report, and the "maximum individual" values (for infants) are between 0.008 and 39.4 times the UNSCEAR 1993 Report value.

4.3 Inhalation Transfer Coefficients

Per the UNSCEAR 1993 report, the deposition-to-dose transfer coefficient for the inhalation pathway is computed using the form described in Equation 8:

$$P_{245} = \frac{P_{14}P_{45}}{P_{12}}$$

where P_{14} is the average breathing rate (e.g., 7300 m^3 a^{-1} [13]), P_{45} is the dose per unit intake factor in nGy Bq^{-1}, and P_{12} is the deposition velocity (e.g., 1.76 cm s^{-1} [13]). The above relationship provides a P_{245} transfer factor with units of nGy Bq^{-1} instead of nSv Bq^{-1}, which is desired for this study. From inspection of the results in the UNSCEAR 1993 Report [13], it appears that a factor of 1 nSv nGy^{-1} was used to convert from the values provided using the relationship in Equation 8 to the P_{245} values provided in nSv Bq^{-1} that were subsequently used to estimate doses.

Various average breathing rates (P_{14}) are provided in Table 60, Table 64, and Table 65; whereas, a value of 7300 m^3 a^{-1} was used in the UNSCEAR 1993 Report [13]. Additional values obtained from

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[24] It is sufficient to define the "maximum individual" based upon the ingestion P_{2345} coefficients because 1) inhalation is a very small part of the total deposition to dose factor and 2) external exposure is not age-dependent.

the 2000 UNSCEAR Report [16,53] are provided in Table 75. The breathing rate values for use in this study are summarized in Table 76.

A single value (i.e., 1.76 cm s^{-1} or $5.54x10^5$ m a^{-1}) of the P_{12} parameter was used in the UNSCEAR 1993 Report [13] for all radionuclides. However, the dry deposition values [6] are 0.2, 0.15, and 0.6 cm s^{-1} for Sr-90, Cs-137, and I-131, respectively. Thus these deposition velocities will be used with the UNSCEAR P_{12} value of 1.76 cm s^{-1} to bracket the likely values of P_{12} for definition of the P_{245} inhalation design space.

The final parameter used in the definition of the UNSCEAR P_{245} factor for inhalation is the effective, committed dose per unit intake, P_{45}, in units of nSv Bq^{-1}. The relevant information concerning the possible values for the effective P_{45} transfer coefficient is summarized in Table 77. When age-dependent values for P_{14} and P_{45} are available, then the P_{245} should be weighted as follows:

Equation 18

$$P_{245} = \sum_4 \left(\frac{1}{P_{12}}\right)(pP_{14}P_{25})_i = \left(\frac{1}{P_{12}}\right)\Sigma_4 (pP_{14}P_{25})_i$$

where P_{12} is the deposition velocity (which is not population dependent) and p_i, $P_{14,i}$, and $P_{45,i}$ are the appropriate population fraction (e.g., as provided in Table 70), breathing rate (e.g., Table 60 and Table 76), and exposure-to-dose coefficient (from Table 77) for the i^{th} age group, respectively. For example, the original Cs-137 P_{245} coefficient for adults was provided using Equation 8:

$$P_{245} = \frac{P_{14}P_{45}}{P_{12}} = \frac{(7300\ m^3\ a^{-1})(8.5\ nSv\ Bq^{-1})}{(5.56x10^5\ m\ a^{-1})} = 0.11\ nSv\ per\ Bq\ m^{-2}\ \text{for}\ ^{137}Cs$$

When the appropriate age-dependent values are used including the age-dependent P_{45} values [20], the P_{245} value becomes:

Equation 19

$$\begin{aligned} P_{245} &= (P_{12})^{-1}\Sigma_4 (pP_{14}P_{45})_i \\ &= (5.56x10^5\ m\ a^{-1})^{-1}\Big[(0.02)(1400\ m^3\ a^{-1})(10.5\ nSv\ Bq^{-1})\ \text{for 0 - 1 year} \\ &\quad + (0.16)(5500\ m^3\ a^{-1})(6.7\ nSv\ Bq^{-1})\ \text{for 1 - 9 years} \\ &\quad + (0.20)(8000\ m^3\ a^{-1})(8.5\ nSv\ Bq^{-1})\ \text{for 9 - 19 years} \\ &\quad + (0.62)(8000\ m^3\ a^{-1})(68.5\ nSv\ Bq^{-1})\ \text{for adults}\Big] \\ &= 0.11\ nSv\ per\ Bq\ m^{-2} \end{aligned}$$

or there is little change in the P_{245} transfer factor for this specific case.

Using the information above for P_{14} and P_{12} as well as the P_{45} information in Table 77, the P_{245} design space for inhalation can be defined as shown in Table 78. The Cs-137 and Sr-90 P_{245} transfer factors for adults, which correspond to the values computed in the UNSCEAR 1993 Report, are between 0.55 and 13.4 times and 0.46 to 9.8 times, respectively, the original UNSCEAR values. For the "maximum individual", or that age group with the highest overall deposition-to-dose transfer coefficient, the values for Cs-137 (for teens) and Sr-90 (for infants) are between 0.40 and 13.3 times and between 0.14 and 8.4 times, respectively, the original UNSCEAR transfer factors. For I-131, the age-weighted P_{245} values, which correspond to those in the UNSCEAR Report, are between 0.56 and 4.9 times the original value, and the "maximum individual" values (for infants) are between 0.10 and 5.7 times the original UNSCEAR value. Thus the three parameters used in the definition of P_{245} for inhalation were lumped into a single P_{245} design parameter to simplify the design. Any significant effects of the inhalation parameter can easily be deconvoluted to identify specific inhalation parameters.

4.4 External Exposure Transfer Coefficients

In addition to internal radiation from inhaled or ingested radionuclides, persons are also irradiated externally from gamma-emitting nuclides dispersed in air and on the ground. As the contamination normally spends much more time on the ground than in the air, the external dose due to irradiation from the earth's surface is normally significantly higher than the dose due to irradiation while the cloud of contamination passes [13]. Therefore, as described above, the external exposure due to radioactive cloud passage will be assumed negligible for the purpose of this study.

As described above, the UNSCEAR P_{25} transfer coefficients for external irradiation due to ground contamination were computed by multiplying the appropriate dose rate conversion factors by the mean lifetime of the radionuclide (i.e., half-life divided by ln(2)) and then by an average factor assuming 80% indoor occupancy with a shielding factor of 0.2. A factor of 0.7 Sv per Gy (i.e., equivalent dose rate in the body per unit absorbed dose rate in air) was also used [54].[25] For I-131 the dose rate conversion factor applying to a plane source was used. For Cs-137, the dose-rate conversion factor applying to an exponential concentration profile in the ground with a mean depth of 3 cm was used. No value was given for Sr-90 (likely because it is a pure beta emitter). Thus the UNSCEAR 1993 values for the external exposure P_{25} coefficients for Cs-137, Sr-90 and I-131 were 97, 0, and 0.12 nSv per Bq m^{-2}, respectively.

To better represent the range of values that might influence the estimation of external exposure, the various factors used to represent daily exposure were considered as illustrated in Table 79.The values provided in Federal Guidance Report No. 12 (FGR-12) [26] are already provided in Sv Bq^{-1} and thus no absorption value is needed. Furthermore, the *maximum* exposure will be when the person spends all their time outside. (Even though this scenario is implausible, it provides an upper limit for this study.) This scenario renders the indoor occupancy and shielding factors moot for the maximum exposure case.

Using the values from Table 79 which will provide maximum dose transfer coefficients (i.e., the case where all time is spent outdoors) and the FGR-12 dose coefficients (i.e., $2.84\text{x}10^{-10}$ and $3.76\text{x}10^{-7}$ Sv per Bq s m^{-2} for Sr-90 and I-131, respectively) for exposure to contaminated ground surface [26], maximum values for P_{25} can be obtained:[26]

Equation 20

$$P_{25} = \left(3.76\text{x}10^{-7}\ \text{Sv s}^{-1}\ \text{per Bq m}^{-2}\right)\left(10^{9}\ \text{nSv per Sv}\right)\left(\frac{t_{1/2}}{\ln(2)}\text{s}\right)\left[(1-R_i)+R_iS_h\right]$$
$$= \left(3.76\text{x}10^{-7}\ \text{Sv s}^{-1}\ \text{per Bq m}^{-2}\right)\left(10^{9}\ \text{nSv per Sv}\right)\left(\frac{6.95\text{x}10^{5}}{\ln(2)}\text{s}\right)\left[(1-0)+(0)(0.7)\right]$$
$$= 0.38\ \text{nSv per Bq m}^{-2}\ \text{for}\ ^{131}\text{I}$$

Equation 21

$$P_{25} = \left(2.84\text{x}10^{-10}\ \text{Sv s}^{-1}\ \text{per Bq m}^{-2}\right)\left(10^{9}\ \text{nSv per Sv}\right)\left(\frac{t_{1/2}}{\ln(2)}\text{s}\right)\left[(1-R_i)+R_iS_h\right]$$
$$= \left(2.84\text{x}10^{-10}\ \text{Sv s}^{-1}\ \text{per Bq m}^{-2}\right)\left(10^{9}\ \text{nSv per Sv}\right)\left(\frac{9.18\text{x}10^{8}}{\ln(2)}\text{s}\right)\left[(1-0)+(0)(0.7)\right]$$
$$= 0.38\ \text{nSv per Bq m}^{-2}\ \text{for}\ ^{90}\text{Sr}$$

---

[25] It is assumed that this factor is used because the dose factors are those based upon soft tissue near the body surface. Because of energy absorption in the body, the interior doses are about 70% of the values measured near the body surface [54].

[26] Note that the quantity, $(1\text{-}R_i) + (R_i)(S_h)$, is referred to as S_f in NRC 1.109 and has values of 0.5 and 0.7 for the general population and maximum individual exposures, respectively. Using the values in Table 79 gives a range of S_f for this study from 0.36 to 1.0; therefore, the NRC 1.109 values will not be explicitly mentioned in this study (as they are represented in the range computed).

where the half-lives of I-131 and Sr-90 are 6.948×10^5 and 9.1764×10^8 s, respectively [6]. Note that the Gy to Sv conversion factor of 0.7 was unnecessary in the above equations. Substituting the external exposure value from NRC 1.109 [46] of 2.10×10^{-7} Sv per Bq s m^{-2} for I-131 provides a value of 0.21 nSv per Bq m^{-2} for I-131. The value provided in NRC 1.109 for Sr-90 is 0 nSv per Bq m^{-2} [46]. Thus the lower values for the P_{25} ranges for Sr-90 and I-131 will be those from the UNSCEAR 1993 Report [13]. The fact that the P_{25} factor for Sr-90 is non-zero may cause some consternation; however, two facts must be taken into consideration: 1) the appropriate coefficient from FGR-12 is non-zero and 2) the Sr-90 dose commitments will be dominated by the ingestion pathway.

As described above, the P_{25} coefficient (i.e., 97 nSv per Bq m^{-2}) for Cs-137 was computed in a different fashion than those for Sr-90 and I-131; the dose-rate conversion factor corresponding to an exponential concentration profile in the ground with mean depth of 3 cm was used [13]. However, it appears that the Cs-137 was assumed to be in secular equilibrium with Ba-137m (which is a valid assumption) and that the dose-rate conversion factor for Ba-137m was used to determine the external irradiation factor for Cs-137.

For example, employing the FGR-12 Cs-137 dose coefficients (i.e., 1.34×10^{-12} Sv s^{-1} per Bq m^{-3} and 3.07×10^{-12} Sv s^{-1} per Bq m^{-3} [26]) for 20% outdoor exposure (i.e., the complement of an 80% indoor exposure) to soil contaminated to depths of 1 cm and 5 cm, respectively (because coefficients for 3 cm were not provided) provides the following P_{25} values:

$$P_{25} = \left(1.34\text{x}10^{-12}\ \text{Sv s}^{-1}\ \text{per Bq m}^{-3}\right)\left(10^{9}\ \text{nSv per Sv}\right)\left(\frac{1}{1\ \text{cm}}\right)\left(100\ \text{cm per m}\right)\left(\frac{t_{1/2}}{\ln(2)}\text{s}\right)$$
$$\text{x}\left[\left(1-R_i\right)+R_iS_h\right]$$

Cs-137 at 1 cm

$$= \left(1.34\text{x}10^{-12}\ \text{Sv s}^{-1}\ \text{per Bq m}^{-3}\right)\left(10^{9}\ \text{nSv per Sv}\right)\left(\frac{1}{1\ \text{cm}}\right)\left(100\ \text{cm per m}\right)\left(\frac{9.5\text{x}10^{8}}{\ln(2)}\text{s}\right)$$
$$\text{x}\left[\left(1-0.8\right)+\left(0.8\right)\left(0.2\right)\right]$$
$$= 0.07\ \text{nSv per Bq m}^{-2}$$

$$P_{25} = \left(3.07\text{x}10^{-12}\ \text{Sv s}^{-1}\ \text{per Bq m}^{-3}\right)\left(10^{9}\ \text{nSv per Sv}\right)\left(\frac{1}{5\ \text{cm}}\right)\left(100\ \text{cm per m}\right)\left(\frac{t_{1/2}}{\ln(2)}\text{s}\right)$$
$$\text{x}\left[\left(1-R_i\right)+R_iS_h\right]$$

Cs-137 at 5 cm

$$= \left(3.07\text{x}10^{-12}\ \text{Sv s}^{-1}\ \text{per Bq m}^{-3}\right)\left(10^{9}\ \text{nSv per Sv}\right)\left(\frac{1}{5\ \text{cm}}\right)\left(100\ \text{cm per m}\right)\left(\frac{9.5\text{x}10^{8}}{\ln(2)}\text{s}\right)$$
$$\text{x}\left[\left(1-0.8\right)+\left(0.8\right)\left(0.2\right)\right]$$
$$= 0.03\ \text{nSv per Bq m}^{-2}$$

If, on the other hand, the FGR-12 values (i.e., 3.76×10^{-9} Sv s^{-1} per Bq m^{-3} and 1.09×10^{-8} Sv s^{-1} per Bq m^{-3} at 1 cm and 5 cm, respectively [26]) for Ba-137m are used, the following P_{25} values are obtained:

$$P_{25} = \left(3.76\text{x}10^{-9}\ \text{Sv s}^{-1}\ \text{per Bq m}^{-3}\right)\left(10^{9}\ \text{nSv per Sv}\right)\left(\frac{1}{1\ \text{cm}}\right)\left(100\ \text{cm per m}\right)\left(\frac{t_{1/2}}{\ln(2)}\text{s}\right)$$
$$\text{x}\left[\left(1-R_i\right)+R_iS_h\right]$$

Ba-137m at 1 cm

$$= \left(3.76\text{x}10^{-9}\ \text{Sv s}^{-1}\ \text{per Bq m}^{-3}\right)\left(10^{9}\ \text{nSv per Sv}\right)\left(\frac{1}{1\ \text{cm}}\right)\left(100\ \text{cm per m}\right)\left(\frac{9.5\text{x}10^{8}}{\ln(2)}\text{s}\right)$$
$$\text{x}\left[\left(1-0.8\right)+\left(0.8\right)\left(0.2\right)\right]$$
$$= 185.6\ \text{nSv per Bq m}^{-2}$$

$$P_{25} = \left(1.09\text{x}10^{-8}\ \text{Sv s}^{-1}\ \text{per Bq m}^{-3}\right)\left(10^{9}\ \text{nSv per Sv}\right)\left(\frac{1}{5\ \text{cm}}\right)\left(100\ \text{cm per m}\right)\left(\frac{t_{1/2}}{\ln(2)}\text{s}\right)$$
$$\text{x}\left[\left(1-R_i\right)+R_iS_h\right]$$

Ba-137m at 5 cm

$$= \left(1.09\text{x}10^{-8}\ \text{Sv s}^{-1}\ \text{per Bq m}^{-3}\right)\left(10^{9}\ \text{nSv per Sv}\right)\left(\frac{1}{5\ \text{cm}}\right)\left(100\ \text{cm per m}\right)\left(\frac{9.5\text{x}10^{8}}{\ln(2)}\text{s}\right)$$
$$\text{x}\left[\left(1-0.8\right)+\left(0.8\right)\left(0.2\right)\right]$$
$$= 107.6\ \text{nSv per Bq m}^{-2}$$

for a value (based upon an exponential concentration profile) at 3 cm of 141.3 nSv per Bq m^{-2}, which is larger than the UNSCEAR value of 97 nSv per Bq m^{-2}. This will be used as one way to obtain an upper bound for Cs-137 because it will be assumed that the Ba-137m is in secular equilibrium with Cs-137.

The upper bound for Cs-137 will thus be the value P_{25} (with 100% outdoor occupancy and no quality factor adjustment) corresponding to 3 cm based upon the following:

$$P_{25} = \left(3.76\text{x}10^{-9}\ \text{Sv s}^{-1}\ \text{per Bq m}^{-3}\right)\left(10^{9}\ \text{nSv per Sv}\right)\left(\frac{1}{1\ \text{cm}}\right)\left(100\ \text{cm per m}\right)\left(\frac{t_{1/2}}{\ln(2)}\text{s}\right)$$
$$\text{x}\left[\left(1-R_i\right)+R_iS_h\right]$$

Ba-137m at 1 cm

$$= \left(3.76\text{x}10^{-9}\ \text{Sv s}^{-1}\ \text{per Bq m}^{-3}\right)\left(10^{9}\ \text{nSv per Sv}\right)\left(\frac{1}{1\ \text{cm}}\right)\left(100\ \text{cm per m}\right)\left(\frac{9.5\text{x}10^{8}}{\ln(2)}\text{s}\right)$$
$$\text{x}\left[\left(1-0\right)+\left(0\right)\left(0.7\right)\right]$$
$$= 515.6\ \text{nSv per Bq m}^{-2}$$

$$P_{25} = \left(1.09\text{x}10^{-8}\ \text{Sv s}^{-1}\ \text{per Bq m}^{-3}\right)\left(10^{9}\ \text{nSv per Sv}\right)\left(\frac{1}{5\ \text{cm}}\right)\left(100\ \text{cm per m}\right)\left(\frac{t_{1/2}}{\ln(2)}\text{s}\right)$$
$$\text{x}\left[\left(1-R_i\right)+R_iS_h\right]$$

Ba-137m at 5 cm

$$= \left(1.09\text{x}10^{-8}\ \text{Sv s}^{-1}\ \text{per Bq m}^{-3}\right)\left(10^{9}\ \text{nSv per Sv}\right)\left(\frac{1}{5\ \text{cm}}\right)\left(100\ \text{cm per m}\right)\left(\frac{9.5\text{x}10^{8}}{\ln(2)}\text{s}\right)$$
$$\text{x}\left[\left(1-0\right)+\left(0\right)\left(0.7\right)\right]$$
$$= 299.0\ \text{nSv per Bq m}^{-2}$$

The value at 3 cm is 392.6 nSv per Bq m^{-2} based upon a logarithmic profile.

In NRC 1.109 [46], the external exposures are not given as a function of depth. Following the computations for I-131 and Sr-90, the minimum and maximum external exposures from Cs-137 for an individual standing on contaminated ground based upon the value of $4.20\text{x}10^{-9}$ mrem h^{-1} per pCi m^{-2} (which converts to a value of $3.15\text{x}10^{-7}$ Sv s^{-1} per Bq m^{-2}) would be:

$$P_{25} = \left(3.15\text{x}10^{-7}\ \text{Sv s}^{-1}\ \text{per Bq m}^{-2}\right)\left(10^{9}\ \text{nSv per Sv}\right)\left(\frac{t_{1/2}}{\ln(2)}\text{s}\right)\left[\left(1-R_i\right)+R_iS_h\right]$$

Minimum Cs-137

$$= \left(3.15\text{x}10^{-7}\ \text{Sv s}^{-1}\ \text{per Bq m}^{-2}\right)\left(10^{9}\ \text{nSv per Sv}\right)\left(\frac{9.5\text{x}10^{8}}{\ln(2)}\text{s}\right)\left[\left(1-0.8\right)+\left(0.8\right)\left(0.2\right)\right]$$
$$= 156\ \text{nSv per Bq m}^{-2}$$

and

$$P_{25} = \left(3.15\text{x}10^{-7}\ \text{Sv s}^{-1}\ \text{per Bq m}^{-2}\right)\left(10^{9}\ \text{nSv per Sv}\right)\left(\frac{t_{1/2}}{\ln(2)}\text{s}\right)\left[\left(1-R_i\right)+R_iS_h\right]$$

Maximum Cs-137

$$= \left(3.15\text{x}10^{-7}\ \text{Sv s}^{-1}\ \text{per Bq m}^{-2}\right)\left(10^{9}\ \text{nSv per Sv}\right)\left(\frac{9.5\text{x}10^{8}}{\ln(2)}\text{s}\right)\left[\left(1-0\right)+\left(0\right)\left(0.7\right)\right]$$

$$= 432\ \text{nSv per Bq m}^{-2}$$

The minimum design value will be that (i.e., 97 nSv per Bq m^{-2}) from the UNSCEAR 1993 Report [13] because it is lowest of those computed for Cs-137. The upper value for Cs-137 will be the largest computed from the NRC 1.109 [46] values. Although the assumptions for which it was computed are somewhat different than those used in the UNSCEAR 1993 Report, the NRC 1.109 value is considered appropriate for use under scenarios such as those postulated in this study and, therefore, the value will be included here as the maximum value for Cs-137. Note that, unlike the NRC 1.109 ingestion and inhalation coefficients, the fundamental assumptions have not changed since its publication and, therefore, these values have been included in this study. Any issues (e.g., secular equilibrium between Ba-137m and Cs-137) used to compute the Cs-137 P_{25} coefficients using the FGR-12 information are less important as said values fall within the range that will be used in this study; they are not used to directly define the range of P_{25} coefficients that will be used.

4.5 Transfer Coefficient Summary Based upon the UNSCEAR Methodology

The design spaces for Cs-137, Sr-90, and I-131 are summarized by the various deposition-to-dose transfer coefficients defined in this memorandum (which will then be multiplied by the pertinent, scaled deposited radiation levels in Bq m^{-2} to provide dose commitment estimates). The deposition-to-dose coefficients for Cs-137, Sr-90, and I-131 are summarized in Table 80, Table 81, and Table 82, respectively, and the factors needed to scale the "unit hypothetical release" of $8.64\text{x}10^{14}$ Bq to values representing various accident scenarios are provided in Table 57. Note that like the UNSCEAR 1993 Report values, the majority of the Cs-137 dose commitment is from the external exposure pathway (although the ingestion pathway can be significant), and the Sr-90 and I-131 dose commitments will be dominated by the ingestion pathway.

Initially "worst-case" scenarios will be examined to indicate whether additional study is necessary. By "worst-case," it is meant that the values associated with those coefficients described above that result in the largest dose commitment for the individual in question will be used. The scenarios the will be considered in this study are the following:

- "maximum individual" dose commitment or that dose resulting from the coefficients corresponding to the maximum coefficients in Table 80 (or the teen group for Cs-137), Table 81 (or the infant group for Sr-90), and Table 82 (or the infant group for I-131),
- maximum adult dose commitments for Cs-137 and Sr-90 and age-weighted dose commitment for I-131, and
- maximum collective dose commitment corresponding to the age-weighted values in Table 80.

The above scenarios appear appropriate because the "maximum individual" dose commitment will illustrate the maximum impact on those persons most effected by the depositions considered in this study. The maximum, adult dose commitments for Cs-137 and Sr-90 and the age-weighted dose commitment for I-131 will show impact that varying the parameters in this study have relative to the UNSCEAR 1993 Report values. The maximum, collective dose commitments will only be computed using the population-weighted values from Table 80, Table 81, and Table 82 as the weighting takes into account the varying ages in the affected population.

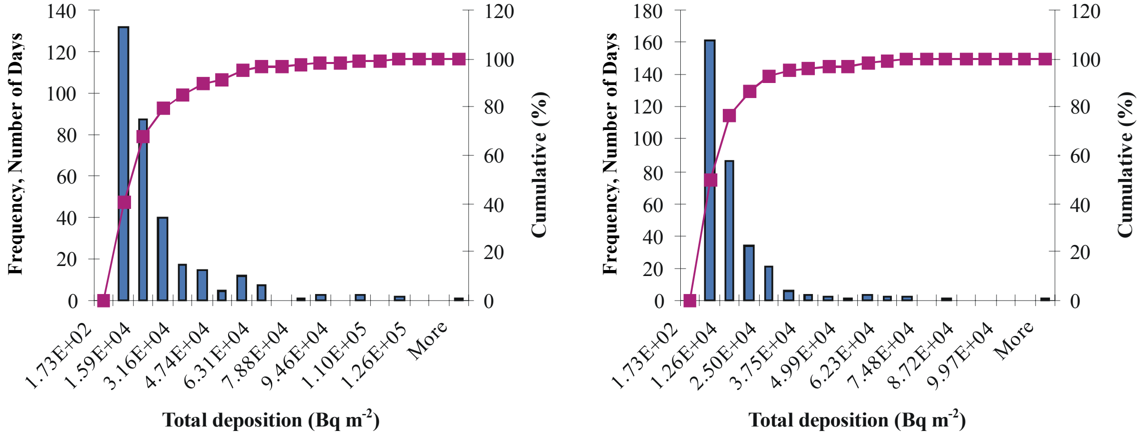
4.6 Adjusted Total Deposition Data Analysis

In this part of the study, the deposition data will be adjusted to be more representative of the types of accidents that can occur. Examination of the adjusted total deposition data for a given site requires adjustment of the original total depositions [6] by the maximum ratio from Table 57 for the site in question. In essence, the source term would be adjusted by the appropriate ratio from Table 57, which would then result in each deposition from Mahura [6] to be adjusted by the same factor. Therefore, it is equivalent to merely adjust the depositions to reflect the result of the new source term. Adjustment of the source term and resulting depositions will have the greatest impact on the Cs-137 results; these values can increase by a factor of more than five for both the PRS and VRS when the maximum values from Table 57 are considered. The impact on the Sr-90 deposition values will be negative; the PRS and VRS values for Sr-90 will be less than 30% of the original "unit hypothetical" value. The largest impact will be on the total I-131 depositions; the resulting depositions for both the PRS and VRS will decrease by more than a factor of 250.

4.6.1 Maximum Adjusted Total Depositions from the PRS

Using the appropriate values from Table 57, the maximum adjusted total deposition values for the releases from the PRS are provided in Table 83, Table 84, and Table 85 for Cs-137, Sr-90, and I-131, respectively. Note that, not surprisingly, the maximum adjusted Cs-137 depositions are now more than an order of magnitude larger than the corresponding maximum Sr-90 values and almost three orders of magnitude larger than the corresponding I-131 depositions. When considering the deposition-to-dose coefficients in Table 80, Table 81, and Table 82 for Cs-137, Sr-90, and I-131, respectively, it is apparent that the radionuclide of primary interest will be Cs-137. This should be obvious when comparing the resulting Cs-137 and I-131 dose commitments because both the Cs-137 maximum depositions and deposition-to-dose factors are orders of magnitude larger for Cs-137 than for I-131. For Sr-90, even though the deposition-to-dose coefficients are larger than their Cs-137 counterparts by a factor of up to 2.5, the maximum Cs-137 depositions will be larger than those for Sr-90 by more than an order of magnitude. Thus the Cs-137 depositions and resulting dose commitments are of primary concern for releases from the PRS.

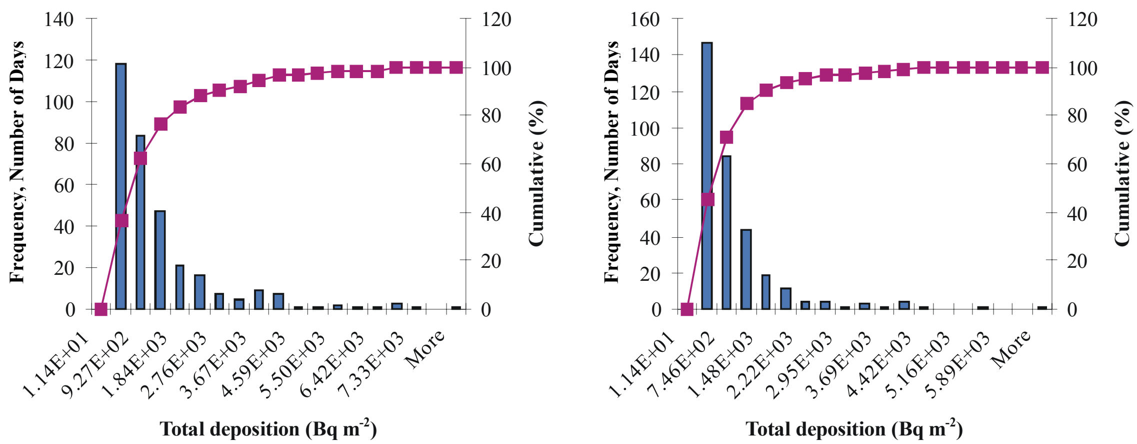
The distribution of maximum daily total depositions corresponding to the adjusted Cs-137 releases from the PRS for the entire region of interest and the transboundary region (i.e., including all areas outside of Russia including ocean) are provided in Figure 57(a) and Figure 57(b), respectively. The maximum depositions for the adjusted releases from the PRS are 1.39×10^5 and 1.10×10^5 Bq m^{-2} for the entire region and transboundary region, respectively. Thus even though there is little impact on the maximum deposition (and thus the corresponding dose commitment) between these two regions, the information in Figure 57 indicates that there are fewer large depositions (i.e., greater than 5×10^4 Bq m^{-2}) in the transboundary region.



(a) Regional (b) Transboundary

Figure 57. Frequency histogram and cumulative percentages for the adjusted PRS Cs-137 total deposition (tdep) maximum values for (a) the entire region of interest and (b) the transboundary region.

To complete the picture, the distributions for the maximum Sr-90 and I-131 depositions resulting from the adjusted releases from the PRS are provided in Figure 58 and Figure 59, respectively. As indicated above, the deposition and dose commitments resulting for these two radionuclides from the adjusted releases from the PRS are much less significant than those for Cs-137.



(a) Regional (b) Transboundary

Figure 58. Frequency histogram and cumulative percentages for the adjusted PRS Sr-90 total deposition (tdep) maximum values for (a) the entire region of interest and (b) the transboundary region.

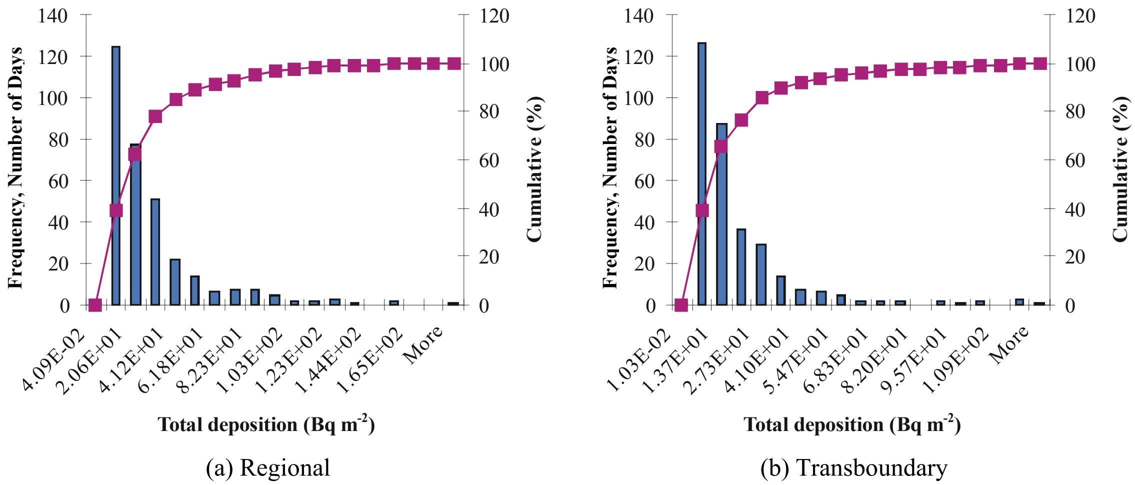


Figure 59. Frequency histogram and cumulative percentages for the adjusted PRS I-131 total deposition (tdep) maximum values in for (a) the entire region of interest and (b) the transboundary region.

4.6.1.1 Specific Case Examples: Japan and U.S. Depositions from the PRS

For the specific examples in this study, only the Cs-137 depositions will be examined as they represent the largest impact of the three radionuclides considered. The distribution of maximum total Cs-137 depositions for Japan resulting from the adjusted PRS releases is illustrated in Figure 60. Note that even though the maximum value is 1380 Bq m^{-2} (from Table 83), 95% of all such depositions in Japan are less than 156 Bq m^{-2} and there are no depositions on 75% of all days in CY2000. Therefore, the impact on Japan from even the maximum adjusted releases from the PRS appears to be minimal when compared to the rest of the transboundary region.

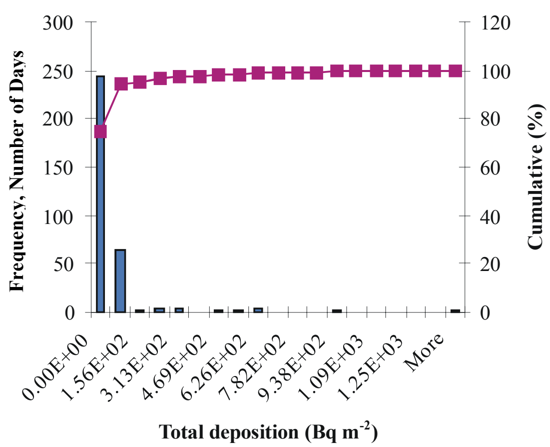
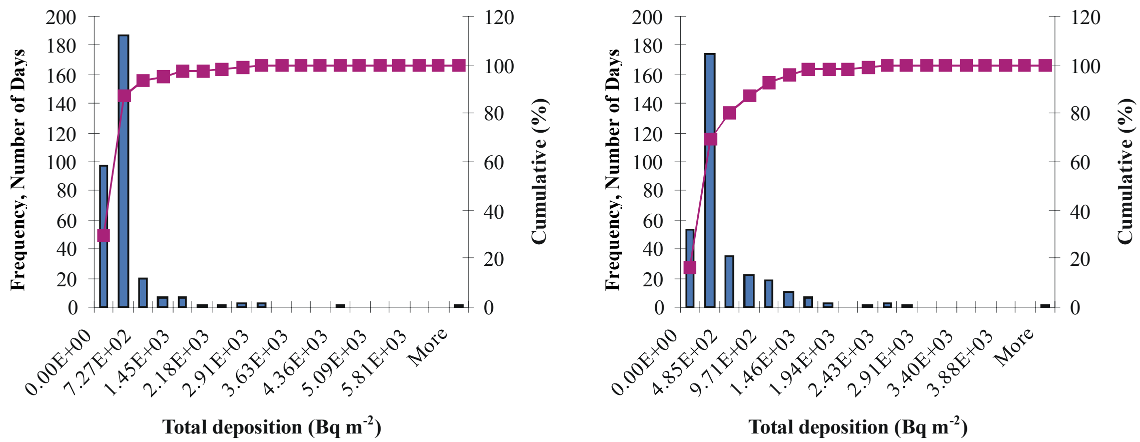


Figure 60. Japan Results: Frequency histogram and cumulative percentages for the PRS Cs-137 total deposition (tdep) adjusted values.

The distributions of the maximum total Cs-137 depositions resulting from the adjusted PRS releases for Alaska and the Aleutian Islands are provided in Figure 61(a) and Figure 61(b), respectively. It should be noted that 1) the impact on both of these U.S. territories is similar and 2) that the impact on these U.S. territories is generally larger than that on Japan. Both the maximum values for the U.S. territories (as illustrated in Table 83) are larger by a factor of at least 3.5, but there are depositions on the U.S. territories considered on many more days than in Japan. Therefore, the adjusted Cs-137 releases from the PRS are more significant to the people living in the U.S. territories than in Japan; however, it is also true that many more people will be impacted by the depositions on Japan than in either U.S. territory considered here. This impact will be addressed below when collective doses are computed.



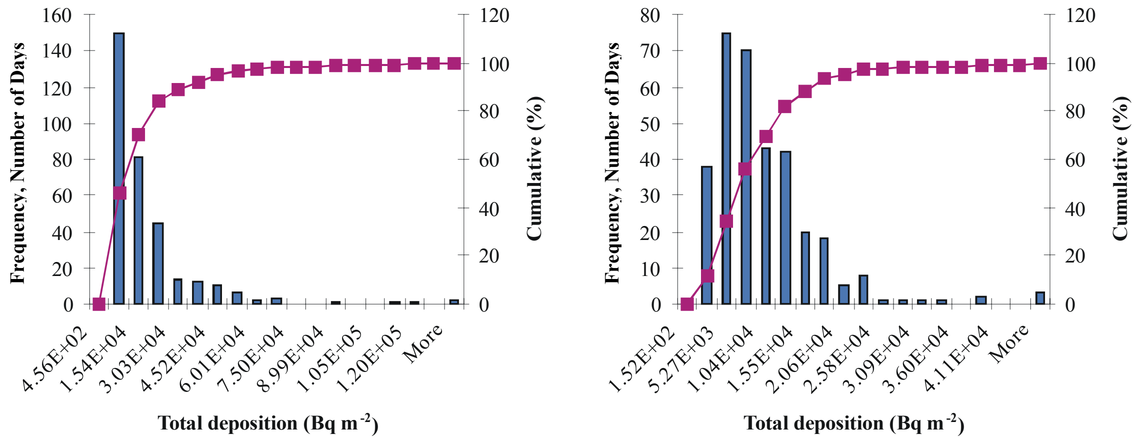
(a) Alaska (U.S.) (b) Aleutian Islands (U.S.)

Figure 61. U.S. Results: Frequency histogram and cumulative percentages for the PRS Cs-137 total deposition (tdep) adjusted values for (a) Alaska and (b) the Aleutian Islands.

4.6.2 Maximum Adjusted Total Depositions from the VRS

Using the appropriate values from Table 57, the maximum total deposition values obtained for the adjusted VRS releases are provided in Table 86, Table 87, and Table 88 for Cs-137, Sr-90, and I-131, respectively. Note that, like those for the corresponding PRS releases, the adjusted Cs-137 depositions are more than an order of magnitude larger than the corresponding maximum Sr-90 values and approximately three orders of magnitude larger than the corresponding I-131 depositions. When considering the deposition-to-dose coefficients, it is apparent that the radionuclide of primary interest will be Cs-137.

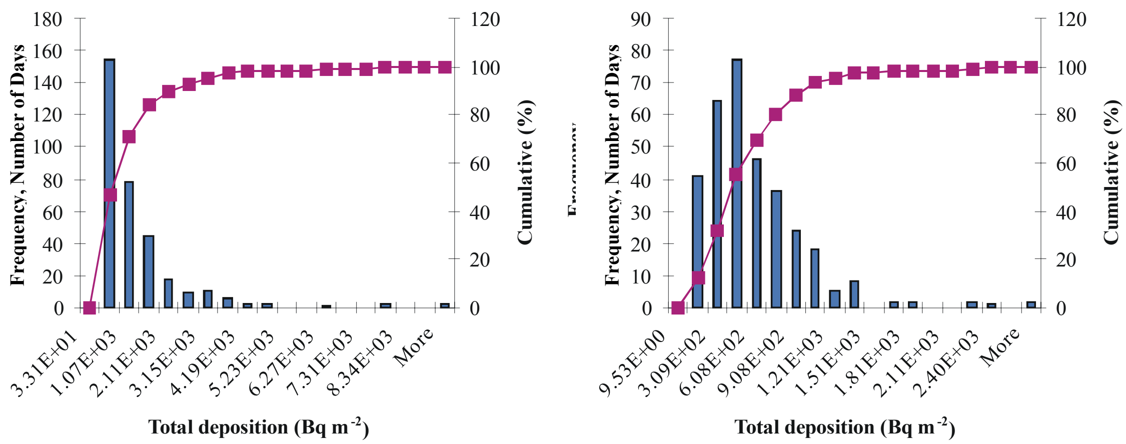
The distribution of maximum daily total depositions corresponding to the adjusted Cs-137 releases from the VRS for the entire region of interest and the transboundary region are provided in Figure 62(a) and Figure 62(b), respectively. The maximum depositions for the adjusted VRS releases are 3.91×10^5 and 1.34×10^5 Bq m^{-2} for the entire region and transboundary region, respectively. Thus even though there is little impact on the maximum deposition (and thus dose commitment) between these two regions, the information in Figure 62 indicates that there are many fewer large depositions in the transboundary region.



(a) Regional (b) Transboundary

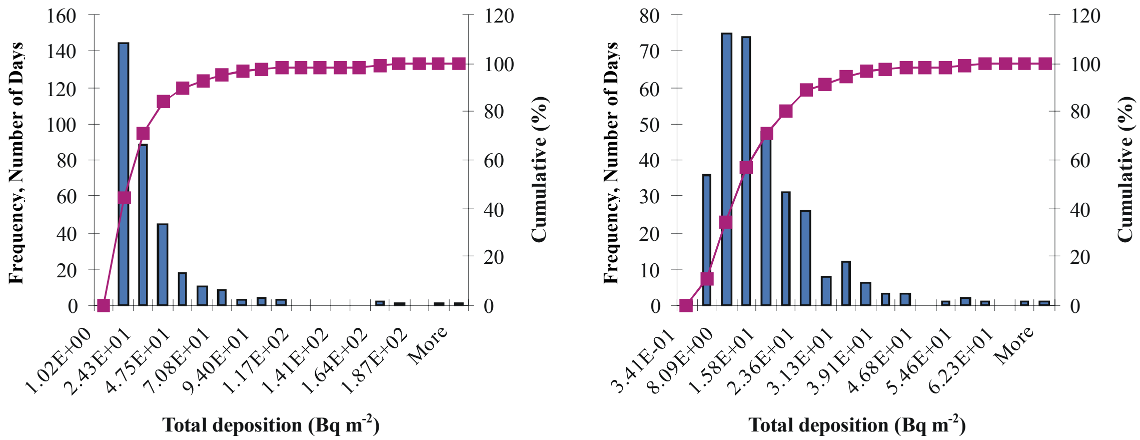
Figure 62. Frequency histogram and cumulative percentages for the adjusted VRS Cs-137 total deposition (tdep) maximum values for (a) the entire region of interest and (b) the transboundary region.

The distributions for the maximum Sr-90 and I-131 depositions resulting from the adjusted VRS releases are provided in Figure 63 and Figure 64, respectively. As indicated above, the deposition and dose commitments resulting for these two radionuclides from the adjusted PRS releases are much less significant than those for Cs-137.



(a) Regional (b) Transboundary

Figure 63. Frequency histogram and cumulative percentages for the adjusted VRS Sr-90 total deposition (tdep) maximum values for (a) the entire region of interest and (b) the transboundary region.



(a) Regional (b) Transboundary

Figure 64. Frequency histogram and cumulative percentages for the adjusted VRS I-131 total deposition (tdep) maximum values for (a) the entire region of interest and (b) the transboundary region.

4.6.2.1 Specific Case Examples: Japan and U.S. Depositions from the VRS

For the specific examples in this study, only the Cs-137 depositions will be examined for the adjusted VRS releases as they represent the largest impact of the three radionuclides considered. The distribution of maximum total Cs-137 depositions for Japan resulting from the adjusted VRS releases is illustrated in Figure 65. Note that the impact on Japan from releases at the VRS is generally much larger than those from the PRS. The maximum deposition resulting from the adjusted VRS release is 5.70×10^4 Bq m^{-2} or more than 40 times that from the corresponding adjusted release from the PRS. Furthermore, the majority of the maximum daily depositions in Japan from the adjusted VRS release are greater than the maximum of all such releases from the PRS. The maximum such value for Japan corresponds to approximately one-half the value for China, a country proximate to the VRS. Therefore, the impact on Japan from the adjusted VRS releases appears to warrant greater consideration. This will be considered in detail below when dose commitments are estimated.

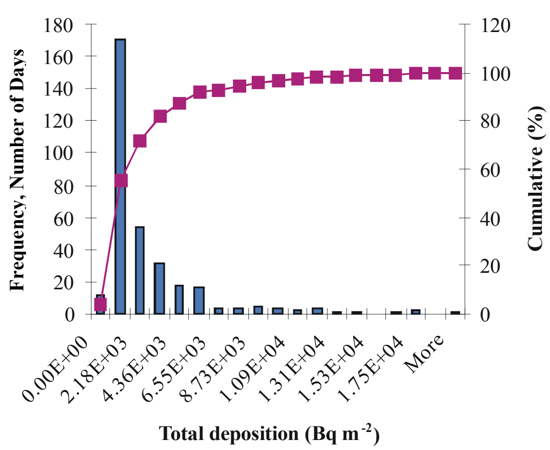
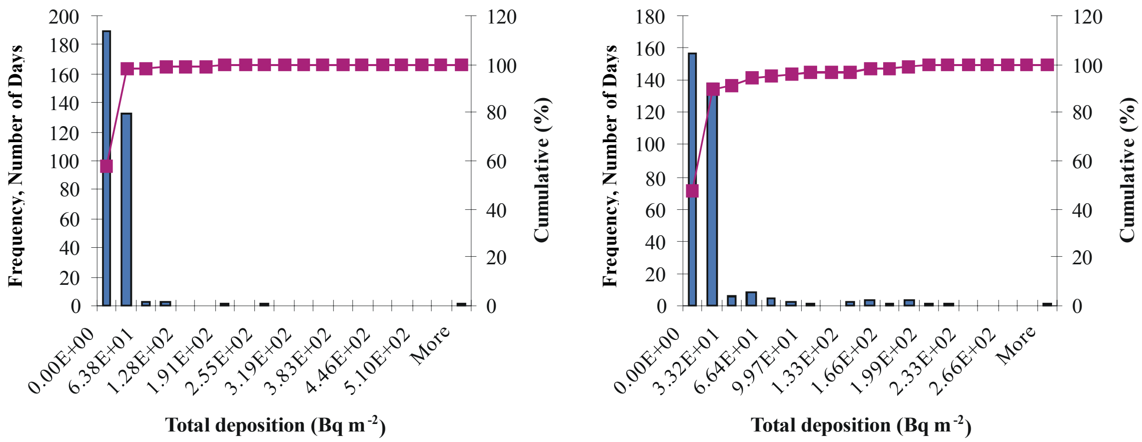


Figure 65. Japan Results: Frequency histogram and cumulative percentages for the VRS Cs-137 total deposition (tdep) adjusted values.

The distributions of the maximum total Cs-137 depositions resulting from the adjusted PRS releases for Alaska and the Aleutian Islands are provided in Figure 66(a) and Figure 66(b), respectively. It should be noted that the impact on both of these U.S. territories is again similar (as found for the corresponding releases from the PRS). However, unlike the VRS, the maximum impact on these U.S. territories is generally smaller than that on Japan by an order of magnitude and there are depositions on approximately half the number of CY2000 days as there are for Japan. Therefore, the adjusted Cs-137 releases from the VRS are more significant to the people living in Japan than those living in the U.S. territories; this is compounded by the fact that many more people will be impacted by the depositions on Japan than in either U.S. territory considered. This impact will be addressed below when collective doses are computed.



(a) Alaska (U.S.)　　　　(b) Aleutian Islands (U.S.)

Figure 66. U.S. Results: Frequency histogram and cumulative percentages for the VRS Cs-137 total deposition (tdep) adjusted values for (a) Alaska and (b) the Aleutian Islands.

4.6.3 Summary of the Adjusted Total Depositions

A summary of the maximum (non-zero) adjusted total depositions for the PRS and VRS is presented in Exhibit 11. Note that the maximum total depositions for Russia (and thus the region) are comparable; however, the total depositions outside of Russia are much larger for the VRS releases than for those from the PRS. Furthermore, the impacts from Cs-137 releases are much larger than their Sr-90 counterparts and orders of magnitude larger than those for I-131. Thus the Cs-137 will be of primary concern under the conditions studied in this report.

Exhibit 11. Summary of Maximum Adjusted Total Depositions (tdep)

PRS

	Maximum Total Deposition (Bq m^{-2})		
Region	**Cs-137**	**Sr-90**	**I-131**
Regional	1.42E+05	8.25E+03	1.85E+02
Transboundary*	1.12E+05	6.63E+03	1.23E+02
China	9.93E+02	5.58E+01	2.47E-07
Hong Kong			
Japan	1.41E+03	9.19E+01	1.53E-01
Mongolia	5.54E+01	3.20E+00	
N. Korea	2.77E+02	1.74E+01	
Russia	1.42E+05	8.25E+03	1.85E+02
S. Korea	2.09E+01	6.16E-01	
Taiwan			
Aleutians (U.S.)	4.37E+03	2.45E+02	2.01E+00
Alaska (U.S.)	6.54E+03	3.93E+02	1.36E-01
Vietnam			

VRS

	Maximum Total Deposition (Bq m^{-2})		
Region	**Cs-137**	**Sr-90**	**I-131**
Regional	1.35E+05	9.38E+03	2.10E+02
Transboundary*	4.62E+04	3.13E+03	7.01E+01
China	3.54E+04	2.27E+03	6.53E+01
Hong Kong	2.84E+01	6.52E-04	
Japan	1.96E+04	1.27E+03	1.04E+01
Mongolia	3.42E+02	2.17E+01	2.33E-06
N. Korea	2.18E+04	1.49E+03	3.93E+01
Russia	1.35E+05	9.38E+03	2.10E+02
S. Korea	5.28E+03	3.44E+02	4.55E+00
Taiwan	9.77E+02	6.27E+01	
Aleutians (U.S.)	2.99E+02	1.74E+01	2.62E-02
Alaska (U.S.)	5.74E+02	1.20E+01	2.13E-14
Vietnam	1.47E-05	1.27E-10	

* The transboundary region includes all land areas (i.e., including ocean) outside of Russia.

4.7 Worst-Case Scenario Maximum Effective Dose Commitment Estimates

Estimation of the maximum dose commitments corresponding to the worst-case scenario for a given site requires multiplying the maximum adjusted total deposition described above by the appropriate deposition-to-dose factor from either Table 80, Table 81, or Table 82 for the radionuclide in question. Results for two specific cases will be computed for each radionuclide corresponding to the UNSCEAR 1993 Report results; these are:

- the maximum individual (i.e., teen) and adult dose commitments for Cs-137,
- the maximum individual (i.e., infant) and adult dose commitments for Sr-90, and
- the maximum individual (i.e., infant) and age-weighted (or person) dose commitments for I-131.

Such adjustments of the deposition-to-dose factors will have the greatest impact on the Sr-90 and I-131 results; these values can increase by factors of more than 30 depending upon the age group in question. The impact on the Cs-137 results will be significantly smaller (i.e., an increase by a factor of five or less). However, because the adjusted Cs-137 depositions can be much larger than those for either Sr-90 or I-131, the Cs-137 dose commitments resulting from the adjusted releases from both sites will be significantly larger than those from either Sr-90 or I-131.

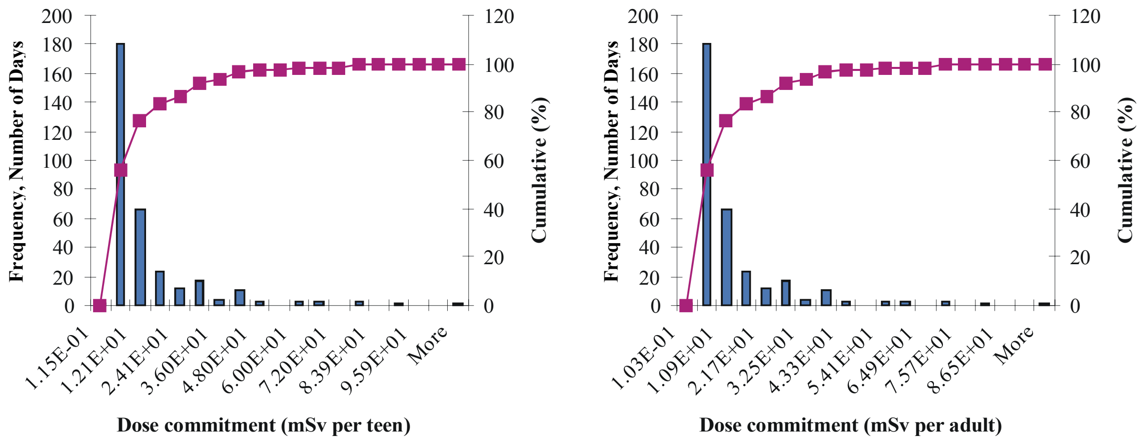
4.7.1 Worst-Case Dose Commitments from the PRS

Despite the fact that the Cs-137 dose commitments will be largest for the conditions considered in this study, the maximum Sr-90 and I-131 dose commitments resulting from the adjusted release from the PRS will also be computed for completeness and as points of comparison. To compute the pertinent dose commitment, the maximum deposition for Cs-137, Sr-90, or I-131 described above will be multiplied by the deposition-to-dose factor obtained by adjusting the UNSCEAR 1993 factor by the following factor:

- 5.01 for teens, the "maximum individual" group, and 4.51 for adults for Cs-137 from Table 80, or
- 31.87 for infant, the "maximum individual" group, and 7.65 for adults for Sr-90 from Table 81, or
- 37.15 for infant, the "maximum individual" group, and 4.34 for the age-weighted value for I-131 from Table 82.

Using the maximum total deposition values for the adjusted releases from the PRS and the appropriate factors from Table 80, Table 81, and Table 82, the maximum dose commitments were computed; for the maximum individual dose commitments, these are provided in Table 89, Table 91, and Table 93 for Cs-137, Sr-90, and I-131, respectively, and the corresponding adult (for Cs-137 and Sr-90) and age-weighted (for I-131) doses are provided in Table 90, Table 92, and Table 94. As predicted above, the worst-case Cs-137 dose commitments for the maximum individual are, in general, more than a factor of five larger than the corresponding Sr-90 values and more than three orders of magnitude larger than the corresponding I-131 values. The adult and age-weighted dose commitments for Cs-137 are even larger than their corresponding Sr-90 and I-131 values. Thus the Cs-137 dose commitments are of primary concern for the adjusted releases from the PRS.

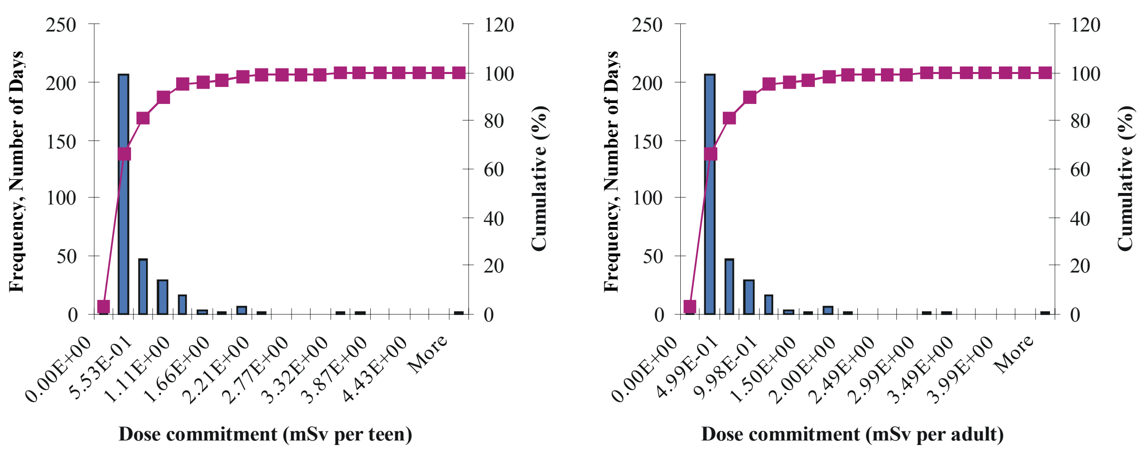
The distribution of maximum daily dose commitments corresponding to the adjusted Cs-137 releases from the PRS for the entire region of interest and the transboundary region (i.e., including all areas outside of Russia excluding oceans) are provided in Figure 67 and Figure 68, respectively, for both the maximum individual (in this case, the teen group) and adult categories. The maximum dose commitments for the adjusted releases from the PRS for the entire region are 108 and 97.3 mSv per person for the maximum individual (or teen) and adult categories, respectively. For the transboundary region, the corresponding dose commitments are 4.98 and 4.49 mSv per person for the maximum individual and adult categories, respectively. Note that by accounting for possible variation in the source term and the parameters used to define the deposition-to-dose transfer coefficients as well as considering the maximum exposed individual, the Cs-137 dose commitments can increase by a factor of approximately 25.



(a) Maximum Individual (Teen) (b) Adult

Figure 67. Frequency histogram and cumulative percentages for the PRS Cs-137 maximum effective dose commitments for (a) the maximum individual and (b) adult.

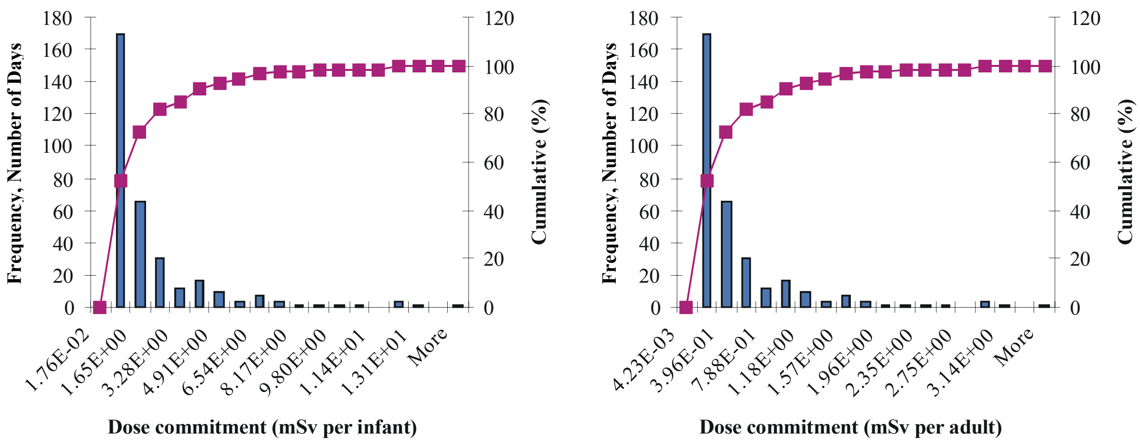
These results illustrate a very interesting fact concerning the maximum dose commitments resulting from the adjusted releases from the PRS for Cs-137. On a regional basis, the majority of the Cs-137 dose commitments to either the maximum individual or adult are larger than the annual 10 mSv per person level below which interventions are rarely justified [17], and there is a single maximum daily value for the maximum individual that exceeds the annual 100 mSv per person level in which interventions are almost always justifiable [17] (although this maximum value is less than the total dose that would be imparted by background radiation over the lifetime of the individual). Examination of the transboundary results indicate that even the worst-case values are all less than the annual 10 mSv per person level below which interventions are rarely justified [17], and over 40% are less than the average annual background dose of 2.4 mSv [13]. Thus even though the impact to Russia from the adjusted PRS release may be large as anticipated, the transboundary implications are much less significant even for the worst-case scenario.



(a) Maximum Individual (Teen) (b) Adult

Figure 68. Transboundary frequency histogram and cumulative percentages for the PRS Cs-137 maximum effective dose commitments for (a) the maximum individual and (b) adult.

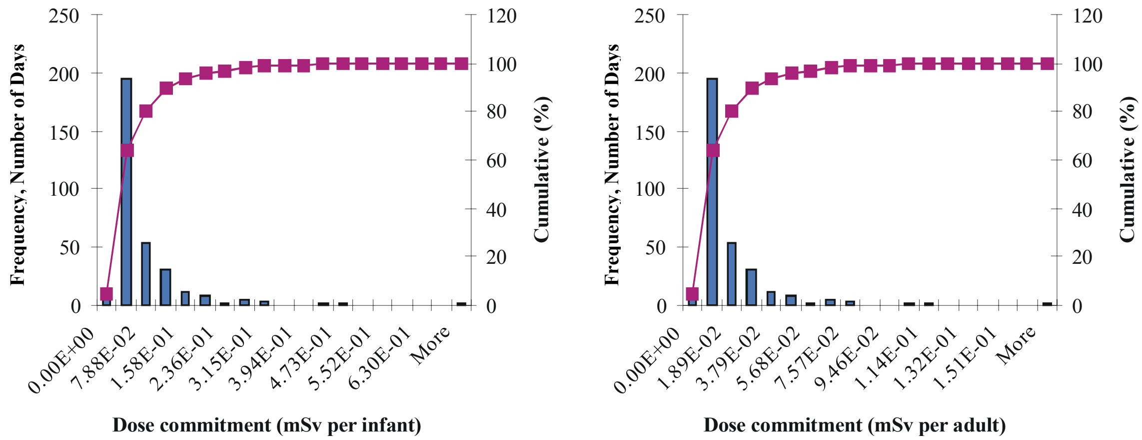
The distribution of maximum daily dose commitments corresponding to the adjusted Sr-90 releases from the PRS for the entire region of interest and the transboundary region (i.e., including all areas outside of Russia excluding oceans) are provided in Figure 69 and Figure 70, respectively, for both the maximum individual (in this case, the infant group) and adult categories. The maximum dose commitments for the adjusted releases from the PRS for the entire region are 14.7 and 3.53 mSv per person for the maximum individual (or infant) and adult categories, respectively. For the transboundary region, the corresponding dose commitments are 0.71 and 0.17 mSv per person for the maximum individual and adult categories, respectively. Note that by accounting for possible variation in the source term and the parameters used to define the deposition-to-dose transfer coefficients as well as considering the maximum exposed individual, the Sr-90 dose commitments can increase by a factor of almost an order of magnitude.



(a) Maximum Individual (Infant) (b) Adult

Figure 69. Frequency histogram and cumulative percentages for the PRS Sr-90 maximum effective dose commitments for (a) the maximum individual and (b) adult.

On a regional basis, less than 2% of the Sr-90 dose commitments to the maximum individual exceed the annual 10 mSv per person level below which interventions are rarely justified [17], and there are no values for the maximum individual that exceed the annual 100 mSv per person level in which interventions are almost always justifiable [17]. All the adult dose commitments from Sr-90 are less than the 10 mSv per person level below which interventions are rarely justified [17], and more than 98% of these dose commitments are less than the average annual background dose of 2.4 mSv [13]. Examination of the transboundary results indicates that all the worst-case values are less than the international annual reference level of 1 mSv per person [17]. Thus the impact to Russia from the adjusted release from the PRS may be significant (although apparently within the variation expected in background doses [13]); the transboundary implications are much less so.

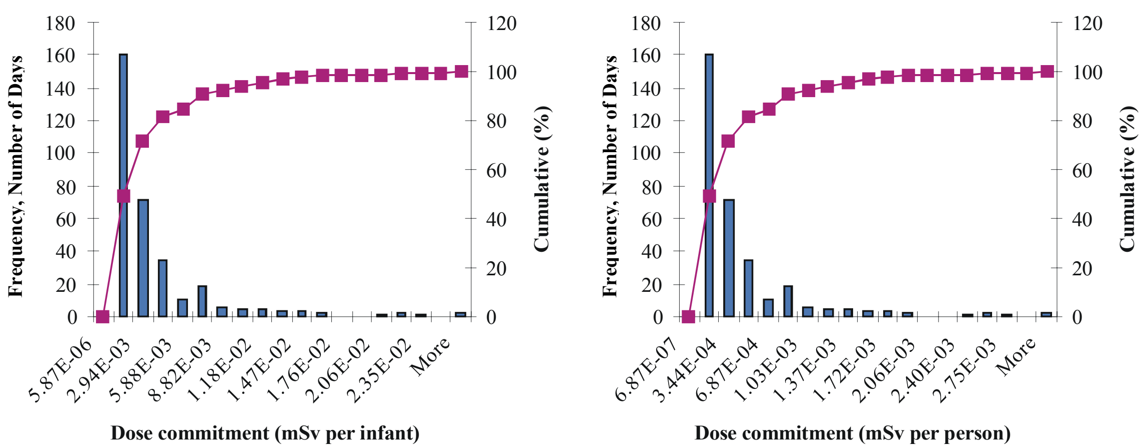


(a) Maximum Individual (Infant)

(b) Adult

Figure 70. Transboundary frequency histogram and cumulative percentages for the PRS Sr-90 maximum effective dose commitments for (a) the maximum individual and (b) adult.

The distribution of maximum daily dose commitments corresponding to the adjusted I-131 releases from the PRS for the entire region of interest and the transboundary region (i.e., including all areas outside of Russia excluding oceans) are provided in Figure 71 and Figure 72, respectively, for both the maximum individual (in this case, the infant group) and age-weighted categories. The maximum dose commitments for the adjusted releases from the PRS for the entire region are 3.30×10^{-2} and 3.86×10^{-3} mSv per person for the maximum individual (or infant) and age-weighted categories, respectively. For the transboundary region, the corresponding dose commitments are 4.41×10^{-4} and 5.16×10^{-5} mSv per person for the maximum individual and adult categories, respectively. Note that by accounting for possible variation in the source term and the parameters used to define the deposition-to-dose transfer coefficients as well as considering the maximum exposed individual, the I-131 dose commitments can decrease by a factor of more than 46.

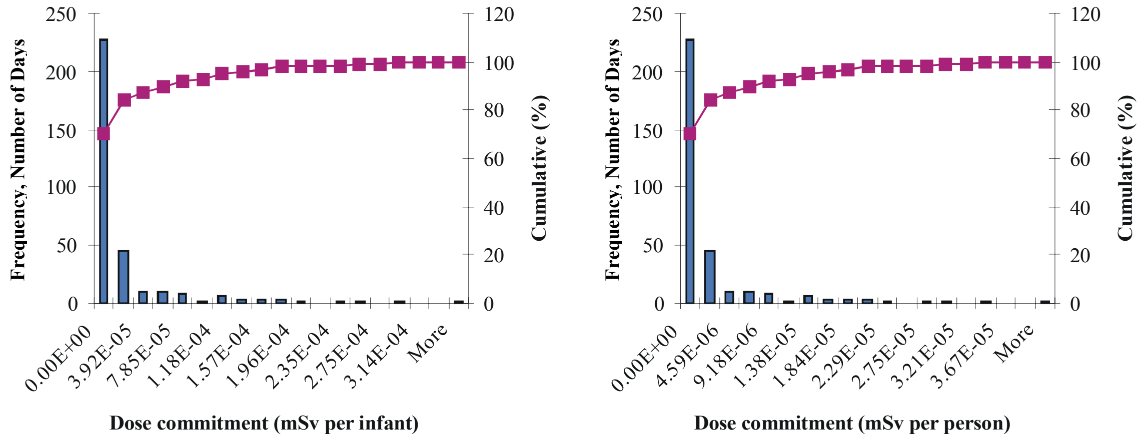


(a) Maximum Individual (Infant)

(b) Age-Weighted

Figure 71. Frequency histogram and cumulative percentages for the PRS I-131 maximum effective dose commitments for (a) the maximum individual and (b) the age-weighted individual.

On both a regional and transboundary basis, the I-131 dose commitments are less than the international annual reference level of 1 mSv per person [17] (and thus the average annual background dose) by at least a factor of 30. Thus the impact from I-131 based upon the conditions in this study will be small.



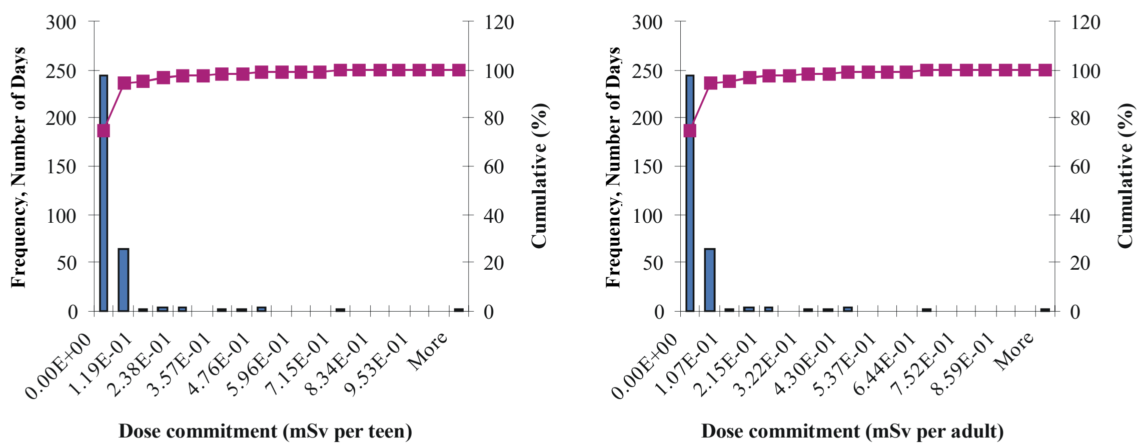
(a) Maximum Individual (Infant)

(b) Age-Weighted

Figure 72. Transboundary frequency histogram and cumulative percentages for the PRS I-131 maximum effective dose commitments for (a) the maximum individual and (b) the age-weighted individual.

4.7.1.1 Specific Case Examples: Japan and U.S. Dose Commitments from the PRS

For the specific examples in this study, only the maximum Cs-137 dose commitments from the adjusted release from the PRS will be examined as they represent the largest impact of the three radionuclides considered. The distribution of maximum Cs-137 dose commitments for Japan resulting from the adjusted PRS releases is illustrated in Figure 73. Note that only a single maximum value for the worst-case scenario (and maximum individual) exceeds the international annual reference level of 1 mSv per person [17]; however, this maximum value is significantly less than the average annual background dose. Therefore, the impact on Japan from even the adjusted PRS releases appears to be minimal from an intervention perspective.

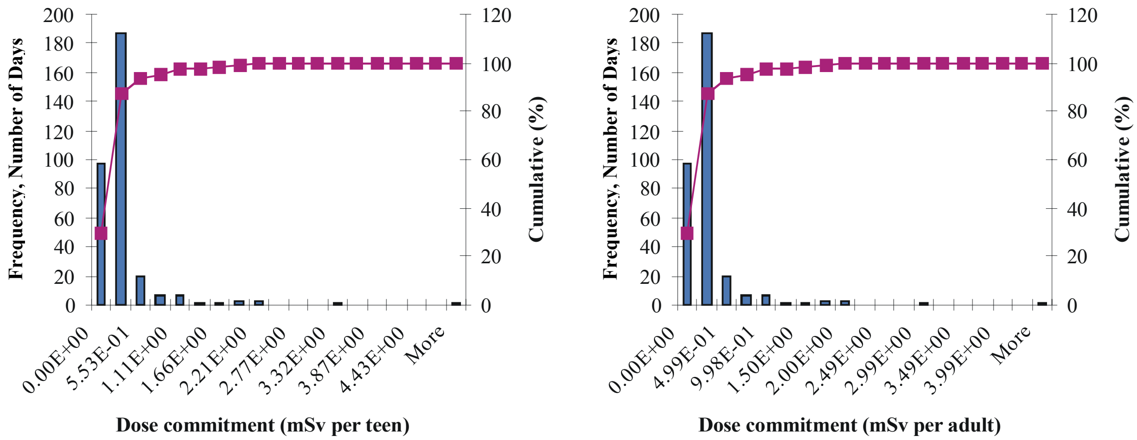


(a) Maximum Individual (Teen)

(b) Adult

Figure 73. Japan Results: Frequency histogram and cumulative percentages for the worst-case PRS Cs-137 maximum effective dose commitments for (a) the maximum individual and (b) adult.

The distribution of maximum Cs-137 dose commitments for Alaska resulting from the adjusted PRS releases is illustrated in Figure 74. Note that none of the maximum values for the worst-case scenario exceed the annual 10 mSv per person level below which interventions are rarely justified [17]. Approximately 95% of all maximum values for the worst-case scenario (and either the maximum individual or adult categories) are less than the international reference level of 1 mSv per person [17], and 99% are less than the average annual background dose of 2.4 mSv [13]. Therefore, the impact on Alaska, although larger than that for Japan, from the adjusted PRS releases appears again to be minimal from an intervention perspective.



(a) Maximum Individual (Teen)

(b) Adult

Figure 74. Alaska (U.S.) Results: Frequency histogram and cumulative percentages for the worst-case PRS Cs-137 maximum effective dose commitments for (a) the maximum individual and (b) adult.

The distribution of maximum Cs-137 dose commitments for the Aleutian Islands resulting from the adjusted PRS releases is illustrated in Figure 75. Note the similarity to the Alaska results provided above. Again none of the maximum values for the worst-case scenario exceed the annual 10 mSv per person level below which interventions are rarely justified [17]. More than 96% of all maximum values for the worst-case scenario (and either the maximum individual or adult categories) are less than the international annual reference level of 1 mSv per person [17], and all but a single value is less than the average annual background dose of 2.4 mSv [13]. Therefore, the impact on the Aleutian Islands—like that for Alaska—appears to be minimal from an intervention perspective.

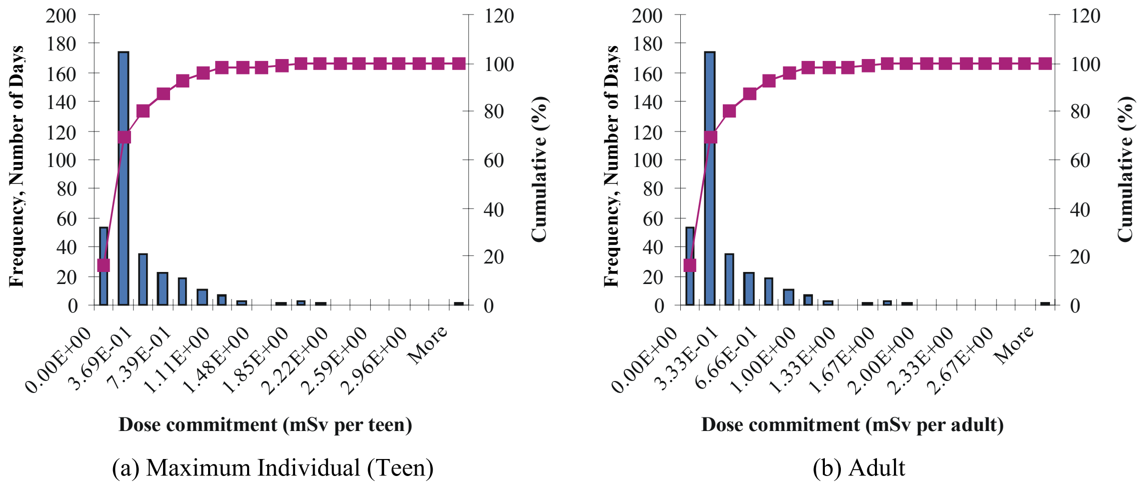


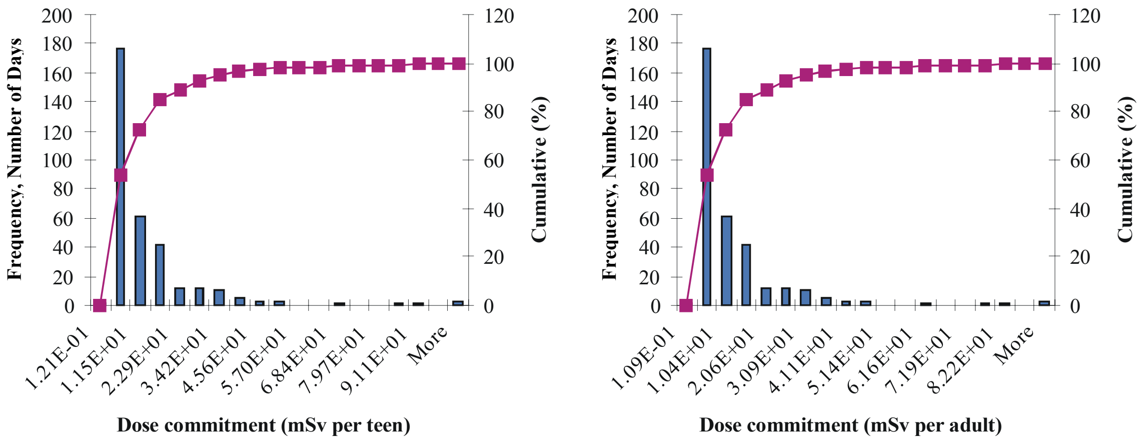
Figure 75. Aleutian Islands (U.S.) Results: Frequency histogram and cumulative percentages for the worst-case PRS Cs-137 maximum effective dose commitments for (a) the maximum individual and (b) adult.

4.7.2 Worst-Case Dose Commitments from the VRS

Despite the fact that the Cs-137 dose commitments will be largest for the conditions considered in this study, the maximum Sr-90 and I-131 dose commitments resulting from the adjusted VRS release will also be computed for completeness. To compute the pertinent dose commitment, the maximum deposition for Cs-137, Sr-90, or I-131 described above will be multiplied by the deposition-to-dose factor obtained by adjusting the UNSCEAR 1993 factor by the appropriate factor from Table 80, Table 81, or Table 82, respectively.

Using the maximum total deposition values for the adjusted VRS releases and the appropriate factors from Table 80, Table 81, and Table 82, the maximum dose commitments were computed; for the maximum individual dose commitments, these are provided in Table 95, Table 97, and Table 99 for Cs-137, Sr-90, and I-131, respectively, and the corresponding adult (for Cs-137 and Sr-90) and age-weighted (for I-131) doses are provided in Table 96, Table 98, and Table 100. As with the PRS results, the worst-case Cs-137 dose commitments for the maximum individual are, in general, more than a factor of five larger than the corresponding Sr-90 values and more than three orders of magnitude larger than the corresponding I-131 values. The adult dose commitments for Cs-137 are even larger than their corresponding Sr-90 and I-131 (age-weighted) values. Thus, similar to the results for the PRS, the Cs-137 dose commitments are of primary concern for the adjusted VRS releases.

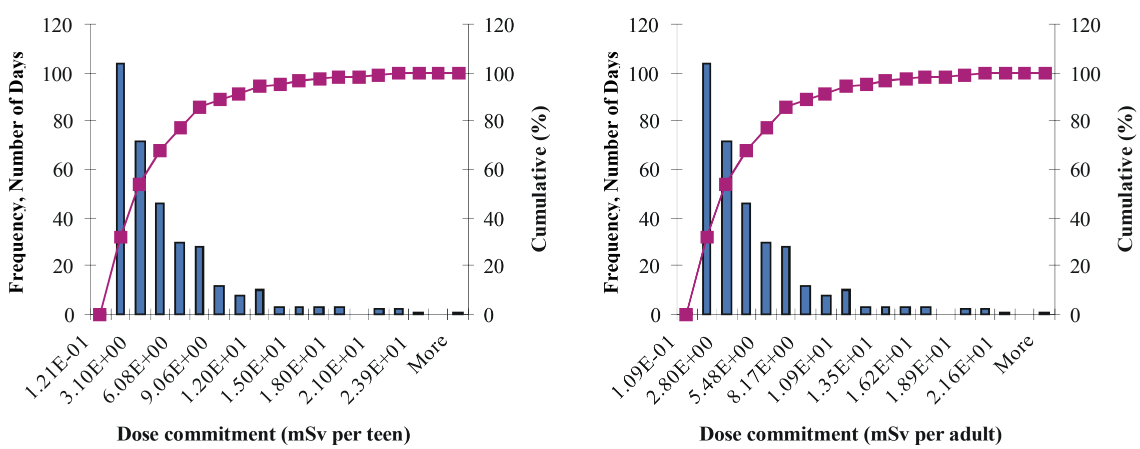
The distribution of maximum daily dose commitments corresponding to the adjusted Cs-137 releases from the PRS for the entire region of interest and the transboundary region (i.e., including all areas outside of Russia excluding oceans) are provided in Figure 76 and Figure 77, respectively, for both the maximum individual (in this case, the teen group) and adult categories. The maximum dose commitments for the adjusted VRS releases for the entire region are 102 and 92.4 mSv per person for the maximum individual (or teen) and adult categories, respectively. For the transboundary region, the corresponding dose commitments are 26.9 and 24.3 mSv per person for the maximum individual and adult categories, respectively. Note that by accounting for possible variation in the source term and the parameters used to define the deposition-to-dose transfer coefficients as well as considering the maximum exposed individual, the Cs-137 dose commitments can increase by more than a factor of 25.



(a) Maximum Individual (Teen) (b) Adult

Figure 76. Frequency histogram and cumulative percentages for the VRS Cs-137 maximum effective dose commitments for (a) the maximum individual and (b) adult.

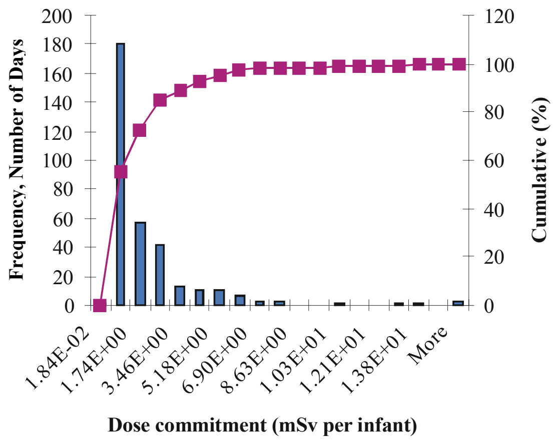
These results illustrate a very interesting fact concerning the maximum dose commitments resulting from the adjusted VRS releases for Cs-137. On a regional basis, more than 30% of the Cs-137 dose commitments to either the maximum individual or adult are larger than the annual 10 mSv per person level below which interventions are rarely justified [17]. Furthermore, two of the maximum dose commitments for the maximum individuals exceed the annual 100 mSv per person level in which interventions are almost always justifiable [17]; none of the maximum dose commitments for the adult group exceed this annual limit. Examination of the transboundary results illustrated in Figure 77 indicate that even the worst-case values are all less than the annual 100 mSv per person level below which interventions are almost always justifiable [17]. Therefore, the impact to Russia from the adjusted VRS release may be large as anticipated; however, the transboundary implications are less significant; however, they may still be important as over 7% of the maximum individual dose commitments are greater than the annual 10 mSv per person level below which interventions are rarely justified [17], and at least 40% are greater than the average annual background dose of 2.4 mSv [13].



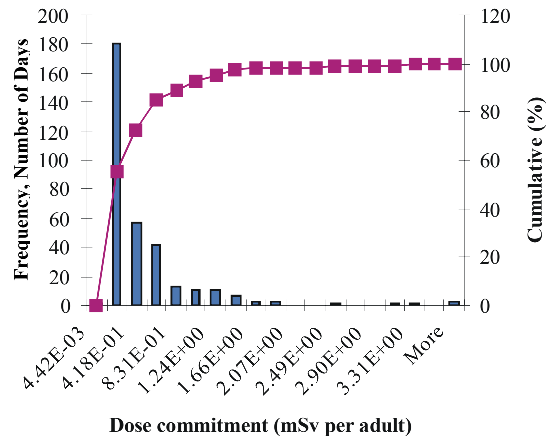
(a) Maximum Individual (Teen) (b) Adult

Figure 77. Transboundary frequency histogram and cumulative percentages for the VRS Cs-137 maximum effective dose commitments for (a) the maximum individual and (b) adult.

The distribution of maximum daily dose commitments corresponding to the adjusted Sr-90 releases from the VRS for the entire region of interest and the transboundary region are provided in Figure 78 and Figure 79, respectively, for both the maximum individual (in this case, the infant group) and adult categories. The maximum dose commitments for the adjusted VRS releases for the entire region are 15.5 and 3.73 mSv per person for the maximum individual (or infant) and adult categories, respectively. For the transboundary region, the corresponding dose commitments are 4.08 and 0.98 mSv per person for the maximum individual and adult categories, respectively. Note that by accounting for possible variation in the source term and the parameters used to define the deposition-to-dose transfer coefficients as well as considering the maximum exposed individual, the Sr-90 dose commitments can increase by almost an order of magnitude.



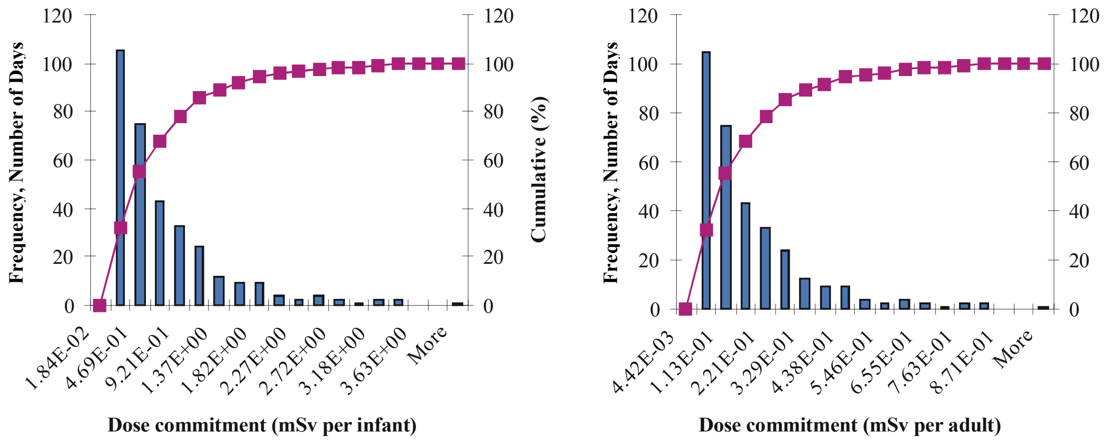
(a) Maximum Individual (Infant)



(b) Adult

Figure 78. Frequency histogram and cumulative percentages for the VRS Sr-90 maximum effective dose commitments for (a) the maximum individual and (b) adult.

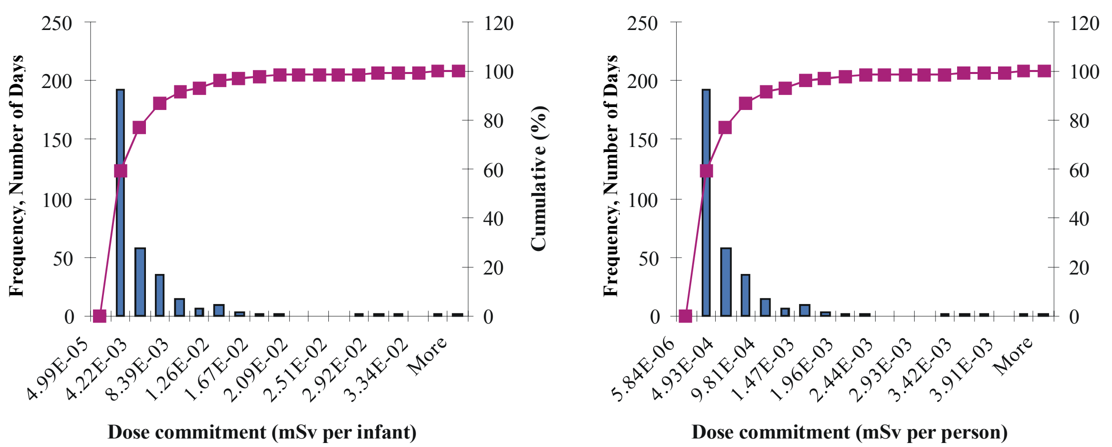
On a regional basis, less than 2% of the Sr-90 dose commitments to the maximum individual are larger than the annual 10 mSv per person level below which interventions are rarely justified [17], and there are no values for the maximum individual that exceed the annual 100 mSv per person level in which interventions are almost always justifiable [17]. For the adult dose commitments from Sr-90, all are less than the annual 10 mSv per person level below which interventions are rarely justified [17], and almost 99% are less than the average annual background dose of 2.4 mSv [13]. Examination of the transboundary results indicates that all of the maximum individual dose commitments are less than the 10 mSv per person level below which interventions are rarely justified [17] and more than 96% are less than the average annual background dose. Also all of the adult dose commitments are below the international annual reference level of 1 mSv per person [17]. Thus the impact to Russia from the adjusted VRS release may be significant in a few cases; however, the transboundary implications are much less.



(a) Maximum Individual (Infant) (b) Adult

Figure 79. Transboundary frequency histogram and cumulative percentages for the VRS Sr-90 maximum effective dose commitments for (a) the maximum individual and (b) adult.

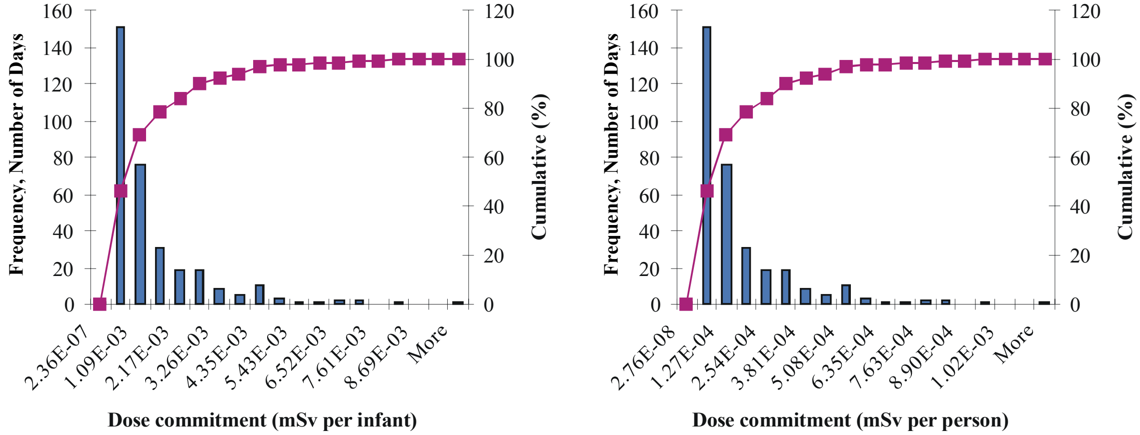
The distribution of maximum daily dose commitments corresponding to the adjusted I-131 releases from the VRS for the entire region of interest and the transboundary region are provided in Figure 80 and Figure 81, respectively, for both the maximum individual (in this case, the infant group) and age-weighted categories. The maximum dose commitments for the adjusted VRS releases for the entire region are 4.70×10^{-2} and 5.49×10^{-3} mSv per person for the maximum individual (or infant) and age-weighted categories, respectively. For the transboundary region, the corresponding dose commitments are 1.22×10^{-2} and 1.43×10^{-3} mSv per person for the maximum individual and adult categories, respectively. Note that by accounting for possible variation in the source term and the parameters used to define the deposition-to-dose transfer coefficients as well as considering the maximum exposed individual, the I-131 dose commitments can decrease by a factor of more than 46.



(a) Maximum Individual (Infant) (b) Age-Weighted

Figure 80. Frequency histogram and cumulative percentages for the VRS I-131 maximum effective dose commitments for (a) the maximum individual and (b) the age-weighted individual.

On both a regional and transboundary basis, the I-131 dose commitments are less than the international annual reference level of 1 mSv per person [17] by at least a factor of 20. Thus the impact from I-131 based upon the conditions in this study will be small.

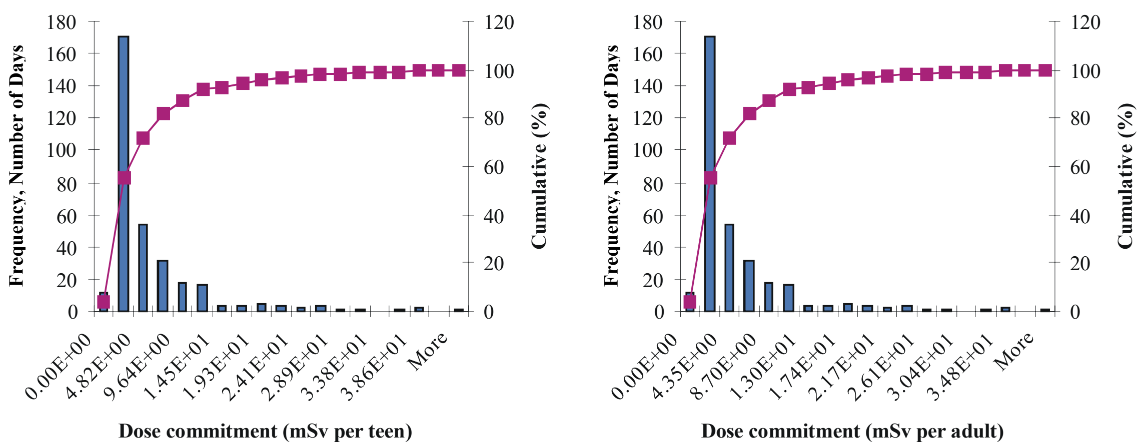


(a) Maximum Individual (Infant) (b) Age-Weighted

Figure 81. Transboundary frequency histogram and cumulative percentages for the VRS I-131 maximum effective dose commitments for (a) the maximum individual and (b) the age-weighted individual.

4.7.2.1 Specific Case Examples: Japan and U.S. Dose Commitments from the VRS

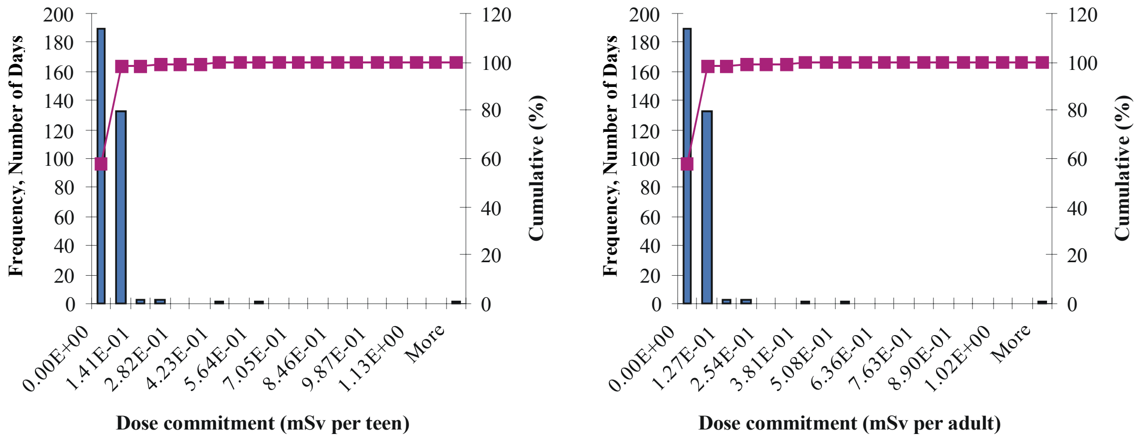
For the specific examples in this study, only the maximum Cs-137 dose commitments from the adjusted VRS release will be examined as they represent the largest impact of the three radionuclides considered. The distribution of maximum Cs-137 dose commitments for Japan resulting from the adjusted VRS releases is illustrated in Figure 82. More than 98% of the maximum individual and adult dose commitments are less than the annual 10 mSv per person level below which interventions are rarely justified [17] and approximately 60% of both are less than the international annual reference level of 1 mSv per person [17]. More than 80% of the maximum dose commitments are less than the average annual background dose of 2.4 mSv [13]. Therefore, the impact on Japan from even the adjusted VRS releases appears to be small from an intervention perspective although there may be isolated cases where intervention may be considered.



(a) Maximum Individual (Teen) (b) Adult

Figure 82. Japan Results: Frequency histogram and cumulative percentages for the worst-case VRS Cs-137 maximum effective dose commitments for (a) the maximum individual and (b) adult.

The distribution of maximum Cs-137 dose commitments for Alaska resulting from the adjusted VRS releases is illustrated in Figure 83. Note that all of the maximum values for the worst-case scenario are less than the international annual reference level of 1 mSv per person [17]. Therefore, the impact on Alaska from the adjusted VRS releases are less than those for Japan and appear to be minimal from an intervention perspective.

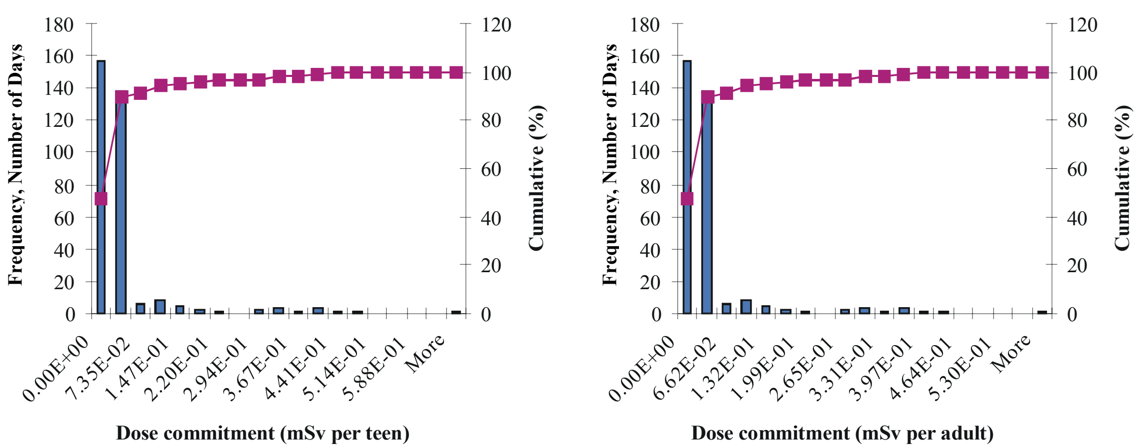


(a) Maximum Individual (Teen)

(b) Adult

Figure 83. Alaska (U.S.) Results: Frequency histogram and cumulative percentages for the worst-case VRS Cs-137 maximum effective dose commitments for (a) the maximum individual and (b) adult.

The distribution of maximum Cs-137 dose commitments for the Aleutian Islands resulting from the adjusted VRS releases is illustrated in Figure 84. Note the similarity to Alaska results illustrated in Figure 83. All of the maximum values for the worst-case scenario (and either the maximum individual or adult categories) are less than the international annual reference level of 1 mSv per person [17]. Therefore, the impact on the Aleutian Islands—like that for Alaska—appears to be small from an intervention perspective.



(a) Maximum Individual (Teen)

(b) Adult

Figure 84. Aleutian Islands (U.S.) Results: Frequency histogram and cumulative percentages for the worst-case VRS Cs-137 maximum effective dose commitments for (a) the maximum individual and (b) adult.

4.7.3 Worst-Case Dose Commitments Summarized and Compared to Reference Levels

A summary of the (non-zero) worst-case maximum effective dose commitments for the maximum individual (i.e., teens for Cs-137 and infants for Sr-90 and I-131) for both the PRS and VRS is presented in Exhibit 12. Note that on a regional basis that the worst-case maximum effective dose commitments are again comparable (because these maximum values reside in Russia). However, the impact outside of Russia is more profound from the VRS than from the PRS. Furthermore, the effects from Cs-137 releases (from either site) appear to be of more concern than those (for the same releases) from either Sr-90 or I-131. A small number of the worst-case case dose commitments for Cs-137 exceed 100 mSv per person, which will be described in more detail below.

Exhibit 12. Summary of the Maximum (Non-Zero) Effective Dose Commitments for the Maximum Individual Using the Worst-Case Scenario

PRS

	Maximum Effective Dose Commitment (mSv)*		
Region	**Cs-137 (Teen)**	**Sr-90 (Infant)**	**I-131 (Infant)**
Regional	1.08E+02	1.47E+01	2.64E-02
Transboundary**	4.98E+00	7.09E-01	3.53E-04
China	7.56E-01	1.01E-01	4.32E-11
Hong Kong		0.00E+00	
Japan	1.07E+00	1.66E-01	2.68E-05
Mongolia	4.22E-02	5.78E-03	
N. Korea	2.11E-01	3.14E-02	
Russia	1.08E+02	1.47E+01	2.64E-02
S. Korea	1.59E-02	1.11E-03	
Taiwan			
Aleutians (U.S.)	3.33E+00	4.42E-01	3.53E-04
Alaska (U.S.)	4.98E+00	7.09E-01	2.38E-05
Vietnam			

VRS

	Maximum Effective Dose Commitment (mSv)*		
Region	**Cs-137 (Teen)**	**Sr-90 (Infant)**	**I-131 (Infant)**
Regional	1.02E+02	1.55E+01	3.76E-02
Transboundary**	2.69E+01	4.08E+00	9.78E-03
China	2.69E+01	4.08E+00	9.78E-03
Hong Kong	2.17E-02	1.18E-06	
Japan	1.49E+01	2.25E+00	1.86E-03
Mongolia	2.60E-01	3.91E-02	4.17E-10
N. Korea	1.66E+01	2.46E+00	6.27E-03
Russia	1.02E+02	1.55E+01	3.76E-02
S. Korea	4.02E+00	6.04E-01	8.78E-04
Taiwan	7.44E-01	1.13E-01	
Aleutians (U.S.)	2.28E-01	3.15E-02	5.27E-06
Alaska (U.S.)	4.37E-01	2.17E-02	4.29E-18
Vietnam	1.12E-08	2.29E-13	

* The effective dose commitments are comprised of the following components (based upon the UNSCEAR 1993 Report [13] methodology):
Cs-137: Ingestion 43.0%, Inhalation 0.2%, External Exposure 56.8%
Sr-90: Ingestion 97.8%, Inhalation 2.2%, External Exposure 0.02%
I-131: Ingestion 99.2%, Inhalation 0.6%, External Exposure 0.2%.

** The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

The values for the maximum individual dose commitments in Exhibit 12 can be compared to the worst-case values for adults (for Cs-137 and Sr-90) and the weighted values (for I-131) that correspond to those computed above using the UNSCEAR 1993 Report methodology. These values are summarized in Exhibit 13. Note that these values are smaller than their maximum individual counterparts, and that, once again, the Cs-137 values would have the largest impact on the area under study. Furthermore, none of these values exceed 100 mSv per person.

Exhibit 13. Summary of the Maximum (Non-Zero) Effective Dose Commitments for the Individuals Corresponding to those in the UNSCEAR 1993 Report Using the Worst-Case Scenario

PRS

	Maximum Effective Dose Commitment (mSv)*		
Region	**Cs-137 (Adult)**	**Sr-90 (Adult)**	**I-131 (Weighted)**
Regional	9.73E+01	3.53E+00	3.09E-03
Transboundary**	4.49E+00	1.70E-01	4.13E-05
China	6.82E-01	2.42E-02	5.05E-12

VRS

	Maximum Effective Dose Commitment (mSv)*		
Region	**Cs-137 (Adult)**	**Sr-90 (Adult)**	**I-131 (Weighted)**
Regional	9.24E+01	3.73E+00	4.39E-03
Transboundary**	2.43E+01	9.80E-01	1.14E-03
China	2.43E+01	9.80E-01	1.14E-03

	PRS		
	Maximum Effective Dose Commitment (mSv)*		
Region	Cs-137 (Adult)	Sr-90 (Adult)	I-131 (Weighted)
Hong Kong			
Japan	9.67E-01	3.99E-02	3.13E-06
Mongolia	3.80E-02	1.39E-03	
N. Korea	1.90E-01	7.55E-03	
Russia	9.73E+01	3.53E+00	3.09E-03
S. Korea	1.43E-02	2.67E-04	
Taiwan			
Aleutians (U.S.)	3.00E+00	1.06E-01	4.13E-05
Alaska (U.S.)	4.49E+00	1.70E-01	2.78E-06
Vietnam			

	VRS		
	Maximum Effective Dose Commitment (mSv)*		
Region	Cs-137 (Adult)	Sr-90 (Adult)	I-131 (Weighted)
Hong Kong	1.95E-02	2.83E-07	
Japan	1.35E+01	5.41E-01	2.17E-04
Mongolia	2.35E-01	9.40E-03	4.88E-11
N. Korea	1.49E+01	5.91E-01	7.33E-04
Russia	9.24E+01	3.73E+00	4.39E-03
S. Korea	3.63E+00	1.45E-01	1.03E-04
Taiwan	6.71E-01	2.72E-02	
Aleutians (U.S.)	2.05E-01	7.56E-03	6.17E-07
Alaska (U.S.)	3.94E-01	5.21E-03	5.01E-19
Vietnam	1.01E-08	5.51E-14	

* The effective dose commitments are comprised of the following components (based upon the UNSCEAR 1993 Report [13] methodology):
Cs-137: Ingestion 36.8%, Inhalation 0.2%, External Exposure 63.0%
Sr-90: Ingestion 89.5%, Inhalation 10.4%, External Exposure 0.09%
I-131: Ingestion 93.8%, Inhalation 4.3%, External Exposure 1.9%.

** The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

The information in Table 101 through Table 104 illustrates the manner in which the maximum worst-case dose commitments (on a day-to-day basis) for the PRS and VRS compare to various reference limits for both the regional and transboundary conditions. As indicated previously, this information indicates that the dose commitments resulting from the adjusted releases of Cs-137 are more problematic than those for Sr-90 or I-131. Furthermore, the impacts from the adjusted VRS releases are more significant than those from the PRS. This is especially true for the transboundary region although there are no maximum dose commitments from the worst-case PRS and VRS releases in this region that exceed the annual 100 mSv per person level in which interventions are almost always justifiable [17]. The more significant impact of the VRS releases is compounded by the fact that many more people are impacted than are from the PRS releases.

4.8 Worst-Case Collective Dose Commitments

The final examination of the dose commitment estimates is what impact might there be on the persons that would be exposed to the adjusted releases described above. That is, the population or collective dose commitments will be computed for the corresponding maximum dose commitments described above. However, unlike the corresponding UNSCEAR analyses for Cs-137 and Sr-90 where only adult deposition-to-dose factors were used, the maximum age-weighted factors will be used in this portion of the variation study because not only adults are impacted by the depositions in the region of interest.

Furthermore, it is likely that a great many people will be exposed to very small doses of radiation. To examine the impact that relatively small doses have on the collective dose, a series of threshold values (i.e., 0.1, 0.15,1.0, and 10.0 mSv per person) were defined above and their potential impacts will be examined. In effect, if the dose commitment at a given location does not exceed the threshold, then the corresponding dose commitment is ignored when computing the collective dose to examine the resulting impact on the earlier assessment using the UNSCEAR results. This is meant in no way to be an endorsement of the "threshold concept," it merely allows assessment of the impact of small doses on collective dose assessment.

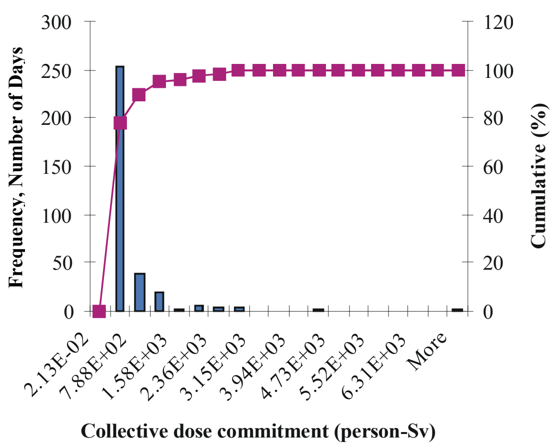
4.8.1 Worst-Case Collective Dose Commitments for the PRS

The effective, maximum collective dose commitments corresponding to the adjusted total depositions for Cs-137, Sr-90, and I-131 in Table 83, Table 84, and Table 85, respectively, were computed for the

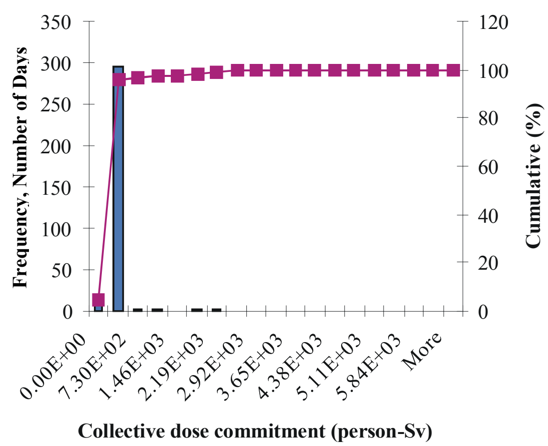
PRS. For Cs-137, Figure 85(a) illustrates the frequency and cumulative percentages for the maximum collective dose commitments for the region of study assuming no threshold. Table 105 and Table 106 provide the maximum collective dose commitment for the region as well as each country in the region as a function of the assumed threshold value. Note that the maximum collective dose commitments (for the PRS no threshold case) are again rank-ordered as follows:

PRS Cs-137: Regional > Japan > Russia > China > Alaska (U.S.) > S. Korea > N. Korea > Aleutians (U.S.) > Mongolia

Therefore, even though the maximum dose commitment was found in Russia, the maximum collective dose is found in Japan (which is not surprising based upon its high population density and relative proximity to the PRS). Using a mortality risk factor of $5x10^{-5}$ per mSv for all ages [19], these results would indicate that there might be up to 355 additional, eventual mortalities in the region based upon the "no threshold" results in Table 105; Japan might have as many as 329 additional mortalities while Russia and China might have as many as 103 and 83, respectively. North and South Korea and Alaska are the other areas with a significant impact of between 10 and 18 additional, eventual mortalities. However, it should be noted that even the mortality impact on Japan is one person out of approximately 300 000 persons impacted by the maximum deposition and dose from the PRS. For comparison, the mortality impact on Russia is one person out of fewer than 10 000 persons impacted by the deposition. Figure 85(b) illustrates the results for the transboundary conditions; note there is a significant impact on the magnitude of the collective dose commitments versus those for the overall region in Figure 85(a).



(a) Regional



(b) Transboundary

Figure 85. Frequency histogram and cumulative percentages for the PRS Cs-137 effective population dose commitments for the (a) Regional and (b) Transboundary areas for CY2000. No Threshold Basis. The corresponding population information is presented in Figure 37 and Figure 38.

Table 105 and Table 106 can also be used to evaluate the impact that small doses in concert with large populations have on the worst-case collective dose estimates. If a value of 0.1 mSv (or 10 mrem) per person is used as a threshold for the collective dose computation, then Japan, which had the highest collective dose commitment (and a possibility of up to 329 additional mortalities), has a collective dose approximately 40% lower than that without a threshold imposed. When a threshold of 0.15 mSv (or 15 mrem) is imposed, the collective dose decreases by approximately 65%. It requires a threshold of 1.0 mSv (or 100 mrem) to result in a collective dose of zero, or, in other words, to have the same impact as a 0.1 mSv threshold on the original UNSCEAR values. Again the impact of such thresholds on the Russian collective doses is negligible.

For Sr-90, Figure 86(a) illustrates the frequency and cumulative percentages for the maximum collective dose commitments for the region of study from the PRS assuming no threshold. Table 107 and Table 108 provide the maximum collective dose commitment for the region as well as each country in the region as a function of the assumed threshold level. Note that the maximum collective PRS dose commitments (for the no threshold hypothesis) have the same ordering as those for the Cs-137. Again, even though the maximum dose commitment was found in Russia, the maximum collective dose is found in Japan (which translates into 17 additional mortalities). The results in Table 107 and Table 108 confirm the potential impacts of small doses in concert with large populations on the collective dose estimates discussed above for Cs-137. With a relatively low threshold of 0.1 mSv (or 10 mrem), the collective dose commitment and potential additional mortalities in Japan become zero, and, other than Russia, only the US territories have non-zero collective dose commitments. Figure 86(b) illustrates the transboundary results for the PRS Sr-90 collective dose commitments; note that these results are necessarily consistent with those for Cs-137 above.

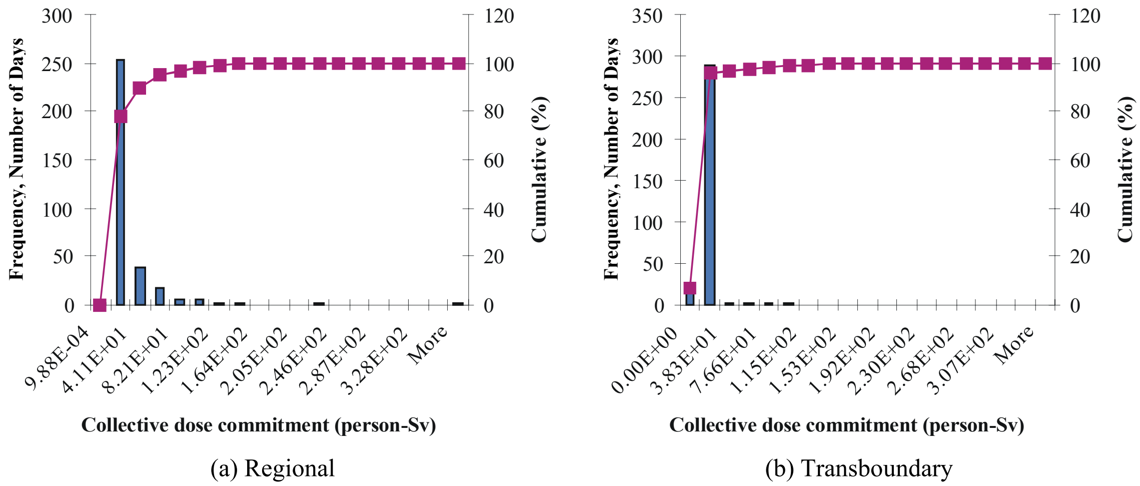


Figure 86. Frequency histogram and cumulative percentages for the PRS Sr-90 effective population dose commitments for the (a) Regional and (b) Transboundary areas for CY2000. No Threshold Basis. The corresponding population information is presented in Figure 39 and Figure 40.

For I-131, Figure 87(a) illustrates the frequency and cumulative percentages for the maximum collective dose commitments for the region of study assuming no threshold. Table 109 and Table 110 provide the maximum collective dose commitment for the region as well as each country as a function of the assumed threshold level. Note that the maximum collective PRS dose commitments (for the no threshold hypothesis) are rank-ordered as follows:

PRS I-131: Regional > Russia > Japan > Aleutians (U.S.) > Alaska (U.S.) > China

Thus for I-131, the maximum dose commitment and collective dose are found in Russia (which is unlike the results for Cs-137 and Sr-90). This is not surprising based upon the higher deposition velocity of I-131. As a matter of fact, the results in Table 109 and Table 110 indicate that little I-131 from PRS impacts any country including Russia. (Even in Russia, there is not enough of a collective dose to translate into a single, additional mortality.) Furthermore, the impact is much smaller than that for either Cs-137 or Sr-90 releases from the PRS. Figure 87(b) illustrates the transboundary results for I-131 from the PRS, which are also negligible for all the countries studied.

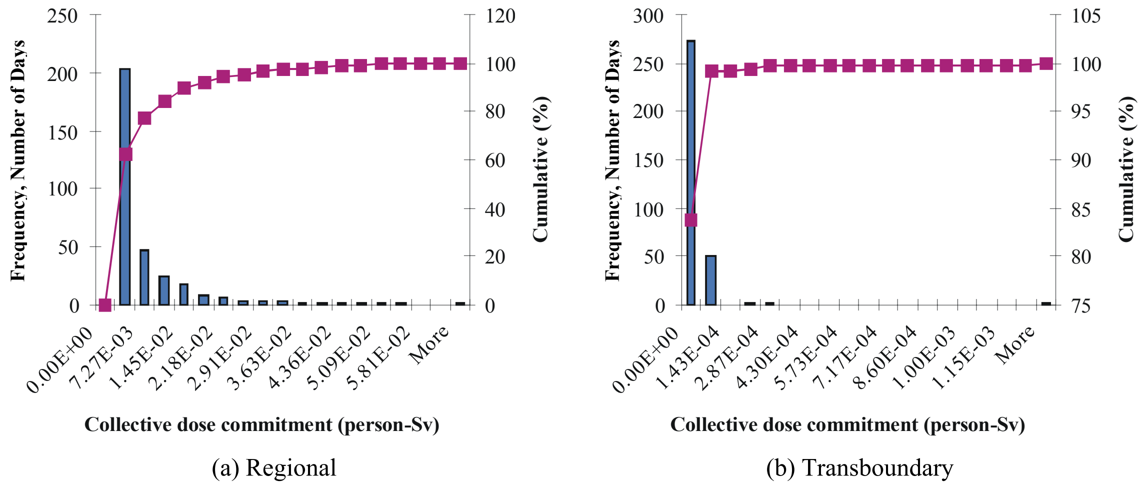


Figure 87. Frequency histogram and cumulative percentages for the PRS I-131 effective population dose commitments for the (a) Regional and (b) Transboundary areas for CY2000. No Threshold Basis. The corresponding population information is presented in Figure 41 and Figure 42.

4.8.1.1 Specific Case Examples: Japan and U.S. Collective Dose Commitments from the PRS

Because it is apparent that air masses from the Asian continent can move rapidly and only slightly diluted across the Pacific Ocean [14,15], it has been decided to examine these areas for possible impacts from the nuclear risk sites. Furthermore, because the Sr-90 depositions necessarily follow those for Cs-137 and the I-131 depositions are smaller and will have significantly less impact on the transboundary region (which includes both Japan and the U.S.), it was decided to examine only Cs-137 for these specific examples.

Figure 88 illustrates the collective dose results for Japan from the PRS releases for CY2000. Using a mortality risk factor of $5x10^{-5}$ per mSv for all ages [19], almost 97% of all maximum collective dose commitments will result in fewer than 18 additional, eventual mortalities from the PRS releases. As mentioned above, the maximum collective dose commitment of 6570 person-Sv, which appears from Figure 88 to be very much an isolated case, would result in as many as 329 additional eventual mortalities.

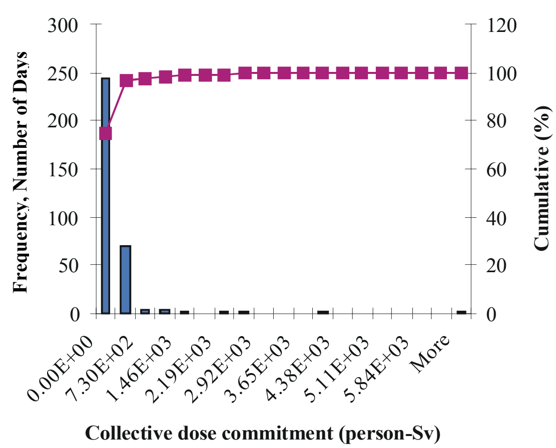
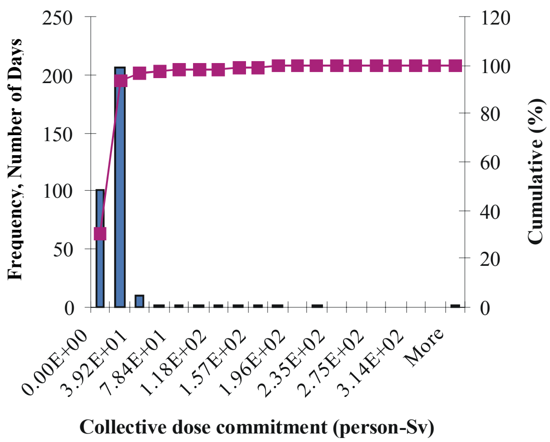
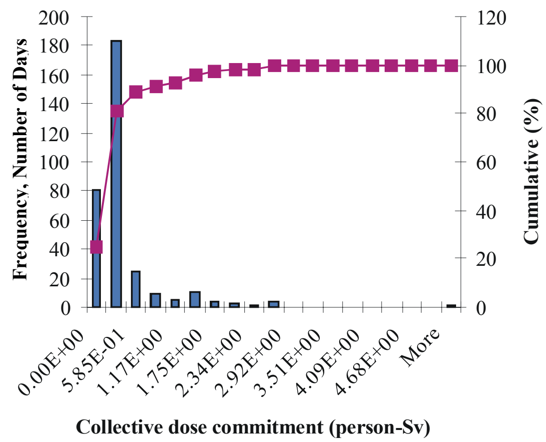


Figure 88. Japan Results: Frequency histogram and cumulative percentages for the weighted PRS Cs-137 effective collective dose commitments for CY2000. No Threshold Basis. The corresponding populations are provided in Figure 43.

The results for the weighted collective dose commitments from the PRS for the U.S. territories considered in this report are illustrated in Figure 89. Note that, when a mortality risk factor of $5x10^{-5}$ per mSv for all ages [19] is employed, approximately 94% of the maximum collective doses for Alaska would result in fewer than one additional mortality and none of the maximum collective dose commitments for the Aleutian Islands would translate into a single, additional mortality from the adjusted PRS releases for CY2000.



(a) Alaska (U.S.)



(b) Aleutian Islands (U.S.)

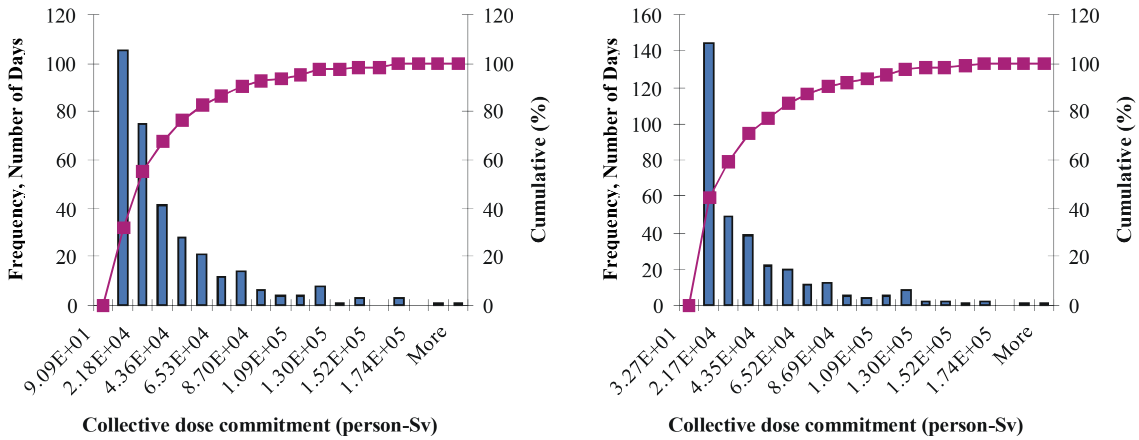
Figure 89. Alaska (U.S.) Results: Frequency histogram and cumulative percentages for the PRS Cs-137 effective collective dose commitments for (a) Alaska and (b) the Aleutian Islands for CY2000. No Threshold Basis. The corresponding population information is found in Figure 44 and Figure 45.

4.8.2 Worst-Case Collective Dose Commitments for the VRS

The effective, maximum collective dose commitments corresponding to the total depositions for Cs-137, Sr-90, and I-131 in Table 86, Table 87, and Table 88, respectively, were computed for the VRS. For Cs-137, Figure 90 illustrates the frequency and cumulative percentages for the maximum collective dose commitments for the overall and transboundary region assuming no threshold. Table 111 and Table 112 provide the maximum collective dose commitment for the region as well as each country in the region as a function of the assumed threshold level. (The collective dose commitments are also broken down by pathway for information purposes.) Note that the maximum collective VRS dose commitments (for the no threshold hypothesis) are rank-ordered as follows:

VRS Cs-137: Regional > Japan > China > N. Korea > S. Korea > Russia > Taiwan > Hong Kong > Alaska (U.S.) > Mongolia > Aleutians (U.S.) > Vietnam

Therefore, even though the maximum dose commitment was found in Russia, the maximum collective dose is found in Japan (which is not surprising based upon its high population density and relative proximity to both the VRS and the PRS). Furthermore, unlike the PRS results, other countries have collective dose commitments within an order of magnitude of that for Japan, and there are many more countries with non-zero collective dose commitments.



(a) Regional (b) Transboundary

Figure 90. Frequency histogram and cumulative percentages for the VRS Cs-137 effective population dose commitments for the (a) Regional and (b) Transboundary areas for CY2000. No Threshold Basis. The corresponding population information is presented in Figure 46 and Figure 47.

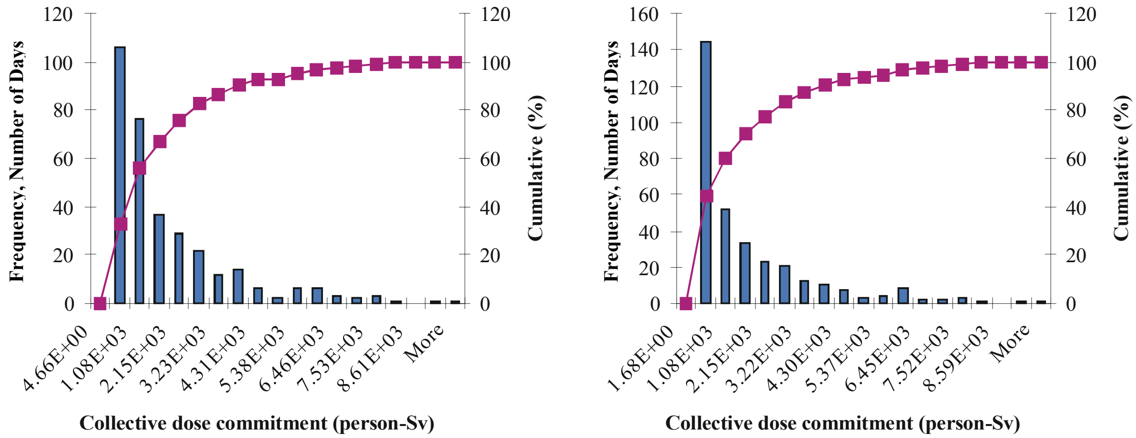
The effects of the VRS releases are potentially much more profound than those from the PRS. For example, the maximum collective dose commitments in Table 111 (for the no threshold case) correspond to up to an additional 9783 mortalities [19] over the entire region and 9771 additional over the transboundary region (using a factor of 5×10^{-5} mortality per mSv for all ages). The additional mortalities from the maximum collective dose commitments for Japan, China, N. Korea, S. Korea, Russia, and Taiwan are 9501, 8575, 2485, 2436, 1614, and 318, respectively. Therefore, even the impact on Taiwan, a country not proximate to the VRS, could be considered significant. The State of Alaska, the Aleutian Islands, and Hong Kong might have an additional two mortalities each from the adjusted releases and worst-case deposition-to-dose factors.

Also unlike the results for the PRS analysis, Table 111 and Table 112 indicate that there is much less of an impact on the magnitudes of the dose commitments in concert with large populations on the collective VRS dose estimates. That is, the collective dose commitments for the countries (e.g., Japan, China, N. Korea, S. Korea, and Russia) in the vicinity of the VRS are relatively insensitive to the introduction of thresholds into the collective dose commitment computation. For example, the results after imposing a threshold of 0.1 mSv (or 0.01 mrem) translate into over 9488 additional mortalities in Japan and significant numbers in other countries of interest. This is a result of much higher dose commitments in these countries from the VRS releases. Even the introduction of a relatively large threshold (e.g., 1.0 mSv) only reduces the impact of the Cs-137 depositions to 8423 additional mortalities.

Unlike the earlier UNSCEAR results, the additional mortalities described above do not appear to be significantly mitigated by being small fractions of very large, affected populations. Said additional mortalities are 1 in 13 105 (or 8 per 100 000) for Japan and 1 in 11 112 (or 9 per 100 000) persons affected by the maximum releases from the VRS.

For Sr-90, Figure 91 illustrates the frequency and cumulative percentages for the maximum collective dose commitments for the overall and transboundary region assuming no threshold. Table 113 and Table 114 provide the maximum collective dose commitment for the region as well as each country in the region as a function of the assumed threshold level. Note that the maximum collective VRS dose commitments (for the no threshold hypothesis) have the same ordering as those for the Cs-137. Again, even though the maximum dose commitment was found in Russia (as indicated in Table 113), the maximum collective dose is found in Japan. The number of additional mortalities can be as high as 484 for the region (and 483 for the transboundary region) and 426 and 477 for China and Japan, respectively, or between 18 and 20 times less than those from the comparable VRS Cs-137 releases.

The results in Table 113 and Table 114 confirm the insensitivity of the collective dose estimates to the magnitudes of the dose commitments as indicated above for Cs-137.



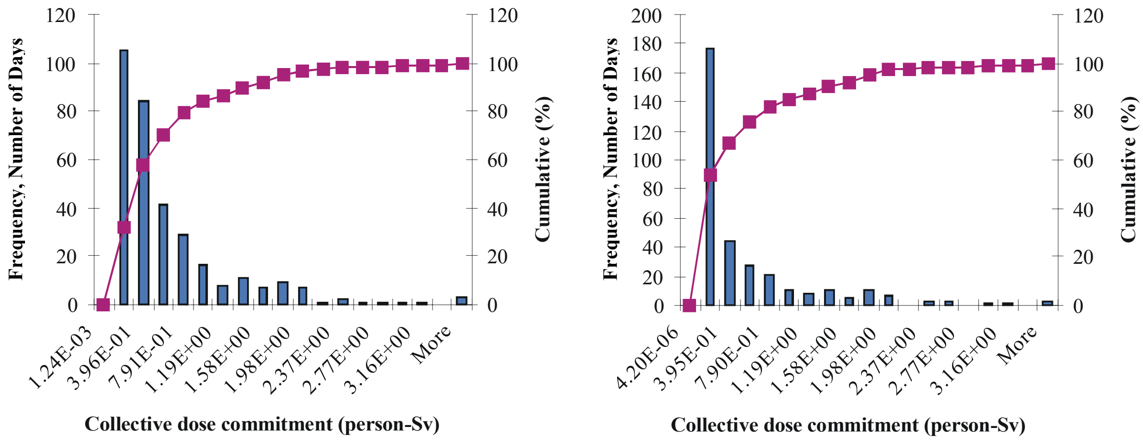
(a) Regional (b) Transboundary

Figure 91. Frequency histogram and cumulative percentages for the VRS Sr-90 effective population dose commitments for the (a) Regional and (b) Transboundary areas for CY2000. No Threshold Basis. The corresponding population information is presented in Figure 48 and Figure 49.

For I-131, Figure 92 illustrates the frequency and cumulative percentages for the maximum collective dose commitments for the overall and transboundary region, respectively, assuming no threshold. Table 115 and Table 116 provide the maximum collective dose commitment for the region as well as each country in the region as a function of the assumed threshold level. Note that the maximum collective PRS dose commitments (for the no threshold hypothesis) are rank-ordered as follows:

PRS I-131: Regional > Japan > China > S. Korea > N. Korea > Russia > Aleutians (U.S.) > Mongolia > Alaska (U.S.)

Thus for I-131, the maximum collective VRS dose commitment is found in Japan (which is unlike the results found for the corresponding PRS releases). Unlike the Cs-137 and Sr-90 results, the I-131 releases translate into no additional mortalities. Also unlike the VRS results for Cs-137 and Sr-90, the collective doses are sensitive to the imposition of a threshold (because of the much smaller dose commitments for I-131 in countries other than Russia). Again, the results in Table 115 and Table 116 indicate that the I-131 from the VRS releases will have an insignificant impact on any country, including Russia.



(a) Regional (b) Transboundary

Figure 92. Frequency histogram and cumulative percentages for the VRS I-131 effective population dose commitments for the (a) Regional and (b) Transboundary areas for CY2000. No Threshold Basis. The corresponding population information is presented in Figure 50 and Figure 51.

4.8.2.1 Specific Case Examples: Japan and U.S. Collective Dose Commitments from the VRS

Figure 93 illustrates the collective dose results for Japan from the VRS releases for CY2000. Using a mortality risk factor of 5×10^{-5} per mSv for all ages [19], the maximum collective dose commitment of 1.90×10^{5} person-Sv (as shown in Table 111) would translate into more than 9500 additional mortalities or 8 additional mortalities for every 100 000 persons. However, the information in Figure 93 indicates that this would be a low-probability event for CY2000. Over 60% of the maximum collective dose commitments are less than 3.17×10^{4} person-Sv, which would translate into 1538 additional mortalities (or between 1 and 2 per 100 000 persons).

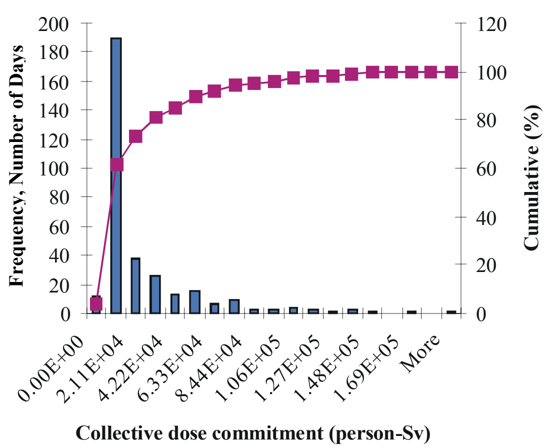
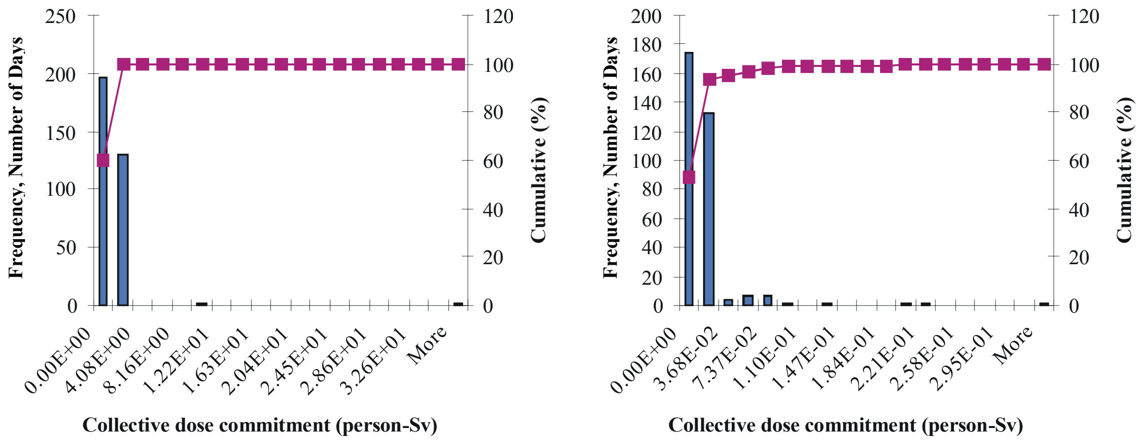


Figure 93. Japan Results: Frequency histogram and cumulative percentages for the weighted VRS Cs-137 effective collective dose commitments for CY2000. No Threshold Basis. The corresponding populations are provided in Figure 52.

The results for the collective dose commitments from the PRS for the U.S. territories considered in this report are illustrated in Figure 94. Note that, when a mortality risk factor of 5×10^{-5} per mSv for all ages [19] is employed, the maximum collective dose commitments shown in these figures translate into two and zero additional mortalities for Alaska and the Aleutian Islands, respectively, from the

VRS releases for CY2000. These can be considered negligible when compared to both background radiation doses and other causes of death.



(a) Alaska (U.S.) (b) Aleutian Islands (U.S.)

Figure 94. Alaska (U.S.) Results: Frequency histogram and cumulative percentages for the VRS Cs-137 effective collective dose commitments for (a) Alaska and (b) the Aleutian Islands for CY2000. No Threshold Basis. The corresponding population information is found in Figure 53 and Figure 54.

4.8.3 Summary of the Effective Collective Worst-Case Dose Commitments

A summary of the (non-zero) maximum effective collective dose commitments (based upon the worst-case methodology described above and assuming no threshold) for both the PRS and VRS is presented in Exhibit 14. Therefore, even though the maximum effective dose commitments from the PRS and VRS were reasonably similar (as illustrated in Exhibit 12 and Exhibit 13), the higher populations impacted from the VRS releases generally resulted in significantly larger collective dose commitments. It again appears that the Cs-137 dose commitments will be of primary concern for either site.

Exhibit 14. Summary of the Maximum (Non-Zero) Collective Effective Dose Commitments for Individuals Corresponding to those in the UNSCEAR 1993 Report Using the Worst-Case Scenario

PRS

	Maximum Effective Collective Dose Commitment (person-Sv)*		
Region	**Cs-137**	**Sr-90**	**I-131**
Regional	7.09E+03	3.69E+02	6.54E-02
Transboundary**	6.57E+03	3.45E+02	1.29E-03
China	1.66E+03	8.10E+01	7.05E-10
Hong Kong			
Japan	6.57E+03	3.45E+02	1.29E-03
Mongolia	3.79E+00	1.74E-01	
N. Korea	2.02E+02	9.82E+00	
Russia	2.05E+03	1.09E+02	6.54E-02
S. Korea	2.32E+02	5.18E+00	
Taiwan			
Aleutians (U.S.)	5.26E+00	2.37E-01	4.31E-05

VRS

	Maximum Effective Collective Dose Commitment (person-Sv)*		
Region	**Cs-137**	**Sr-90**	**I-131**
Regional	1.96E+05	9.68E+03	3.56E+00
Transboundary**	1.95E+05	9.67E+03	3.56E+00
China	1.72E+05	8.53E+03	3.05E+00
Hong Kong	3.78E+01	1.08E-03	
Japan	1.90E+05	9.55E+03	3.56E+00
Mongolia	3.21E+01	1.38E+00	1.96E-09
N. Korea	4.97E+04	2.53E+03	1.58E+00
Russia	3.23E+04	1.64E+03	1.15E+00
S. Korea	4.87E+04	2.48E+03	1.70E+00
Taiwan	6.35E+03	3.28E+02	
Aleutians (U.S.)	3.31E-01	9.57E-03	8.20E-09

	PRS		
	Maximum Effective Collective Dose Commitment (person-Sv)*		
Region	Cs-137	Sr-90	I-131
Alaska (U.S.)	3.53E+02	1.51E+01	1.23E-06
Vietnam			

	VRS		
	Maximum Effective Collective Dose Commitment (person-Sv)*		
Region	Cs-137	Sr-90	I-131
Alaska (U.S.)	3.67E+01	2.52E-01	8.57E-20
Vietnam	1.44E-07	1.01E-12	

* The effective collective dose commitments are comprised of the following components (based upon the UNSCEAR 1993 Report [13] methodology):
Cs-137: Ingestion 38.8%, Inhalation 0.2%, External Exposure 61.0%
Sr-90: Ingestion 90.9%, Inhalation 9.1%, External Exposure 0.1%
I-131: Ingestion 93.8%, Inhalation 4.3%, External Exposure 1.9%.

** The transboundary region includes only land areas outside of Russia.

A study of the impact of imposing threshold values on the various collective dose commitments for the worst-case scenario was also undertaken. Figure 95 illustrates the impact of such thresholds on the maximum collective Cs-137 dose commitments for those areas where the impact would be at least one additional mortality (using a mortality risk factor of $5x10^{-5}$ per mSv for all ages [19]). Note that only the collective doses for the entire region, transboundary area, and Russia do not fall to zero using a threshold value of 1.0 mSv per person. Therefore, there would be a significant impact on collective doses if a relatively small threshold of 1.0 mSv is imposed on the calculation. This is analogous to the results when a 0.1 mSv threshold was applied to the corresponding UNSCEAR collective dose commitments as illustrated in Figure 55.

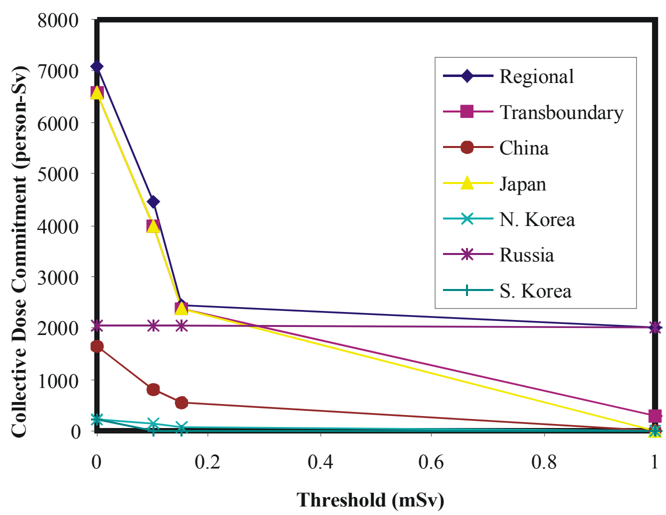


Figure 95. Impact of Imposing Hypothetical Threshold Values on the Worst-Case Maximum Effective Collective Cs-137 Dose Commitments for the PRS. Only those values are shown where at least one additional mortality would result for the no threshold case.

The corresponding relationship between the maximum collective dose commitments and threshold for the VRS is provided in Figure 96 (where the maximum value of the abscissa has been increased to 10 mSv). Notice that the impact of thresholds on the VRS collective dose commitments is much smaller than that for the corresponding PRS doses; in fact, the imposition of thresholds up to 1 mSv appears to have little impact for most countries impacted by the VRS releases.

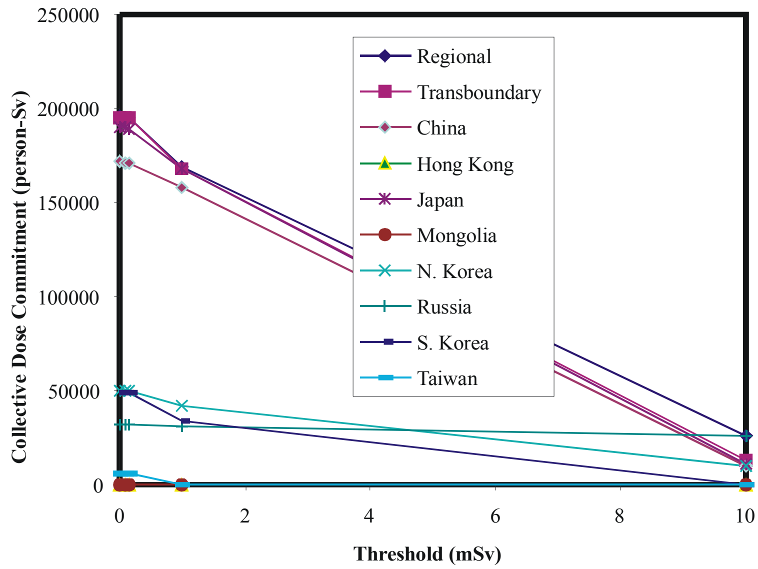


Figure 96. Impact of Imposing Hypothetical Threshold Values on the Worst-Case Maximum Effective Collective Cs-137 Dose Commitments for the VRS. Only those values are shown where at least one additional mortality would result for the no threshold case.

5 Summary and Conclusions

The main purpose of this study was to estimate the worst-case dose commitments and potential consequences of accidental releases at nuclear risk sites in the Russian Far East. The nuclear risk sites of concern for this study are at Petropavlovsk (52°55'N & 158°30'E) and Vladivostok (42°55'N & 132°25'E). The region of interest includes the territories of the Russia Far East, China, Japan, North and South Korea, State of Alaska, the Aleutian Islands, Mongolia, Burma, Hong Kong, Laos, Taiwan, Thailand, and Vietnam. In this study, those regions that are at highest risk from the hypothetical accidental releases at the nuclear risk sites will be determined as well as the potential impact of the releases. The transboundary region (i.e., that outside of Russia) is of primary interest because it is likely that the highest doses will reside in Russia and these would be examined using site specific information and detailed models unavailable for this study. However, the transboundary region can be examined, in general, using existing information and models. The methodology from the UNSCEAR 1993 Report was used in this study.

The research tool used to generate the deposition data used as the basis for this study is a long-range transport model—the Danish Emergency Response Model of the Atmosphere (DERMA)—which was used to simulate the 5-d atmospheric transport, dispersion and deposition of Cs-137 for a one-day release at a rate of 10^{10} Bq s^{-1} for a total "unit hypothetical release" of 8.64×10^{14} Bq. The meteorological data from the European Center for Medium-Range Weather Forecasts (ECMWF, Reading, UK) based on the ECMWF global model forecast and analysis were used as input data for the model simulation. Using the DERMA model, several Cs-137 indicators were computed for over 90% of the days in calendar year 2000 including: 1) surface air concentration, 2) time-integrated surface concentration, 3) dry deposition, and 4) wet deposition. The meteorological data was missing for the remaining days.

5.1 Maximum Total Deposition Results

The main conclusions that can be drawn for the deposition data, which are those used to estimate doses, is that the dry deposition values are high in the vicinity of the risk sites and decrease significantly with increasing distance from the release point. The wet deposition values can also be high near the risk sites; however, they are irregular as they are dependent upon the rainfall pattern. Some of these values can exceed the corresponding dry deposition value by an order of magnitude. However, it is the total deposition values (i.e., the sum of the wet and dry depositions at a given time and locale) that are of primary interest in this report because they are used to estimate effective dose commitments. The other indicators are summarized in the body of the report for completeness.

Radionuclides other than Cs-137 can be of concern depending upon the inventory of the risk site and conditions under which the release is made. In this report, Sr-90 and I-131 were such radionuclides. However, because of a lack of time and resources, the necessary indicators above were not computed for these radionuclides for all calendar year 2000 days with full meteorological data. There were Sr-90 and I-131 concentration and deposition data provided for five days considered representative of the variation of the climactic conditions for the region for year 2000. These data were used to generate simple, linear relationships between the unavailable Sr-90 and I-131 concentration and deposition data and the corresponding Cs-137 data [6]. These relationships were found to be sufficiently accurate for the general examination undertaken in this report.

For the Petropavlovsk nuclear risk site, the original Cs-137, Sr-90, and I-131 total depositions had maximum values of 2.78×10^4, 2.86×10^4, and 4.65×10^4 Bq m^{-2}, respectively, and were located in Russia. For the transboundary region (i.e., that outside of Russia including oceans), the maximum total deposition values for Cs-137, Sr-90, and I-131 were 2.20×10^4, 2.30×10^4, and 3.09×10^4 Bq m^{-2}, respectively. However, the maximum total transboundary depositions were located in the ocean surrounding the Petropavlovsk risk site. The maximum total transboundary depositions found on land for Cs-137, Sr-90, and I-131 were 1280, 1360, and 506 Bq m^{-2}, respectively. These were located in the U.S. territories (i.e., State of Alaska for Cs-137 and Sr-90 and the Aleutian Islands for I-131) examined in this study. Note that the total depositions in the U.S. territories were generally three to four times higher than those in Japan, the transboundary country with the next highest maximum total depositions resulting from accidental releases from the Petropavlovsk risk site.

For the Vladivostok site, the original Cs-137, Sr-90, and I-131 total depositions had maximum values of 2.64×10^4, 3.26×10^4, and 5.28×10^4 Bq m^{-2}, respectively, and were again located in Russia. For the transboundary region, the maximum total deposition values for Cs-137, Sr-90, and I-131 were 9060, 1.09×10^4, and 1.76×10^4 Bq m^{-2}, respectively. The maximum total transboundary depositions were again located in the ocean surrounding the risk site. The maximum total transboundary depositions found on land for Cs-137, Sr-90, and I-131 were 6930, 7870, and 1.64×10^4 Bq m^{-2}, respectively. Unlike the maximum values for the Petropavlovsk releases, these maximum values were located in China, which is proximate to the Vladivostok site. The maximum total depositions for Japan and N. Korea were approximately the same (i.e., within a factor of two) as that for China. Note that the total depositions in the U.S. territories were generally more than a factor of 60 lower than those in China, the transboundary country with the highest maximum total depositions resulting from accidental releases from the Vladivostok risk site.

5.2 UNSCEAR Maximum Effective Dose Commitment Results

The initial portion of this study was concerned with estimating effective dose commitments from the deposition data either provided by Mahura [6] (for Cs-137) or derived from said data (for Sr-90 and I-131) and the methodology described in the UNSCEAR 1993 Report. It is recognized that this methodology is not the only acceptable manner in which to estimate such doses; the methodology was selected because it is independent, defensible, and, because it is based upon a multiplicative model, lends itself to a facile examination of parameter variation, the results of which will be described below.

For the Petropavlovsk nuclear risk site, the maximum Cs-137, Sr-90, and I-131 total depositions translated into maximum effective dose commitments of 4.22, 1.60, and 0.18 mSv per person, respectively, and were located in Russia. For the transboundary region (i.e., that area outside of Russia over land), the maximum effective dose commitments for Cs-137, Sr-90, and I-131 were much smaller—0.20, 0.08, and $2x10^{-3}$ mSv per person, respectively. These were located in U.S. territory (i.e., State of Alaska for Cs-137 and Sr-90 and the Aleutian Islands for I-131). The maximum effective dose commitments in the U.S. territories were generally three to four times higher than those in Japan, the transboundary country with the next highest dose commitments resulting from accidental releases from the Petropavlovsk risk site. The results of this study indicate that the Cs-137 dose commitments will dominate for the conditions studied in this report. Thus only the Cs-137 results will be discussed in this section; however, complete results are provided in the body of the report.

For the Vladivostok site, the maximum Cs-137 total deposition translated into a maximum effective dose commitment of 4.01 mSv per person, which was located in Russia. For the transboundary region, the maximum effective dose commitment for Cs-137 was 1.05 mSv per person, which was located in China. The maximum effective dose commitments for Japan and N. Korea were approximately the same (i.e., within a factor of two) as that for China. Note that the maximum effective dose commitments in the U.S. territories were generally more than a factor of 60 lower than those in China, the transboundary country with the highest maximum dose commitments resulting from accidental releases from the Vladivostok risk site.

5.3 UNSCEAR Maximum Collective Effective Dose Commitment Results

Collective dose commitments were also computed and examined for hypothetical accidental releases from the Petropavlovsk and Vladivostok sites. Even though the maximum effective dose commitments from Petropavlovsk and Vladivostok releases were reasonably similar, the higher populations impacted from the Vladivostok releases generally resulted in significantly larger collective dose commitments. The Cs-137 dose commitments were again of primary concern for either site and will be the only collective dose commitments described here. The doses for the other radionuclides are provided in the body of the report.

For the Petropavlovsk nuclear risk site, the maximum collective effective dose commitment was 298 person-Sv for the entire region using the UNSCEAR 1993 Report methodology (although such an aggregation of doses over a very large area is contrary to ICRP recommendations as indicated in ICRP Publication 82). The maximum transboundary collective dose commitment of 276 person-Sv was located in Japan (which would translate into 14 additional mortalities); this value was more than an order of magnitude greater than that found in the U.S. territories examined in this study.

For the Vladivostok nuclear risk site, the maximum collective effective dose commitment was 8230 person-Sv for the entire region. The maximum transboundary collective dose commitment of 7990 person-Sv was again located in Japan, which would translate into an additional 399 mortalities. China, N. Korea, and S. Korea also had similar collective dose commitments; however, it should be noted that none of the collective dose commitments (including those for the releases from the Petropavlovsk site) translated into a single additional mortality per 100 000 persons in the impacted area. Furthermore, the maximum collective doses in the U.S. territories studied in this report were more than three orders of magnitude lower than those for Japan.

5.3.1 Examination of the Impact of Small Doses on Large Populations

Because the aggregation of doses over large areas is contrary to ICRP recommendations, the impact of aggregating small doses in this manner on any conclusions was examined by imposing a series of threshold limits on the collective dose computations to determine whether the conclusions would change dramatically. This is intended in no way to endorse the "threshold concept," it merely allows assessment of the impact of small doses on the collective dose computations. The results of this examination indicated that the collective effective dose commitments for the transboundary region associated with releases from the Petropavlovsk site were very sensitive to the imposition of such a threshold. For example, all collective dose commitments in the transboundary region (including Japan) were zero if a threshold of 0.1 mSv per person was used.

On the other hand, the collective dose commitments in the transboundary region associated with releases from the Vladivostok site were much less sensitive. For example, the imposition of a threshold of 0.1 mSv per person resulted in the approximate halving of the collective dose for many affected countries; however, it required a threshold of 1.0 mSv per person to result in collective doses of zero for the transboundary region. That is, the threshold limit must be an order of magnitude larger for the Vladivostok results to have the same impact as was found on the collective doses resulting from hypothetical releases from the Petropavlovsk site.

5.4 Parameter Variation Study and Worst-Case Study

The total depositions from Mahura and the dose commitments associated with the UNSCEAR 1993 Report were computed to provide a baseline for comparing worst-case values. The original total depositions [6] were available for 90% of the days from a single calendar year (2000) and thus do not provide a rigorously defensible basis for projecting the results from this study to other years. However, the maximum values for all depositions and dose commitments were analyzed which should provide meaningful worst-case information for other years. Also the "hypothetical unit release" term used to generate the original deposition data was examined in light of known inventories and possible release fractions to better gauge the magnitudes of the deposition values. It is thought that by using the maximum values on a day-to-day basis and adjusting the total depositions based upon possible source terms that meaningful, general conclusions can be drawn from the year 2000 data for the two risk sites.

Other sources of potential variation were the UNSCEAR 1993 Report deposition-to-dose transfer factors. Given a total deposition at a specific location, these factors provide an estimate of the effective dose commitment that would be imparted to an adult (except for the case of I-131 where an age-weighted value is used) under average or nominal conditions using information that is dated and not necessarily concerning the region of interest. The UNSCEAR methodology is sound; however, little account was taken for the countries of interest in the UNSCEAR Report. The parameters used to define the necessary deposition-to-dose transfer factors were adjusted to provide worst-case factors, which were those factors providing the largest effective dose commitments for the range of parameters defined in this report. These worst-case transfer factors were then used to estimate dose commitments associated with the adjusted total depositions.

The final source of variation primarily impacted the collective dose commitment estimates; this was the population information used in the study. The population data used in this study are from 1995 and, therefore, are somewhat dated. However, these data were used "as-is" as any adjustment of the data would be arbitrary and likely to introduce more error than warranted in the type of general examination being made in this study.

The approach taken in this study was to define reasonable ranges for the source term and various parameters used in defining the deposition-to-dose coefficients and then, using these values, compute the resulting transfer factor ranges and maximum effective dose commitments for both the maximum individual case and that case corresponding to the UNSCEAR results (i.e., adults for Cs-137 and Sr-90 and age-weighted for I-131). These results were analyzed to determine whether accounting for reasonable variation in the source term and deposition-to-dose transfer coefficients would alter the conclusions drawn from examination of the dose commitments computed using the UNSCEAR values for the "unit hypothetical release."

5.4.1 Source Term Examination and Adjusted Total Depositions

For Cs-137 and Sr-90, the isotopic inventories for the nuclear submarines and other facilities pertinent to the Russian Far East nuclear risk sites were examined on a spent fuel assembly basis. The maximum Cs-137 and Sr-90 inventories for conceivable accident scenarios were 5.67 and 4.80 times higher than the "unit hypothetical release" of 8.64×10^{14} Bq used to generate the data for this study. The potential inventory for I-131 is more straightforward to determine as it primarily depends on the fission yield of the accident. Using a bounding total number of fissions of 1×10^{20}, the maximum inventory of I-131 was estimated to be $4.3x10^{12}$ Bq. Even the maximum I-131 inventory is more than 200 times lower than the "unit hypothetical release" used to generate the data for this study.

However, the release fraction (i.e., the fraction of the inventory that is released into the atmosphere) for a given accident scenario also determines the environmental release source term. The release fractions for each radionuclide considered in this study can vary over several orders of magnitude depending upon the severity and type of accident scenario. Also note that, depending upon the accident scenario, almost all the Cs-137 or I-131 can be released into the atmosphere, whereas the Sr-90 tends to stay within the fuel assemblies even during the most severe accident scenarios.

By combining the various inventories and release fractions, the potential maximum environmental source terms pertinent to this study were estimated. The "unit hypothetical release" used to generate the deposition data used in this report is significantly greater than the median values examined but less than the maximum values for Cs-137, greater than the maximum values for Sr-90, and more than 250 times greater than the maximum value for I-131. Therefore, the choice of the "unit hypothetical release" appeared to be representative for Cs-137, conservative for Sr-90, and overly conservative for I-131. The adjusted total depositions values for Cs-137, Sr-90, and I-131 were obtained by scaling the original values by 5.10, 0.29, and $4x10^{-3}$, respectively, the ratios of the appropriate maximum source terms to the "unit hypothetical release" used to provide the original deposition data.

The adjusted total Cs-137 depositions were more than an order of magnitude larger than the corresponding maximum Sr-90 values and almost three orders of magnitude larger than the corresponding I-131 depositions. When considering the appropriate deposition-to-dose coefficients (provided in the report), it was apparent that the radionuclide of primary interest was Cs-137. For example, both the Cs-137 maximum total depositions and the worst-case deposition-to-dose factors are orders of magnitude larger for Cs-137 than for I-131. For Sr-90, even though the worst-case deposition-to-dose coefficients were larger than their Cs-137 counterparts by a factor of up to 2.5, the maximum total Cs-137 depositions will be larger than those for Sr-90 by more than an order of magnitude. Thus the Cs-137 depositions and resulting dose commitments were of primary concern for releases from both risk sites.

5.4.2 Worst-Case Maximum Effective Dose Commitments

The UNSCEAR 1993 Report methodology employed a multiplicative model to estimate effective dose commitments. Three pathways (i.e., ingestion, inhalation, and external exposure from ground deposition) were found dominant when computing effective dose commitments for the conditions considered in the UNSCEAR 1993 Report; these were also found to be dominant for this study. The various components used to derive the deposition-to-dose transfer factors for these pathways were examined in light of the region of interest, and reasonable ranges were computed using more relevant data. These were then used to compute worst-case effective dose commitments from the adjusted deposition results.

For the ingestion pathway, the Cs-137 and Sr-90 deposition-to-dose transfer coefficients for adults, which correspond to the values computed in the UNSCEAR 1993 Report, were between 0.13 and 4.6 times and 0.12 to 7.4 times, respectively, the original UNSCEAR values. For the "maximum individual", or that age group with the highest deposition-to-dose transfer coefficient, the values for Cs-137 (for teens) and Sr-90 (for infants) were between 0.13 and 6.0 times and between 0.014 and 34.3 times, respectively, the original UNSCEAR coefficients. For I-131, the age-weighted values, which correspond to those in the UNSCEAR 1993 Report, were between 0.008 and 4.4 times the original value, and the "maximum individual" values (for infants) are between 0.008 and 39.4 times the original UNSCEAR value.

For the inhalation pathway, the Cs-137 and Sr-90 deposition-to-dose transfer factors for adults, which correspond to the original UNSCEAR values, were between 0.55 and 13.4 times and 0.46 to 9.8 times, respectively, the UNSCEAR values. For the maximum individual, the values for Cs-137 (for teens) and Sr-90 (for infants) were between 0.40 and 13.3 times and between 0.14 and 8.4 times, respectively, the original UNSCEAR transfer factors. For I-131, the age-weighted values, which correspond to those in the UNSCEAR Report, were between 0.56 and 4.9 times the original value, and the maximum individual values (for infants) were between 0.10 and 5.7 times the original UNSCEAR value.

For the external exposure (from ground deposition) pathway, the lower bounding values were those provided in the UNSCEAR 1993 Report (where a deposition-to-dose coefficient for Sr-90 of zero was provided; likely because it is a pure beta-emitter). The upper bounds for the external exposure transfer factor for Cs-137 and I-131 were 4.5 and 3.2 times larger, respectively, than their UNSCEAR counterparts. The upper bound computed for Sr-90 was approximately the same as that for I-131 (which occurred by happenstance).

It should be noted, however, that only the overall Cs-137 deposition-to-dose transfer factor had a significant contribution from the external exposure pathway (although there was significant contribution from the ingestion pathway). The Sr-90 and I-131 dose commitments were dominated by the ingestion pathway. The worst-case overall deposition-to-dose transfer factors for Cs-137, Sr-90, and I-131 corresponding to those in the UNSCEAR Report were 4.5 (for adults), 7.7 (for adults), and 4.3 (age-weighted) times higher, respectively, than the corresponding UNSCEAR values. For the maximum individual groups, the worst-case overall transfer factors were 5.0 (for teens), 31.9 (for infants), and 37.1 (for infants) times higher, respectively, than the corresponding UNSCEAR values. However, even though the relative changes in the overall Sr-90 and I-131 deposition-to-dose transfer factors are much larger than those for Cs-137, when the adjusted total deposition values are taken into account, the impact of Cs-137 will dominate (which also applies to collective doses). Thus only the Cs-137 results will be provided below; the corresponding Sr-90 and I-131 values were provided in the body of the report for completeness.

For the Petropavlovsk nuclear risk site, the maximum adjusted Cs-137 total deposition (located in Russia) translated into worst-case maximum effective dose commitments of 97 and 108 mSv per person for adults and maximum individuals (or teens), respectively. For the transboundary region (i.e., that area outside of Russia over land), the maximum effective dose commitments for Cs-137 were 4.5 and 5.0 mSv per person for adults and teens, respectively. These maximum values were located in the U.S. territories (i.e., State of Alaska); the maximum effective dose commitments for the Aleutian Islands were 3.0 and 3.3 mSv per person for adults and teens, respectively. The maximum effective dose commitments in the U.S. territories were generally three to four times higher than those in Japan, the transboundary country with the next highest maximum dose commitments resulting from accidental releases from the Petropavlovsk risk site.

For the Vladivostok site, the maximum adjusted Cs-137 total deposition (located again in Russia) translated into worst-case maximum effective dose commitments of 92 and 102 mSv per person for adults and maximum exposed individuals (or teens), respectively. For the transboundary region, the maximum effective dose commitments for Cs-137 were 24 and 27 mSv per person for adults and teens, respectively. These maximum values were located in China, which is proximate to the Vladivostok site. The maximum effective dose commitments for Japan and N. Korea are approximately the same (i.e., within a factor of two) as that for China. Note that the maximum effective dose commitments in the U.S. territories are generally more than a factor of 60 lower than those in China, the transboundary country with the highest maximum dose commitments resulting from accidental releases from the Vladivostok risk site.

The maximum worst-case dose commitments (on a day-to-day basis) corresponding to the Petropavlovsk and Vladivostok releases for both the regional and transboundary conditions were also compared to various annual reference levels (i.e., 0.15, 1.0, 10, and 100 mSv per person) discussed in the ICRP 82 Report pertaining to practices and interventions and the annual background radiation dose (i.e., 2.4 mSv per person) provided in the UNSCEAR 1993 Report. These comparisons are conservative because the effective dose commitments computed in this report are being compared to annual reference values and background doses. The body of the report should be referred to for specific results; however, it should be noted that the worst-case maximum dose commitments for the transboundary region on over 99% of all year 2000 days studied for the releases from the Petropavlovsk site are less than the average annual background radiation dose. For the corresponding

Vladivostok releases, the worst-case maximum dose commitments are less than the average annual background radiation dose for over 44% of all year 2000 days studied. Furthermore, the maximum dose commitments corresponding to the adjusted Vladivostok releases are less than the annual 10 mSv per person level in which interventions are rarely justified for more than 90% of all year 2000 days studied and are all less than the annual 100 mSv per person level in which interventions are almost always justifiable according to ICRP 82. Therefore, the impacts from the adjusted Vladivostok releases were more significant than those from Petropavlovsk, which could be considered negligible when compared to average annual background doses. The more significant impact of the adjusted Vladivostok releases were compounded by the fact that many more people were impacted than from the corresponding hypothetical Petropavlovsk releases.

5.4.3 Worst-Case Maximum Collective Effective Dose Commitment Results

The final examination of the dose commitment estimates was the potential impact on those persons exposed to the depositions resulting from the accidental releases. That is, the maximum collective dose commitments corresponding to the worst-case dose commitments were computed. However, unlike the corresponding UNSCEAR analysis, only the maximum age-weighted deposition-to-dose factors were used in this portion of the variation study because not only adults were impacted by the depositions in the region of interest.

The results indicate that even though the maximum effective dose commitments from the Petropavlovsk and Vladivostok releases were reasonably similar, the higher populations impacted by the Vladivostok releases generally resulted in significantly larger collective dose commitments and thus potential mortalities than those for the Petropavlovsk releases. For example, the maximum number of additional mortalities on a regional basis resulting from the adjusted Petropavlovsk releases would be 355; there would be as many as 329 in Japan, 83 in China, 18 in the State of Alaska, and 10 in S. Korea. However, for the Vladivostok releases, there might be as many as 9771 additional mortalities on a regional basis, and the additional mortalities for Japan, China, N. Korea, S. Korea, Russia, and Taiwan would be 9501, 8575, 2485, 2436, 1614, and 318, respectively. The U.S. territories and Hong Kong might have an additional two mortalities each from the adjusted Vladivostok releases and worst-case deposition to dose factors. However, even though these mortality numbers may appear large, it should be noted that none of the transboundary values exceed 9 mortalities per 100 000 persons, found in N. Korea resulting from the worst-case deposition-to-dose coefficients applied to the maximum adjusted Cs-137 total deposition values from the Vladivostok releases.

Because the aggregation of doses over large areas is contrary to the recommendation of the ICRP, a series of threshold values were imposed on the worst-case results to determine whether the conclusions would change dramatically. The impact on the maximum worst-case collective dose commitments for the Petropavlovsk releases would remain significant although a larger threshold (i.e., 1.0 mSv per person) would have to be imposed to have an impact corresponding to that found for the analogous UNSCEAR values. However, the impact of imposing such thresholds on the maximum collective dose commitments from the hypothetical Vladivostok releases was much less profound than that for the corresponding Petropavlovsk dose commitments; in fact, the imposition of thresholds up to 1 mSv per person had little impact on the collective dose commitments for most countries that would have been impacted by the Vladivostok releases. Even though the impact on the collective doses related to the Vladivostok releases was small, it remains true that the worst-case impacts of the effective dose commitments for the releases from both the Vladivostok and Petropavlovsk sites were negligible when compared to metrics such as the average annual background dose and other causes of death in the affected countries.

6 Recommendation and Future Studies

The results of this work were general in nature and should only be used as an initial indication of the location and magnitude of potential problems associated with accidental releases from the two Russian Far East nuclear sites considered. The conclusions of this report indicate that the potential impact of the accidental releases from these sites will be small when compared to background radiation although some individuals could get a dose commitment that is larger than that from annual background radiation. It is recognized that it is prudent to apply site-specific information wherever possible to determine risks for areas of primary concern, such as Russia, not covered in this report. It is conceivable that there might be cases where significant impacts are possible for the accident scenarios examined in this report; however, every attempt was made to make the conclusions of this report as conservative and meaningful as warranted.

Despite the successful attempts to make the conclusions meaningful, there are a number of areas that could be further investigated:

- The concentration and deposition data were generated for a single calendar year (2000). It would provide a more rigorous basis of analysis if the concentration and deposition data used as the basis for the conclusions of this report were generated over as many years as possible. Then a statistical analysis could be applied to the results instead of merely examining the maximum values for the data provided.
- The potential source term information (i.e., inventories and potential release fractions) available for the Russian Far East nuclear sites will continue to improve. Such information has a direct bearing on the conclusions of a study such as this one and should be incorporated when available.
- The population information used in this study was from 1995. When updated population information is available, the information in this report should be updated.
- The parameters and methodology provided in the UNSCEAR 1993 Report were used ato compute the baseline case and then updated using area-specific information where available. However, such area-specific information was not available for all parameters (e.g., the deposition-to-diet transfer factors for the ingestion pathway), and these parameters were merely adjusted by 10% to provide some measure of variation for the parameter study. When such specific data are available, they can be incorporated into the study.
- The information in the UNSCEAR 2000 Report was examined, and it was determined that there would be no significant impact on the conclusions of this study if the minor differences in methodology were incorporated into this study. Any pertinent pathway information was incorporated into this report; however, it would seem prudent to update the report to reflect the latest methodology.
- Other, more concrete assessments of the potential impacts can be made. For example, restrictions on the slaughter and distribution of sheep and reindeer are still in force in some Nordic countries [55]. A limit such as that used for reindeer removal can be applied to the results of this study.
- The analysis in this report could be applied to the other nuclear risk sites in the North Pacific region including nuclear-weapon related facilities in the northern regions of China and nuclear fuel reprocessing facilities located in the northern regions of both China and Japan.
- The approach for those regions proximate to the risk sites (e.g., Russia, China, Japan, the Koreas, etc.) could be modified to reflect the localized scale.
- The initiating event could be investigated to determine if other, co-located energy sources could send the plume higher into the atmosphere and, therefore, reach distant sites more quickly.
- The impact onregional fisheries and dosages to fish consumers could be determined.

The above additions and changes to the report could only make the conclusions drawn from this study more meaningful.

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53 International Commission on Radiological Protection. "Age-dependent doses to members of the public from intake of radionuclides: Part 4. Inhalation Dose Coefficients," ICRP Publication 71, Annals of the ICRP, Vol. 25(3-4), Pergamon Press, Oxford, 1995.

54 John R. Lamarsh, **Introduction to Nuclear Engineering**, Second Edition, Addison-Wesley Publishing Company, Reading, Massachusetts, 1983.

55 *CHERNOBYL: Assessment of Radiological and Health Impacts (2002 Update of Chernobyl: Ten Years On)*, OECD/NEA, Paris 2002.

8 Appendices

8.1 Appendix A
Detailed Report Figures

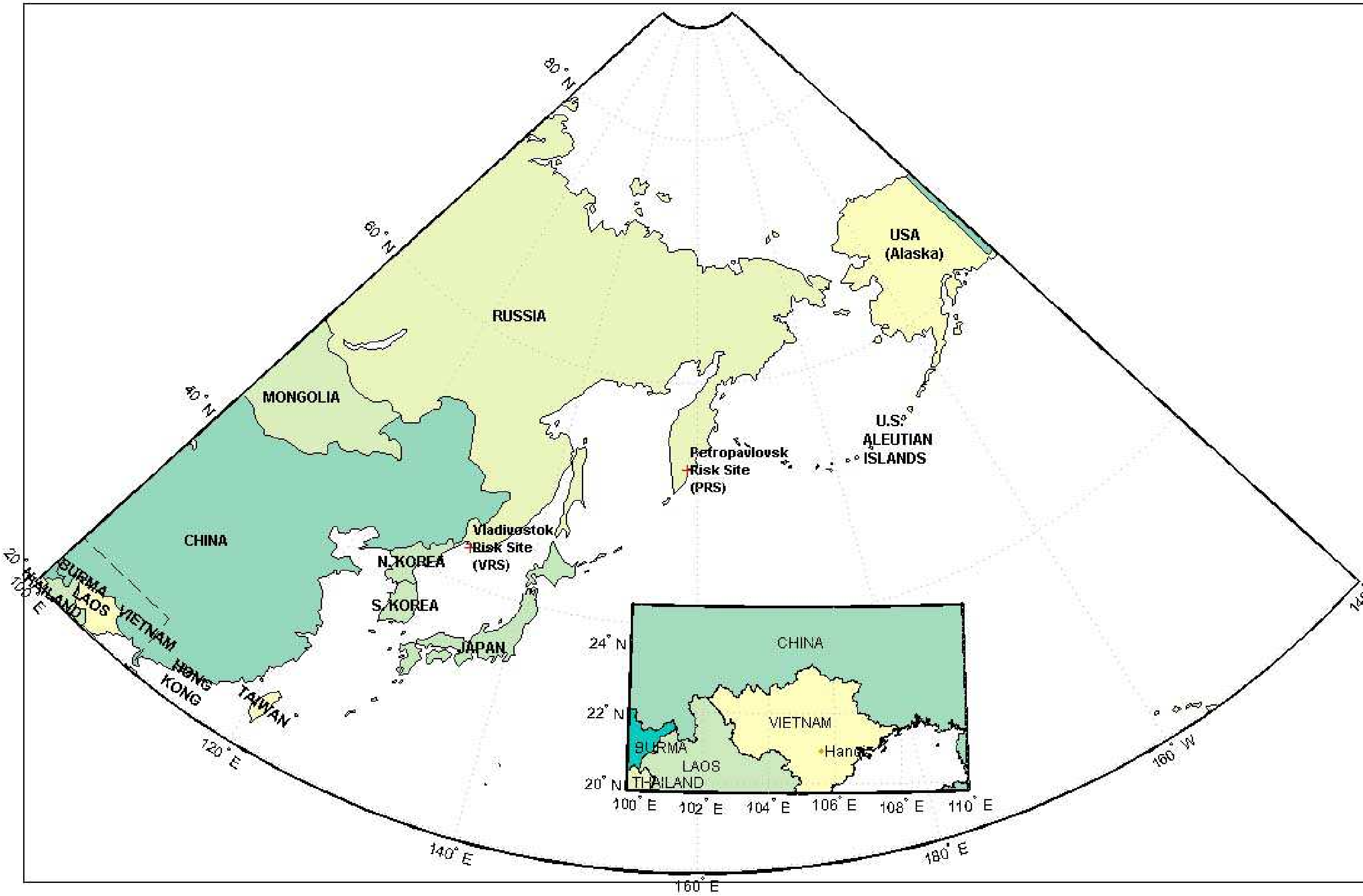

Figure A 1. **This figure represents the region of interest for this study. Both the Petropavlovsk (PRS) and Vladivostok (VRS) Nuclear Risk Sites are shown. The inset illustrates the lower left-hand corner of this region where the countries of Burma, Thailand, Laos, and Vietnam are located.**

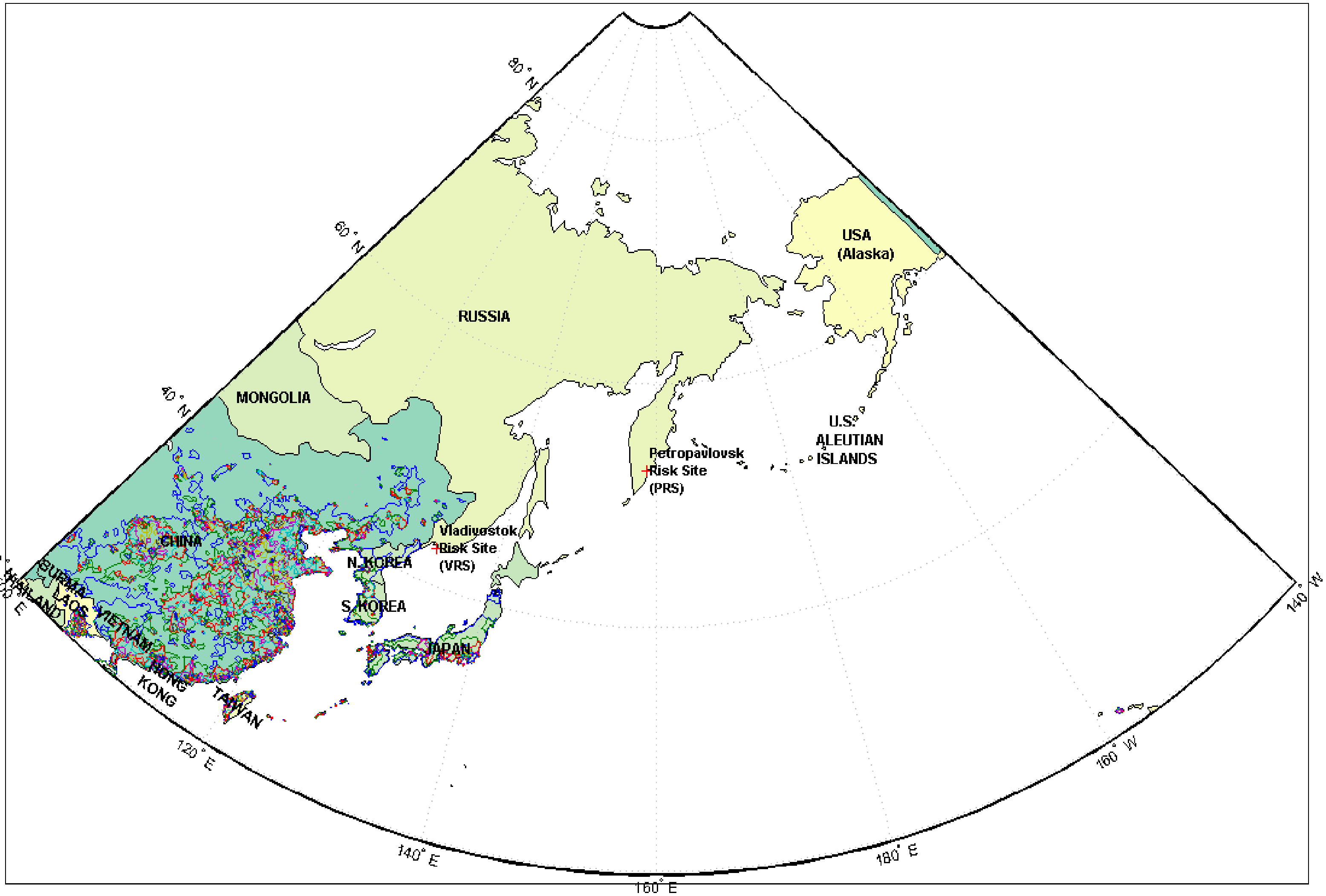

Figure A 2. This figure illustrates a contour plot (employing 150 equally-spaced lines) of the original population data (i.e., 12 cells per degree) used in this study.

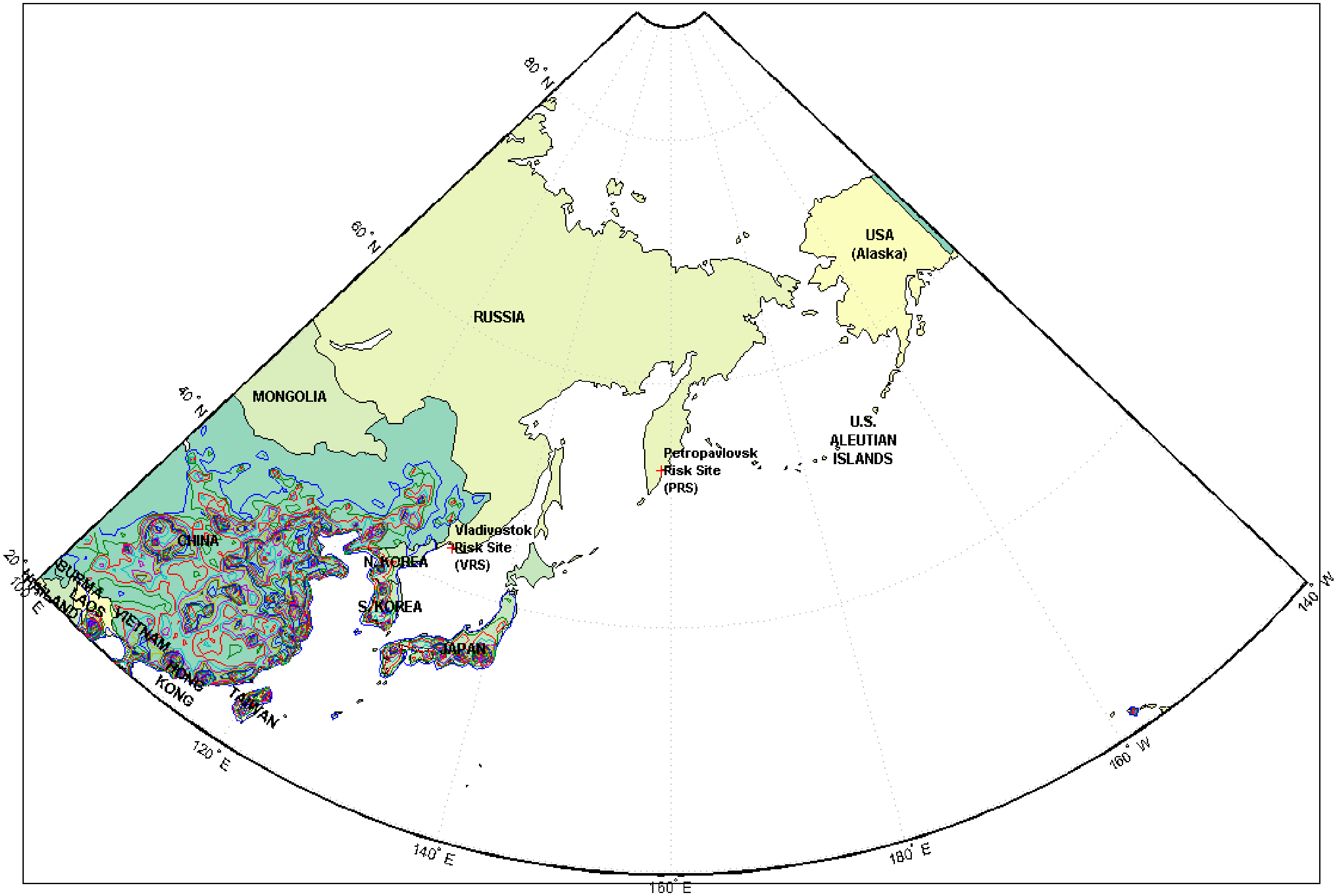

Figure A 3. This figure illustrates a contour plot (employing 75 equally-spaced lines) of the converted population data (i.e., 2 cells per degree) used in this study.

8.2 Appendix B
Alternative Development of the I-131 Ingestion Coefficient

A different representation of the P_{2345} ingestion transfer coefficient for I-131 from that above can be developed by using the population-weighted value for milk consumption, or:

Equation 22

$$
\begin{aligned}
P_{34}^{(c)} &= \Sigma_4 \left(pP_{34}\right)_i \\
&= (0.02)\left(330\ \mathrm{L\ a^{-1}}\right) \text{ for 0 - 1 year} \\
&\quad + (0.16)\left(180\ \mathrm{L\ a^{-1}}\right) \text{ for 1 - 9 years} \\
&\quad + (0.20)\left(150\ \mathrm{L\ a^{-1}}\right) \text{ for 9 - 19 years} \\
&\quad + (0.62)\left(90\ \mathrm{L\ a^{-1}}\right) \text{ for adults} \\
P_{34}^{(c)} &= 121.2\ \mathrm{L\ a^{-1}} \text{ for } {}^{131}\mathrm{I}
\end{aligned}
$$

versus an average value of 109.5 L a^{-1} used in the UNSCEAR 1993 Report. It can be show to be mathematically identical to then use the following milk consumption-weighted I-131 P_{45} value:

Equation 23

$$
\begin{aligned}
P_{45}^{(c)} &= \sum_4 \left[\left(\frac{pP_{34}}{P_{34}^{(c)}}\right) P_{45}\right]_i \\
&= \left(\frac{(0.02)\left(330\ \mathrm{L\ a^{-1}}\right)}{121.2\ \mathrm{L\ a^{-1}}}\right)\left(210\ \mathrm{nSv\ Bq^{-1}}\right) \text{ for 0 - 1 years} \\
&\quad + \left(\frac{(0.16)\left(180\ \mathrm{L\ a^{-1}}\right)}{121.2\ \mathrm{L\ a^{-1}}}\right)\left(110\ \mathrm{nSv\ Bq^{-1}}\right) \text{ for 1 - 9 years} \\
&\quad + \left(\frac{(0.20)\left(150\ \mathrm{L\ a^{-1}}\right)}{121.2\ \mathrm{L\ a^{-1}}}\right)\left(29\ \mathrm{nSv\ Bq^{-1}}\right) \text{ for 9 - 19 years} \\
&\quad + \left(\frac{(0.62)\left(90\ \mathrm{L\ a^{-1}}\right)}{121.2\ \mathrm{L\ a^{-1}}}\right)\left(22\ \mathrm{nSv\ Bq^{-1}}\right) \text{ for adults} \\
P_{45}^{(c)} &= 54.9\ \mathrm{nSv\ Bq^{-1}} \text{ for } {}^{131}\mathrm{I}
\end{aligned}
$$

to compute the P_{2345} transfer coefficient. In other words, the overall ingestion transfer coefficient obtained using the consumption-weighted values is:

Equation 24

$$
\begin{aligned}
P_{2345} &= P_{23} P_{34}^{(c)} P_{45}^{(c)} \\
&= \left(0.63\mathrm{x}10^{-3}\ \mathrm{Bq\ a\ L^{-1}} \text{ per } \mathrm{Bq\ m^{-2}}\right)\left(121.2\ \mathrm{L\ a^{-1}}\right)\left(54.9\ \mathrm{nSv\ Bq^{-1}}\right) \\
&= 4.2\ \mathrm{nSv} \text{ per } \mathrm{Bq\ m^{-2}} \text{ for } {}^{131}\mathrm{I}
\end{aligned}
$$

or the same value as obtained above.

If, on the other hand, a population-weighted value of the P_{45} coefficient is desired, then the necessary P_{34} coefficient must be weighted using the population for the P_{45} coefficients in a manner analogous to that above. These coefficients would be:

Equation 25

$$P_{45}^{(p)} = \sum_4 (pP_{45})_i = (0.02)(210 \text{ nSv Bq}^{-1}) \text{ for 0 - 1 years}$$
$$+(0.16)(110 \text{ nSv Bq}^{-1}) \text{ for 1 - 9 years}$$
$$+(0.20)(29 \text{ nSv Bq}^{-1}) \text{ for 9 - 19 years}$$
$$+(0.62)(22 \text{ nSv Bq}^{-1}) \text{ for adults}$$
$$P_{45}^{(p)} = 41.2 \text{ nSv Bq}^{-1} \text{ for } {}^{131}\text{I}$$

and

Equation 26

$$P_{34}^{(p)} = \sum_4 \left[P_{34} \left(\frac{pP_{45}}{P_{45}^{(p)}} \right) \right]_i$$
$$= (330 \text{ L a}^{-1}) \left(\frac{(0.02)(210 \text{ nSv Bq}^{-1})}{41.2 \text{ nSv Bq}^{-1}} \right) \text{ for 0 - 1 years}$$
$$+ (180 \text{ L a}^{-1}) \left(\frac{(0.16)(110 \text{ nSv Bq}^{-1})}{41.2 \text{ nSv Bq}^{-1}} \right) \text{ for 1 - 9 years}$$
$$+ (150 \text{ L a}^{-1}) \left(\frac{(0.20)(29 \text{ nSv Bq}^{-1})}{41.2 \text{ nSv Bq}^{-1}} \right) \text{ for 9 - 19 years}$$
$$+ (90 \text{ L a}^{-1}) \left(\frac{(0.62)(22 \text{ nSv Bq}^{-1})}{41.2 \text{ nSv Bq}^{-1}} \right) \text{ for adults}$$
$$P_{34}^{(p)} = 161.3 \text{ L a}^{-1} \text{ for } {}^{131}\text{I}$$

where

Equation 27

$$P_{2345} = P_{23} P_{34}^{(p)} P_{45}^{(p)}$$
$$= (0.63\text{x}10^{-3} \text{ Bq a L}^{-1} \text{ per Bq m}^{-2})(161.3 \text{ L a}^{-1})(41.2 \text{ nSv Bq}^{-1})$$
$$= 4.2 \text{ nSv per Bq m}^{-2} \text{ for } {}^{131}\text{I}$$

Therefore, there are a number of equivalent ways to compute the ingestion transfer coefficient for I-131 when using population or age-weighted values. However, note that using the two population-weighted values does not provide the correct transfer coefficient:

Equation 28

$$P_{2345} = P_{23} P_{34}^{(c)} P_{45}^{(p)}$$
$$= (0.63\text{x}10^{-3} \text{ Bq a L}^{-1} \text{ per Bq m}^{-2})(121.2 \text{ L a}^{-1})(41.2 \text{ nSv Bq}^{-1})$$
$$= 3.2 \text{ nSv per Bq m}^{-2} \text{ for } {}^{131}\text{I}$$

In fact, the transfer factor is significantly lower than the one computed above; therefore, simply multiplying the population-weighted values will not provide the appropriate transfer coefficient.

8.3 Appendix C
RESRAD Verification Information and Files

Listing 1. Microsoft Word 2000 MailMerge File Site2_RAD_template2.doc

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&DB
IHAFTIM = «IHAFTIM»,
DFFILE = 'FGR 13 Morbidity',
RISKLIB= 'FGR 13 Morbidity',
NANUC =  «NANUC» ,
NIY =  8 ,
NPD =  «NANUC» ,
NPTS =  1024 ,
NS =  1 ,
NPDS =  «NANUC» ,
U_activity = 'Bq' ,
U_dose_unit = 'mSv' ,
&END
&INDATA
TITLE = «TITLE»,
NPTS = 1024 ,
TDISK = '', VERS = '6.2',
XSPACE = 'LOG',
FINDPEAK = 1 ,
LYMAX = 17 ,
KYMAX = 513 ,
COVER0 = 0,
DENSCV = 1.5,
VCV = .001,
DENSCZ = 1.5,
VCZ = .001,
TPCZ = .4,
FCCZ = .2,
HCCZ = 10,
BCZ = 5.3,
HUMID = 8,
EVAPTR = .5,
PRECIP = 1,
RI = .2,
IDITCH = 0,
RUNOFF = .2,
WAREA = 1000000,
EPS = .001,
NS = 1,
TI = 0,
DENSAQ = 1.5,
TPSZ = .4,
EPSZ = .2,
FCSZ = .2,
HCSZ = 100,
HGWT = .02,
BSZ = 5.3,
VWT = .001,
DWIBWT = 10,
MODEL = 0,
UW = 250,
AREA = «AREA»,
THICK0 = «THICK0»,
LCZPAQ = «LCZPAQ»,
BRDL = «BRDL»,
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T(2) = 1,
T(3) = 3,
T(4) = 10,
T(5) = 30,
T(6) = 100,
T(7) = 300,
T(8) = 1000,
T(9) = 0,
T(10) = 0,
INHALR = 8400,
MLINH = .0001,
ED = «ED»,
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FIND = «FIND»,
FOTD = «FOTD»,
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RAD_SHAPE(2) = 70.710680,
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FRACA(5) = 0.000000,
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DIET(3) = «Dmk»,
DIET(4) = «Dmt»,
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DIET(6) = 0.000000,
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FHHW = 1,
FLW = 1,
FIRW = 1,
FR9 = «FR9»,
FPLANT =-1,
FMEAT =-1,
FMILK =-1,
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LFI6 = 55,
LWI5 = 50,
LWI6 = 160,
LSI = .5,
MLFD = .0001,
DM = .15,
DROOT = «DROOT»,
FGWDW = 1,
FGWHH = 1,
FGWLW = 1,
FGWIR = 1,
STOR_T(1) = 14,
STOR_T(2) = 1,
STOR_T(3) = 1,
STOR_T(4) = 20,
STOR_T(5) = 7,
STOR_T(6) = 7,
STOR_T(7) = 1,
STOR_T(8) = 1,
STOR_T(9) = 45,
FLOOR1 = .15,
DENSFL = 2.4,
TPCV = .4,
TPFL = .1,
PH2OCV = .05,
PH2OFL = .03,
DIFCV = .000002,
DIFFL = .0000003,
DIFCZ = .000002,
HMIX = 2,
WIND = 2,
REXG = .5,
HRM = 2.5,
FAI = 0,
DMFL =-1,
EMANA(1) = 0.250000,
EMANA(2) = 0.150000,
C12WTR = .00002,
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C12CZ = .03,
CSOIL = .02,
CAIR = .98,
DMC = .3,
EVSN = .0000007,
REVSN = 1E-10,
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AVFG5 = .2,
CO2F = 88.94,
H(1) = «H1»,
H(2) = 4.000000,
H(3) = 4.000000,
H(4) = 4.000000,
H(5) = 4.000000,
DENSUZ(1) = 1.500000,
DENSUZ(2) = 1.500000,
DENSUZ(3) = 1.500000,
DENSUZ(4) = 1.500000,
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HCUZ(3) = 10.000000,
HCUZ(4) = 10.000000,
HCUZ(5) = 10.000000,
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NUMDISTANCES = 0,
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LIDHEIGHT = 1000,
SOURCEHEIGHT = 10,
AGVEG(1) = 0.000000,
AGVEG(2) = 0.500000,
AGVEG(3) = 0.500000,
AGMILK(1) = 0.000000,
AGMILK(2) = 0.500000,
AGMILK(3) = 0.500000,
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AGMEAT(2) = 0.500000,
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YV(3) = 1.100000,
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TE(3) = 0.080000,
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RWET(2) = 0.250000,
RWET(3) = 0.250000,
RDRY(1) = 0.250000,
RDRY(2) = 0.250000,
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W = , «NANUC»*0,
DCACTC = «DCACT_1», «DCACT_2», «DCACT_3»,
DCACTU1 = «DCACT_1», «DCACT_2», «DCACT_3»,
DCACTS = «DCACT_1», «DCACT_2», «DCACT_3»,
RLEACH = , «NANUC»*0,
SOLUBK0 = , «NANUC»*0,
NSENA = 0,
NUM_SAMPS = 0, NUMVAR = 0,
UNCPPD = 1 ,
UNCPND = 1 ,
SELPATH = 255,
&END
&DCF
T_DCF2= «T_DCF2_1», «T_DCF2_2», «T_DCF2_3»,
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BIOFAC2= «BIOFAC2_1», «BIOFAC2_2», «BIOFAC2_3»,
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RTF2= «RTF2_1», «RTF2_2», «RTF2_3»,
RTF3= «RTF3_1», «RTF3_2», «RTF3_3»,
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SLPF2= «SLPF2_1», «SLPF2_2», «SLPF2_3»,
SLPF3= «SLPF3_1», «SLPF3_2», «SLPF3_3»,
SLPF4= «SLPF4_1», «SLPF4_2», «SLPF4_3»,
SLPF5= «SLPF5_1», «SLPF5_2», «SLPF5_3»,
T_SLPFRN=  1.8E-12,  1.9E-13,  3.7E-12,  3E-15,  6.2E-12,  3.9E-11,
 1.5E-11,  3.7E-11,
T_KFACTR= 760,  150,  570,  250,
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S_DCF2 =  .0094,  7.29E-06,
S_DCF3 =  .0019,  3.67E-06,
S_SLPF1=  3.95E-11,  6.98E-09,
S_SLPF2=  1.45E-08,  1.45E-11,
S_SLPF3=  2.25E-09,  4.7E-12,
S_SLPF4=  1.77E-09,  3.33E-12,
S_SLPF5=  2.25E-09,  4.7E-12,
&END
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Listing 2. Partial Listing of MS Excel 2000 Data File, 2000_krs_Cs137_RESRAD.xls, for Input to the MS Word 2000 MailMerge Tool

IHAFTIM	NANUC	TITLE	AREA	THICK0	LCZPAQ	BRDL	H1	ED	SHF3	SHF1	FIND	FOTD	FR9	DROOT	Dnl	Dl	Dmk	Dmt	NUC_1	S_1	DCACT_1
0	1	'January 01, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	2.55884	1000
0	1	'January 02, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	2.067434564	1000
0	1	'January 03, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.443952729	1000
0	1	'January 04, 2000'	1824722000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.146256311	1000
0	1	'January 05, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.131936427	1000
0	1	'January 06, 2000'	1824722000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	1.320926063	1000
0	1	'January 07, 2000'	1824722000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	1.568941254	1000
0	1	'January 08, 2000'	1758936000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.175935271	1000
0	1	'January 09, 2000'	1824722000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.177857396	1000
0	1	'January 10, 2000'	1867857000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.108600541	1000
0	1	'January 11, 2000'	1824722000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.588292799	1000
0	1	'January 12, 2000'	1824722000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.213717208	1000
0	1	'January 13, 2000'	1802936000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.229046232	1000
0	1	'January 16, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.818107921	1000
0	1	'January 17, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.605472079	1000
0	1	'January 18, 2000'	1867857000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.909529617	1000
0	1	'January 19, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	1.157484785	1000
0	1	'January 20, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.388090729	1000
0	1	'January 21, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.282493521	1000
0	1	'January 22, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.667340627	1000
0	1	'January 23, 2000'	1736726000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.297209875	1000
0	1	'January 24, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.513930337	1000
0	1	'January 25, 2000'	1867857000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.578321835	1000
0	1	'January 26, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	2.579863136	1000
0	1	'January 27, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	2.426092706	1000
0	1	'January 28, 2000'	1910399000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.026358455	1000
0	1	'January 29, 2000'	1910399000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.098124908	1000
0	1	'January 30, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.920221254	1000
0	1	'January 31, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.819309175	1000
0	1	'February 01, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	3.516302509	1000
0	1	'February 02, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	3.295858118	1000
0	1	'February 03, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	1.645826667	1000
0	1	'February 04, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	1.839841882	1000
0	1	'February 05, 2000'	1910399000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.232037521	1000
0	1	'February 06, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	1.053569175	1000
0	1	'February 07, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	6.240927062	1000
0	1	'February 08, 2000'	1802936000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.965812056	1000
0	1	'February 09, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	11.45482904	1000
0	1	'February 10, 2000'	1910399000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	0.187473868	1000
0	1	'February 11, 2000'	1867857000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	1.664399117	1000
0	1	'February 12, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	2.203248177	1000
0	1	'February 13, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	4.477969803	1000
0	1	'February 14, 2000'	1889203000	0.15	100	25	4	50	0	0.2	0.8	0.2	0.5	0.9	155	123.333	148.8669903	66.667	'Cs-137'	2.308962509	1000

Listing 3. MatLab File, test_run_3.m, used to generate RESRAD dose estimates from files generated using the MS Word 2000 MailMerge tool

```
% An MS Word MailMerge tool has been used to produce the appropriate files.
close all;
clear all;
% The files (of form Site##.txt) are contained in the following directory:
testdirname = 'D:\kgb\RESRAD\Test Folder';
% and the result files (i.e., SUMMARY##.REP will be placed this directory as well).
% NOTE: It is assumed that only test files--AND NOT SUMMARY.REP files--are located in this irectory to start.
% The RESRAD directory is:
resraddirname = 'D:\Program Files\RESRAD_Family\RESRAD';
% Save current directory
fid0 = pwd;
% Put the file information into the following variable:
files = dir(testdirname);
% The first two represent directories--so skip
for i = 3:length(files)
    cd(testdirname);
    copyfile(files(i).name, strcat(resraddirname, '\Site2.RAD'));
    cd(resraddirname);
    % Run the calculation using RESCALC.EXE
    !rescalc Site2.RAD 0 >nul
    % Copy the results placed in SUMMARY.REP back to the Test Folder defined above
    copyfile('SUMMARY.REP', strcat(testdirname, '\SUMMARY', sprintf('%04d',i-2), '.REP'));
    % as well as the other files that may be of interest later
    copyfile('DETAILED.REP', strcat(testdirname, '\DETAILED', sprintf('%04d',i-2), '.REP'));
    copyfile('DAUDOSE.REP', strcat(testdirname, '\DAUDOSE', sprintf('%04d',i-2), '.REP'));
    copyfile('CONCENT.REP', strcat(testdirname, '\CONCENT', sprintf('%04d',i-2), '.REP'));
    copyfile('INTRISK.REP', strcat(testdirname, '\INTRISK', sprintf('%04d',i-2), '.REP'));
    copyfile('DEBUG.OUT', strcat(testdirname, '\DEBUG', sprintf('%04d',i-2), '.OUT'));
end;
% And back to the original directory ....
cd(fid0);
clear testdirname resraddirname fid0 files i;
% You can summarize the results from all the files using summarypp.m
```

Listing 4. MatLab File, summarypp3.m, used to collect RESRAD dose information after processing through MatLab with test_run_3.m

```
% Now postprocess the various SUMMARY##.REP files to gather the desired information.
close all;
clear all;
% The results files (of form SUMMARY##.REP) are contained in the following directory:
testdirname = 'D:\kgb\RESRAD\Test Folder';
% NOTE: There will likely also be test files located in this directory so they should be excluded from the following.
fid0 = pwd;
% Put the file information (containing directories and SUMMARY and test files) into the following variable:
files = dir(testdirname);
cd(testdirname);
counter = 0;
for i = 3:length(files)
    ycount = 1;
    ids0 = '';
    allconcs = [];
    if strfind(files(i).name, 'SUMMARY')
        fid = fopen(files(i).name);
        counter = counter+1;
        while 1
            tline = fgetl(fid);
            if ~ischar(tline), break, end % end if string is empty
            % Get the contaminated zone area (AREA)
            front = ' R011 | Area of contaminated zone (m**2)';
            if strfind(tline, front)
                init(counter).area = getthing(front, tline);
            end
            % Get the contaminated zone thickness (THICK0)
            front = ' R011 | Thickness of contaminated zone (m)';
            if strfind(tline, front)
                init(counter).thick0 = getthing(front, tline);
            end
            % Get the length parallel to aquifer flow (LCZPAQ)
            front = ' R011 | Length parallel to aquifer flow (m)';
            if strfind(tline, front)
                init(counter).lczpaq = getthing(front, tline);
            end
            % Get the basic radiation dose limit (BRDL)
            front = ' R011 | Basic radiation dose limit (mSv/yr)';
            if strfind(tline, front)
                init(counter).brdl = getthing(front, tline);
            end
            % Get the Unsaturated zone 1 thickness (H(1))
            front = ' R015 | Unsat. zone 1, thickness (m)';
            if strfind(tline, front)
                init(counter).h1 = getthing(front, tline);
            end
            % Get the Exposure Duration (ED)
```

```
front = ' R017 | Exposure duration';
if strfind(tline, front)
    init(counter).ed = getthing(front, tline);
end
% Get the Inhalation Shielding Factor (SHF3)
front = ' R017 | Shielding factor, inhalation';
if strfind(tline, front)
    init(counter).shf3 = getthing(front, tline);
end
% Get the External Gamma Shielding Factor (SHF1)
front = ' R017 | Shielding factor, external gamma';
if strfind(tline, front)
    init(counter).shf1 = getthing(front, tline);
end
% Get the Fraction Spent Indoors (FIND)
front = ' R017 | Fraction of time spent indoors';
if strfind(tline, front)
    init(counter).find = getthing(front, tline);
end
% Get the Fraction Spent Outdoors (FOTD)
% Should there not be a unit sum or just a maximum constraint on FIND+FOTD???
front = ' R017 | Fraction of time spent outdoors (on site)';
if strfind(tline, front)
    init(counter).fotd = getthing(front, tline);
end
% Get the Aquatic Food Contamination Factor (FR9)
front = ' R018 | Contamination fraction of aquatic food';
if strfind(tline, front)
    init(counter).fr9 = getthing(front, tline);
end
% Get the Depth of Roots (DROOT)
front = ' R019 | Depth of roots (m)';
if strfind(tline, front)
    init(counter).droot = getthing(front, tline);
end
% Get the Non-leafy Vegetable Consumption (DIET(1))
front = ' R018 | Fruits, vegetables and grain consumption (kg/yr)';
if strfind(tline, front)
    init(counter).diet(1) = getthing(front, tline);
end
% Get the Leafy Vegetable Consumption (DIET(2))
front = ' R018 | Leafy vegetable consumption (kg/yr)';
if strfind(tline, front)
    init(counter).diet(2) = getthing(front, tline);
end
% Get the Milk Consumption (DIET(3))
front = ' R018 | Milk consumption (L/yr)';
if strfind(tline, front)
    init(counter).diet(3) = getthing(front, tline);
end
```

```
% Get the Meat Consumption (DIET(4))
front = ' R018 | Meat and poultry consumption (kg/yr)';
if strfind(tline, front)
    init(counter).diet(4) = getthing(front, tline);
end
% I am not currenlty concerned with the Fish and Other Seafood consumption values in DIET(5) and DIET(6), respectively.
% Get the density of the contaminated zone (DENSCZ)
front = ' R013 | Density of contaminated zone (g/cm**3)';
if strfind(tline, front)
    init(counter).denscz = getthing(front, tline);
end
% Get the Soil Ingestion Rate (SOIL)
front = ' R018 | Soil ingestion rate (g/yr)';
if strfind(tline, front)
    init(counter).soil = getthing(front, tline);
end
% Get the radionuclide ID's and concentrations
if strfind(tline, 'R012 | Initial principal radionuclide (Bq/g):')
    [id0, conc] = getconc(tline);
    ids0 = strvcat(ids0, id0);
    allconcs = [allconcs, conc];
end
% Process doses and fractions for each year considered
if strfind(tline, 'As mSv/yr and Fraction of Total Dose At t = 0.000E+00 years') % had to add the 0.000E+00 years to prevent error
    tlinep1 = fgetl(fid); % get the next line to see if the path is water independent
        if strfind(tlinep1, 'Water Independent Pathways')
            year = getyear(tline);
            % disp(num2str(year));
            % Now go to the beginning of the results by skipping the next four (4) lines
            for j = 1:4
                fgetl(fid);
            end
            count = 1;
            ids = '';
            alldoses = [];
            allfractions = [];
            while 1
                tline = fgetl(fid);
                [id, tline] = strtok(tline);
                if strcmp(id, '======='), break, end % the line above the totals
                ids = strvcat(ids, id);
                % now get doses
                [doses, fractions] = getdoses(tline);
                alldoses = [alldoses; doses];
                allfractions = [allfractions; fractions];
            end
            results(counter, ycount).year = year;
            results(counter, ycount).ids = ids;
            results(counter, ycount).doses = alldoses;
            results(counter, ycount).fractions = allfractions;
```

```
                        ycount = ycount + 1;
                    end
            end
        end
        fclose(fid);
        init(counter).ids = ids0;
        init(counter).concs = allconcs;
        % Now compute the initial radionuclide loadings
        %init(counter).loadings = (1000*allconcs)*(1000*init(counter).denscz)*init(counter).thick0;
        % But let's try it in Bq/g instead
        init(counter).loadings = allconcs;
    end
end
cd(fid0);
clear testdirname fid0 files i ids0 allconcs fid tline front id0 conc ycount;
clear tlinep1 year j count ids doses fractions alldoses allfractions id;
% Now process the results using process_results.m to return the dose conversion factors in the variable dosefactors
% and save them into a tab-delimited file
% process_results
```

Listing 5. MatLab File, process_results3.m, used to generate a file containing the RESRAD dose information after generating the summary information with summarypp3.m

```
% M-file to process results (in both init and results variables) from summarypp.m run
% and generate dose factors at time zero (0)
% This m-file will also write the results from processing a series of SUMMARY reports from
% RESRAD 6.2 to a tab-delimited files for input to Excel or similar
% The variables are contained in the original Excel files used to generate the runs
% and thus only the results will be placed in the file
% There are r files and c times in years in the results files
[r, cc] = size(results);
% For now, pick the values at zero (0) years corresponding to c = 1
yindex = 1; % corresponding to results(:,yindex).year value
year = results(1,yindex).year
% The directory name to put the results file:
dirname = 'D:\kgb\RESRAD';
% Save current directory
fid0 = pwd;
% Go to directory where you want the results.
cd(dirname);
% Use clock function to make a new (and likely unique) filename....
c = clock;
filename = strcat('t', num2str(results(1,yindex).year), '-', num2str(c(3)), '-', num2str(c(2)), '-', num2str(c(1)));
filename = strcat(filename, '-', num2str(c(4)), '-', num2str(c(5)), '-', num2str(round(c(6))), '.txt');
fid = fopen(filename, 'w');
% Now generate the heading string
heading = '%s\tGround\tInhalation\tRadon\tPlant\tMeat\tMilk\tSoil';
fprintf(fid, heading, 'Dose'); fprintf(fid, '\t'), fprintf(fid, heading, 'DCF'); fprintf(fid, '\t');
fprintf(fid, heading, 'Dose'); fprintf(fid, '\t'), fprintf(fid, heading, 'DCF'); fprintf(fid, '\t');
fprintf(fid, heading, 'Dose'); fprintf(fid, '\t'), fprintf(fid, heading, 'DCF'); fprintf(fid, '\n');
for i = 1:r
    ids = results(i,yindex).ids;
    doses = results(i,yindex).doses;
    [dr, dc] = size(doses);
    diet = init(i).diet;
    loadings = init(i).loadings;
    dosefactors(i).ids = init(i).ids; % I think this is already available above in ids
    % Factors for Ground, Inhalation, Radon, Plant, Meat, Milk, and Soil
    factors = [365*24, 365*24, 1, diet(1)+diet(2), diet(4), diet(3), init(i).soil];
    for j = 1:dr
        fprintf(fid,'%s\t', ids(j,:));
        % Write out the doses
        for k = 1:dc
            fprintf(fid,'%6.3E\t', doses(j,k));
        end
        % Compute and write the dose conversion factors (DCF's)--check summarypp3.m for denominator used
        fprintf(fid,'%s\t', ids(j,:));
        for k = 1:dc
            % Check for division(s) by zero
```

```
            if (loadings(j) * factors(k)) > 0
                dosefactors(i).factors(j,k) = doses(j,k) / loadings(j) / factors(k);
            else
                dosefactors(i).factors(j,k) = NaN
            end
            fprintf(fid,'%6.3E\t', dosefactors(i).factors(j,k));
        end
    end
    fprintf(fid, '\n');
end
% and now close the file
fclose(fid);
% And back to the original directory ....
cd(fid0);
clear r cc i doses dr dc diet loadings factors j k ids filename heading fid fid0 dirname;
```

9 Tables

Table 1. Correlations for I-131 versus Cs-137 "raw" Dry Deposition (ddep) results (in Bq m^{-2}) for the PRS

	I-131(t_d hr)						
Cs-137(t_p hr)	**Max**	**144**	**120**	**096**	**072**	**048**	**024**
Cs-137(Max)	0.868	0.888	0.888	0.887	0.885	0.865	0.514
Cs-137(144)	0.868	0.888	0.888	0.887	0.885	0.865	0.514
Cs-137(138)	0.868	0.889	0.888	0.887	0.885	0.865	0.514
Cs-137(132)	0.868	0.889	0.889	0.888	0.886	0.865	0.514
Cs-137(126)	0.869	0.890	0.890	0.888	0.887	0.866	0.515
Cs-137(120)	0.870	0.891	0.891	0.890	0.888	0.867	0.515
Cs-137(114)	0.871	0.892	0.892	0.891	0.889	0.869	0.516
Cs-137(108)	0.872	0.893	0.893	0.892	0.891	0.870	0.517
Cs-137(102)	0.873	0.893	0.893	0.893	0.891	0.871	0.518
Cs-137(096)	0.873	0.894	0.894	0.894	0.892	0.871	0.518
Cs-137(090)	0.874	0.895	0.895	0.895	0.893	0.873	0.519
Cs-137(084)	0.875	0.895	0.895	0.896	0.895	0.874	0.520
Cs-137(078)	0.876	0.896	0.896	0.896	0.896	0.875	0.521
Cs-137(072)	0.877	0.897	0.897	0.898	0.897	0.877	0.522
Cs-137(066)	0.879	0.899	0.899	0.899	0.899	0.880	0.524
Cs-137(060)	0.884	0.904	0.904	0.904	0.904	0.887	0.531
Cs-137(054)	0.892	0.910	0.910	0.910	0.911	0.898	0.543
Cs-137(048)	0.909	0.925	0.925	0.925	0.925	0.916	0.573
Cs-137(042)	**0.963**	**0.972**	**0.972**	**0.972**	**0.972**	**0.969**	0.695
Cs-137(036)	0.962	0.955	0.955	0.956	0.956	0.963	0.858
Cs-137(030)	0.879	0.861	0.861	0.862	0.862	0.877	0.907
Cs-137(024)	0.869	0.848	0.848	0.848	0.848	0.863	**0.986**
Cs-137(018)	0.660	0.638	0.638	0.638	0.638	0.648	0.881
Cs-137(012)	0.287	0.271	0.271	0.271	0.271	0.276	0.422
Cs-137(006)	0.198	0.184	0.184	0.184	0.184	0.188	0.290

Table 2. PRS Dry Deposition (ddep) Maximum Values for Cs-137 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	09-Feb	326	100.0	1.91E+04	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	1.91E+04	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	1.91E+04	52.50	157.50	87	1.89E+09	1944
Transboundary**	07-Feb	326	100.0	1.56E+04	52.50	159.00	65	1.89E+09	0	07-Feb	100.0	1.56E+04	52.50	159.00	65	1.89E+09	0	07-Feb	100.0	1.56E+04	52.50	159.00	65	1.89E+09	0
Burma	None									None								None							
China	07-Jan	58	17.8	6.75E+01	43.50	130.50	2306	2.25E+09	70383	07-Jan	17.8	6.75E+01	43.50	130.50	2306	2.25E+09	70383	04-Dec	1.5	5.45E-04	52.50	123.00	2365	1.89E+09	5976
Hong Kong	None									None								None							
Japan	26-Apr	82	25.2	2.76E+02	43.50	142.50	1581	2.25E+09	155808	26-Apr	25.2	2.76E+02	43.50	142.50	1581	2.25E+09	155808	02-Jan	3.1	4.42E+01	44.50	145.50	1338	2.21E+09	2136
Laos	None									None								None							
Mongolia	04-Jan	13	4.0	4.13E+00	46.50	119.50	2855	2.13E+09	1835	04-Jan	4.0	4.13E+00	46.50	119.50	2855	2.13E+09	1835	None							
N. Korea	07-Jan	18	5.5	4.24E+01	43.00	130.00	2372	2.26E+09	175327	07-Jan	5.5	4.24E+01	43.00	130.00	2372	2.26E+09	175327	04-Dec	0.3	9.93E-13	43.00	130.00	2372	2.26E+09	175327
Russia	09-Feb	326	100.0	1.91E+04	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	1.91E+04	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	1.91E+04	52.50	157.50	87	1.89E+09	1944
S. Korea	06-Jan	5	1.5	3.04E+00	37.50	129.50	2818	2.45E+09	1434	06-Jan	1.5	3.04E+00	37.50	129.50	2818	2.45E+09	1434	None							
Taiwan	None									None								None							
Thailand	None									None								None							
Aleutians (U.S.)	20-May	273	83.7	4.76E+02	52.50	174.00	1043	1.89E+09	0	20-May	83.7	4.76E+02	52.50	174.00	1043	1.89E+09	0	20-May	32.5	3.60E+02	52.50	173.00	976	1.89E+09	0
Alaska (U.S.)	18-Feb	229	70.2	7.00E+02	58.50	198.00	2507	1.62E+09	22	18-Feb	70.2	7.00E+02	58.50	198.00	2507	1.62E+09	22	20-Jan	3.4	5.27E+01	54.50	195.00	2379	1.80E+09	38
Vietnam	None									None								None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.

** The transboundary region includes all areas, including ocean, outside of Russia.

Table 3. PRS Wet Deposition (wdep) Maximum Values for Cs-137 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	21-Mar	326	100.0	1.79E+04	52.50	157.50	87	1.89E+09	1944	21-Mar	100.0	1.79E+04	52.50	157.50	87	1.89E+09	1944	21-Mar	98.8	1.79E+04	52.50	157.50	87	1.89E+09	1944
Transboundary**	05-Nov	326	100.0	1.55E+04	52.50	159.00	65	1.89E+09	0	05-Nov	100.0	1.55E+04	52.50	159.00	65	1.89E+09	0	05-Nov	98.8	1.55E+04	52.50	159.00	65	1.89E+09	0
Burma	None									None								None							
China	05-Jan	45	13.8	1.43E+02	52.50	126.00	2169	1.89E+09	7721	05-Jan	13.8	1.43E+02	52.50	126.00	2169	1.89E+09	7721	04-Dec	1.2	4.71E-04	52.50	121.50	2463	1.89E+09	17115
Hong Kong	None									None								None							
Japan	01-Jan	45	13.8	4.05E+01	45.00	142.50	1462	2.19E+09	71857	01-Jan	13.8	4.05E+01	45.00	142.50	1462	2.19E+09	71857	01-Jan	1.8	4.05E+01	45.00	142.50	1462	2.19E+09	71857
Laos	None									None								None							
Mongolia	04-Jan	10	3.1	6.98E+00	46.50	118.50	2922	2.13E+09	1978	04-Jan	3.1	6.98E+00	46.50	118.50	2922	2.13E+09	1978	None							
N. Korea	07-Jan	17	5.2	1.30E+01	42.50	130.50	2375	2.28E+09	227852	07-Jan	5.2	1.30E+01	42.50	130.50	2375	2.28E+09	227852	04-Dec	0.3	2.17E-12	43.00	130.00	2372	2.26E+09	175327
Russia	21-Mar	320	98.2	1.79E+04	52.50	157.50	87	1.89E+09	1944	21-Mar	98.2	1.79E+04	52.50	157.50	87	1.89E+09	1944	21-Mar	89.3	1.79E+04	52.50	157.50	87	1.89E+09	1944
S. Korea	05-Jan	5	1.5	1.57E+00	36.50	126.00	3112	2.49E+09	26386	05-Jan	1.5	1.57E+00	36.50	126.00	3112	2.49E+09	26386	None							
Taiwan	None									None								None							
Thailand	None									None								None							
Aleutians (U.S.)	24-Jan	269	82.5	6.39E+02	52.50	185.50	1807	1.89E+09	63	24-Jan	82.5	6.39E+02	52.50	185.50	1807	1.89E+09	63	10-Mar	28.5	1.42E+02	53.00	172.50	935	1.87E+09	0
Alaska (U.S.)	18-Feb	225	69.0	5.81E+02	58.50	198.00	2507	1.62E+09	22	18-Feb	69.0	5.81E+02	58.50	198.00	2507	1.62E+09	22	20-Jan	3.4	1.70E+01	56.00	198.00	2537	1.74E+09	26
Vietnam	None									None								None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.

** The transboundary region includes all areas, including ocean, outside of Russia.

Table 4. PRS Total Deposition (tdep) Maximum Values for Cs-137 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	21-Mar	326	100.0	2.78E+04	52.50	157.50	87	1.89E+09	1944	21-Mar	100.0	2.78E+04	52.50	157.50	87	1.89E+09	1944	21-Mar	100.0	2.78E+04	52.50	157.50	87	1.89E+09	1944
Transboundary**	05-Nov	326	100.0	2.20E+04	52.50	159.00	65	1.89E+09	0	05-Nov	100.0	2.20E+04	52.50	159.00	65	1.89E+09	0	05-Nov	100.0	2.20E+04	52.50	159.00	65	1.89E+09	0
Burma	None									None								None							
China	05-Jan	58	17.8	1.95E+02	52.50	126.00	2169	1.89E+09	7721	05-Jan	17.8	1.95E+02	52.50	126.00	2169	1.89E+09	7721	04-Dec	1.5	9.99E-04	52.50	123.00	2365	1.89E+09	5976
Hong Kong	None									None								None							
Japan	26-Apr	82	25.2	2.76E+02	43.50	142.50	1581	2.25E+09	155808	26-Apr	25.2	2.76E+02	43.50	142.50	1581	2.25E+09	155808	01-Jan	3.1	7.05E+01	45.50	142.00	1454	2.17E+09	34622
Laos	None									None								None							
Mongolia	04-Jan	13	4.0	1.09E+01	46.50	119.50	2855	2.13E+09	1835	04-Jan	4.0	1.09E+01	46.50	119.50	2855	2.13E+09	1835	None							
N. Korea	07-Jan	18	5.5	5.42E+01	43.00	130.00	2372	2.26E+09	175327	07-Jan	5.5	5.42E+01	43.00	130.00	2372	2.26E+09	175327	04-Dec	0.3	3.17E-12	43.00	130.00	2372	2.26E+09	175327
Russia	21-Mar	326	100.0	2.78E+04	52.50	157.50	87	1.89E+09	1944	21-Mar	100.0	2.78E+04	52.50	157.50	87	1.89E+09	1944	21-Mar	100.0	2.78E+04	52.50	157.50	87	1.89E+09	1944
S. Korea	05-Jan	5	1.5	4.09E+00	37.50	126.50	3001	2.45E+09	2006368	05-Jan	1.5	4.09E+00	37.50	126.50	3001	2.45E+09	2006368	None							
Taiwan	None									None								None							
Thailand	None									None								None							
Aleutians (U.S.)	24-Jan	273	83.7	8.56E+02	52.50	185.50	1807	1.89E+09	63	24-Jan	83.7	8.56E+02	52.50	185.50	1807	1.89E+09	63	20-May	32.5	3.66E+02	52.50	173.00	976	1.89E+09	0
Alaska (U.S.)	18-Feb	229	70.2	1.28E+03	58.50	198.00	2507	1.62E+09	22	18-Feb	70.2	1.28E+03	58.50	198.00	2507	1.62E+09	22	20-Jan	3.4	5.27E+01	54.50	195.00	2379	1.80E+09	38
Vietnam	None									None								None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.

** The transboundary region includes all areas, including ocean, outside of Russia.

Table 5. PRS Integrated Concentration Maximum Values for Cs-137 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	09-Feb	326	100.0	3.53E+03	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	3.53E+03	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	3.53E+03	52.50	157.50	87	1.89E+09	1944
Transboundary**	07-Feb	326	100.0	2.89E+03	52.50	159.00	65	1.89E+09	0	07-Feb	100.0	2.89E+03	52.50	159.00	65	1.89E+09	0	07-Feb	100.0	2.88E+03	52.50	159.00	65	1.89E+09	0
Burma	None									None								None							
China	07-Jan	58	17.8	1.25E+01	43.50	130.50	2306	2.25E+09	70383	07-Jan	17.8	1.25E+01	43.50	130.50	2306	2.25E+09	70383	04-Dec	1.5	1.01E-04	52.50	123.00	2365	1.89E+09	5976
Hong Kong	None									None								None							
Japan	26-Apr	82	25.2	5.11E+01	43.50	142.50	1581	2.25E+09	155808	26-Apr	25.2	5.11E+01	43.50	142.50	1581	2.25E+09	155808	02-Jan	3.1	8.18E+00	44.50	145.50	1338	2.21E+09	2136
Laos	None									None								None							
Mongolia	04-Jan	13	4.0	7.64E-01	46.50	119.50	2855	2.13E+09	1835	04-Jan	4.0	7.64E-01	46.50	119.50	2855	2.13E+09	1835	None							
N. Korea	07-Jan	18	5.5	7.85E+00	43.00	130.00	2372	2.26E+09	175327	07-Jan	5.5	7.85E+00	43.00	130.00	2372	2.26E+09	175327	04-Dec	0.3	1.84E-13	43.00	130.00	2372	2.26E+09	175327
Russia	09-Feb	326	100.0	3.53E+03	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	3.53E+03	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	3.53E+03	52.50	157.50	87	1.89E+09	1944
S. Korea	06-Jan	5	1.5	5.63E-01	37.50	129.50	2818	2.45E+09	1434	06-Jan	1.5	5.63E-01	37.50	129.50	2818	2.45E+09	1434	None							
Taiwan	None									None								None							
Thailand	None									None								None							
Aleutians (U.S.)	20-May	273	83.7	8.81E+01	52.50	174.00	1043	1.89E+09	0	20-May	83.7	8.81E+01	52.50	174.00	1043	1.89E+09	0	20-May	32.5	6.67E+01	52.50	173.00	976	1.89E+09	0
Alaska (U.S.)	18-Feb	229	70.2	1.30E+02	58.50	198.00	2507	1.62E+09	22	18-Feb	70.2	1.30E+02	58.50	198.00	2507	1.62E+09	22	20-Jan	3.4	9.75E+00	54.50	195.00	2379	1.80E+09	38
Vietnam	None									None								None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.

** The transboundary region includes all areas, including ocean, outside of Russia.

Table 6. Least-Squares Fitted Parameters Relating I-131 to Cs-137 from Five Days in CY2000

I-131 PRS ddep	Corr.	Cs137Raw(t_d)	R^2	$A_{ddep,td}$		I-131 VRS ddep	Corr.	Cs137Raw(t_d)	R^2	$A_{ddep,td}$
MaxRaw	0.9631	Cs137Raw042	0.9280	2.0877		MaxRaw	0.9555	Cs137Raw042	0.9136	2.4144
I131Raw144	0.9721	Cs137Raw042	0.9450	1.4396		I131Raw144	0.9634	Cs137Raw042	0.9283	1.7046
I131Raw120	0.9721	Cs137Raw042	0.9451	1.5692		I131Raw120	0.9635	Cs137Raw042	0.9286	1.8579
I131Raw096	0.9722	Cs137Raw042	0.9453	1.7102		I131Raw096	0.9636	Cs137Raw042	0.9290	2.0240
I131Raw072	0.9724	Cs137Raw042	0.9458	1.8633		I131Raw072	0.9676	Cs137Raw042	0.9368	2.1891
I131Raw048	0.9695	Cs137Raw042	0.9403	1.9856		I131Raw048	0.9651	Cs137Raw042	0.9322	2.2541
I131Raw024	0.9860	Cs137Raw024	0.9724	2.7837		I131Raw024	0.9912	Cs137Raw024	0.9825	2.9590
I-131 PRS ddep	**Corr.**	**Cs137Raw(t_d)**	**R^2**	**$A_{ddep,td}$**		**I-131 VRS ddep**	**Corr.**	**Cs137Raw(t_d)**	**R^2**	**$A_{ddep,td}$**
MaxFrac	0.9625	Cs137Frac042	0.9268	2.0999		MaxFrac	0.9555	Cs137Frac042	0.9136	2.4144
I131Frac144	0.9715	Cs137Frac042	0.9438	1.4469		I131Frac144	0.9634	Cs137Frac042	0.9283	1.7046
I131Frac120	0.9715	Cs137Frac042	0.9440	1.5771		I131Frac120	0.9635	Cs137Frac042	0.9286	1.8579
I131Frac096	0.9716	Cs137Frac042	0.9442	1.7188		I131Frac096	0.9636	Cs137Frac042	0.9290	2.0240
I131Frac072	0.9719	Cs137Frac042	0.9448	1.8727		I131Frac072	0.9676	Cs137Frac042	0.9368	2.1891
I131Frac048	0.9690	Cs137Frac042	0.9395	1.9964		I131Frac048	0.9651	Cs137Frac042	0.9322	2.2541
I131Frac024	0.9860	Cs137Frac024	0.9724	2.7945		I131Frac024	0.9912	Cs137Frac024	0.9825	2.9590
I-131 PRS wdep	**Corr.**	**Cs137Raw(t_d)**	**R^2**	**$A_{wdep,td}$**		**I-131 VRS wdep**	**Corr.**	**Cs137Raw(t_d)**	**R^2**	**$A_{wdep,td}$**
MaxRaw	0.9844	Cs137Raw042	0.9691	0.5429		MaxRaw	0.9808	Cs137Raw078	0.9621	0.6129
I131Raw144	0.9856	Cs137Raw042	0.9715	0.3690		I131Raw144	0.9698	Cs137Raw078	0.9408	0.4281
I131Raw120	0.9856	Cs137Raw042	0.9715	0.4022		I131Raw120	0.9698	Cs137Raw078	0.9409	0.4666
I131Raw096	0.9859	Cs137Raw042	0.9721	0.4384		I131Raw096	0.9699	Cs137Raw078	0.9409	0.5086
I131Raw072	0.9858	Cs137Raw042	0.9719	0.4775		I131Raw072	0.9986	Cs137Raw054	0.9972	0.5349
I131Raw048	0.9874	Cs137Raw042	0.9750	0.5185		I131Raw048	0.9997	Cs137Raw048	0.9994	0.5831
I131Raw024	0.9912	Cs137Raw024	0.9825	0.6338		I131Raw024	0.9997	Cs137Raw024	0.9994	0.6617
I-131 PRS wdep	**Corr.**	**Cs137Raw(t_d)**	**R^2**	**$A_{wdep,td}$**		**I-131 VRS wdep**	**Corr.**	**Cs137Raw(t_d)**	**R^2**	**$A_{wdep,td}$**
MaxFrac	0.9851	Cs137Frac042	0.9705	0.5467		MaxFrac	0.9827	Cs137Frac078	0.9659	0.6105
I131Frac144	0.9865	Cs137Frac042	0.9732	0.3714		I131Frac144	0.9735	Cs137Frac078	0.9480	0.4227
I131Frac120	0.9865	Cs137Frac042	0.9732	0.4048		I131Frac120	0.9736	Cs137Frac078	0.9481	0.4608
I131Frac096	0.9867	Cs137Frac042	0.9736	0.4412		I131Frac096	0.9736	Cs137Frac078	0.9481	0.5022
I131Frac072	0.9865	Cs137Frac042	0.9733	0.4806		I131Frac072	0.9985	Cs137Frac054	0.9969	0.5351
I131Frac048	0.9878	Cs137Frac042	0.9759	0.5220		I131Frac048	0.9997	Cs137Frac048	0.9994	0.5832
I131Frac024	0.9910	Cs137Frac024	0.9821	0.6366		I131Frac024	0.9997	Cs137Frac024	0.9994	0.6618
I-131 PRS dose	**Corr.**	**Cs137Raw(t_d)**	**R^2**	**$A_{dose,td}$**		**I-131 VRS dose**	**Corr.**	**Cs137Raw(t_d)**	**R^2**	**$A_{dose,td}$**
MaxRaw	0.9660	Cs137Raw042	0.9334	0.5483		MaxRaw	0.9627	Cs137Raw042	0.9286	0.6612
I131Raw144	0.9660	Cs137Raw042	0.9334	0.5483		I131Raw144	0.9627	Cs137Raw042	0.9286	0.6612
I131Raw120	0.9660	Cs137Raw042	0.9335	0.5482		I131Raw120	0.9627	Cs137Raw042	0.9288	0.6612
I131Raw096	0.9661	Cs137Raw042	0.9336	0.5482		I131Raw096	0.9628	Cs137Raw042	0.9291	0.6609
I131Raw072	0.9662	Cs137Raw042	0.9339	0.5480		I131Raw072	0.9651	Cs137Raw042	0.9330	0.6570
I131Raw048	0.9625	Cs137Raw042	0.9270	0.5369		I131Raw048	0.9775	Cs137Raw036	0.9534	0.7447
I131Raw024	0.9844	Cs137Raw024	0.9691	0.7131		I131Raw024	0.9900	Cs137Raw024	0.9806	0.7680

Table 7. Least-Squares Fitted Parameters Relating Sr-90 to Cs-137 from Five Days in CY2000

Sr-90 PRS ddep	**Corr.**	**Cs137Raw(t_d)**	**R^2**	**$A_{ddep,td}$**		**Sr-90 VRS ddep**	**Corr.**	**Cs137Raw(t_d)**	**R^2**	**$A_{ddep,td}$**
MaxRaw	0.9981	Cs137Raw138	0.9961	1.1752		MaxRaw	0.9970	Cs137Raw126	0.9942	1.1359
SR90Raw144	0.9981	Cs137Raw138	0.9961	1.1751		SR90Raw144	0.9970	Cs137Raw126	0.9942	1.1359
SR90Raw120	0.9982	Cs137Raw120	0.9964	1.1766		SR90Raw120	0.9971	Cs137Raw114	0.9944	1.1357
SR90Raw096	0.9984	Cs137Raw096	0.9968	1.1793		SR90Raw096	0.9976	Cs137Raw090	0.9952	1.1544
SR90Raw072	0.9985	Cs137Raw072	0.9970	1.1823		SR90Raw072	0.9988	Cs137Raw066	0.9976	1.2431
SR90Raw048	0.9988	Cs137Raw048	0.9976	1.2001		SR90Raw048	0.9988	Cs137Raw048	0.9976	1.2313
SR90Raw024	0.9998	Cs137Raw024	0.9996	1.2854		SR90Raw024	0.9999	Cs137Raw024	0.9997	1.2961

Sr-90 PRS ddep	**Corr.**	**Cs137Raw(t_d)**	**R^2**	**$A_{ddep,td}$**		**Sr-90 VRS ddep**	**Corr.**	**Cs137Raw(t_d)**	**R^2**	**$A_{ddep,td}$**
MaxFrac	0.9981	Cs137Frac138	0.9962	1.1765		MaxFrac	0.9969	Cs137Frac126	0.9940	1.1399
I131Frac144	0.9981	Cs137Frac138	0.9962	1.1764		SR90Frac144	0.9969	Cs137Frac126	0.9940	1.1399
I131Frac120	0.9982	Cs137Frac120	0.9964	1.1778		SR90Frac120	0.9970	Cs137Frac114	0.9942	1.1395
I131Frac096	0.9984	Cs137Frac096	0.9968	1.1805		SR90Frac096	0.9975	Cs137Frac090	0.9950	1.1577
I131Frac072	0.9985	Cs137Frac072	0.9970	1.1834		SR90Frac072	0.9988	Cs137Frac066	0.9976	1.2449
I131Frac048	0.9988	Cs137Frac048	0.9976	1.2011		SR90Frac048	0.9988	Cs137Frac048	0.9977	1.2339
I131Frac024	0.9998	Cs137Frac024	0.9996	1.2859		SR90Frac024	0.9999	Cs137Frac024	0.9997	1.2965

Sr-90 PRS wdep	**Corr.**	**Cs137Raw(t_d)**	**R^2**	**$A_{wdep,td}$**		**Sr-90 VRS wdep**	**Corr.**	**Cs137Raw(t_d)**	**R^2**	**$A_{wdep,td}$**
MaxRaw	0.9994	Cs137Raw138	0.9989	0.9311		MaxRaw	0.9988	Cs137Raw138	0.9976	0.8920
SR90Raw144	0.9994	Cs137Raw138	0.9989	0.9309		SR90Raw144	0.9988	Cs137Raw138	0.9976	0.8919
SR90Raw120	0.9995	Cs137Raw120	0.9989	0.9311		SR90Raw120	0.9988	Cs137Raw120	0.9977	0.8919
SR90Raw096	0.9995	Cs137Raw090	0.9990	0.9323		SR90Raw096	0.9991	Cs137Raw090	0.9983	0.9033
SR90Raw072	0.9996	Cs137Raw072	0.9991	0.9329		SR90Raw072	0.9993	Cs137Raw072	0.9997	0.9529
SR90Raw048	0.9997	Cs137Raw048	0.9994	0.9377		SR90Raw048	1.0000	Cs137Raw048	1.0000	0.9555
SR90Raw024	0.9999	Cs137Raw024	0.9998	0.9540		SR90Raw024	1.0000	Cs137Raw024	1.0000	0.9600

Sr-90 PRS wdep	**Corr.**	**Cs137Raw(t_d)**	**R^2**	**$A_{wdep,td}$**		**Sr-90 VRS wdep**	**Corr.**	**Cs137Raw(t_d)**	**R^2**	**$A_{wdep,td}$**
MaxFrac	0.9995	Cs137Frac138	0.9990	0.9329		MaxFrac	0.9987	Cs137Frac138	0.9974	0.8972
I131Frac144	0.9995	Cs137Frac138	0.9990	0.9327		SR90Frac144	0.9987	Cs137Frac138	0.9974	0.8970
I131Frac120	0.9995	Cs137Frac114	0.9990	0.9330		SR90Frac120	0.9987	Cs137Frac120	0.9975	0.8971
I131Frac096	0.9995	Cs137Frac090	0.9991	0.9338		SR90Frac096	0.9991	Cs137Frac090	0.9982	0.9079
I131Frac072	0.9996	Cs137Frac072	0.9992	0.9344		SR90Frac072	0.9999	Cs137Frac072	0.9997	0.9527
I131Frac048	0.9997	Cs137Frac048	0.9995	0.9389		SR90Frac048	1.0000	Cs137Frac048	1.0000	0.9555
I131Frac024	0.9999	Cs137Frac024	0.9998	0.9545		SR90Frac024	1.0000	Cs137Frac024	1.0000	0.9600

Sr-90 PRS dose	**Corr.**	**Cs137Raw(t_d)**	**R^2**	**$A_{dose,td}$**		**Sr-90 VRS dose**	**Corr.**	**Cs137Raw(t_d)**	**R^2**	**$A_{dose,td}$**
MaxRaw	0.9981	Cs137Raw138	0.9961	0.8814		MaxRaw	0.9970	Cs137Raw126	0.9942	0.8519
SR90Raw144	0.9981	Cs137Raw138	0.9961	0.8814		SR90Raw144	0.9970	Cs137Raw126	0.9942	0.8519
SR90Raw120	0.9982	Cs137Raw120	0.9850	0.8825		SR90Raw120	0.9971	Cs137Raw114	0.9943	0.8518
SR90Raw096	0.9984	Cs137Raw096	0.9968	0.8845		SR90Raw096	0.9976	Cs137Raw090	0.9952	0.8658
SR90Raw072	0.9985	Cs137Raw072	0.9970	0.8867		SR90Raw072	0.9988	Cs137Raw066	0.9976	0.9324
SR90Raw048	0.9988	Cs137Raw048	0.9976	0.9001		SR90Raw048	0.9988	Cs137Raw048	0.9976	0.9235
SR90Raw024	0.9998	Cs137Raw024	0.9996	0.9640		SR90Raw024	0.9999	Cs137Raw024	0.9997	0.9721

Table 8. PRS Dry Deposition (ddep) Maximum Values for Sr-90 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	09-Feb	326	100.0	2.29E+04	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	2.24E+04	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	2.29E+04	52.50	157.50	87	1.89E+09	1944
Transboundary**	07-Feb	326	100.0	1.87E+04	52.50	159.00	65	1.89E+09	0	07-Feb	100.0	1.83E+04	52.50	159.00	65	1.89E+09	0	07-Feb	100.0	1.87E+04	52.50	159.00	65	1.89E+09	0
Burma	None									None								None							
China	07-Jan	50	15.3	7.93E+01	43.50	130.50	2306	2.25E+09	70383	07-Jan	15.3	7.93E+01	43.50	130.50	2306	2.25E+09	70383	04-Dec	1.5	6.53E-04	52.50	123.00	2365	1.89E+09	5976
Hong Kong	None									None								None							
Japan	26-Apr	76	23.3	3.19E+02	43.50	142.50	1581	2.25E+09	155808	26-Apr	23.3	3.19E+02	43.50	142.50	1581	2.25E+09	155808	02-Jan	3.1	5.30E+01	44.50	145.50	1338	2.21E+09	2136
Laos	None									None								None							
Mongolia	04-Jan	11	3.4	4.85E+00	46.50	119.50	2855	2.13E+09	1835	04-Jan	3.4	4.85E+00	46.50	119.50	2855	2.13E+09	1835	None							
N. Korea	07-Jan	14	4.3	4.96E+01	43.00	130.00	2372	2.26E+09	175327	07-Jan	4.3	4.96E+01	43.00	130.00	2372	2.26E+09	175327	04-Dec	0.3	1.19E-12	43.00	130.00	2372	2.26E+09	175327
Russia	09-Feb	326	100.0	2.29E+04	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	2.24E+04	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	2.29E+04	52.50	157.50	87	1.89E+09	1944
S. Korea	05-Jan	5	1.5	1.72E+00	38.00	126.50	2962	2.44E+09	612497	05-Jan	1.5	1.72E+00	38.00	126.50	2962	2.44E+09	612497	None							
Taiwan	None									None								None							
Thailand	None									None								None							
Aleutians (U.S.)	20-May	269	82.5	5.61E+02	52.50	174.00	1043	1.89E+09	0	20-May	82.5	5.59E+02	52.50	174.00	1043	1.89E+09	0	20-May	32.5	4.32E+02	52.50	173.00	976	1.89E+09	0
Alaska (U.S.)	18-Feb	215	66.0	8.23E+02	58.50	198.00	2507	1.62E+09	22	18-Feb	66.0	8.23E+02	58.50	198.00	2507	1.62E+09	22	20-Jan	3.4	6.32E+01	54.50	195.00	2379	1.80E+09	38
Vietnam	None									None								None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all areas, including ocean, outside of Russia.

Table 9. PRS Wet Deposition (wdep) Maximum Values for Sr-90 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	21-Mar	326	100.0	1.68E+04	52.50	157.50	87	1.89E+09	1944	21-Mar	100.0	1.66E+04	52.50	157.50	87	1.89E+09	1944	21-Mar	98.8	1.68E+04	52.50	157.50	87	1.89E+09	1944
Transboundary**	05-Nov	326	100.0	1.47E+04	52.50	159.00	65	1.89E+09	0	05-Nov	100.0	1.44E+04	52.50	159.00	65	1.89E+09	0	05-Nov	98.8	1.45E+04	52.50	159.00	65	1.89E+09	0
Burma	None									None								None							
China	05-Jan	39	12.0	1.34E+02	52.50	126.00	2169	1.89E+09	7721	05-Jan	12.0	1.33E+02	52.50	126.00	2169	1.89E+09	7721	04-Dec	1.2	4.41E-04	52.50	121.50	2463	1.89E+09	17115
Hong Kong	None																								
Japan	01-Jan	42	12.9	3.80E+01	45.00	142.50	1462	2.19E+09	71857	01-Jan	12.9	3.77E+01	45.00	142.50	1462	2.19E+09	71857	01-Jan	1.8	3.80E+01	45.00	142.50	1462	2.19E+09	71857
Laos	None									None								None							
Mongolia	04-Jan	8	2.5	6.50E+00	46.50	118.50	2922	2.13E+09	1978	04-Jan	2.5	6.50E+00	46.50	118.50	2922	2.13E+09	1978	None							
N. Korea	07-Jan	14	4.3	1.15E+01	42.50	130.50	2375	2.28E+09	227852	07-Jan	4.3	1.15E+01	42.50	130.50	2375	2.28E+09	227852	04-Dec	0.3	2.04E-12	43.00	130.00	2372	2.26E+09	175327
Russia	21-Mar	319	97.9	1.68E+04	52.50	157.50	87	1.89E+09	1944	21-Mar	97.9	1.66E+04	52.50	157.50	87	1.89E+09	1944	21-Mar	89.3	1.68E+04	52.50	157.50	87	1.89E+09	1944
S. Korea	05-Jan	5	1.5	5.37E-01	37.50	126.50	3001	2.45E+09	2006368	05-Jan	1.5	5.37E-01	37.50	126.50	3001	2.45E+09	2006368	None							
Taiwan	None									None								None							
Thailand	None									None								None							
Aleutians (U.S.)	24-Jan	265	81.3	5.96E+02	52.50	185.50	1807	1.89E+09	63	24-Jan	81.3	5.95E+02	52.50	185.50	1807	1.89E+09	63	10-Mar	28.5	1.33E+02	53.00	172.50	935	1.87E+09	0
Alaska (U.S.)	18-Feb	211	64.7	5.41E+02	58.50	198.00	2507	1.62E+09	22	18-Feb	64.7	5.41E+02	58.50	198.00	2507	1.62E+09	22	20-Jan	3.4	1.60E+01	56.00	198.00	2537	1.74E+09	26
Vietnam	None									None								None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all areas, including ocean, outside of Russia.

Table 10. PRS Total Deposition (tdep) Maximum Values for Sr-90 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	21-Mar	326	100.0	2.86E+04	52.50	157.50	87	1.89E+09	1944	21-Mar	100.0	2.83E+04	52.50	157.50	87	1.89E+09	1944	21-Mar	100.0	2.86E+04	52.50	157.50	87	1.89E+09	1944
Transboundary**	05-Nov	326	100.0	2.30E+04	52.50	159.00	65	1.89E+09	0	05-Nov	100.0	2.20E+04	52.50	159.00	65	1.89E+09	0	05-Nov	100.0	2.23E+04	52.50	159.00	65	1.89E+09	0
Burma	None									None								None							
China	05-Jan	50	15.3	1.93E+02	52.50	126.00	2169	1.89E+09	7721	05-Jan	15.3	1.93E+02	52.50	126.00	2169	1.89E+09	7721	04-Dec	1.5	1.08E-03	52.50	123.00	2365	1.89E+09	5976
Hong Kong	None									None								None							
Japan	26-Apr	76	23.3	3.19E+02	43.50	142.50	1581	2.25E+09	155808	26-Apr	23.3	3.19E+02	43.50	142.50	1581	2.25E+09	155808	01-Jan	3.1	7.42E+01	45.50	142.00	1454	2.17E+09	34622
Laos	None									None								None							
Mongolia	04-Jan	11	3.4	1.11E+01	46.50	119.50	2855	2.13E+09	1835	04-Jan	3.4	1.11E+01	46.50	119.50	2855	2.13E+09	1835	None							
N. Korea	07-Jan	14	4.3	6.04E+01	43.00	130.00	2372	2.26E+09	175327	07-Jan	4.3	6.04E+01	43.00	130.00	2372	2.26E+09	175327	04-Dec	0.3	3.23E-12	43.00	130.00	2372	2.26E+09	175327
Russia	21-Mar	326	100.0	2.86E+04	52.50	157.50	87	1.89E+09	1944	21-Mar	100.0	2.83E+04	52.50	157.50	87	1.89E+09	1944	21-Mar	100.0	2.86E+04	52.50	157.50	87	1.89E+09	1944
S. Korea	05-Jan	5	1.5	2.14E+00	37.50	126.50	3001	2.45E+09	2006368	05-Jan	1.5	2.14E+00	37.50	126.50	3001	2.45E+09	2006368	None							
Taiwan	None									None								None							
Thailand	None									None								None							
Aleutians (U.S.)	24-Jan	269	82.5	8.51E+02	52.50	185.50	1807	1.89E+09	63	24-Jan	82.5	8.49E+02	52.50	185.50	1807	1.89E+09	63	20-May	32.5	4.38E+02	52.50	173.00	976	1.89E+09	0
Alaska (U.S.)	18-Feb	215	66.0	1.36E+03	58.50	198.00	2507	1.62E+09	22	18-Feb	66.0	1.36E+03	58.50	198.00	2507	1.62E+09	22	20-Jan	3.4	6.32E+01	54.50	195.00	2379	1.80E+09	38
Vietnam	None									None								None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all areas, including ocean, outside of Russia.

Table 11. PRS Integrated Concentration Maximum Values for Sr-90 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	09-Feb	326	100.0	3.18E+03	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	3.11E+03	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	3.18E+03	52.50	157.50	87	1.89E+09	1944
Transboundary**	07-Feb	326	100.0	2.59E+03	52.50	159.00	65	1.89E+09	0	07-Feb	100.0	2.55E+03	52.50	159.00	65	1.89E+09	0	07-Feb	100.0	2.59E+03	52.50	159.00	65	1.89E+09	0
Burma	None									None								None							
China	07-Jan	50	15.3	1.10E+01	43.50	130.50	2306	2.25E+09	70383	07-Jan	15.3	1.10E+01	43.50	130.50	2306	2.25E+09	70383	04-Dec	1.5	9.07E-05	52.50	123.00	2365	1.89E+09	5976
Hong Kong	None									None								None							
Japan	26-Apr	76	23.3	4.43E+01	43.50	142.50	1581	2.25E+09	155808	26-Apr	23.3	4.43E+01	43.50	142.50	1581	2.25E+09	155808	02-Jan	3.1	7.37E+00	44.50	145.50	1338	2.21E+09	2136
Laos	None									None								None							
Mongolia	04-Jan	11	3.4	6.74E-01	46.50	119.50	2855	2.13E+09	1835	04-Jan	3.4	6.73E-01	46.50	119.50	2855	2.13E+09	1835	None							
N. Korea	07-Jan	14	4.3	6.89E+00	43.00	130.00	2372	2.26E+09	175327	07-Jan	4.3	6.89E+00	43.00	130.00	2372	2.26E+09	175327	04-Dec	0.3	1.66E-13	43.00	130.00	2372	2.26E+09	175327
Russia	09-Feb	326	100.0	3.18E+03	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	3.11E+03	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	3.18E+03	52.50	157.50	87	1.89E+09	1944
S. Korea	05-Jan	5	1.5	2.39E-01	38.00	126.50	2962	2.44E+09	612497	05-Jan	1.5	2.39E-01	38.00	126.50	2962	2.44E+09	612497	None							
Taiwan	None									None								None							
Thailand	None									None								None							
Aleutians (U.S.)	20-May	269	82.5	7.79E+01	52.50	174.00	1043	1.89E+09	0	20-May	82.5	7.77E+01	52.50	174.00	1043	1.89E+09	0	20-May	32.5	6.00E+01	52.50	173.00	976	1.89E+09	0
Alaska (U.S.)	18-Feb	215	66.0	1.14E+02	58.50	198.00	2507	1.62E+09	22	18-Feb	66.0	1.14E+02	58.50	198.00	2507	1.62E+09	22	20-Jan	3.4	8.78E+00	54.50	195.00	2379	1.80E+09	38
Vietnam	None									None								None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all areas, including ocean, outside of Russia.

Table 12. PRS Dry Deposition (ddep) Maximum Values for I-131 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	12-Jun	326	100.0	4.65E+04	54.00	159.00	116	1.82E+09	1872	09-Feb	100.0	2.75E+04	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	3.79E+04	52.50	157.50	87	1.89E+09	1944
Transboundary**	07-Feb	326	100.0	3.09E+04	52.50	159.00	65	1.89E+09	0	07-Feb	100.0	2.24E+04	52.50	159.00	65	1.89E+09	0	07-Feb	100.0	3.09E+04	52.50	159.00	65	1.89E+09	0
Burma	None									None								None							
China	04-Dec	4	1.2	5.22E-05	52.50	123.00	2365	1.89E+09	5976	04-Dec	1.2	3.78E-05	52.50	123.00	2365	1.89E+09	5976	04-Dec	1.2	5.22E-05	52.50	123.00	2365	1.89E+09	5976
Hong Kong	None									None								None							
Japan	03-Jan	10	3.1	3.83E+01	44.50	145.50	1338	2.21E+09	2136	03-Jan	3.1	2.78E+01	44.50	145.50	1338	2.21E+09	2136	03-Jan	3.1	3.83E+01	44.50	145.50	1338	2.21E+09	2136
Laos	None									None								None							
Mongolia	None									None								None							
N. Korea	None									None								None							
Russia	12-Jun	326	100.0	4.65E+04	54.00	159.00	116	1.82E+09	1872	09-Feb	100.0	2.75E+04	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	3.79E+04	52.50	157.50	87	1.89E+09	1944
S. Korea	None									None								None							
Taiwan	None									None								None							
Thailand	None									None								None							
Aleutians (U.S.)	18-Jan	86	26.4	5.06E+02	52.50	174.00	1043	1.89E+09	0	18-Jan	26.4	3.67E+02	52.50	174.00	1043	1.89E+09	0	18-Jan	26.4	5.06E+02	52.50	174.00	1043	1.89E+09	0
Alaska (U.S.)	20-Jan	7	2.1	3.41E+01	54.50	195.00	2379	1.80E+09	38	20-Jan	2.1	2.47E+01	54.50	195.00	2379	1.80E+09	38	20-Jan	2.1	3.41E+01	54.50	195.00	2379	1.80E+09	38
Vietnam	None									None								None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all areas, including ocean, outside of Russia.

Table 13. PRS Wet Deposition (wdep) Maximum Values for I-131 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	05-Nov	316	96.9	9.77E+03	52.50	159.00	65	1.89E+09	0	21-Mar	96.9	6.59E+03	52.50	157.50	87	1.89E+09	1944	21-Mar	96.9	9.27E+03	52.50	157.50	87	1.89E+09	1944
Transboundary**	05-Nov	316	96.9	9.77E+03	52.50	159.00	65	1.89E+09	0	05-Nov	96.9	5.72E+03	52.50	159.00	65	1.89E+09	0	05-Nov	96.9	8.03E+03	52.50	159.00	65	1.89E+09	0
Burma	None									None								None							
China	04-Dec	3	0.9	9.72E-06	52.50	123.00	2365	1.89E+09	5976	04-Dec	0.9	6.92E-06	52.50	123.00	2365	1.89E+09	5976	04-Dec	0.9	9.72E-06	52.50	123.00	2365	1.89E+09	5976
Hong Kong	None									None								None							
Japan	01-Jan	6	1.8	9.18E+00	45.50	142.00	1454	2.17E+09	34622	01-Jan	1.8	6.54E+00	45.50	142.00	1454	2.17E+09	34622	01-Jan	1.8	9.18E+00	45.50	142.00	1454	2.17E+09	34622
Laos	None									None								None							
Mongolia	None									None								None							
N. Korea	None									None								None							
Russia	21-Mar	285	87.4	9.27E+03	52.50	157.50	87	1.89E+09	1944	21-Mar	87.4	6.59E+03	52.50	157.50	87	1.89E+09	1944	21-Mar	87.4	9.27E+03	52.50	157.50	87	1.89E+09	1944
S. Korea	None									None								None							
Taiwan	None									None								None							
Thailand	None									None								None							
Aleutians (U.S.)	10-Mar	71	21.8	7.24E+01	53.00	172.50	935	1.87E+09	0	10-Mar	21.8	5.15E+01	53.00	172.50	935	1.87E+09	0	10-Mar	21.8	7.24E+01	53.00	172.50	935	1.87E+09	0
Alaska (U.S.)	23-Jan	7	2.1	2.11E-01	54.50	195.00	2379	1.80E+09	38	23-Jan	2.1	1.50E-01	54.50	195.00	2379	1.80E+09	38	23-Jan	2.1	2.11E-01	54.50	195.00	2379	1.80E+09	38
Vietnam	None									None								None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all areas, including ocean, outside of Russia.

Table 14. PRS Total Deposition (tdep) Maximum Values for I-131 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	12-Jun	326	100.0	4.65E+04	54.00	159.00	116	1.82E+09	1872	09-Feb	100.0	2.75E+04	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	3.79E+04	52.50	157.50	87	1.89E+09	1944
Transboundary**	07-Feb	326	100.0	3.09E+04	52.50	159.00	65	1.89E+09	0	07-Feb	100.0	2.24E+04	52.50	159.00	65	1.89E+09	0	07-Feb	100.0	3.09E+04	52.50	159.00	65	1.89E+09	0
Burma	None									None								None							
China	04-Dec	4	1.2	6.19E-05	52.50	123.00	2365	1.89E+09	5976	04-Dec	1.2	4.48E-05	52.50	123.00	2365	1.89E+09	5976	04-Dec	1.2	6.19E-05	52.50	123.00	2365	1.89E+09	5976
Hong Kong	None									None								None							
Japan	03-Jan	10	3.1	3.83E+01	44.50	145.50	1338	2.21E+09	2136	03-Jan	3.1	2.78E+01	44.50	145.50	1338	2.21E+09	2136	03-Jan	3.1	3.83E+01	44.50	145.50	1338	2.21E+09	2136
Laos	None									None								None							
Mongolia	None									None								None							
N. Korea	None									None								None							
Russia	12-Jun	326	100.0	4.65E+04	54.00	159.00	116	1.82E+09	1872	09-Feb	100.0	2.75E+04	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	3.79E+04	52.50	157.50	87	1.89E+09	1944
S. Korea	None									None								None							
Taiwan	None									None								None							
Thailand	None									None								None							
Aleutians (U.S.)	18-Jan	86	26.4	5.06E+02	52.50	174.00	1043	1.89E+09	0	18-Jan	26.4	3.67E+02	52.50	174.00	1043	1.89E+09	0	18-Jan	26.4	5.06E+02	52.50	174.00	1043	1.89E+09	0
Alaska (U.S.)	20-Jan	7	2.1	3.41E+01	54.50	195.00	2379	1.80E+09	38	20-Jan	2.1	2.47E+01	54.50	195.00	2379	1.80E+09	38	20-Jan	2.1	3.41E+01	54.50	195.00	2379	1.80E+09	38
Vietnam	None									None								None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all areas, including ocean, outside of Russia.

Table 15. PRS Integrated Concentration Maximum Values for I-131 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	12-Jun	326	100.0	2.21E+03	54.00	159.00	116	1.82E+09	1872	09-Feb	100.0	1.94E+03	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	1.90E+03	52.50	157.50	87	1.89E+09	1944
Transboundary**	07-Feb	326	100.0	1.58E+03	52.50	159.00	65	1.89E+09	0	07-Feb	100.0	1.58E+03	52.50	159.00	65	1.89E+09	0	07-Feb	100.0	1.55E+03	52.50	159.00	65	1.89E+09	0
Burma	None									None								None							
China	04-Dec	4	1.2	2.67E-06	52.50	123.00	2365	1.89E+09	5976	04-Dec	1.2	2.67E-06	52.50	123.00	2365	1.89E+09	5976	04-Dec	1.2	2.61E-06	52.50	123.00	2365	1.89E+09	5976
Hong Kong	None									None								None							
Japan	03-Jan	10	3.1	1.96E+00	44.50	145.50	1338	2.21E+09	2136	03-Jan	3.1	1.96E+00	44.50	145.50	1338	2.21E+09	2136	03-Jan	3.1	1.92E+00	44.50	145.50	1338	2.21E+09	2136
Laos	None									None								None							
Mongolia	None									None								None							
N. Korea	None									None								None							
Russia	12-Jun	326	100.0	2.21E+03	54.00	159.00	116	1.82E+09	1872	09-Feb	100.0	1.94E+03	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	1.90E+03	52.50	157.50	87	1.89E+09	1944
S. Korea	None									None								None							
Taiwan	None									None								None							
Thailand	None									None								None							
Aleutians (U.S.)	18-Jan	86	26.4	2.59E+01	52.50	174.00	1043	1.89E+09	0	18-Jan	26.4	2.59E+01	52.50	174.00	1043	1.89E+09	0	18-Jan	26.4	2.53E+01	52.50	174.00	1043	1.89E+09	0
Alaska (U.S.)	20-Jan	7	2.1	1.74E+00	54.50	195.00	2379	1.80E+09	38	20-Jan	2.1	1.74E+00	54.50	195.00	2379	1.80E+09	38	20-Jan	2.1	1.71E+00	54.50	195.00	2379	1.80E+09	38
Vietnam	None									None								None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all areas, including ocean, outside of Russia.

Table 16. VRS Dry Deposition (ddep) Maximum Values Cs-137 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	12-Jun	329	100.0	2.62E+04	43.50	133.50	134	2.25E+09	34008	12-Jun	100.0	2.62E+04	43.50	133.50	134	2.25E+09	34008	12-Jun	100.0	2.43E+04	43.50	133.50	134	2.25E+09	34008
Transboundary**	12-Jun	329	100.0	8.74E+03	42.50	133.50	135	2.28E+09	717	12-Jun	100.0	8.74E+03	42.50	133.50	135	2.28E+09	717	12-Jun	100.0	8.10E+03	42.50	133.50	135	2.28E+09	717
Burma	None									None								None							
China	07-Jun	262	79.6	6.90E+03	43.50	131.50	69	2.25E+09	42463	07-Jun	79.6	6.90E+03	43.50	131.50	69	2.25E+09	42463	07-Jun	73.6	6.10E+03	43.50	131.50	69	2.25E+09	42463
Hong Kong	12-Sep	9	2.7	5.57E+00	22.50	114.50	2794	2.85E+09	125994	12-Sep	2.7	5.57E+00	22.50	114.50	2794	2.85E+09	125994	None							
Japan	16-Dec	317	96.4	3.69E+03	40.50	141.00	796	2.35E+09	358298	16-Dec	96.4	3.68E+03	40.50	141.00	796	2.35E+09	358298	13-Jan	74.2	1.67E+03	34.50	132.00	945	2.55E+09	496677
Laos	None									None								None							
Mongolia	10-May	40	12.2	6.70E+01	47.00	120.00	1042	2.11E+09	33341	10-May	12.2	6.70E+01	47.00	120.00	1042	2.11E+09	33341	27-Jul	1.5	4.75E-02	50.00	116.50	1415	1.99E+09	4443
N. Korea	20-Aug	202	61.4	3.80E+03	42.00	129.00	270	2.30E+09	200822	20-Aug	61.4	3.80E+03	42.00	129.00	270	2.30E+09	200822	20-Aug	37.7	3.80E+03	42.00	129.00	270	2.30E+09	200822
Russia	12-Jun	324	98.5	2.62E+04	43.50	133.50	134	2.25E+09	34008	12-Jun	98.5	2.62E+04	43.50	133.50	134	2.25E+09	34008	12-Jun	97.9	2.43E+04	43.50	133.50	134	2.25E+09	34008
S. Korea	11-Jan	156	47.4	9.75E+02	38.50	127.50	628	2.42E+09	292252	11-Jan	47.4	9.75E+02	38.50	127.50	628	2.42E+09	292252	15-Nov	21.0	7.89E+02	38.50	127.50	628	2.42E+09	292252
Taiwan	29-Nov	32	9.7	1.91E+02	24.00	121.50	2322	2.82E+09	152461	29-Nov	9.7	1.91E+02	24.00	121.50	2322	2.82E+09	152461	None							
Thailand	None									None								None							
Aleutians (U.S.)	23-Apr	172	52.3	5.86E+01	52.00	177.00	3464	1.91E+09	0	23-Apr	52.3	5.86E+01	52.00	177.00	3464	1.91E+09	0	29-May	0.6	2.15E-04	53.00	172.50	3162	1.87E+09	0
Alaska (U.S.)	25-Mar	140	42.6	4.62E+01	58.50	204.00	5071	1.62E+09	36	25-Mar	42.6	4.62E+01	58.50	204.00	5071	1.62E+09	36	None							
Vietnam	29-Nov	1	0.3	2.73E-06	20.50	107.00	3416	2.89E+09	13869	29-Nov	0.3	2.73E-06	20.50	107.00	3416	2.89E+09	13869	None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all areas, including ocean, outside of Russia.

Table 17. VRS Wet Deposition (wdep) Maximum Values for Cs-137 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	18-Nov	329	100.0	7.42E+03	42.00	133.50	166	2.30E+09	0	18-Nov	100.0	7.42E+03	42.00	133.50	166	2.30E+09	0	18-Nov	97.9	7.42E+03	42.00	133.50	166	2.30E+09	0
Transboundary**	18-Nov	329	100.0	7.42E+03	42.00	133.50	166	2.30E+09	0	18-Nov	100.0	7.42E+03	42.00	133.50	166	2.30E+09	0	18-Nov	97.6	7.42E+03	42.00	133.50	166	2.30E+09	0
Burma	None									None								None							
China	01-Jan	233	70.8	4.62E+03	43.50	130.50	134	2.25E+09	70383	01-Jan	70.8	4.62E+03	43.50	130.50	134	2.25E+09	70383	01-Jan	61.1	4.62E+03	43.50	130.50	134	2.25E+09	70383
Hong Kong	None									None								None							
Japan	30-Jan	296	90.0	1.81E+03	36.00	138.00	933	2.50E+09	405254	30-Jan	90.0	1.81E+03	36.00	138.00	933	2.50E+09	405254	30-Jan	53.2	1.81E+03	36.00	138.00	933	2.50E+09	405254
Laos	None									None								None							
Mongolia	02-Jan	27	8.2	1.01E-01	45.00	114.00	1454	2.19E+09	1583	02-Jan	8.2	1.01E-01	45.00	114.00	1454	2.19E+09	1583	05-Jan	0.6	4.92E-09	48.00	119.00	1154	2.07E+09	3738
N. Korea	01-Jan	171	52.0	2.11E+03	43.00	130.00	163	2.26E+09	175327	01-Jan	52.0	2.11E+03	43.00	130.00	163	2.26E+09	175327	01-Jan	26.1	2.11E+03	43.00	130.00	163	2.26E+09	175327
Russia	20-Mar	306	93.0	5.54E+03	43.50	133.50	134	2.25E+09	34008	20-Mar	93.0	5.54E+03	43.50	133.50	134	2.25E+09	34008	20-Mar	77.2	5.54E+03	43.50	133.50	134	2.25E+09	34008
S. Korea	11-Jan	127	38.6	1.63E+02	37.50	129.00	662	2.45E+09	155901	11-Jan	38.6	1.63E+02	37.50	129.00	662	2.45E+09	155901	27-Mar	14.0	1.48E+01	36.50	126.00	886	2.49E+09	26386
Taiwan	15-Nov	3	0.9	9.78E-05	25.50	121.50	2168	2.78E+09	3122073	15-Nov	0.9	9.78E-05	25.50	121.50	2168	2.78E+09	3122073	None							
Thailand	None									None								None							
Aleutians (U.S.)	06-Mar	161	48.9	1.46E+01	52.50	174.00	3260	1.89E+09	0	06-Mar	48.9	1.46E+01	52.50	174.00	3260	1.89E+09	0	07-Nov	0.3	2.74E-08	52.00	177.00	3464	1.91E+09	0
Alaska (U.S.)	24-Mar	137	41.6	8.67E+01	60.00	210.00	5359	1.55E+09	1314	24-Mar	41.6	8.67E+01	60.00	210.00	5359	1.55E+09	1314	None							
Vietnam	29-Nov	1	0.3	1.47E-07	20.50	107.00	3416	2.89E+09	13869	29-Nov	0.3	1.47E-07	20.50	107.00	3416	2.89E+09	13869	None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all areas, including ocean, outside of Russia.

Table 18. VRS Total Deposition (tdep) Maximum Values for Cs-137 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	02-Aug	329	100.0	2.64E+04	43.50	133.50	134	2.25E+09	34008	02-Aug	100.0	2.64E+04	43.50	133.50	134	2.25E+09	34008	02-Aug	100.0	2.44E+04	43.50	133.50	134	2.25E+09	34008
Transboundary**	18-Nov	329	100.0	9.06E+03	42.00	133.50	166	2.30E+09	0	18-Nov	100.0	9.06E+03	42.00	133.50	166	2.30E+09	0	18-Nov	100.0	9.04E+03	42.00	133.50	166	2.30E+09	0
Burma	None									None								None							
China	07-Jun	262	79.6	6.93E+03	43.50	131.50	69	2.25E+09	42463	07-Jun	79.6	6.93E+03	43.50	131.50	69	2.25E+09	42463	07-Jun	73.6	6.10E+03	43.50	131.50	69	2.25E+09	42463
Hong Kong	12-Sep	9	2.7	5.57E+00	22.50	114.50	2794	2.85E+09	125994	12-Sep	2.7	5.57E+00	22.50	114.50	2794	2.85E+09	125994	None							
Japan	16-Dec	317	96.4	3.85E+03	40.50	141.00	796	2.35E+09	358298	16-Dec	96.4	3.85E+03	40.50	141.00	796	2.35E+09	358298	30-Jan	74.2	2.66E+03	36.00	138.00	933	2.50E+09	405254
Laos	None									None								None							
Mongolia	10-May	40	12.2	6.70E+01	47.00	120.00	1042	2.11E+09	33341	10-May	12.2	6.70E+01	47.00	120.00	1042	2.11E+09	33341	27-Jul	1.5	4.75E-02	50.00	116.50	1415	1.99E+09	4443
N. Korea	20-Aug	202	61.4	4.26E+03	42.00	129.00	270	2.30E+09	200822	20-Aug	61.4	4.26E+03	42.00	129.00	270	2.30E+09	200822	20-Aug	37.7	4.26E+03	42.00	129.00	270	2.30E+09	200822
Russia	02-Aug	324	98.5	2.64E+04	43.50	133.50	134	2.25E+09	34008	02-Aug	98.5	2.64E+04	43.50	133.50	134	2.25E+09	34008	02-Aug	97.9	2.44E+04	43.50	133.50	134	2.25E+09	34008
S. Korea	11-Jan	156	47.4	1.03E+03	38.50	127.50	628	2.42E+09	292252	11-Jan	47.4	1.03E+03	38.50	127.50	628	2.42E+09	292252	15-Nov	21.0	7.90E+02	38.50	127.50	628	2.42E+09	292252
Taiwan	29-Nov	32	9.7	1.91E+02	24.00	121.50	2322	2.82E+09	152461	29-Nov	9.7	1.91E+02	24.00	121.50	2322	2.82E+09	152461	None							
Thailand	None									None								None							
Aleutians (U.S.)	23-Apr	172	52.3	5.86E+01	52.00	177.00	3464	1.91E+09	0	23-Apr	52.3	5.86E+01	52.00	177.00	3464	1.91E+09	0	29-May	0.6	2.15E-04	53.00	172.50	3162	1.87E+09	0
Alaska (U.S.)	24-Mar	140	42.6	1.12E+02	60.00	210.00	5359	1.55E+09	1314	24-Mar	42.6	1.12E+02	60.00	210.00	5359	1.55E+09	1314	None							
Vietnam	29-Nov	1	0.3	2.88E-06	20.50	107.00	3416	2.89E+09	13869	29-Nov	0.3	2.88E-06	20.50	107.00	3416	2.89E+09	13869	None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.

** The transboundary region includes all areas, including ocean, outside of Russia.

Table 19. VRS Integrated Concentration Maximum Values for Cs-137 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	12-Jun	329	100.0	4.86E+03	43.50	133.50	134	2.25E+09	34008	12-Jun	100.0	4.86E+03	43.50	133.50	134	2.25E+09	34008	12-Jun	100.0	4.50E+03	43.50	133.50	134	2.25E+09	34008
Transboundary**	12-Jun	329	100.0	1.62E+03	42.50	133.50	135	2.28E+09	717	12-Jun	100.0	1.62E+03	42.50	133.50	135	2.28E+09	717	12-Jun	100.0	1.50E+03	42.50	133.50	135	2.28E+09	717
Burma	None									None								None							
China	07-Jun	262	79.6	1.28E+03	43.50	131.50	69	2.25E+09	42463	07-Jun	79.6	1.28E+03	43.50	131.50	69	2.25E+09	42463	07-Jun	73.6	1.13E+03	43.50	131.50	69	2.25E+09	42463
Hong Kong	12-Sep	9	2.7	1.03E+00	22.50	114.50	2794	2.85E+09	125994	12-Sep	2.7	1.03E+00	22.50	114.50	2794	2.85E+09	125994	None							
Japan	16-Dec	317	96.4	6.82E+02	40.50	141.00	796	2.35E+09	358298	16-Dec	96.4	6.82E+02	40.50	141.00	796	2.35E+09	358298	13-Jan	74.2	3.09E+02	34.50	132.00	945	2.55E+09	496677
Laos	None									None								None							
Mongolia	10-May	40	12.2	1.24E+01	47.00	120.00	1042	2.11E+09	33341	10-May	12.2	1.24E+01	47.00	120.00	1042	2.11E+09	33341	27-Jul	1.5	8.80E-03	50.00	116.50	1415	1.99E+09	4443
N. Korea	20-Aug	202	61.4	7.04E+02	42.00	129.00	270	2.30E+09	200822	20-Aug	61.4	7.04E+02	42.00	129.00	270	2.30E+09	200822	20-Aug	37.7	7.04E+02	42.00	129.00	270	2.30E+09	200822
Russia	12-Jun	324	98.5	4.86E+03	43.50	133.50	134	2.25E+09	34008	12-Jun	98.5	4.86E+03	43.50	133.50	134	2.25E+09	34008	12-Jun	97.9	4.50E+03	43.50	133.50	134	2.25E+09	34008
S. Korea	11-Jan	156	47.4	1.81E+02	38.50	127.50	628	2.42E+09	292252	11-Jan	47.4	1.81E+02	38.50	127.50	628	2.42E+09	292252	15-Nov	21.0	1.46E+02	38.50	127.50	628	2.42E+09	292252
Taiwan	29-Nov	32	9.7	3.54E+01	24.00	121.50	2322	2.82E+09	152461	29-Nov	9.7	3.54E+01	24.00	121.50	2322	2.82E+09	152461	None							
Thailand	None									None								None							
Aleutians (U.S.)	23-Apr	172	52.3	1.09E+01	52.00	177.00	3464	1.91E+09	0	23-Apr	52.3	1.09E+01	52.00	177.00	3464	1.91E+09	0	29-May	0.6	3.99E-05	53.00	172.50	3162	1.87E+09	0
Alaska (U.S.)	25-Mar	140	42.6	8.55E+00	58.50	204.00	5071	1.62E+09	36	25-Mar	42.6	8.55E+00	58.50	204.00	5071	1.62E+09	36	None							
Vietnam	29-Nov	1	0.3	5.06E-07	20.50	107.00	3416	2.89E+09	13869	29-Nov	0.3	5.06E-07	20.50	107.00	3416	2.89E+09	13869	None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.

** The transboundary region includes all areas, including ocean, outside of Russia.

Table 20. VRS Dry Deposition (ddep) Maximum Values Sr-90 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	12-Jun	329	100.0	3.24E+04	43.50	133.50	134	2.25E+09	34008	12-Jun	100.0	2.98E+04	43.50	133.50	134	2.25E+09	34008	12-Jun	100.0	2.99E+04	43.50	133.50	134	2.25E+09	34008
Transboundary**	12-Jun	329	100.0	1.08E+04	42.50	133.50	135	2.28E+09	717	12-Jun	100.0	9.93E+03	42.50	133.50	135	2.28E+09	717	12-Jun	100.0	9.98E+03	42.50	133.50	135	2.28E+09	717
Burma	None									None								None							
China	07-Jun	257	78.1	7.84E+03	43.50	131.50	69	2.25E+09	42463	07-Jun	78.1	7.81E+03	43.50	131.50	69	2.25E+09	42463	07-Jun	73.6	7.51E+03	43.50	131.50	69	2.25E+09	42463
Hong Kong	29-Nov	4	1.2	2.26E-03	22.50	114.50	2794	2.85E+09	125994	29-Nov	1.2	2.26E-03	22.50	114.50	2794	2.85E+09	125994	None							
Japan	16-Dec	316	96.0	4.25E+03	40.50	141.00	796	2.35E+09	358298	16-Dec	96.0	4.19E+03	40.50	141.00	796	2.35E+09	358298	13-Jan	74.2	2.05E+03	34.50	132.00	945	2.55E+09	496677
Laos	None									None								None							
Mongolia	10-May	34	10.3	7.52E+01	47.00	120.00	1042	2.11E+09	33341	10-May	10.3	7.52E+01	47.00	120.00	1042	2.11E+09	33341	27-Jul	1.5	5.85E-02	50.00	116.50	1415	1.99E+09	4443
N. Korea	20-Aug	194	59.0	4.72E+03	42.00	129.00	270	2.30E+09	200822	20-Aug	59.0	4.32E+03	42.00	129.00	270	2.30E+09	200822	20-Aug	37.7	4.68E+03	42.00	129.00	270	2.30E+09	200822
Russia	12-Jun	324	98.5	3.24E+04	43.50	133.50	134	2.25E+09	34008	12-Jun	98.5	2.98E+04	43.50	133.50	134	2.25E+09	34008	12-Jun	97.9	2.99E+04	43.50	133.50	134	2.25E+09	34008
S. Korea	11-Jan	147	44.7	1.15E+03	38.50	127.50	628	2.42E+09	292252	11-Jan	44.7	1.11E+03	38.50	127.50	628	2.42E+09	292252	15-Nov	21.0	9.72E+02	38.50	127.50	628	2.42E+09	292252
Taiwan	29-Nov	21	6.4	2.17E+02	24.00	121.50	2322	2.82E+09	152461	29-Nov	6.4	2.17E+02	24.00	121.50	2322	2.82E+09	152461	None							
Thailand	None									None								None							
Aleutians (U.S.)	23-Apr	135	41.0	6.05E+01	52.00	177.00	3464	1.91E+09	0	23-Apr	41.0	6.05E+01	52.00	177.00	3464	1.91E+09	0	29-May	0.6	2.65E-04	53.00	172.50	3162	1.87E+09	0
Alaska (U.S.)	25-Mar	87	26.4	4.17E+01	58.50	202.50	4986	1.62E+09	15	25-Mar	26.4	4.17E+01	58.50	202.50	4986	1.62E+09	15	None							
Vietnam	None									None								None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all areas, including ocean, outside of Russia.

Table 21. VRS Wet Deposition (wdep) Maximum Values for Sr-90 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	18-Nov	329	100.0	7.11E+03	42.00	133.50	166	2.30E+09	0	18-Nov	100.0	6.62E+03	42.00	133.50	166	2.30E+09	0	18-Nov	97.9	7.09E+03	42.00	133.50	166	2.30E+09	0
Transboundary**	18-Nov	329	100.0	7.11E+03	42.00	133.50	166	2.30E+09	0	18-Nov-00	100.0	6.62E+03	42.00	133.50	166	2.30E+09	0	18-Nov-00	97.6	7.09E+03	42.00	133.50	166	2.30E+09	0
Burma	None									None								None							
China	01-Jan	230	69.9	4.41E+03	43.50	130.50	134	2.25E+09	70383	01-Jan	69.9	4.12E+03	43.50	130.50	134	2.25E+09	70383	01-Jan	61.1	4.41E+03	43.50	130.50	134	2.25E+09	70383
Hong Kong	None									None								None							
Japan	30-Jan	295	89.7	1.73E+03	36.00	138.00	933	2.50E+09	405254	30-Jan	89.7	1.61E+03	36.00	138.00	933	2.50E+09	405254	30-Jan	53.2	1.73E+03	36.00	138.00	933	2.50E+09	405254
Laos	None									None								None							
Mongolia	02-Jan	24	7.3	4.00E-02	46.50	111.00	1698	2.13E+09	2016	02-Jan	7.3	4.00E-02	46.50	111.00	1698	2.13E+09	2016	05-Jan	0.6	4.70E-09	48.00	119.00	1154	2.07E+09	3738
N. Korea	01-Jan	170	51.7	2.01E+03	43.00	130.00	163	2.26E+09	175327	01-Jan	51.7	1.88E+03	43.00	130.00	163	2.26E+09	175327	01-Jan	26.1	2.01E+03	43.00	130.00	163	2.26E+09	175327
Russia	20-Mar	302	91.8	5.29E+03	43.50	133.50	134	2.25E+09	34008	20-Mar	91.8	4.94E+03	43.50	133.50	134	2.25E+09	34008	20-Mar	77.2	5.29E+03	43.50	133.50	134	2.25E+09	34008
S. Korea	11-Jan	122	37.1	1.50E+02	37.50	129.00	662	2.45E+09	155901	11-Jan	37.1	1.45E+02	37.50	129.00	662	2.45E+09	155901	27-Mar	14.0	1.41E+01	36.50	126.00	886	2.49E+09	26386
Taiwan	None									None								None							
Thailand	None									None								None							
Aleutians (U.S.)	06-Mar	149	45.3	1.30E+01	52.50	174.00	3260	1.89E+09	0	06-Mar	45.3	1.30E+01	52.50	174.00	3260	1.89E+09	0	07-Nov	0.3	2.62E-08	52.00	177.00	3464	1.91E+09	0
Alaska (U.S.)	25-Mar	119	36.2	2.13E+01	60.00	210.00	5359	1.55E+09	1314	25-Mar	36.2	2.13E+01	60.00	210.00	5359	1.55E+09	1314	None							
Vietnam	29-Nov	1	0.3	4.41E-10	20.50	107.00	3416	2.89E+09	13869	29-Nov	0.3	4.41E-10	20.50	107.00	3416	2.89E+09	13869	None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all areas, including ocean, outside of Russia.

Table 22. VRS Total Deposition (tdep) Maximum Values for Sr-90 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	02-Aug	329	100.0	3.26E+04	43.50	133.50	134	2.25E+09	34008	12-Jun	100.0	2.98E+04	43.50	133.50	134	2.25E+09	34008	12-Jun	100.0	3.00E+04	43.50	133.50	134	2.25E+09	34008
Transboundary**	02-Aug	329	100.0	1.09E+04	42.50	133.50	135	2.28E+09	717	12-Jun	100.0	9.95E+03	42.50	133.50	135	2.28E+09	717	12-Jun	100.0	1.00E+04	42.50	133.50	135	2.28E+09	717
Burma	None									None								None							
China	07-Jun	259	78.7	7.87E+03	43.50	131.50	69	2.25E+09	42463	07-Jun	78.7	7.84E+03	43.50	131.50	69	2.25E+09	42463	07-Jun	73.6	7.51E+03	43.50	131.50	69	2.25E+09	42463
Hong Kong	29-Nov	4	1.2	2.26E-03	22.50	114.50	2794	2.85E+09	125994	29-Nov	1.2	2.26E-03	22.50	114.50	2794	2.85E+09	125994	None							
Japan	16-Dec	316	96.0	4.40E+03	40.50	141.00	796	2.35E+09	358298	16-Dec	96.0	4.33E+03	40.50	141.00	796	2.35E+09	358298	30-Jan	74.2	2.78E+03	36.00	138.00	933	2.50E+09	405254
Laos	None									None								None							
Mongolia	10-May	36	10.9	7.52E+01	47.00	120.00	1042	2.11E+09	33341	10-May	10.9	7.52E+01	47.00	120.00	1042	2.11E+09	33341	27-Jul	1.5	5.85E-02	50.00	116.50	1415	1.99E+09	4443
N. Korea	20-Aug	199	60.5	5.16E+03	42.00	129.00	270	2.30E+09	200822	20-Aug	60.5	4.73E+03	42.00	129.00	270	2.30E+09	200822	20-Aug	37.7	5.12E+03	42.00	129.00	270	2.30E+09	200822
Russia	02-Aug	324	98.5	3.26E+04	43.50	133.50	134	2.25E+09	34008	12-Jun	98.5	2.98E+04	43.50	133.50	134	2.25E+09	34008	12-Jun	97.9	3.00E+04	43.50	133.50	134	2.25E+09	34008
S. Korea	11-Jan	151	45.9	1.19E+03	38.50	127.50	628	2.42E+09	292252	11-Jan	45.9	1.16E+03	38.50	127.50	628	2.42E+09	292252	15-Nov	21.0	9.72E+02	38.50	127.50	628	2.42E+09	292252
Taiwan	29-Nov	21	6.4	2.17E+02	24.00	121.50	2322	2.82E+09	152461	29-Nov	6.4	2.17E+02	24.00	121.50	2322	2.82E+09	152461	None							
Thailand	None									None								None							
Aleutians (U.S.)	23-Apr	154	46.8	6.05E+01	52.00	177.00	3464	1.91E+09	0	23-Apr	46.8	6.05E+01	52.00	177.00	3464	1.91E+09	0	29-May	0.6	2.65E-04	53.00	172.50	3162	1.87E+09	0
Alaska (U.S.)	25-Mar	119	36.2	4.17E+01	58.50	202.50	4986	1.62E+09	15	25-Mar	36.2	4.17E+01	58.50	202.50	4986	1.62E+09	15	None							
Vietnam	29-Nov	1	0.3	4.41E-10	20.50	107.00	3416	2.89E+09	13869	29-Nov	0.3	4.41E-10	20.50	107.00	3416	2.89E+09	13869								

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all areas, including ocean, outside of Russia.

Table 23. VRS Integrated Concentration Maximum Values for Sr-90 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	12-Jun	329	100.0	4.51E+03	43.50	133.50	134	2.25E+09	34008	12-Jun	100.0	4.14E+03	43.50	133.50	134	2.25E+09	34008	12-Jun	100.0	4.16E+03	43.50	133.50	134	2.25E+09	34008
Transboundary**	12-Jun	329	100.0	1.50E+03	42.50	133.50	135	2.28E+09	717	12-Jun	100.0	1.38E+03	42.50	133.50	135	2.28E+09	717	12-Jun	100.0	1.39E+03	42.50	133.50	135	2.28E+09	717
Burma	None									None								None							
China	07-Jun	257	78.1	1.09E+03	43.50	131.50	69	2.25E+09	42463	07-Jun	78.1	1.09E+03	43.50	131.50	69	2.25E+09	42463	07-Jun	73.6	1.04E+03	43.50	131.50	69	2.25E+09	42463
Hong Kong	29-Nov	4	1.2	3.14E-04	22.50	114.50	2794	2.85E+09	125994	29-Nov	1.2	3.14E-04	22.50	114.50	2794	2.85E+09	125994	None							
Japan	16-Dec	316	96.0	5.91E+02	40.50	141.00	796	2.35E+09	358298	16-Dec	96.0	5.81E+02	40.50	141.00	796	2.35E+09	358298	13-Jan	74.2	2.85E+02	34.50	132.00	945	2.55E+09	496677
Laos	None									None								None							
Mongolia	10-May	34	10.3	1.04E+01	47.00	120.00	1042	2.11E+09	33341	10-May	10.3	1.04E+01	47.00	120.00	1042	2.11E+09	33341	27-Jul	1.5	8.12E-03	50.00	116.50	1415	1.99E+09	4443
N. Korea	20-Aug	194	59.0	6.56E+02	42.00	129.00	270	2.30E+09	200822	20-Aug	59.0	6.00E+02	42.00	129.00	270	2.30E+09	200822	20-Aug	37.7	6.50E+02	42.00	129.00	270	2.30E+09	200822
Russia	12-Jun	324	98.5	4.51E+03	43.50	133.50	134	2.25E+09	34008	12-Jun	98.5	4.14E+03	43.50	133.50	134	2.25E+09	34008	12-Jun	97.9	4.16E+03	43.50	133.50	134	2.25E+09	34008
S. Korea	11-Jan	147	44.7	1.59E+02	38.50	127.50	628	2.42E+09	292252	11-Jan	44.7	1.54E+02	38.50	127.50	628	2.42E+09	292252	15-Nov	21.0	1.35E+02	38.50	127.50	628	2.42E+09	292252
Taiwan	29-Nov	21	6.4	3.02E+01	24.00	121.50	2322	2.82E+09	152461	29-Nov	6.4	3.02E+01	24.00	121.50	2322	2.82E+09	152461	None							
Thailand	None									None								None							
Aleutians (U.S.)	23-Apr	135	41.0	8.41E+00	52.00	177.00	3464	1.91E+09	0	23-Apr	41.0	8.41E+00	52.00	177.00	3464	1.91E+09	0	29-May	0.6	3.68E-05	53.00	172.50	3162	1.87E+09	0
Alaska (U.S.)	25-Mar	87	26.4	5.79E+00	58.50	202.50	4986	1.62E+09	15	25-Mar	26.4	5.79E+00	58.50	202.50	4986	1.62E+09	15	None							
Vietnam	None									None								None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all areas, including ocean, outside of Russia.

Table 24. VRS Dry Deposition (ddep) Maximum Values for I-131 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	12-Jun	329	100.0	5.28E+04	43.50	133.50	134	2.25E+09	34008	12-Jun	100.0	3.99E+04	43.50	133.50	134	2.25E+09	34008	12-Jun	100.0	5.28E+04	43.50	133.50	134	2.25E+09	34008
Transboundary**	12-Jun	329	100.0	1.76E+04	42.50	133.50	135	2.28E+09	717	12-Jun	100.0	1.33E+04	42.50	133.50	135	2.28E+09	717	12-Jun	100.0	1.76E+04	42.50	133.50	135	2.28E+09	717
Burma	None									None								None							
China	07-Jun	238	72.3	1.64E+04	43.50	131.50	69	2.25E+09	42463	07-Jun	72.3	1.04E+04	43.50	131.50	69	2.25E+09	42463	07-Jun	72.3	1.37E+04	43.50	131.50	69	2.25E+09	42463
Hong Kong	None									None								None							
Japan	20-Nov	222	67.5	2.61E+03	36.00	138.00	933	2.50E+09	405254	20-Nov	67.5	1.98E+03	36.00	138.00	933	2.50E+09	405254	20-Nov	67.5	2.61E+03	36.00	138.00	933	2.50E+09	405254
Laos	None									None								None							
Mongolia	21-Apr	3	0.9	5.86E-04	47.00	120.00	1042	2.11E+09	33341	21-Apr	0.9	4.43E-04	47.00	120.00	1042	2.11E+09	33341	21-Apr	0.9	5.86E-04	47.00	120.00	1042	2.11E+09	33341
N. Korea	20-Aug	110	33.4	9.59E+03	42.00	129.00	270	2.30E+09	200822	20-Aug	33.4	6.47E+03	42.00	129.00	270	2.30E+09	200822	20-Aug	33.4	8.55E+03	42.00	129.00	270	2.30E+09	200822
Russia	12-Jun	322	97.9	5.28E+04	43.50	133.50	134	2.25E+09	34008	12-Jun	97.9	3.99E+04	43.50	133.50	134	2.25E+09	34008	12-Jun	97.9	5.28E+04	43.50	133.50	134	2.25E+09	34008
S. Korea	11-Jan	59	17.9	1.14E+03	37.50	129.00	662	2.45E+09	155901	11-Jan	17.9	8.64E+02	37.50	129.00	662	2.45E+09	155901	11-Jan	17.9	1.14E+03	37.50	129.00	662	2.45E+09	155901
Taiwan	None									None								None							
Thailand	None									None								None							
Aleutians (U.S.)	07-Nov	1	0.3	1.34E-13	52.50	173.00	3192	1.89E+09	0	07-Nov	0.3	1.02E-13	52.50	173.00	3192	1.89E+09	0	07-Nov	0.3	1.34E-13	52.50	173.00	3192	1.89E+09	0
Alaska (U.S.)	None									None								None							
Vietnam	None									None								None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all areas, including ocean, outside of Russia.

Table 25. VRS Wet Deposition (wdep) Maximum Values for I-131 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	18-Nov	328	99.7	4.90E+03	42.00	133.50	166	2.30E+09	0	18-Nov	99.7	3.18E+03	42.00	133.50	166	2.30E+09	0	18-Nov	97.9	4.33E+03	42.00	133.50	166	2.30E+09	0
Transboundary**	18-Nov	328	99.7	4.90E+03	42.00	133.50	166	2.30E+09	0	18-Nov	99.7	3.18E+03	42.00	133.50	166	2.30E+09	0	18-Nov	97.6	4.33E+03	42.00	133.50	166	2.30E+09	0
Burma	None									None								None							
China	01-Jan	214	65.0	2.69E+03	43.50	130.50	134	2.25E+09	70383	01-Jan	65.0	1.98E+03	43.50	130.50	134	2.25E+09	70383	01-Jan	61.1	2.69E+03	43.50	130.50	134	2.25E+09	70383
Hong Kong	None									None								None							
Japan	30-Jan	248	75.4	1.05E+03	36.00	138.00	933	2.50E+09	405254	30-Jan	75.4	7.74E+02	36.00	138.00	933	2.50E+09	405254	30-Jan	53.2	1.05E+03	36.00	138.00	933	2.50E+09	405254
Laos	None									None								None							
Mongolia	05-Jan	4	1.2	9.01E-05	46.50	119.50	1060	2.13E+09	1835	05-Jan	1.2	7.59E-05	46.50	119.50	1060	2.13E+09	1835	05-Jan	0.6	2.87E-09	48.00	119.00	1154	2.07E+09	3738
N. Korea	01-Jan	126	38.3	1.23E+03	43.00	130.00	163	2.26E+09	175327	01-Jan	38.3	9.02E+02	43.00	130.00	163	2.26E+09	175327	01-Jan	26.1	1.23E+03	43.00	130.00	163	2.26E+09	175327
Russia	20-Mar	277	84.2	3.23E+03	43.50	133.50	134	2.25E+09	34008	20-Mar	84.2	2.37E+03	43.50	133.50	134	2.25E+09	34008	20-Mar	77.2	3.23E+03	43.50	133.50	134	2.25E+09	34008
S. Korea	11-Jan	76	23.1	8.24E+01	37.50	129.00	662	2.45E+09	155901	11-Jan	23.1	6.94E+01	37.50	129.00	662	2.45E+09	155901	27-Mar	14.0	8.60E+00	36.50	126.00	886	2.49E+09	26386
Taiwan	None									None								None							
Thailand	None									None								None							
Aleutians (U.S.)	07-Mar	25	7.6	6.59E+00	52.00	177.00	3464	1.91E+09	0	07-Mar	7.6	5.55E+00	52.00	177.00	3464	1.91E+09	0	07-Nov	0.3	1.60E-08	52.00	177.00	3464	1.91E+09	0
Alaska (U.S.)	14-Nov	5	1.5	5.36E-12	55.00	198.00	4801	1.78E+09	46	14-Nov	1.5	4.51E-12	55.00	198.00	4801	1.78E+09	46	None							
Vietnam	None									None								None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all areas, including ocean, outside of Russia.

Table 26. VRS Total Deposition (tdep) Maximum Values for I-131 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	12-Jun	329	100.0	5.28E+04	43.50	133.50	134	2.25E+09	34008	12-Jun	100.0	3.99E+04	43.50	133.50	134	2.25E+09	34008	12-Jun	100.0	5.28E+04	43.50	133.50	134	2.25E+09	34008
Transboundary**	12-Jun	329	100.0	1.76E+04	42.50	133.50	135	2.28E+09	717	12-Jun	100.0	1.33E+04	42.50	133.50	135	2.28E+09	717	12-Jun	100.0	1.76E+04	42.50	133.50	135	2.28E+09	717
Burma	None									None								None							
China	07-Jun	245	74.5	1.64E+04	43.50	131.50	69	2.25E+09	42463	07-Jun	74.5	1.04E+04	43.50	131.50	69	2.25E+09	42463	07-Jun	72.6	1.37E+04	43.50	131.50	69	2.25E+09	42463
Hong Kong	None									None								None							
Japan	20-Nov	270	82.1	2.61E+03	36.00	138.00	933	2.50E+09	405254	20-Nov	82.1	1.98E+03	36.00	138.00	933	2.50E+09	405254	20-Nov	70.2	2.61E+03	36.00	138.00	933	2.50E+09	405254
Laos	None									None								None							
Mongolia	21-Apr	5	1.5	5.86E-04	47.00	120.00	1042	2.11E+09	33341	21-Apr	1.5	4.43E-04	47.00	120.00	1042	2.11E+09	33341	21-Apr	0.9	5.86E-04	47.00	120.00	1042	2.11E+09	33341
N. Korea	20-Aug	150	45.6	9.86E+03	42.00	129.00	270	2.30E+09	200822	20-Aug	45.6	6.67E+03	42.00	129.00	270	2.30E+09	200822	20-Aug	35.6	8.82E+03	42.00	129.00	270	2.30E+09	200822
Russia	12-Jun	324	98.5	5.28E+04	43.50	133.50	134	2.25E+09	34008	12-Jun	98.5	3.99E+04	43.50	133.50	134	2.25E+09	34008	12-Jun	97.9	5.28E+04	43.50	133.50	134	2.25E+09	34008
S. Korea	11-Jan	89	27.1	1.14E+03	37.50	129.00	662	2.45E+09	155901	11-Jan	27.1	9.33E+02	37.50	129.00	662	2.45E+09	155901	11-Jan	18.8	1.14E+03	37.50	129.00	662	2.45E+09	155901
Taiwan	None									None								None							
Thailand	None									None								None							
Aleutians (U.S.)	07-Mar	25	7.6	6.59E+00	52.00	177.00	3464	1.91E+09	0	07-Mar	7.6	5.55E+00	52.00	177.00	3464	1.91E+09	0	07-Nov	0.3	1.60E-08	52.00	177.00	3464	1.91E+09	0
Alaska (U.S.)	14-Nov	5	1.5	5.36E-12	55.00	198.00	4801	1.78E+09	46	14-Nov	1.5	4.51E-12	55.00	198.00	4801	1.78E+09	46	None							
Vietnam	None									None								None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all areas, including ocean, outside of Russia.

Table 27. VRS Integrated Concentration Maximum Values for I-131 for CY2000

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	12-Jun	329	100.0	2.87E+03	43.50	133.50	134	2.25E+09	34008	12-Jun	100.0	2.87E+03	43.50	133.50	134	2.25E+09	34008	12-Jun	100.0	2.82E+03	43.50	133.50	134	2.25E+09	34008
Transboundary**	12-Jun	329	100.0	9.55E+02	42.50	133.50	135	2.28E+09	717	12-Jun	100.0	9.55E+02	42.50	133.50	135	2.28E+09	717	12-Jun	100.0	9.39E+02	42.50	133.50	135	2.28E+09	717
Burma	None									None								None							
China	07-Jun	238	72.3	8.39E+02	43.50	131.50	69	2.25E+09	42463	07-Jun	72.3	7.47E+02	43.50	131.50	69	2.25E+09	42463	07-Jun	70.5	8.39E+02	43.50	131.50	69	2.25E+09	42463
Hong Kong	None									None								None							
Japan	20-Nov	222	67.5	1.42E+02	36.00	138.00	933	2.50E+09	405254	20-Nov	67.5	1.42E+02	36.00	138.00	933	2.50E+09	405254	27-Jan	62.9	1.01E+02	39.00	140.00	805	2.40E+09	239517
Laos	None									None								None							
Mongolia	21-Apr	3	0.9	3.18E-05	47.00	120.00	1042	2.11E+09	33341	21-Apr	0.9	3.18E-05	47.00	120.00	1042	2.11E+09	33341	21-Apr	0.6	2.97E-08	48.00	119.00	1154	2.07E+09	3738
N. Korea	20-Aug	110	33.4	5.20E+02	42.00	129.00	270	2.30E+09	200822	20-Aug	33.4	4.65E+02	42.00	129.00	270	2.30E+09	200822	20-Aug	28.9	5.20E+02	42.00	129.00	270	2.30E+09	200822
Russia	12-Jun	322	97.9	2.87E+03	43.50	133.50	134	2.25E+09	34008	12-Jun	97.9	2.87E+03	43.50	133.50	134	2.25E+09	34008	12-Jun	97.9	2.82E+03	43.50	133.50	134	2.25E+09	34008
S. Korea	15-Sep	59	17.9	6.95E+01	37.50	127.50	721	2.45E+09	1269429	11-Jan	17.9	6.21E+01	37.50	129.00	662	2.45E+09	155901	15-Sep	14.0	6.95E+01	37.50	127.50	721	2.45E+09	1269429
Taiwan	None									None								None							
Thailand	None									None								None							
Aleutians (U.S.)	07-Nov	1	0.3	7.29E-15	53.00	172.50	3162	1.87E+09	0	07-Nov	0.3	7.29E-15	53.00	172.50	3162	1.87E+09	0	None							
Alaska (U.S.)	None									None								None							
Vietnam	None									None								None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all areas, including ocean, outside of Russia.

Table 28. UNSCEAR P_{23} Transfer Coefficient in mBq a kg^{-1} per Bq m^{-2}

	Sr-90			Cs-137		
Specific Pathway	**Min**	**Max**	**Ave**	**Min**	**Max**	**Ave**
Milk products	2.6	4.9	3.7	5.7	8.8	6.8
Grain Products	4.1	17.2	9.1	8.9	26.6	15.7
Vegetables	0.4	4	2.5	1.8	4.4	3.2
Fruit	1	2.5	1.8	3.1	3.5	3.3
Meat	0.4	3	1.4	7.9	26.2	20.1*
Total Diet	**Min**	**Max**	**Ave**	**Min**	**Max**	**Ave**
Sum of Weighted Components	2.7	5.6	3.6	5.8	11.4	8.4
Fit on Total Diet	3.0	5.5	3.8	5.1	11.4	8.2

* Average not provided in Reference 13. The value (i.e., 20.1) provided is the average of the values (i.e., 7.9, 26.2, and 26.2) given in Reference 13. The value (i.e., 26.2) was the same for two of the countries.

Table 29. 1993 UNSCEAR P_{34} Type Transfer Coefficients in kg a^{-1} (500 kg a^{-1} Consumption Rate Basis)

	Sr-90					Cs-137			
Pathway	**Argentina**	**Denmark**	**U.S.**	**Ave**		**Argentina**	**Denmark**	**U.S.**	**Ave**
Milk Products	130	175	155	153.3		130	175	165	156.7
Grain products	100	80	75	85.0		100	80	70	83.3
Vegetables	120	120	95	111.7		155	120	95	123.3
Fruit	100	50	75	75.0		80	50	85	71.7
Meat	40	75	95	70.0		40	75	85	66.7

Table 30. Percentage Contributions from the Ingestion Pathways

Pathway	Cs-137	Sr-90	I-131
Milk Products	24.52	30.62	100.00
Grain products	30.11	41.74	---
Vegetables	9.08	15.07	---
Fruit	5.44	7.29	---
Meat	30.84	5.29	---

Table 31. Transfer Coefficients based upon UNSCEAR 1993 Report

	Cs-137		Sr-90		I-131	
Pathway	**nSv per Bq m^{-2}**	**% of Total**	**nSv per Bq m^{-2}**	**% of Total**	**nSv per Bq m^{-2}**	**% of Total**
Ingestion, P_{2345}	56.48	36.49	51.88	91.86	4.20	93.50
Milk Products	13.85	8.95	15.89	28.13	4.20	93.50
Grain products	17.01	10.99	21.66	38.35	---	---
Vegetables	5.13	3.31	7.82	13.84	---	---
Fruit	3.07	1.99	3.78	6.69	---	---
Meat	17.42	11.26	2.74	4.86	---	---
Inhalation, P_{245}	0.11	0.07	4.60	8.14	0.17	3.80
External Exposure, P_{25}	98.18	63.43	0.00	0.00	0.12	2.70
Total	154.78	100.00	56.48	100.00	4.49	100.00

Table 32. PRS UNSCEAR Cs-137 Maximum Total Dose Commitment (per Person) Estimates and Breakdown by Type

Region	Date	N	N (%)	MaxTot (mSv)	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Ingest (mSv)	Ingest (%)	Inhalat (mSv)	Inhalat (%)	ExtExp (mSv)	ExtExp (%)
Regional	21-Mar-00	326	100.0	4.22E+00	52.50	157.50	87	1.89E+09	1944	1.53E+00	36.2	3.05E-03	0.1	2.69E+00	63.8
Transboundary**	18-Feb-00	316	96.9	1.95E-01	58.50	198.00	2507	1.62E+09	22	7.05E-02	36.2	1.41E-04	0.1	1.24E-01	63.8
Burma	None														
China	05-Jan-00	58	17.8	2.96E-02	52.50	126.00	2169	1.89E+09	7721	1.07E-02	36.2	2.14E-05	0.1	1.89E-02	63.8
Hong Kong	None														
Japan	26-Apr-00	82	25.2	4.20E-02	43.50	142.50	1581	2.25E+09	155808	1.52E-02	36.2	3.03E-05	0.1	2.68E-02	63.8
Laos	None														
Mongolia	04-Jan-00	13	4.0	1.65E-03	46.50	119.50	2855	2.13E+09	1835	5.97E-04	36.2	1.19E-06	0.1	1.05E-03	63.8
N. Korea	07-Jan-00	18	5.5	8.25E-03	43.00	130.00	2372	2.26E+09	175327	2.98E-03	36.2	5.97E-06	0.1	5.26E-03	63.8
Russia	21-Mar-00	326	100.0	4.22E+00	52.50	157.50	87	1.89E+09	1944	1.53E+00	36.2	3.05E-03	0.1	2.69E+00	63.8
S. Korea	05-Jan-00	5	1.5	6.22E-04	37.50	126.50	3001	2.45E+09	2006368	2.25E-04	36.2	4.50E-07	0.1	3.97E-04	63.8
Taiwan	None														
Thailand	None														
Aleutians (U.S.)	24-Jan-00	273	83.7	1.30E-01	52.50	185.50	1807	1.89E+09	63	4.71E-02	36.2	9.41E-05	0.1	8.30E-02	63.8
Alaska (U.S.)	18-Feb-00	229	70.2	1.95E-01	58.50	198.00	2507	1.62E+09	22	7.05E-02	36.2	1.41E-04	0.1	1.24E-01	63.8
Vietnam	None														

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 33. PRS UNSCEAR Sr-90 Maximum Total Dose Commitment (per Person) Estimates and Breakdown by Type

Region	Date	N	N (%)	MaxTot (mSv)	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Ingest (mSv)	Ingest (%)	Inhalat (mSv)	Inhalat (%)	ExtExp (mSv)	ExtExp (%)
Regional	21-Mar-00	326	100.0	1.60E+00	52.50	157.50	87	1.89E+09	1944	1.47E+00	91.9	1.30E-01	8.1	0.00E+00	0.0
Transboundary**	18-Feb-00	215	66.0	7.72E-02	58.50	198.00	2507	1.62E+09	22	7.09E-02	91.9	6.27E-03	8.1	0.00E+00	0.0
Burma	None														
China	05-Jan-00	50	15.3	1.09E-02	52.50	126.00	2169	1.89E+09	7721	1.01E-02	91.9	8.90E-04	8.1	0.00E+00	0.0
Hong Kong	None														
Japan	26-Apr-00	76	23.3	1.81E-02	43.50	142.50	1581	2.25E+09	155808	1.66E-02	91.9	1.47E-03	8.1	0.00E+00	0.0
Laos	None														
Mongolia	04-Jan-00	11	3.4	6.29E-04	46.50	119.50	2855	2.13E+09	1835	5.78E-04	91.9	5.11E-05	8.1	0.00E+00	0.0
N. Korea	07-Jan-00	14	4.3	3.42E-03	43.00	130.00	2372	2.26E+09	175327	3.14E-03	91.9	2.78E-04	8.1	0.00E+00	0.0
Russia	21-Mar-00	326	100.0	1.60E+00	52.50	157.50	87	1.89E+09	1944	1.47E+00	91.9	1.30E-01	8.1	0.00E+00	0.0
S. Korea	05-Jan-00	5	1.5	1.21E-04	37.50	126.50	3001	2.45E+09	2006368	1.11E-04	91.9	9.83E-06	8.1	0.00E+00	0.0
Taiwan	None														
Thailand	None														
Aleutians (U.S.)	24-Jan-00	269	82.5	4.81E-02	52.50	185.50	1807	1.89E+09	63	4.42E-02	91.9	3.91E-03	8.1	0.00E+00	0.0
Alaska (U.S.)	18-Feb-00	215	66.0	7.72E-02	58.50	198.00	2507	1.62E+09	22	7.09E-02	91.9	6.27E-03	8.1	0.00E+00	0.0
Vietnam	None														

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 34. PRS UNSCEAR I-131 Maximum Total Dose Commitment (per Person) Estimates and Breakdown by Type

Region	Date	N	N (%)	MaxTot (mSv)	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Ingest (mSv)	Ingest (%)	Inhalat (mSv)	Inhalat (%)	ExtExp (mSv)	ExtExp (%)
Regional	09-Feb-00	326	100.0	1.79E-01	52.50	157.50	87	1.89E+09	1944	1.67E-01	93.5	6.77E-03	3.8	4.78E-03	2.7
Transboundary**	18-Jan-00	98	30.1	2.39E-03	52.50	174.00	1043	1.89E+09	0	2.23E-03	93.5	9.04E-05	3.8	6.38E-05	2.7
Burma	None														
China	04-Dec-00	4	1.2	2.92E-10	52.50	123.00	2365	1.89E+09	5976	2.73E-10	93.5	1.11E-11	3.8	7.81E-12	2.7
Hong Kong	None														
Japan	03-Jan-00	10	3.1	1.81E-04	44.50	145.50	1338	2.21E+09	2136	1.69E-04	93.5	6.85E-06	3.8	4.84E-06	2.7
Laos	None														
Mongolia	None														
N. Korea	None														
Russia	09-Feb-00	326	100.0	1.79E-01	52.50	157.50	87	1.89E+09	1944	1.67E-01	93.5	6.77E-03	3.8	4.78E-03	2.7
S. Korea	None														
Taiwan	None														
Thailand	None														
Aleutians (U.S.)	18-Jan-00	86	26.4	2.39E-03	52.50	174.00	1043	1.89E+09	0	2.23E-03	93.5	9.04E-05	3.8	6.38E-05	2.7
Alaska (U.S.)	20-Jan-00	7	2.1	1.61E-04	54.50	195.00	2379	1.80E+09	38	1.51E-04	93.5	6.10E-06	3.8	4.30E-06	2.7
Vietnam	None														

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 35. Selected Site-Specific Parameter Summary from RESRAD 6 Results

Menu	Parameter	User Input	Default	Parameter Name
R011	Area of contaminated zone (m**2)	1.89E+09	1.00E+04	AREA
R011	Thickness of contaminated zone (m)	3.00E-02	2.00E+00	THICK0
R011	Basic radiation dose limit (mSv/yr)	2.50E-01	2.50E-01	BRDL
R012	Initial principal radionuclide (Bq/g): Cs-137	9.47E-02	0.00E+00	S1(1)
R013	Cover depth (m)	0.00E+00	0.00E+00	COVER0
R013	Density of contaminated zone (g/cm**3)	1.50E+00	1.50E+00	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	0.00E+00	1.00E-03	VCZ
R017	Inhalation rate (m**3/yr)	8.40E+03	8.40E+03	INHALR
R017	Exposure duration	5.00E+01	3.00E+01	ED
R017	Shielding factor, inhalation	0.00E+00	4.00E-01	SHF3
R017	Shielding factor, external gamma	2.00E-01	7.00E-01	SHF1
R017	Fraction of time spent indoors	8.00E-01	5.00E-01	FIND
R017	Fraction of time spent outdoors (on site)	2.00E-01	2.50E-01	FOTD
R018	Fruits, vegetables and grain consumption (kg/yr)	1.55E+02	1.60E+02	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	1.23E+02	1.40E+01	DIET(2)
R018	Milk consumption (L/yr)	1.49E+02	9.20E+01	DIET(3)
R018	Meat and poultry consumption (kg/yr)	6.67E+01	6.30E+01	DIET(4)
R018	Fish consumption (kg/yr)	0.00E+00	5.40E+00	DIET(5)
R018	Other seafood consumption (kg/yr)	0.00E+00	9.00E-01	DIET(6)
R018	Soil ingestion rate (g/yr)	0.00E+00	3.65E+01	SOIL
R018	Drinking water intake (L/yr)	0.00E+00	5.10E+02	DWI

Table 36. VRS UNSCEAR Cs-137 Maximum Total Dose Commitment Estimates and Breakdown by Type

Region	Date	N	N (%)	MaxTot (mSv)	Lat	Lon	Dist (km)	Area (m^2)	Pop	Ingest (mSv)	Ingest (%)	Inhalat (mSv)	Inhalat (%)	ExtExp (mSv)	ExtExp (%)
Regional	02-Aug-00	329	100.0	4.01E+00	43.50	133.50	134	2.25E+09	34008	1.45E+00	36.2	2.90E-03	0.1	2.56E+00	63.8
Transboundary**	07-Jun-00	329	100.0	1.05E+00	43.50	131.50	69	2.25E+09	42463	3.81E-01	36.2	7.62E-04	0.1	6.72E-01	63.8
Burma	None														
China	07-Jun-00	262	79.6	1.05E+00	43.50	131.50	69	2.25E+09	42463	3.81E-01	36.2	7.62E-04	0.1	6.72E-01	63.8
Hong Kong	12-Sep-00	9	2.7	8.48E-04	22.50	114.50	2794	2.85E+09	125994	3.07E-04	36.2	6.13E-07	0.1	5.41E-04	63.8
Japan	16-Dec-00	317	96.4	5.85E-01	40.50	141.00	796	2.35E+09	358298	2.12E-01	36.2	4.23E-04	0.1	3.73E-01	63.8
Laos	None														
Mongolia	10-May-00	40	12.2	1.02E-02	47.00	120.00	1042	2.11E+09	33341	3.68E-03	36.2	7.37E-06	0.1	6.50E-03	63.8
N. Korea	20-Aug-00	202	61.4	6.48E-01	42.00	129.00	270	2.30E+09	200822	2.34E-01	36.2	4.69E-04	0.1	4.13E-01	63.8
Russia	02-Aug-00	324	98.5	4.01E+00	43.50	133.50	134	2.25E+09	34008	1.45E+00	36.2	2.90E-03	0.1	2.56E+00	63.8
S. Korea	11-Jan-00	156	47.4	1.57E-01	38.50	127.50	628	2.42E+09	292252	5.69E-02	36.2	1.14E-04	0.1	1.00E-01	63.8
Taiwan	29-Nov-00	32	9.7	2.91E-02	24.00	121.50	2322	2.82E+09	152461	1.05E-02	36.2	2.11E-05	0.1	1.86E-02	63.8
Thailand	None														
Aleutians (U.S.)	23-Apr-00	172	52.3	8.91E-03	52.00	177.00	3464	1.91E+09	0	3.22E-03	36.2	6.44E-06	0.1	5.68E-03	63.8
Alaska (U.S.)	24-Mar-00	140	42.6	1.71E-02	60.00	210.00	5359	1.55E+09	1314	6.18E-03	36.2	1.24E-05	0.1	1.09E-02	63.8
Vietnam	29-Nov-00	1	0.3	4.38E-10	20.50	107.00	3416	2.89E+09	13869	1.58E-10	36.2	3.17E-13	0.1	2.79E-10	63.8

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 37. VRS UNSCEAR Sr-90 Maximum Total Dose Commitment Estimates and Breakdown by Type

Region	Date	N	N (%)	MaxTot (mSv)	Lat	Lon	Dist (km)	Area (m^2)	Pop	Ingest (mSv)	Ingest (%)	Inhalat (mSv)	Inhalat (%)	ExtExp (mSv)	ExtExp (%)
Regional	12-Jun-00	329	100.0	1.69E+00	43.50	133.50	134	2.25E+09	34008	1.55E+00	91.9	1.37E-01	8.1	0.00E+00	0.0
Transboundary**	07-Jun-00	329	100.0	4.44E-01	43.50	131.50	69	2.25E+09	42463	4.08E-01	91.9	3.61E-02	8.1	0.00E+00	0.0
Burma	None														
China	07-Jun-00	259	78.7	4.44E-01	43.50	131.50	69	2.25E+09	42463	4.08E-01	91.9	3.61E-02	8.1	0.00E+00	0.0
Hong Kong	29-Nov-00	4	1.2	1.28E-07	22.50	114.50	2794	2.85E+09	125994	1.18E-07	91.9	1.04E-08	8.1	0.00E+00	0.0
Japan	16-Dec-00	316	96.0	2.45E-01	40.50	141.00	796	2.35E+09	358298	2.25E-01	91.9	1.99E-02	8.1	0.00E+00	0.0
Laos	None														
Mongolia	10-May-00	36	10.9	4.26E-03	47.00	120.00	1042	2.11E+09	33341	3.91E-03	91.9	3.46E-04	8.1	0.00E+00	0.0
N. Korea	20-Aug-00	199	60.5	2.68E-01	42.00	129.00	270	2.30E+09	200822	2.46E-01	91.9	2.18E-02	8.1	0.00E+00	0.0
Russia	12-Jun-00	324	98.5	1.69E+00	43.50	133.50	134	2.25E+09	34008	1.55E+00	91.9	1.37E-01	8.1	0.00E+00	0.0
S. Korea	11-Jan-00	151	45.9	6.57E-02	38.50	127.50	628	2.42E+09	292252	6.04E-02	91.9	5.34E-03	8.1	0.00E+00	0.0
Taiwan	29-Nov-00	21	6.4	1.23E-02	24.00	121.50	2322	2.82E+09	152461	1.13E-02	91.9	1.00E-03	8.1	0.00E+00	0.0
Thailand	None														
Aleutians (U.S.)	23-Apr-00	154	46.8	3.43E-03	52.00	177.00	3464	1.91E+09	0	3.15E-03	91.9	2.79E-04	8.1	0.00E+00	0.0
Alaska (U.S.)	25-Mar-00	119	36.2	2.36E-03	58.50	202.50	4986	1.62E+09	15	2.17E-03	91.9	1.92E-04	8.1	0.00E+00	0.0
Vietnam	29-Nov-00	1	0.3	2.50E-14	20.50	107.00	3416	2.89E+09	13869	2.29E-14	91.9	2.03E-15	8.1	0.00E+00	0.0

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 38. VRS UNSCEAR I-131 Maximum Total Dose Commitment Estimates and Breakdown by Type

Region	Date	N	N (%)	MaxTot (mSv)	Lat	Lon	Dist (km)	Area (m^2)	Pop	Ingest (mSv)	Ingest (%)	Inhalat (mSv)	Inhalat (%)	ExtExp (mSv)	ExtExp (%)
Regional	12-Jun-00	329	100.0	2.54E-01	43.50	133.50	134	2.25E+09	34008	2.38E-01	93.5	9.62E-03	3.8	6.79E-03	2.7
Transboundary**	07-Jun-00	329	100.0	6.61E-02	43.50	131.50	69	2.25E+09	42463	6.19E-02	93.5	2.50E-03	3.8	1.77E-03	2.7
Burma	None														
China	07-Jun-00	245	74.5	6.61E-02	43.50	131.50	69	2.25E+09	42463	6.19E-02	93.5	2.50E-03	3.8	1.77E-03	2.7
Hong Kong	None														
Japan	20-Nov-00	270	82.1	1.26E-02	36.00	138.00	933	2.50E+09	405254	1.18E-02	93.5	4.76E-04	3.8	3.36E-04	2.7
Laos	None														
Mongolia	21-Apr-00	5	1.5	2.82E-09	47.00	120.00	1042	2.11E+09	33341	2.64E-09	93.5	1.07E-10	3.8	7.54E-11	2.7
N. Korea	20-Aug-00	150	45.6	4.24E-02	42.00	129.00	270	2.30E+09	200822	3.97E-02	93.5	1.61E-03	3.8	1.13E-03	2.7
Russia	12-Jun-00	324	98.5	2.54E-01	43.50	133.50	134	2.25E+09	34008	2.38E-01	93.5	9.62E-03	3.8	6.79E-03	2.7
S. Korea	11-Jan-00	89	27.1	5.94E-03	37.50	129.00	662	2.45E+09	155901	5.56E-03	93.5	2.25E-04	3.8	1.59E-04	2.7
Taiwan	None														
Thailand	None														
Aleutians (U.S.)	07-Mar-00	25	7.6	3.57E-05	52.00	177.00	3464	1.91E+09	0	3.34E-05	93.5	1.35E-06	3.8	9.53E-07	2.7
Alaska (U.S.)	14-Nov-00	5	1.5	2.90E-17	55.00	198.00	4801	1.78E+09	46	2.71E-17	93.5	1.10E-18	3.8	7.74E-19	2.7
Vietnam	None														

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.

** The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 39. UNSCEAR Maximum Regional Dose Commitments Compared to Reference Limits [17]

	PRS*						VRS*					
	Cs-137		Sr-90		I-131		Cs-137		Sr-90		I-131	
Criterion	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**
<0.15 mSv	135	41.4	219	67.2	323	99.1	125	38.0	220	66.9	324	98.48
<1.0 mSv	155	47.5	100	30.7	3	0.9	173	52.6	104	31.6	5	1.52
<10.0 mSv	36	11.0	7	2.1	0	0.0	31	9.4	5	1.5	0	0.00
<100.0 mSv	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.00
>100.0 mSv	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.00
Total	326	100.0	326	100.0	326	100.0	329	100.0	329	100.0	329	100.00

* As stated above, there were complete data (i.e., all 144 hours) for 326 and 329 out of 366 days of CY2000 for the PRS and VRS, respectively.

Table 40. UNSCEAR Maximum Transboundary Dose Commitments Compared to Reference Limits [17]

	PRS*						VRS*					
	Cs-137		Sr-90		I-131		Cs-137		Sr-90		I-131	
Criterion	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**
<0.15 mSv	325	99.7	326	100.0	326	100.0	202	61.4	295	89.7	329	100.00
<1.0 mSv	1	0.3	0	0.0	0	0.0	126	38.3	34	10.3	0	0.00
<10.0 mSv	0	0.0	0	0.0	0	0.0	1	0.3	0	0.0	0	0.00
<100.0 mSv	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.00
>100.0 mSv	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.00
Total	326	100	326	100.0	326	100.0	329	100.0	329	100.0	329	100.00

* As stated above, there were complete data (i.e., all 144 hours) for 326 and 329 out of 366 days of CY2000 for the PRS and VRS, respectively.

Table 41. PRS UNSCEAR Cs-137 Maximum Collective Dose Estimates for Threshold Values of 0.0, 0.1 and 0.15 mSv

	No Threshold						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	1-Jan	2.98E+02	1.08E+02	2.16E-01	1.90E+02	1.89E+12	1.38E+08
Transboundary*	1-Jan	2.76E+02	9.99E+01	2.00E-01	1.76E+02	1.02E+12	1.34E+08
Burma	None						
China	4-Jan	6.96E+01	2.52E+01	5.04E-02	4.44E+01	1.48E+12	1.13E+08
Hong Kong	None						
Japan	1-Jan	2.76E+02	9.99E+01	2.00E-01	1.76E+02	4.28E+11	9.75E+07
Laos	None						
Mongolia	4-Jan	1.59E-01	5.76E-02	1.15E-04	1.02E-01	3.11E+11	3.43E+05
N. Korea	7-Jan	8.47E+00	3.06E+00	6.13E-03	5.40E+00	1.72E+11	2.63E+07
Russia	14-Jun	8.63E+01	3.12E+01	6.24E-02	5.50E+01	1.76E+12	9.98E+05
S. Korea	5-Jan	9.75E+00	3.52E+00	7.05E-03	6.22E+00	1.52E+11	4.48E+07
Taiwan	None						
Thailand	None						
Aleutians (U.S.)	24-Jan	2.21E-01	8.00E-02	1.60E-04	1.41E-01	5.29E+10	5.47E+03
Alaska (U.S.)	13-Oct	1.48E+01	5.37E+00	1.07E-02	9.46E+00	9.93E+11	4.61E+05
Vietnam	None						

	Threshold of 0.1 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	14-Jun	8.28E+01	2.99E+01	5.99E-02	5.28E+01	1.22E+11	1.17E+05
Transboundary*	24-Jan	1.47E-01	5.31E-02	1.06E-04	9.37E-02	7.60E+09	1.38E+03
Burma	None						
China	None						
Hong Kong	None						
Japan	None						
Laos	None						
Mongolia	None						
N. Korea	None						
Russia	14-Jun	8.28E+01	2.99E+01	5.99E-02	5.28E+01	1.22E+11	1.17E+05
S. Korea	None						
Taiwan	None						
Thailand	None						
Aleutians (U.S.)	24-Jan	1.47E-01	5.31E-02	1.06E-04	9.37E-02	7.60E+09	1.38E+03
Alaska (U.S.)	18-Feb	7.45E-02	2.69E-02	5.39E-05	4.75E-02	1.12E+10	5.86E+02
Vietnam	None						

	Threshold of 0.15 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	14-Jun	8.21E+01	2.97E+01	5.94E-02	5.24E+01	1.16E+11	1.11E+05
Transboundary*	18-Feb	1.66E-02	6.00E-03	1.20E-05	1.06E-02	4.85E+09	1.00E+02
Burma	None						
China	None						
Hong Kong	None						
Japan	None						
Laos	None						
Mongolia	None						
N. Korea	None						
Russia	14-Jun	8.21E+01	2.97E+01	5.94E-02	5.24E+01	1.16E+11	1.11E+05
S. Korea	None						
Taiwan	None						
Thailand	None						
Aleutians (U.S.)	None						
Alaska (U.S.)	18-Feb	1.66E-02	6.00E-03	1.20E-05	1.06E-02	4.85E+09	1.00E+02
Vietnam	None						

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 42. PRS UNSCEAR Cs-137 Maximum Collective Dose Estimates for Threshold Values of 1.0 and 10.0 mSv

	Threshold of 1.0 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	21-Mar	6.00E+01	2.17E+01	4.34E-02	3.82E+01	3.41E+10	2.81E+04
Transboundary*	None						
Burma	None						
China	None						
Hong Kong	None						
Japan	None						
Laos	None						
Mongolia	None						
N. Korea	None						
Russia	21-Mar	6.00E+01	2.17E+01	4.34E-02	3.82E+01	3.41E+10	2.81E+04
S. Korea	None						
Taiwan	None						
Thailand	None						
Aleutians (U.S.)	None						
Alaska (U.S.)	None						
Vietnam	None						

Threshold of 10.0 mSv per person						
Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
No dose commitments at this threshold value						

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 43. PRS UNSCEAR Sr-90 Maximum Collective Dose Estimates for Threshold Values of 0.0, 0.1 and 0.15 mSv

	No Threshold							Threshold of 0.1 mSv per person							Threshold of 0.15 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	1-Jan	1.27E+02	1.17E+02	1.03E+01		1.23E+12	1.19E+08	14-Jun	3.47E+01	3.19E+01	2.82E+00		1.01E+11	9.62E+04	14-Jun	3.22E+01	2.96E+01	2.62E+00		7.94E+10	7.52E+04
Transboundary*	1-Jan	1.19E+02	1.09E+02	9.64E+00		7.23E+11	1.16E+08	None							None						
Burma	None							None							None						
China	7-Jan	2.78E+01	2.56E+01	2.26E+00		1.03E+12	7.61E+07	None							None						
Hong Kong	None							None							None						
Japan	1-Jan	1.19E+02	1.09E+02	9.63E+00		4.28E+11	9.75E+07	None							None						
Laos	None							None							None						
Mongolia	4-Jan	5.98E-02	5.50E-02	4.86E-03		3.11E+11	3.43E+05	None							None						
N. Korea	7-Jan	3.38E+00	3.10E+00	2.74E-01		1.27E+11	1.42E+07	None							None						
Russia	14-Jun	3.76E+01	3.46E+01	3.06E+00		1.73E+12	9.94E+05	14-Jun	3.47E+01	3.19E+01	2.82E+00		1.01E+11	9.62E+04	14-Jun	3.22E+01	2.96E+01	2.62E+00		7.94E+10	7.52E+04
S. Korea	5-Jan	1.78E+00	1.63E+00	1.45E-01		1.49E+11	4.48E+07	None							None						
Taiwan	None							None							None						
Thailand	None							None							None						
Aleutians (U.S.)	24-Jan	8.15E-02	7.49E-02	6.63E-03		5.29E+10	5.47E+03	None							None						
Alaska (U.S.)	13-Oct	5.20E+00	4.77E+00	4.22E-01		8.69E+11	4.54E+05	None							None						
Vietnam	None							None							None						

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 44. PRS UNSCEAR Sr-90 Maximum Collective Dose Estimates for Threshold Values of 1.0 and 10.0 mSv

	Threshold of 1.0 mSv per person							Threshold of 10.0 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	21-Mar	6.00E+01	2.17E+01	4.34E-02	3.82E+01	3.41E+10	2.81E+04	**No dose commitments at this threshold value**						
Transboundary*	None													
Burma	None													
China	None													
Hong Kong	None													
Japan	None													
Laos	None													
Mongolia	None													
N. Korea	None													
Russia	21-Mar	6.00E+01	2.17E+01	4.34E-02	3.82E+01	3.41E+10	2.81E+04							
S. Korea	None													
Taiwan	None													
Thailand	None													
Aleutians (U.S.)	None													
Alaska (U.S.)	None													
Vietnam	None													

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 45. PRS UNSCEAR I-131 Maximum Collective Dose Estimates for Threshold Values of 0.0, 0.1 and 0.15 mSv

	No Threshold							Threshold of 0.1 mSv per person							Threshold of 0.15 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	14-Jun	3.78E+00	3.54E+00	1.43E-01	1.01E-01	2.99E+11	2.54E+05	9-Feb	1.28E+00	1.20E+00	4.84E-02	3.42E-02	9.45E+09	9.73E+03	9-Feb	3.48E-01	3.25E-01	1.32E-02	9.29E-03	1.89E+09	1.94E+03
Transboundary**	1-Jan	7.46E-02	6.98E-02	2.83E-03	1.99E-03	8.04E+10	3.63E+06	None							None						
Burma	None							None							None						
China	4-Dec	4.08E-08	3.81E-08	1.54E-09	1.09E-09	5.62E+11	2.16E+07	None							None						
Hong Kong	None							None							None						
Japan	1-Jan	7.46E-02	6.98E-02	2.83E-03	1.99E-03	8.04E+10	3.63E+06	None							None						
Laos	None							None							None						
Mongolia	None							None							None						
N. Korea	None							None							None						
Russia	14-Jun	3.78E+00	3.54E+00	1.43E-01	1.01E-01	2.99E+11	2.54E+05	9-Feb	1.28E+00	1.20E+00	4.84E-02	3.42E-02	9.45E+09	9.73E+03	9-Feb	3.48E-01	3.25E-01	1.32E-02	9.29E-03	1.89E+09	1.94E+03
S. Korea	None							None							None						
Taiwan	None							None							None						
Thailand	None							None							None						
Aleutians (U.S.)	20-Jan	2.49E-03	2.33E-03	9.43E-05	6.66E-05	5.29E+10	5.47E+03	None							None						
Alaska (U.S.)	12-Oct	7.10E-05	6.64E-05	2.69E-06	1.90E-06	5.47E+10	3.10E+03	None							None						
Vietnam	None							None							None						

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 46. PRS UNSCEAR I-131 Maximum Collective Dose Estimates for Threshold Values of 1.0 and 10.0 mSv

	Threshold of 1.0 mSv per person							Threshold of 10.0 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional														
Transboundary**														
Burma														
China														
Hong Kong														
Japan														
Laos														
Mongolia	**No dose commitments at this threshold value**							**No dose commitments at this threshold value**						
N. Korea														
Russia														
S. Korea														
Taiwan														
Thailand														
Aleutians (U.S.)														
Alaska (U.S.)														
Vietnam														

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 47. VRS UNSCEAR Cs-137 Maximum Collective Dose Estimates for Threshold Values of 0.0, 0.1 and 0.15 mSv

	No Threshold						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	21-Nov	8.23E+03	2.97E+03	5.95E+00	5.25E+03	2.10E+12	2.70E+08
Transboundary**	21-Nov	8.22E+03	2.97E+03	5.94E+00	5.24E+03	1.21E+12	2.69E+08
Burma	None						
China	9-May	7.21E+03	2.61E+03	5.21E+00	4.60E+03	1.71E+12	2.17E+08
Hong Kong	12-Sep	1.59E+00	5.75E-01	1.15E-03	1.01E+00	5.70E+09	5.42E+06
Japan	21-Nov	7.99E+03	2.89E+03	5.78E+00	5.09E+03	6.37E+11	1.25E+08
Laos	None						
Mongolia	10-May	1.35E+00	4.88E-01	9.75E-04	8.60E-01	4.06E+11	4.77E+05
N. Korea	12-Sep	2.09E+03	7.56E+02	1.51E+00	1.33E+03	1.84E+11	2.76E+07
Russia	2-Aug	1.36E+03	4.91E+02	9.81E-01	8.65E+02	6.64E+11	6.09E+06
S. Korea	27-Sep	2.05E+03	7.41E+02	1.48E+00	1.31E+03	1.52E+11	4.48E+07
Taiwan	29-Nov	2.67E+02	9.66E+01	1.93E-01	1.70E+02	6.49E+10	2.17E+07
Thailand	None						
Aleutians (U.S.)	6-Mar	1.39E-02	5.04E-03	1.01E-05	8.89E-03	5.29E+10	5.47E+03
Alaska (U.S.)	24-Mar	1.54E+00	5.58E-01	1.12E-03	9.84E-01	1.01E+12	4.66E+05
Vietnam	29-Nov	6.07E-09	2.20E-09	4.39E-12	3.87E-09	2.89E+09	1.39E+04

	Threshold of 0.1 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	30-Jan	5.40E+03	1.95E+03	3.91E+00	3.44E+03	6.52E+10	3.58E+07
Transboundary**	30-Jan	5.40E+03	1.95E+03	3.91E+00	3.44E+03	6.52E+10	3.58E+07
Burma	None						
China	9-May	3.95E+03	1.43E+03	2.85E+00	2.52E+03	1.63E+11	3.01E+07
Hong Kong	None						
Japan	30-Jan	5.40E+03	1.95E+03	3.91E+00	3.44E+03	6.52E+10	3.58E+07
Laos	None						
Mongolia	None						
N. Korea	7-Jun	1.49E+03	5.39E+02	1.08E+00	9.50E+02	6.02E+10	5.28E+06
Russia	2-Aug	1.26E+03	4.57E+02	9.15E-01	8.07E+02	1.53E+11	1.77E+06
S. Korea	11-Jan	2.46E+02	8.91E+01	1.78E-01	1.57E+02	2.68E+10	2.01E+06
Taiwan	None						
Thailand	None						
Aleutians (U.S.)	None						
Alaska (U.S.)	None						
Vietnam	None						

	Threshold of 0.15 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	30-Jan	3.04E+03	1.10E+03	2.20E+00	1.94E+03	3.51E+10	1.55E+07
Transboundary**	30-Jan	3.04E+03	1.10E+03	2.20E+00	1.94E+03	3.51E+10	1.55E+07
Burma	None						
China	30-Aug	2.02E+03	7.30E+02	1.46E+00	1.29E+03	9.88E+10	9.98E+06
Hong Kong	None						
Japan	30-Jan	3.04E+03	1.10E+03	2.20E+00	1.94E+03	3.51E+10	1.55E+07
Laos	None						
Mongolia	None						
N. Korea	7-Jun	1.36E+03	4.90E+02	9.80E-01	8.64E+02	5.08E+10	4.19E+06
Russia	2-Aug	1.21E+03	4.38E+02	8.76E-01	7.72E+02	1.04E+11	1.33E+06
S. Korea	11-Jan	6.95E+01	2.51E+01	5.03E-02	4.43E+01	4.87E+09	4.48E+05
Taiwan	None						
Thailand	None						
Aleutians (U.S.)	None						
Alaska (U.S.)	None						
Vietnam	None						

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 48. VRS UNSCEAR Cs-137 Maximum Collective Dose Estimates for Threshold Values of 1.0 and 10.0 mSv

	Threshold of 1.0 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	2-Aug	9.47E+02	3.42E+02	6.85E-01	6.04E+02	3.13E+10	4.61E+05
Transboundary**	7-Jun	4.48E+01	1.62E+01	3.24E-02	2.85E+01	2.25E+09	4.25E+04
Burma	None						
China	7-Jun	4.48E+01	1.62E+01	3.24E-02	2.85E+01	2.25E+09	4.25E+04
Hong Kong	None						
Japan	None						
Laos	None						
Mongolia	None						
N. Korea	None						
Russia	2-Aug	9.47E+02	3.42E+02	6.85E-01	6.04E+02	3.13E+10	4.61E+05
S. Korea	None						
Taiwan	None						
Thailand	None						
Aleutians (U.S.)	None						
Alaska (U.S.)	None						
Vietnam	None						

Threshold of 10.0 mSv per person						
Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
No dose commitments at this threshold value						

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 49. VRS UNSCEAR Sr-90 Maximum Collective Dose Estimates for Threshold Values of 0.0, 0.1 and 0.15 mSv

	No Threshold							Threshold of 0.1 mSv per person							Threshold of 0.15 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	21-Nov	3.33E+03	3.06E+03	2.70E+02		1.84E+12	2.40E+08	7-Jun	7.39E+02	6.79E+02	6.01E+01		9.27E+10	4.07E+06	7-Jun	5.92E+02	5.44E+02	4.81E+01		7.01E+10	2.93E+06
Transboundary**	21-Nov	3.32E+03	3.05E+03	2.70E+02		1.10E+12	2.39E+08	7-Nov	7.04E+02	6.46E+02	5.72E+01		2.50E+10	5.03E+06	7-Jun	4.87E+02	4.47E+02	3.96E+01		4.09E+10	2.54E+06
Burma	None							None							None						
China	9-May	2.93E+03	2.69E+03	2.38E+02		1.55E+12	1.91E+08	26-Aug	4.50E+02	4.13E+02	3.66E+01		3.51E+10	3.18E+06	7-Jun	3.02E+02	2.78E+02	2.46E+01		3.17E+10	1.50E+06
Hong Kong	29-Nov	3.72E-04	3.42E-04	3.02E-05		5.70E+09	5.42E+06	None							None						
Japan	21-Nov	3.28E+03	3.01E+03	2.67E+02		6.28E+11	1.25E+08	7-Nov	7.04E+02	6.46E+02	5.72E+01		2.50E+10	5.03E+06	16-Dec	2.56E+02	2.35E+02	2.08E+01		1.18E+10	1.31E+06
Laos	None							None							None						
Mongolia	10-May	4.74E-01	4.36E-01	3.86E-02		3.86E+11	4.43E+05	None							None						
N. Korea	12-Sep	8.68E+02	7.98E+02	7.06E+01		1.84E+11	2.76E+07	7-Jun	4.47E+02	4.11E+02	3.63E+01		3.22E+10	2.72E+06	7-Jun	3.44E+02	3.16E+02	2.80E+01		2.06E+10	1.93E+06
Russia	2-Aug	5.63E+02	5.17E+02	4.58E+01		6.64E+11	6.09E+06	2-Aug	4.64E+02	4.27E+02	3.77E+01		5.13E+10	7.39E+05	2-Aug	4.51E+02	4.14E+02	3.67E+01		4.48E+10	6.19E+05
S. Korea	27-Sep	8.53E+02	7.84E+02	6.93E+01		1.52E+11	4.48E+07	None							None						
Taiwan	29-Nov	1.13E+02	1.04E+02	9.18E+00		6.49E+10	2.17E+07	None							None						
Thailand	None							None							None						
Aleutians (U.S.)	6-Mar	3.29E-03	3.02E-03	2.67E-04		5.29E+10	5.47E+03	None							None						
Alaska (U.S.)	25-Mar	8.66E-02	7.96E-02	7.04E-03		8.62E+11	3.78E+05	None							None						
Vietnam	29-Nov	3.46E-13	3.18E-13	2.81E-14		2.89E+09	1.39E+04	None							None						

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 50. VRS UNSCEAR Sr-90 Maximum Collective Dose Estimates for Threshold Values of 1.0 and 10.0 mSv

	Threshold of 1.0 mSv per person							Threshold of 10.0 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	2-Aug	2.11E+02	1.94E+02	1.72E+01		1.12E+10	1.69E+05	No dose commitments at this threshold value						
Transboundary**	None													
Burma	None													
China	None													
Hong Kong	None													
Japan	None													
Laos	None													
Mongolia	None													
N. Korea	None													
Russia	2-Aug	2.11E+02	1.94E+02	1.72E+01		1.12E+10	1.69E+05							
S. Korea	None													
Taiwan	None													
Thailand	None													
Aleutians (U.S.)	None													
Alaska (U.S.)	None													
Vietnam	None													

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 51. VRS UNSCEAR I-131 Maximum Collective Dose Estimates for Threshold Values of 0.0, 0.1 and 0.15 mSv

	No Threshold							Threshold of 0.1 mSv per person							Threshold of 0.15 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	30-Jan	2.06E+02	1.92E+02	7.79E+00	5.50E+00	2.37E+11	8.58E+07	12-Jun	4.57E+01	4.28E+01	1.73E+00	1.22E+00	2.02E+10	2.93E+05	12-Jun	3.16E+01	2.96E+01	1.20E+00	8.44E-01	1.12E+10	1.69E+05
Transboundary**	30-Jan	2.06E+02	1.92E+02	7.79E+00	5.50E+00	2.25E+11	8.57E+07	None							None						
Burma	None							None							None						
China	10-May	1.76E+02	1.65E+02	6.68E+00	4.71E+00	8.68E+11	1.04E+08	None							None						
Hong Kong	None							None							None						
Japan	30-Jan	2.06E+02	1.92E+02	7.79E+00	5.50E+00	2.25E+11	8.57E+07	None							None						
Laos	None							None							None						
Mongolia	21-Apr	1.13E-07	1.06E-07	4.29E-09	3.03E-09	1.48E+10	4.92E+04	None							None						
N. Korea	14-Sep	9.12E+01	8.53E+01	3.45E+00	2.44E+00	1.84E+11	2.76E+07	None							None						
Russia	12-Jun	6.68E+01	6.25E+01	2.53E+00	1.78E+00	3.06E+11	4.29E+06	12-Jun	4.57E+01	4.28E+01	1.73E+00	1.22E+00	2.02E+10	2.93E+05	12-Jun	3.16E+01	2.96E+01	1.20E+00	8.44E-01	1.12E+10	1.69E+05
S. Korea	15-Sep	9.82E+01	9.18E+01	3.72E+00	2.62E+00	1.47E+11	4.48E+07	None							None						
Taiwan	None							None							None						
Thailand	None							None							None						
Aleutians (U.S.)	14-Nov	4.74E-07	4.44E-07	1.80E-08	1.27E-08	4.73E+10	5.47E+03	None							None						
Alaska (U.S.)	14-Nov	4.95E-18	4.63E-18	1.88E-19	1.32E-19	3.66E+10	2.16E+03	None							None						
Vietnam	None							None							None						

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 52. VRS UNSCEAR I-131 Maximum Collective Dose Estimates for Threshold Values of 1.0 and 10.0 mSv

	Threshold of 1.0 mSv per person							Threshold of 10.0 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional														
Transboundary**														
Burma														
China														
Hong Kong														
Japan														
Laos														
Mongolia	No dose commitments at this							No dose commitments at this						
N. Korea	threshold value							threshold value						
Russia														
S. Korea														
Taiwan														
Thailand														
Aleutians (U.S.)														
Alaska (U.S.)														
Vietnam														

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 53. Isotopic Inventories for Nuclear Submarines and Major Facilities Pertinent to the PRS and VRS

	Inventory (Bq)				
Name	Cs-137	Sr-90	Site(s)	Ref.	Description
Reference NS*	$4.9x10^{15}$	$4.15x10^{15}$	PRS, VRS	28	Typical NS reactor core 3 years after shutdown assuming 42 GWd burnup.
NS K-541 NS K-541x2	$5.73x10^{14}$ $1.23x10^{13}$ $5.85x10^{14}$	$5.39x10^{14}$ $1.20x10^{13}$ $5.51x10^{14}$	PRS, VRS	29,30	Starboard reactor Port (Damaged) reactor Total Activity
NS K-610 NS K-610x2	$1.04x10^{15}$ $1.04x10^{15}$ $2.08x10^{15}$	$9.47x10^{14}$ $9.47x10^{14}$ $1.89x10^{15}$	PRS, VRS	29,30	Starboard reactor Port (Damaged) reactor Total Activity
PM-32	$8.00x10^{14}$ $1.20x10^{15}$	$7.62x10^{14}$ $1.10x10^{15}$	PRS	29 30	126 SFA's* of different cores from 1st generation NS [30]
PM-74**	$1.12x10^{16}$ $1.48x10^{16}$	$1.04x10^{16}$ $1.37x10^{16}$	VRS	29 30	2 1st gen. cores (10 GWd) and 4 2nd gen. core (20 GWd). 1368 SFA's [30]
PM-80	$1.14x10^{15}$ $2.19x10^{14}$	$1.09x10^{15}$ $2.01x10^{14}$	VRS	29 30	113 SFA's*** of different cores from 1st generation NS [29] 23 SFA's* of different cores from 1st generation NS [30]
PM-125	$4.83x10^{15}$ $1.90x10^{15}$	$4.50x10^{15}$ $1.90x10^{15}$	VRS	29 30	2 1st gen. cores (10 GWd). 360 SFA's* [30]
PM-133	$4.83x10^{15}$ $4.45x10^{15}$	$4.50x10^{15}$ $4.13x10^{15}$	VRS	29 30	2 2nd gen. cores (20 GWd). 560 SFA's* [30]
Storage Site 11	$3.74x10^{15}$[29] $3.98x10^{15}$[30]	$3.48x10^{15}$[29] $3.70x10^{15}$[30]	VRS	31,32	Total activity is $8.14x10^{15}$ Bq. PM-74 isotopic concentrations**.
Storage Site 30	$6.07x10^{16}$[29] $6.47x10^{16}$[30]	$5.64x10^{16}$[29] $6.02x10^{16}$[30]	VRS	31,32	Total activity is $1.32x10^{17}$ Bq. PM-74 isotopic concentrations**.
Storage Site 7	$1.70x10^{15}$[29] $1.81x10^{15}$[30]	$1.58x10^{15}$[29] $1.68x10^{15}$[30]	VRS	29,31 32	Total activity is $3.70x10^{15}$ Bq. PM-74 isotopic concentrations**.
Storage Site 31	$9.93x10^{14}$[29] $1.06x10^{15}$[30]	$9.22x10^{14}$[29] $9.82x10^{14}$[30]	VRS	29,31 32	Total activity is $2.16x10^{15}$ Bq. PM-74 isotopic concentrations**.
Transport Cask†	$8.37x10^{14}$	$7.17x10^{14}$	VRS	28,32	Ref. NS core with 287 SFA's* [32] 49 assemblies per TUK-18 [32]
RadLeg NS*	$0.4x10^{15}$	$0.4x10^{15}$	PRS, VRS	33	2 years after shutdown. No GWd given.
NATO NS5*,††	$3.40x10^{15}$	$3.40x10^{15}$	PRS, VRS	34	NS reactor core after 31 GWd followed by a 5-y cooling period after shutdown.

* Nuclear Submarine (NS) and spent fuel assembly (SFA). Most first and second generation NS's have two reactors and thus the inventory would be twice that shown.

** Note that the total activity for the PM-74 is between $2.44x10^{16}$ [29] and $3.02x10^{16}$ [30]. Thus, of the total, 46.0 to 48.9% is Cs-137 and 42.7 to 45.5% is Sr-90 [29,30]. The PM-74 values are used for Buildings 11 and 30 and Constructions 7 and 31 per Reference 32.

*** The number of fuel assemblies representing the PM-80 inventory provided in Reference 29 was not obvious from the information provided. From inspection of the total inventory and other information provided in Reference 30, the number of spent fuel assemblies appears to be 113; this is the value used in these computations.

† For this study, the transport cask is assumed to be a fully loaded type TUK-18 cask holding 49 SFA's [32]. The values in the table are based upon the Reference NS [28] with a core of 287 SFA's [32].

†† Inventories are also provided in Reference 34 for 0 and 1 year cooling periods after shutdown (for a burnup of 31 GWd). These are $3.8x10^{15}$ and $3.7x10^{15}$ Bq for both Cs-137 and Sr-90 for 0 and 1 year, respectively. A value of $6.2x10^{16}$ Bq is given for I-131 for the same conditions without cooling.

Table 54. Cs-137 and Sr-90 Inventories (in Bq) by Spent Fuel Assembly (SFA)

	Inventory (Bq)				SFA*		Inventory / SFA (Bq)	
Name	Cs-137	Sr-90	Site(s)	Ref.	Type	No.	Cs-137	Sr-90
Reference NS*	$4.90x10^{15}$	$4.15x10^{15}$	PRS, VRS	28	Unknown	287	$1.71x10^{13}$	$1.45x10^{13}$
NS K-541 (starboard)	$5.73x10^{14}$	$5.39x10^{14}$	PRS, VRS	29,30	Unknown	287	$2.00x10^{12}$	$1.88x10^{12}$
NS K-541 (port)	$1.23x10^{13}$	$1.20x10^{13}$	PRS, VRS	29,30	Unknown	287	$4.29x10^{10}$	$4.18x10^{10}$
NS K-610 (starboard)	$1.04x10^{15}$	$9.47x10^{14}$	PRS, VRS	29,30	Unknown	287	$3.62x10^{12}$	$3.30x10^{12}$
NS K-610 (port)	$1.04x10^{15}$	$9.47x10^{14}$	PRS, VRS	29,30	Unknown	287	$3.62x10^{12}$	$3.30x10^{12}$
PM-32	$8.00x10^{14}$	$7.62x10^{14}$	PRS	29	1st gen. only	126	$6.35x10^{12}$	$6.05x10^{12}$
	$1.20x10^{15}$	$1.10x10^{15}$	PRS	30	1st gen. only	126	$9.52x10^{12}$	$8.73x10^{12}$
PM-74	$1.12x10^{16}$	$1.04x10^{16}$	VRS	29	1st and 2nd gen.	1368	$8.19x10^{12}$	$7.60x10^{12}$
	$1.48x10^{16}$	$1.37x10^{16}$	VRS	30	1st and 2nd gen.	1368	$1.08x10^{13}$	$1.00x10^{13}$
PM-80	$1.14x10^{15}$	$1.09x10^{15}$	VRS	29	1st gen. only	113**	$1.01x10^{13}$	$9.65x10^{12}$
	$2.19x10^{14}$	$2.01x10^{14}$	VRS	30	1st gen. only	23	$9.52x10^{12}$	$8.74x10^{12}$
PM-125	$4.83x10^{15}$	$4.50x10^{15}$	VRS	29	1st gen. only	360	$1.34x10^{13}$	$1.25x10^{13}$
	$1.90x10^{15}$	$1.90x10^{15}$	VRS	30	1st gen. only	360	$5.28x10^{12}$	$5.28x10^{12}$
PM-133	$4.83x10^{15}$	$4.50x10^{15}$	VRS	29	2nd gen. only	560	$8.63x10^{12}$	$8.04x10^{12}$
	$4.45x10^{15}$	$4.13x10^{15}$	VRS	30	2nd gen. only	560	$7.95x10^{12}$	$7.38x10^{12}$
RadLeg NS	$4.00x10^{14}$	$4.00x10^{14}$	PRS, VRS	33	Unknown	287	$1.39x10^{12}$	$1.39x10^{12}$
NATO NS5	$3.40x10^{15}$	$3.40x10^{15}$	PRS, VRS	34	Unknown	287	$1.18x10^{13}$	$1.18x10^{13}$
NATO NS1	$3.70x10^{15}$	$3.70x10^{15}$	PRS, VRS	34	Unknown	287	$1.29x10^{13}$	$1.29x10^{13}$
NATO NS0	$3.80x10^{15}$	$3.80x10^{15}$	PRS, VRS	34	Unknown	287	$1.32x10^{13}$	$1.32x10^{13}$
Overall Minimum	$1.23x10^{13}$	$1.20x10^{13}$	PRS	---	Minimum	---	$4.29x10^{10}$	$4.18x10^{10}$
Overall Mean	$1.90x10^{15}$	$1.80x10^{15}$	PRS	---	Mean	---	$7.42x10^{12}$	$7.01x10^{12}$
Overall Median	$1.04x10^{15}$	$9.47x10^{14}$	PRS	---	Median	---	$6.35x10^{12}$	$6.05x10^{12}$
Overall Maximum	$4.90x10^{15}$	$4.15x10^{15}$	PRS	---	Maximum	---	$1.71x10^{13}$	$1.45x10^{13}$
Overall Minimum	$1.23x10^{13}$	$1.20x10^{13}$	VRS	---	Minimum	---	$4.29x10^{10}$	$4.18x10^{10}$
Overall Mean	$3.66x10^{15}$	$3.43x10^{15}$	VRS	---	Mean	---	$8.21x10^{12}$	$7.74x10^{12}$
Overall Median	$3.40x10^{15}$	$3.40x10^{15}$	VRS	---	Median	---	$8.63x10^{12}$	$8.04x10^{12}$
Overall Maximum	$1.48x10^{16}$	$1.37x10^{16}$	VRS	---	Maximum	---	$4.96x10^{13}$	$4.74x10^{13}$

* Spent fuel assemblies (SFA) and nuclear submarine (NS). The number of fuel assemblies per core for the nuclear submarines was not available; thus a value of 287 fuel assemblies per NS core [32] was used.

** The number of fuel assemblies representing the PM-80 inventory provided in Reference 29 was not obvious from the information given. From inspection of the total inventory and other information provided in Reference 30, the number of spent fuel assemblies appears to be 113; this is the value used in these computations.

Table 55. Range of Inventories (Bq) Pertinent to PRS and VRS*

Site	Name	SFA	Cs-137	Ratio**	Sr-90	Ratio**	I-131***	Ratio**
PRS	NS Minimum	180	$7.71x10^{12}$	$8.9x10^{-3}$	$7.53x10^{12}$	$8.7x10^{-3}$	$1.30x10^{10}$	$1.50x10^{-5}$
PRS	NS Median	230	$8.33x10^{14}$	0.96	$7.59x10^{14}$	0.88	$1.45x10^{11}$	$1.68x10^{-4}$
PRS	NS Maximum	287	$4.90x10^{15}$	5.67	$4.15x10^{15}$	4.80	$4.30x10^{12}$	$4.98x10^{-3}$
PRS	PM-32	126	$1.20x10^{15}$	1.39	$1.10x10^{15}$	1.27	---	---
VRS	NS Minimum	180	$7.71x10^{12}$	$8.9x10^{-3}$	$7.53x10^{12}$	$8.7x10^{-3}$	$1.30x10^{10}$	$1.50x10^{-5}$
VRS	NS Median	230	$8.33x10^{14}$	0.96	$7.59x10^{14}$	0.88	$1.45x10^{11}$	$1.68x10^{-4}$
VRS	NS Maximum	287	$4.90x10^{15}$	5.67	$4.15x10^{15}$	4.80	$4.30x10^{12}$	$4.98x10^{-3}$
VRS	Cask Maximum	49	$8.37x10^{14}$	0.97	$7.09x10^{14}$	0.82	---	---

* Spent fuel assemblies (SFA) and nuclear submarine (NS).

** Ratio of Inventory to the "unit hypothetical release" of $8.64x10^{14}$ Bq.

*** The values for I-131 are based upon the total number of fissions from a criticality accident.

Table 56. Atmospheric Release Fractions for Different Accident Scenarios*

	Release Fraction				
Name	**Cs-137**	**Sr-90**	**I-131**	**Ref.**	**Description**
High-Temperature Fire	0.9	$2x10^{-3}$	0.8	32,37	Severe criticality accident resulting in melting of fuel cladding with a consequent steam explosion. Self-sustaining cladding oxidation.
Low-Temperature Fire	10^{-6}–10^{-8}	10^{-8}	$3x10^{-3}$	32,37	Less severe accident in which fuel exposed to air but no cladding ignition.
Heated Spent Fuel	0.2	0.03	0.05	32,38 36	Alternative release terms based upon Department of Energy source.
Mechanical Destruction	0.05	0	0.05	32,36	Complete cladding failure leading to the release of the volatile material in gaps between the fuel matrix and cladding.
WASH-1400 Study	0.4–0.5	0.05–0.06	0.7	39	NUREG study of commercial U.S. nuclear reactor safety
Chernobyl	0.2–0.4	0.04–0.06	0.5–0.6	40	Evaluation of Chernobyl accident
Khlopkin/Kurchatov	0.01	0.002	0.01	41	Release fractions proposed by Kurchatov Institute
NATO	0.1	0.02	0.2	34	Values used in the NATO Study [34]
Lysenko Case A	10^{-3}–10^{-2}	10^{-3}–10^{-2}	---	28	Helicopter crash on NS during SNF removal
Lysenko Case B	10^{-4}–10^{-3}	10^{-4}–10^{-3}	---	28	Airplane crash on shore storage of SNF
Minimum	$1x10^{-8}$	$1x10^{-8}$	$3x10^{-3}$	---	Minimum including endpoints of ranges
Median	0.075	0.0125	0.125	---	Median using midpoints of ranges
Maximum	0.9	0.06	0.8	---	Maximum including endpoints of ranges

* Spent nuclear fuel (SNF) and nuclear submarine (NS).

Table 57. Possible Environmental Source Terms, A_0, (in Bq) for PRS and VRS*

Site	Name	Cs-137	Ratio**	Sr-90	Ratio**	I-131	Ratio**
PRS	NS Minimum	$7.71x10^{4}$	$8.9x10^{-11}$	$7.53x10^{4}$	$8.7x10^{-11}$	$3.90x10^{7}$	$5x10^{-8}$
	NS Median	$1.26x10^{14}$	0.15	$9.49x10^{12}$	0.01	$1.81x10^{10}$	$2x10^{-5}$
	NS Maximum	$4.41x10^{15}$	5.10	$2.49x10^{14}$	0.29	$3.44x10^{12}$	$4x10^{-3}$
	PM-32	$1.08x10^{15}$	1.25	$6.60x10^{13}$	0.08	---	---
VRS	NS Minimum	$7.71x10^{4}$	$8.9x10^{-11}$	$7.53x10^{14}$	$8.7x10^{-11}$	$3.90x10^{7}$	$5x10^{-8}$
	NS Median	$1.26x10^{14}$	0.15	$9.49x10^{12}$	0.01	$1.81x10^{10}$	$2x10^{-5}$
	NS Maximum	$4.41x10^{15}$	5.10	$2.49x10^{14}$	0.29	$3.44x10^{12}$	$4x10^{-3}$
	Cask Maximum	$7.53x10^{14}$	0.87	$4.25x10^{13}$	0.05	---	---

* Spent fuel assemblies (SFA) and nuclear submarine (NS).
** Ratio of Inventory to the "unit hypothetical release" of $8.64x10^{14}$ Bq.

Table 58. Design Basis for the P_{23} Transfer Coefficient in mBq a kg^{-1} per Bq m^{-2}

	Cs-137 P_{23}				Sr-90 P_{23}			
	UNSCEAR		Adjusted (10%)		UNSCEAR		Adjusted (10%)	
Pathway	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Milk products	5.7	8.8	5.13	9.68	2.6	4.9	2.34	5.39
Grain Products	8.9	26.6	8.01	29.26	4.1	17.2	3.69	18.92
Vegetables	1.8	4.4	1.62	4.84	0.4	4	0.36	4.4
Fruit	3.1	3.5	2.79	3.85	1	2.5	0.9	2.75
Meat	7.9	26.2	7.11	28.82	0.4	3	0.36	3.3

Table 59. 1993 UNSCEAR P_{34} Type Transfer Coefficients in kg a^{-1} (500 kg a^{-1} Consumption Rate Basis)

	Cs-137					Sr-90				
Pathway	**Argentina**	**Denmark**	**U.S.**	**Min**	**Max**	**Argentina**	**Denmark**	**U.S.**	**Min**	**Max**
Milk Products	130	175	165	130	175	130	175	155	130	175
Grain products	100	80	70	70	100	100	80	75	75	100
Vegetables	155	120	95	95	155	120	120	95	95	120
Fruit	80	50	85	50	85	100	50	75	50	100
Meat	40	75	85	40	85	40	75	95	40	95

Table 60. UNSCEAR 1982 Reference [42] **Annual Intake of Food (P_{34}) and Air (P_{14})**

	Food Consumption (kg a^{-1})		
Intake, P_{34}	**Adults***	**Children**	**Infants**
Milk products	105	110	120
Meat products	50	35	15
Grain products	140	90	45
Leafy vegetables	60	40	20
Roots and fruits	170	110	60
Fish products	25	10	5
Water and beverages	500	350	150
	Breathing Rate (m^3 a^{-1})		
Intake, P_{14}	**Adults***	**Children**	**Infants**
Air	8,000	5,500	1,400

* Considered to apply to both adults and 9-19 year olds.

Table 61. Trends in food available for consumption from 1962-96 for Asian countries grouped by income levels (annual quantity of food in kg/capita) [43]

		Year								1996	
Food group	**Level**	**1962**	**1967**	**1972**	**1977**	**1982**	**1987**	**1992**	**1996**	**Min***	**Max***
Milk products (Dairy Only)	High income	5.1	4.6	7	10.2	14.8	19.9	25.6	27.9	10.1	55
	Middle income	12.4	14.5	14.7	17.6	16.8	18.8	34.5	40.8		
	Small islands	9.5	12.6	15	14	14.2	14.5	16.3	16.7		
	Upper Low income	2.9	2.5	6.5	3.3	4.2	5.5	8.9	10.1		
	Lower low income	38.5	35.5	35.7	37.8	41.7	46.8	50.2	55		
Grain Products (Cereals and starchy roots)	High income	217.8	244.2	262.1	242.4	207.4	201	180.1	181.7	165.3	296
	Middle income	155.2	154.9	157	173.3	165.9	158.1	173.9	165.3		
	Small islands	343.8	341.2	333.2	323.3	316.9	311.8	300.3	296		
	Upper Low income	231	254.2	260.1	266.8	276.3	264.4	256.7	254.7		
	Lower low income	159.3	159.3	168.9	169.1	175.5	179.3	185.1	193		
Vegetables (Vegetables Only)	High income	70.4	84.4	97.1	168.7	171.2	160.5	167.6	169.5	46.3	169.5
	Middle income	47.6	47	48.7	47.6	47.6	45.6	45.3	48.5		
	Small islands	65.7	69.6	70.5	70	71.5	73	71.7	67.9		
	Upper Low income	59.1	42.2	36.7	38.2	47.8	71.8	88.6	123.2		
	Lower low income	32.5	35.3	37.5	38.8	41.1	43.8	44.4	46.3		
Fruit (Fruit Only)	High income	11.5	19.9	26.1	33.5	44.6	55.1	82.8	94.9	33.4	165.9
	Middle income	81.8	81	73.3	100	109.6	105.3	88	93.5		
	Small islands	176.3	179.5	181.7	181.1	176.6	168.6	173.6	165.9		
	Upper Low income	16.3	14.4	13.9	14.3	17.5	28	33.1	51.5		
	Lower low income	26.6	28.1	26	25.4	27	29.1	29.8	33.4		
Meat (Meat/Poultry)	High income	8.6	10.8	13.5	16.8	23.7	28.8	40.2	48.1	6.9	48.1
	Middle income	12.7	15.2	15	15.8	18.1	18.7	27.7	30.6		
	Small islands	15.9	17.8	20.9	22.8	22.9	25.5	27.9	27.3		
	Upper Low income	4.6	8.6	9.2	9.4	13.7	19.2	26.9	35.2		
	Lower low income	4.9	5	4.9	4.9	5.3	5.8	6.5	6.9		

* The minimum and maximum pertain to those for the 1996 values for a given food group.

Table 62. CY2000 Per Capita Food Supply in kg a^{-1} (adapted from UNFAO, 2000 [44])

	China	Japan	Mongolia	N. Korea	Russia	S. Korea	Thailand	U.S.	Vietnam	Min	Max
Milk Products	9.73	68.53	151.48	3.84	154.48	28.49	21.27	261.38	4.71	3.84	261.38
Grains	283.45	192.26	135.39	230.58	311.27	231.59	271.57	265.68	262.11	135.39	311.27
Vegetables	211.2	125.12	23.01	156.57	98.76	243.86	43.54	152.06	77.46	23.01	243.86
Fruits	43.05	51	54.75	54.75	37.25	68.46	124.79	124.79	47.67	37.25	124.79
Meat	55.43	48.72	112.58	10.31	50.71	52.27	26.15	129.48	27.17	10.31	129.48
Eggs	16.13	19.26	0.15	4.62	12.72	9.52	9.89	14.58	2.31	0.15	19.26
Fish, Seafood	25.03	64.76	0.05	8.22	19.87	51.4	28.66	21.39	19.21	0.05	64.76

Table 63. Food Consumption Rates by Individuals in kg a^{-1} [45]

Country	Milk	Grain	Leafy Vegetables	Fruit/ Vegetables	Meat	Total
USSR	332*	133	37	118	63	683
China	5*	229	29	173	30	466
Japan	50	193	30	180	120	573
United States	174	91	25	260	146	696
Minimum	50	91	25	118	30	466
Maximum	174	229	37	260	146	696

* Unusually high or low values indicated per Reference 45. Although the milk value is relatively close to that used in the UNSCEAR 1993 Report [13] for the calculation of the I-131 transfer factor.

Table 64. Recommended Consumption Values for Average Individual from NRC 1.109 [46]

Pathway	Infant	Child	Teen	Adult
Milk (L a^{-1})	---	170	200	110
Grain (kg a^{-1})	---	48	57.6	45.6
Vegetables (kg a^{-1})	---	108	129.6	102.6
Fruit (kg a^{-1})	---	44	52.8	41.8
Meat (kg a^{-1})	---	37	59	95
Total (kg a^{-1})*	---	407	499	395
Inhalation (m^3 a^{-1})	---	3700	8000	8000

* Using a milk specific gravity of 1.03.

Table 65. Recommended Consumption Values for Maximum Exposed Individual from NRC 1.109 [46]

Pathway	Infant	Child	Teen	Adult
Milk (L a^{-1})	330	330	400	310
Grain (kg a^{-1})	---	124.8	151.2	124.8
Vegetables (kg a^{-1})	---	306.8	382.2	344.8
Fruit (kg a^{-1})	---	114.4	138.6	114.4
Meat (kg a^{-1})	---	41	65	110
Total (kg a^{-1})*	339.9	926.9	1149	1013.3
Inhalation (m^3 a^{-1})	1400	3700	8000	8000

* Using a milk specific gravity of 1.03.

Table 66. Ranges of Consumption Rates in kg a^{-1}

Pathway	Min	Source	Max	Source
Milk products	3.84	Table 62	412	Table 65*
Grain Products	45	Table 60	311.3	Table 62
Vegetables	20	Table 60	382.2	Table 65
Fruit	33.4	Table 61	170	Table 60
Meat	6.9	Table 61	146	Table 63
Sum	109.14	N/A	1421.5	N/A

* NRC 1.109 value of 400 L a^{-1} for teens [46] converted to kg a^{-1} using a milk specific gravity of 1.03.

Table 67. Age-specific Consumption Values as They Relate to Adult Consumption Rates (%)

Pathway	Type	Infant*	Child	Teen
Milk (L a^{-1} or kg a^{-1})	Min	106.45	104.76	100.00**
	Max	366.67	200.00	181.82
Grain (kg a^{-1})	Min	28.93	57.14	100.00**
	Max	35.36	105.26	126.32
Vegetables (kg a^{-1})	Min	30.00	66.67	100.00**
	Max	36.67	105.26	126.32
Fruit (kg a^{-1})	Min	31.76	64.71	100.00**
	Max	38.82	105.26	126.32
Meat (kg a^{-1})	Min	27.00	37.27	59.09
	Max	33.00	70.00	100.00**

* Other than milk, only a single value was available. Therefore, an arbitrary 10% adjustment was made to provide a suitable range.

** The maximum or minimum was adjusted to be the same as that for adult consumption to provide a suitable range for study.

Table 68. Ingestion P_{34} Design Space (in kg a^{-1})

Pathway	Type	Ref.	Adult	Infant	Child	Teen
Milk	Min	Table 62	4.0	4.2	4.1	4.0
	Max	Table 65	319.3	1170.8	638.6	580.5
Grain	Min	Table 64	45.6	13.2	26.1	45.6
	Max	Table 62	311.3	110.1	327.7	393.2
Vegetables	Min	Table 62	23.0	6.9	15.3	23.0
	Max	Table 65	344.8	126.4	362.9	435.5
Fruit	Min	Table 61	33.4	10.6	21.6	33.4
	Max	Table 60	170.0	66.0	178.9	214.7
Meat	Min	Table 61	6.9	1.9	2.6	4.1
	Max	Table 63	146.0	48.2	102.2	146.0
Total	Min	N/a	112.9	36.8	69.7	110.0
	Max	N/a	1291.4	1521.4	1610.3	1770.0

Table 69. Exposure-to-Dose Conversion Factor, P_{45}, for Ingestion (Effective Committed Dose Equivalent per Unit Intake in nSv Bq^{-1})

Radio-nuclide	Source	Uptake Factor, f1	T(y)	3-mo	1-y	Infant Ave*	Child 5-y	Teen 15-y	Adult
Cs-137	UNSCEAR [13,20]	1E+0 I	50/70**	21	10	15.5	10	13	13
Cs-137	FGR-11 [27]	1.0	50	---	---	---	---	---	13.5
Cs-137	ICRP 72 [47]	1.000	70	21	12	16.5	9.6	13	13
Cs-137	NRC 1.109 [46]***	max	50	---	---	11.7	12.5	14.0	19.3
Sr-90	UNSCEAR [13,20]	3E-1 I	50/70**	260	120	190	74	30	28
Sr-90	FGR-11 [27]	$3\ 10^{-1}$	50	---	---	---	---	---	38.5
Sr-90	ICRP 72 [47]	0.300	70	230	73	151.5	47	80	28
Sr-90	NRC 1.109 [46]***	max	50	---	---	1273	1165	554	503
I-131	UNSCEAR [13,20]	1E+0 I	50/70**	240	180	210	110	29	22
I-131	FGR-11 [27]	1.0	50	---	---	---	---	---	14.4
I-131	ICRP 72 [47]	1.000	70	180	180	180	100	34	22
I-131	NRC 1.109 [46]***	max	50	---	---	5.0	2.7	1.2	0.92

* Average of the 3-mo and 1-y values.

** Dose integration period is to age 70 for infants and children and age 50 for adults. The P_{45} value given in Reference 13 for I-131 is 61 nSv Bq^{-1}, which was computed at a P_{34} value of 109.5 L a^{-1} of milk as shown in Equation 7.

*** Population considered to be comprised of infants (0-1 year), children (1-11 years), teenagers (11-17 years), and adults. Thus the infant category will be used for the 3-mo, 1-y and average values, the children category for 5-y, and the teenager for 15-y. The dose conversion factors are based on continuous intake for the "maximum individual" over a one-year exposure period and a dose commitment extending over a 50-year period from the initiation of intake [46].

Table 70. Selected Population Statistics (in %)

Ages	**UNSCEAR**[13]	**Alaska**[50]	**Japan**[51]	**S. Korea**[52]	Minimum	Maximum
0-1	2	3.0	1.8	2.4	1.8	3.0
1-9	16	13.2	7.5	11.3	7.5	16.0
9-19	20	17.0	10.8	14.0	10.8	20.0
Adult	62	66.8	79.9	72.3	62.0	79.9

Table 71. Extreme Vertex Design for the Population Data in Table 70

	Ages			
Vertex	0-1	1-9	9-19	Adult
e01	2.00	16.00	20.00	62.00
e02	3.00	15.00	20.00	62.00
e03	3.00	16.00	19.00	62.00
e04	1.80	7.50	10.80	79.90
e05	3.00	7.50	10.80	78.70
e06	1.80	16.00	10.80	71.40
e07	3.00	16.00	10.80	70.20
e08	1.80	7.50	20.00	70.70
e09	3.00	7.50	20.00	69.50
e10	1.80	16.00	20.00	62.20
centroid	2.42	12.50	16.22	68.86

Table 72. Ingestion P_{2345} Ranges for Cs-137 in nSv per Bq m^{-2}

P_{2345}	Infant		Child		Teen		Adult		Weighted	
Pathway	**Min**	**Max**	**Min**	**Max**	**Max**	**Max**	**Min**	**Max**	**Min**	**Max**
Milk products	0.28	187.00	0.20	83.45	0.27	75.86	0.27	41.73	0.26	58.23
Grain Products	1.37	53.16	2.01	129.44	4.75	155.32	4.75	122.97	4.22	129.04
Vegetables	0.15	10.09	0.24	23.71	0.48	28.46	0.48	22.53	0.44	23.65
Fruit	0.38	4.19	0.58	9.30	1.21	11.16	1.21	8.84	1.09	9.28
Meat	0.18	22.92	0.18	39.76	0.38	56.80	0.64	56.80	0.50	54.84
Total	2.36	277.36	3.20	285.67	7.09	327.60	7.35	252.86	6.50	275.03
UNSCEAR[13]	55									

Table 73. Ingestion P_{2345} Ranges for Sr-90 nSv per Bq m^{-2}

P_{2345}	Infant		Child		Teen		Adult		Weighted	
Pathway	**Min**	**Max**	**Min**	**Max**	**Max**	**Max**	**Min**	**Max**	**Min**	**Max**
Milk products	0.28	1199.02	3.69	893.04	0.26	250.31	0.26	66.26	0.26	132.89
Grain Products	1.36	395.79	0.27	254.71	4.71	595.15	4.71	226.76	4.29	274.45
Vegetables	0.07	105.67	2.70	458.81	0.23	153.30	0.23	58.41	0.21	70.78
Fruit	0.27	34.48	0.15	118.16	0.84	47.23	0.84	18.00	0.78	21.86
Meat	0.02	30.22	0.54	36.41	0.04	38.54	0.07	18.55	0.06	19.17
Total	1.99	1765.18	0.03	24.96	6.09	1084.53	6.12	387.97	5.60	519.15
UNSCEAR[13]	52									

Table 74. Ingestion P_{2345} Ranges for I-131

Parameter	Min	Max
P_{23} (mBq a L^{-1} per Bq m^{-2})	0.57	0.69
P_{34} (L a^{-1}) at $\rho = 1.03$ (Milk)	Table 68	
P_{45} (nSv Bq^{-1})	Table 69	
P_{2345} (nSv per Bq m^{-2})	**Min**	**Max**
Infant	0.033	165.42
Child	0.033	47.26
Teen	0.032	23.82
Adult	0.032	13.10
Weighted	0.032	18.29
UNSCEAR P_{25} [13]	4.2	

Table 75. Breathing Rate Information from the 2000 UNSCEAR Report [16,53]

Age group	Breathing rate m^3 d^{-1}	m^3 y^{-1}	UNSCEAR group	Rate (m^3 y^{-1}) Min	Max
0-1	2.86	1044	Infant	1044	1044
1-2	5.16	1883	Child*	1883	3183
2-7	8.72	3183	Teen**	5585	7337
7-12	15.3	5585	Adult	8103	8103
12-17	20.1	7337			
>17	22.2	8103			

* Child data are from the 1-2 and 2-7 age groups.
** Teen data are from the 7-12 and 12-17 age groups.

Table 76. Summary of Breathing Rate (P_{14}) Information (in $m^3\ a^{-1}$)

Age Group	Minimum	Ref.	Maximum	Ref.
Infant	1044	16,53	1400	42,46
Child	1883	16,53	5500	42
Teen	5585	16,53	8000	42,46
Adult	7300	13	8103	16,53

Table 77. Exposure-to-Dose Conversion Factor, P_{45}, for Inhalation (Effective Committed Dose Equivalent per Unit Intake in nSv Bq^{-1})

Radio-nuclide	Source	Class*	T(y)	3-mo	1-y	Infant Ave**	Child 5-y	Teen 15-y	Adult
Cs-137	UNSCEAR [13,20]	D	50/70***	14	7.0	10.5	6.7	8.3	8.5
Cs-137	FGR-11 [27]	D	50	---	---	---	---	---	8.63
Cs-137	ICRP 72 [47]	F	70	8.8	5.4	7.1	3.6	4.4	4.6
Cs-137	NRC 1.109 [46]	D	50	---	---	8.8	9.4	10.5	14.5
Sr-90	UNSCEAR [13,20]	Y	50/70***	1900	1600	1750	990	370	350
Sr-90	FGR-11 [27]	Y	50	---	---	---	---	---	351
Sr-90	ICRP 72 [47]	S	70	420	400	410	270	160	160
Sr-90	NRC 1.109 [46]	Y	50	---	---	500	470	226	206
I-131	UNSCEAR [13,20]	D	50/70***	150	110	130	67	18	13
I-131	FGR-11 [27]	D	50	---	---	---	---	---	8.89
I-131	ICRP 72 [47]	F	70	72	72	72	37	11	7.4
I-131	NRC 1.109 [46]	D	50	---	---	3.8	2.0	0.89	0.69

* ICRP 72 [47] classes Fast (F), Moderate (M), and Slow (S) correspond to classes Days (D), Months (M), and Years (Y) used previously.

** Average of the 3-mo and 1-y values per the 1993 UNSCEAR Report [13].

*** Dose integration period is to age 70 for infants and children and age 50 for adults. The P_{45} value given in Reference 13 for inhalation of I-131 is 13 nSv Bq^{-1}.

Table 78. Inhalation P_{245} Design Space (in nSv per Bq m^{-2})

P_{245}	Cs-137		Sr-90		I-131	
Age Group	Min	Max	Min	Max	Min	Max
Infant	0.013	0.311	0.658	38.82	0.017	0.961
Child	0.012	1.003	0.916	86.27	0.030	1.946
Teen	0.044	1.459	1.609	46.90	0.089	0.761
Adult	0.060	1.477	2.103	45.06	0.097	0.556
Weighted	0.048	1.418	1.779	51.83	0.095	0.830
UNSCEAR	0.11		4.6		0.17	

Table 79. External Exposure Parameters

Parameter	UNSCEAR[13]	Min	Source	Max	Source
Outdoor occupancy	0.2	0.2	UNSCEAR [13]	1	Max. possible
Indoor occupancy	0.8	0	Min. possible	0.8	UNSCEAR [13]
Building shielding factor	0.2	0.2	UNSCEAR [13]	0.7	RESRAD [25]

Table 80. Possible Ranges of Cs-137 Deposition-to-Dose Coefficients in nSv per Bq m^{-2}

nSv per Bq m^{-2}	Infant		Child		Teen		Adult		Weighted	
Ingestion, P_{2345}	**Min**	**Max**	**Min**	**Max**	**Max**	**Max**	**Min**	**Max**	**Min**	**Max**
Milk products	0.28	187.0	0.20	83.5	0.27	75.9	0.27	41.7	0.26	58.2
Grain Products	1.37	53.2	2.01	129.4	4.75	155.3	4.75	123.0	4.22	129.0
Vegetables	0.15	10.1	0.24	23.7	0.48	28.5	0.48	22.5	0.44	23.6
Fruit	0.38	4.2	0.58	9.3	1.21	11.2	1.21	8.8	1.09	9.3
Meat	0.18	22.9	0.18	39.8	0.38	56.8	0.64	56.8	0.50	54.8
Total	2.36	277.4	3.20	285.7	7.09	327.6	7.35	252.9	6.50	275.0
UNSCEAR P_{2345}	55									
Inhalation, P_{245}	0.01	0.31	0.01	1.0	0.04	1.5	0.06	1.5	0.05	1.4
UNSCEAR P_{245}	0.11									
Ext. Exposure, P_{25}	97.00	432.4	97.00	432.4	97.00	432.4	97.00	432.4	97.00	432.4
UNSCEAR P_{25}	97									
$P_{2345}+P_{245}+P_{25}$	99.37	710.1	100.22	719.1	104.13	761.5	104.41	686.7	103.5	708.8
UNSCEAR Total	152.11									
Ratio to UNSCEAR	0.65	4.67	0.66	4.73	0.68	5.01	0.69	4.51	0.68	4.66

Table 81. Possible Ranges of Sr-90 Deposition-to-Dose Coefficients in nSv per Bq m^{-2}

nSv per Bq m^{-2}	Infant		Child		Teen		Adult		Weighted	
Ingestion, P_{2345}	**Min**	**Max**	**Min**	**Max**	**Max**	**Max**	**Min**	**Max**	**Min**	**Max**
Milk products	0.28	1199	3.69	893	0.26	250	0.26	66	0.26	133
Grain Products	1.36	396	0.27	255	4.71	595	4.71	227	4.29	274
Vegetables	0.07	106	2.70	459	0.23	153	0.23	58	0.21	71
Fruit	0.27	34	0.15	118	0.84	47	0.84	18	0.78	22
Meat	0.02	30	0.54	36	0.04	39	0.07	19	0.06	19
Total	1.99	1765	0.03	25	6.09	1085	6.12	388	5.60	519
UNSCEAR P_{2345}	52									
Inhalation, P_{245}	0.66	39	0.92	86	1.61	47	2.10	45	1.78	52
UNSCEAR P_{245}	4.6									
Ext. Exposure, P_{25}	0	0.38	0	0.38	0	0.38	0	0.38	0	0.38
UNSCEAR P_{25}	0									
$P_{2345}+P_{245}+P_{25}$	2.65	1804	0.95	112	7.70	1132	8.22	433	7.38	571
UNSCEAR Total	56.6									
Ratio to UNSCEAR	0.05	31.87	0.02	1.98	0.14	20.00	0.15	7.65	0.13	10.09

Table 82. Possible Ranges of I-131 Deposition-to-Dose Coefficients in nSv per Bq m^{-2}

nSv per Bq m^{-2}	Infant		Child		Teen		Adult		Weighted	
Ingestion, P_{2345}	**Min**	**Max**	**Min**	**Max**	**Max**	**Max**	**Min**	**Max**	**Min**	**Max**
Milk products	0.033	165.4	0.033	47.3	0.032	23.82	0.032	13.1	0.032	18.29
UNSCEAR P_{2345}	4.2									
Inhalation, P_{245}	0.017	0.96	0.03	1.95	0.089	0.76	0.097	0.56	0.095	0.83
UNSCEAR P_{245}	0.17									
Ext. Exposure, P_{25}	0.12	0.38	0.12	0.38	0.12	0.38	0.12	0.38	0.12	0.38
UNSCEAR P_{25}	0.12									
$P_{2345}+P_{245}+P_{25}$	0.17	166.8	0.183	49.6	0.241	24.96	0.249	14.04	0.25	19.5
UNSCEAR Total	4.49									
Ratio to UNSCEAR	0.04	37.15	0.04	11.05	0.05	5.56	0.06	3.13	0.06	4.34

Table 83. PRS Adjusted CY2000 Total Deposition (tdep) Values for Cs-137

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	21-Mar	326	100.0	1.42E+05	52.50	157.50	87	1.89E+09	1944	21-Mar	100.0	1.42E+05	52.50	157.50	87	1.89E+09	1944	21-Mar	100.0	1.42E+05	52.50	157.50	87	1.89E+09	1944
Transboundary**	05-Nov	326	100.0	1.12E+05	52.50	159.00	65	1.89E+09	0	05-Nov	100.0	1.12E+05	52.50	159.00	65	1.89E+09	0	05-Nov	100.0	1.12E+05	52.50	159.00	65	1.89E+09	0
Burma	None									None								None							
China	05-Jan	58	17.8	9.93E+02	52.50	126.00	2169	1.89E+09	7721	05-Jan	17.8	9.93E+02	52.50	126.00	2169	1.89E+09	7721	04-Dec	1.5	5.10E-03	52.50	123.00	2365	1.89E+09	5976
Hong Kong	None									None								None							
Japan	26-Apr	82	25.2	1.41E+03	43.50	142.50	1581	2.25E+09	155808	26-Apr	25.2	1.41E+03	43.50	142.50	1581	2.25E+09	155808	01-Jan	3.1	3.60E+02	45.50	142.00	1454	2.17E+09	34622
Laos	None									None								None							
Mongolia	04-Jan	13	4.0	5.54E+01	46.50	119.50	2855	2.13E+09	1835	04-Jan	4.0	5.54E+01	46.50	119.50	2855	2.13E+09	1835	None							
N. Korea	07-Jan	18	5.5	2.77E+02	43.00	130.00	2372	2.26E+09	175327	07-Jan	5.5	2.77E+02	43.00	130.00	2372	2.26E+09	175327	04-Dec	0.3	1.62E-11	43.00	130.00	2372	2.26E+09	175327
Russia	21-Mar	326	100.0	1.42E+05	52.50	157.50	87	1.89E+09	1944	21-Mar	100.0	1.42E+05	52.50	157.50	87	1.89E+09	1944	21-Mar	100.0	1.42E+05	52.50	157.50	87	1.89E+09	1944
S. Korea	05-Jan	5	1.5	2.09E+01	37.50	126.50	3001	2.45E+09	2006368	05-Jan	1.5	2.09E+01	37.50	126.50	3001	2.45E+09	2006368	None							
Taiwan	None									None								None							
Thailand	None									None								None							
Aleutians (U.S.)	24-Jan	273	83.7	4.37E+03	52.50	185.50	1807	1.89E+09	63	24-Jan	83.7	4.37E+03	52.50	185.50	1807	1.89E+09	63	20-May	32.5	1.87E+03	52.50	173.00	976	1.89E+09	0
Alaska (U.S.)	18-Feb	229	70.2	6.54E+03	58.50	198.00	2507	1.62E+09	22	18-Feb	70.2	6.54E+03	58.50	198.00	2507	1.62E+09	22	20-Jan	3.4	2.69E+02	54.50	195.00	2379	1.80E+09	38
Vietnam	None									None								None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.

** The transboundary region includes all areas, including ocean, outside of Russia.

Table 84. PRS Adjusted CY2000 Total Deposition (tdep) Values for Sr-90

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	21-Mar	326	100.0	8.25E+03	52.50	157.50	87	1.89E+09	1944	21-Mar	100.0	8.14E+03	52.50	157.50	87	1.89E+09	1944	21-Mar	100.0	8.25E+03	52.50	157.50	87	1.89E+09	1944
Transboundary**	05-Nov	326	100.0	6.63E+03	52.50	159.00	65	1.89E+09	0	05-Nov	100.0	6.35E+03	52.50	159.00	65	1.89E+09	0	05-Nov	100.0	6.42E+03	52.50	159.00	65	1.89E+09	0
Burma	None									None								None							
China	05-Jan	50	15.3	5.58E+01	52.50	126.00	2169	1.89E+09	7721	05-Jan	15.3	5.57E+01	52.50	126.00	2169	1.89E+09	7721	04-Dec	1.5	3.11E-04	52.50	123.00	2365	1.89E+09	5976
Hong Kong	None									None								None							
Japan	26-Apr	76	23.3	9.19E+01	43.50	142.50	1581	2.25E+09	155808	26-Apr	23.3	9.19E+01	43.50	142.50	1581	2.25E+09	155808	01-Jan	3.1	2.14E+01	45.50	142.00	1454	2.17E+09	34622
Laos	None									None								None							
Mongolia	04-Jan	11	3.4	3.20E+00	46.50	119.50	2855	2.13E+09	1835	04-Jan	3.4	3.20E+00	46.50	119.50	2855	2.13E+09	1835	None							
N. Korea	07-Jan	14	4.3	1.74E+01	43.00	130.00	2372	2.26E+09	175327	07-Jan	4.3	1.74E+01	43.00	130.00	2372	2.26E+09	175327	04-Dec	0.3	9.30E-13	43.00	130.00	2372	2.26E+09	175327
Russia	21-Mar	326	100.0	8.25E+03	52.50	157.50	87	1.89E+09	1944	21-Mar	100.0	8.14E+03	52.50	157.50	87	1.89E+09	1944	21-Mar	100.0	8.25E+03	52.50	157.50	87	1.89E+09	1944
S. Korea	05-Jan	5	1.5	6.16E-01	37.50	126.50	3001	2.45E+09	2006368	05-Jan	1.5	6.16E-01	37.50	126.50	3001	2.45E+09	2006368	None							
Taiwan	None									None								None							
Thailand	None									None								None							
Aleutians (U.S.)	24-Jan	269	82.5	2.45E+02	52.50	185.50	1807	1.89E+09	63	24-Jan	82.5	2.45E+02	52.50	185.50	1807	1.89E+09	63	20-May	32.5	1.26E+02	52.50	173.00	976	1.89E+09	0
Alaska (U.S.)	18-Feb	215	66.0	3.93E+02	58.50	198.00	2507	1.62E+09	22	18-Feb	66.0	3.93E+02	58.50	198.00	2507	1.62E+09	22	20-Jan	3.4	1.82E+01	54.50	195.00	2379	1.80E+09	38
Vietnam	None									None								None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.

** The transboundary region includes all areas, including ocean, outside of Russia.

Table 85. PRS Adjusted CY2000 Total Deposition (tdep) Values for I-131

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	12-Jun	326	100.0	1.85E+02	54.00	159.00	116	1.82E+09	1872	09-Feb	100.0	1.09E+02	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	1.51E+02	52.50	157.50	87	1.89E+09	1944
Transboundary**	07-Feb	326	100.0	1.23E+02	52.50	159.00	65	1.89E+09	0	07-Feb	100.0	8.92E+01	52.50	159.00	65	1.89E+09	0	07-Feb	100.0	1.23E+02	52.50	159.00	65	1.89E+09	0
Burma	None									None								None							
China	04-Dec	4	1.2	2.47E-07	52.50	123.00	2365	1.89E+09	5976	04-Dec	1.2	1.78E-07	52.50	123.00	2365	1.89E+09	5976	04-Dec	1.2	2.47E-07	52.50	123.00	2365	1.89E+09	5976
Hong Kong	None									None								None							
Japan	03-Jan	10	3.1	1.53E-01	44.50	145.50	1338	2.21E+09	2136	03-Jan	3.1	1.11E-01	44.50	145.50	1338	2.21E+09	2136	03-Jan	3.1	1.53E-01	44.50	145.50	1338	2.21E+09	2136
Laos	None									None								None							
Mongolia	None									None								None							
N. Korea	None									None								None							
Russia	12-Jun	326	100.0	1.85E+02	54.00	159.00	116	1.82E+09	1872	09-Feb	100.0	1.09E+02	52.50	157.50	87	1.89E+09	1944	09-Feb	100.0	1.51E+02	52.50	157.50	87	1.89E+09	1944
S. Korea	None									None								None							
Taiwan	None									None								None							
Thailand	None									None								None							
Aleutians (U.S.)	18-Jan	86	26.4	2.01E+00	52.50	174.00	1043	1.89E+09	0	18-Jan	26.4	1.46E+00	52.50	174.00	1043	1.89E+09	0	18-Jan	26.4	2.01E+00	52.50	174.00	1043	1.89E+09	0
Alaska (U.S.)	20-Jan	7	2.1	1.36E-01	54.50	195.00	2379	1.80E+09	38	20-Jan	2.1	9.85E-02	54.50	195.00	2379	1.80E+09	38	20-Jan	2.1	1.36E-01	54.50	195.00	2379	1.80E+09	38
Vietnam	None									None								None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all areas, including ocean, outside of Russia.

Table 86. VRS Adjusted CY2000 Total Deposition (tdep) Values for Cs-137

Region	Date	N	N(%)	Max (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr (Bq m^{-2})	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	02-Aug	329	100.0	1.35E+05	43.50	133.50	134	2.25E+09	34008	02-Aug	100.0	1.35E+05	43.50	133.50	134	2.25E+09	34008	02-Aug	100.0	1.25E+05	43.50	133.50	134	2.25E+09	34008
Transboundary**	18-Nov	329	100.0	4.62E+04	42.00	133.50	166	2.30E+09	0	18-Nov	100.0	4.62E+04	42.00	133.50	166	2.30E+09	0	18-Nov	100.0	4.62E+04	42.00	133.50	166	2.30E+09	0
Burma	None									None								None							
China	07-Jun	262	79.6	3.54E+04	43.50	131.50	69	2.25E+09	42463	07-Jun	79.6	3.54E+04	43.50	131.50	69	2.25E+09	42463	07-Jun	73.6	3.11E+04	43.50	131.50	69	2.25E+09	42463
Hong Kong	12-Sep	9	2.7	2.84E+01	22.50	114.50	2794	2.85E+09	125994	12-Sep	2.7	2.84E+01	22.50	114.50	2794	2.85E+09	125994	None							
Japan	16-Dec	317	96.4	1.96E+04	40.50	141.00	796	2.35E+09	358298	16-Dec	96.4	1.96E+04	40.50	141.00	796	2.35E+09	358298	30-Jan	74.2	1.36E+04	36.00	138.00	933	2.50E+09	405254
Laos	None									None								None							
Mongolia	10-May	40	12.2	3.42E+02	47.00	120.00	1042	2.11E+09	33341	10-May	12.2	3.42E+02	47.00	120.00	1042	2.11E+09	33341	27-Jul	1.5	2.42E-01	50.00	116.50	1415	1.99E+09	4443
N. Korea	20-Aug	202	61.4	2.18E+04	42.00	129.00	270	2.30E+09	200822	20-Aug	61.4	2.18E+04	42.00	129.00	270	2.30E+09	200822	20-Aug	37.7	2.18E+04	42.00	129.00	270	2.30E+09	200822
Russia	02-Aug	324	98.5	1.35E+05	43.50	133.50	134	2.25E+09	34008	02-Aug	98.5	1.35E+05	43.50	133.50	134	2.25E+09	34008	02-Aug	97.9	1.25E+05	43.50	133.50	134	2.25E+09	34008
S. Korea	11-Jan	156	47.4	5.28E+03	38.50	127.50	628	2.42E+09	292252	11-Jan	47.4	5.28E+03	38.50	127.50	628	2.42E+09	292252	15-Nov	21.0	4.03E+03	38.50	127.50	628	2.42E+09	292252
Taiwan	29-Nov	32	9.7	9.77E+02	24.00	121.50	2322	2.82E+09	152461	29-Nov	9.7	9.77E+02	24.00	121.50	2322	2.82E+09	152461	None							
Thailand	None									None								None							
Aleutians (U.S.)	23-Apr	172	52.3	2.99E+02	52.00	177.00	3464	1.91E+09	0	23-Apr	52.3	2.99E+02	52.00	177.00	3464	1.91E+09	0	29-May	0.6	1.10E-03	53.00	172.50	3162	1.87E+09	0
Alaska (U.S.)	24-Mar	140	42.6	5.74E+02	60.00	210.00	5359	1.55E+09	1314	24-Mar	42.6	5.74E+02	60.00	210.00	5359	1.55E+09	1314	None							
Vietnam	29-Nov	1	0.3	1.47E-05	20.50	107.00	3416	2.89E+09	13869	29-Nov	0.3	1.47E-05	20.50	107.00	3416	2.89E+09	13869	None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all areas, including ocean, outside of Russia.

Table 87. VRS Adjusted CY2000 Total Deposition (tdep) Values for Sr-90

Region	Date	N	N(%)	Max ($Bq\ m^{-2}$)	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h ($Bq\ m^{-2}$)	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr ($Bq\ m^{-2}$)	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	02-Aug	329	100.0	9.38E+03	43.50	133.50	134	2.25E+09	34008	12-Jun	100.0	8.60E+03	43.50	133.50	134	2.25E+09	34008	12-Jun	100.0	8.64E+03	43.50	133.50	134	2.25E+09	34008
Transboundary**	02-Aug	329	100.0	3.13E+03	42.50	133.50	135	2.28E+09	717	12-Jun	100.0	2.87E+03	42.50	133.50	135	2.28E+09	717	12-Jun	100.0	2.88E+03	42.50	133.50	135	2.28E+09	717
Burma	None									None								None							
China	07-Jun	259	78.7	2.27E+03	43.50	131.50	69	2.25E+09	42463	07-Jun	78.7	2.26E+03	43.50	131.50	69	2.25E+09	42463	07-Jun	73.6	2.16E+03	43.50	131.50	69	2.25E+09	42463
Hong Kong	29-Nov	4	1.2	6.52E-04	22.50	114.50	2794	2.85E+09	125994	29-Nov	1.2	6.52E-04	22.50	114.50	2794	2.85E+09	125994	None							
Japan	16-Dec	316	96.0	1.27E+03	40.50	141.00	796	2.35E+09	358298	16-Dec	96.0	1.25E+03	40.50	141.00	796	2.35E+09	358298	30-Jan	74.2	8.00E+02	36.00	138.00	933	2.50E+09	405254
Laos	None									None								None							
Mongolia	10-May	36	10.9	2.17E+01	47.00	120.00	1042	2.11E+09	33341	10-May	10.9	2.17E+01	47.00	120.00	1042	2.11E+09	33341	27-Jul	1.5	1.69E-02	50.00	116.50	1415	1.99E+09	4443
N. Korea	20-Aug	199	60.5	1.49E+03	42.00	129.00	270	2.30E+09	200822	20-Aug	60.5	1.36E+03	42.00	129.00	270	2.30E+09	200822	20-Aug	37.7	1.48E+03	42.00	129.00	270	2.30E+09	200822
Russia	02-Aug	324	98.5	9.38E+03	43.50	133.50	134	2.25E+09	34008	12-Jun	98.5	8.60E+03	43.50	133.50	134	2.25E+09	34008	12-Jun	97.9	8.64E+03	43.50	133.50	134	2.25E+09	34008
S. Korea	11-Jan	151	45.9	3.44E+02	38.50	127.50	628	2.42E+09	292252	11-Jan	45.9	3.34E+02	38.50	127.50	628	2.42E+09	292252	15-Nov	21.0	2.80E+02	38.50	127.50	628	2.42E+09	292252
Taiwan	29-Nov	21	6.4	6.27E+01	24.00	121.50	2322	2.82E+09	152461	29-Nov	6.4	6.27E+01	24.00	121.50	2322	2.82E+09	152461	None							
Thailand	None									None								None							
Aleutians (U.S.)	23-Apr	154	46.8	1.74E+01	52.00	177.00	3464	1.91E+09	0	23-Apr	46.8	1.74E+01	52.00	177.00	3464	1.91E+09	0	29-May	0.6	7.64E-05	53.00	172.50	3162	1.87E+09	0
Alaska (U.S.)	25-Mar	119	36.2	1.20E+01	58.50	202.50	4986	1.62E+09	15	25-Mar	36.2	1.20E+01	58.50	202.50	4986	1.62E+09	15	None							
Vietnam	29-Nov	1	0.3	1.27E-10	20.50	107.00	3416	2.89E+09	13869	29-Nov	0.3	1.27E-10	20.50	107.00	3416	2.89E+09	13869	None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all areas, including ocean, outside of Russia.

Table 88. VRS Adjusted CY2000 Total Deposition (tdep) Values for I-131

Region	Date	N	N(%)	Max ($Bq\ m^{-2}$)	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	144-h ($Bq\ m^{-2}$)	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Date	N(%)	048-hr ($Bq\ m^{-2}$)	Lat	Lon	Dist* (km)	Area* (m^2)	Pop
Regional	12-Jun	329	100.0	2.10E+02	43.50	133.50	134	2.25E+09	34008	12-Jun	100.0	1.59E+02	43.50	133.50	134	2.25E+09	34008	12-Jun	100.0	2.10E+02	43.50	133.50	134	2.25E+09	34008
Transboundary**	12-Jun	329	100.0	7.01E+01	42.50	133.50	135	2.28E+09	717	12-Jun	100.0	5.30E+01	42.50	133.50	135	2.28E+09	717	12-Jun	100.0	7.01E+01	42.50	133.50	135	2.28E+09	717
Burma	None									None								None							
China	07-Jun	245	74.5	6.53E+01	43.50	131.50	69	2.25E+09	42463	07-Jun	74.5	4.14E+01	43.50	131.50	69	2.25E+09	42463	07-Jun	72.6	5.47E+01	43.50	131.50	69	2.25E+09	42463
Hong Kong	None									None								None							
Japan	20-Nov	270	82.1	1.04E+01	36.00	138.00	933	2.50E+09	405254	20-Nov	82.1	7.87E+00	36.00	138.00	933	2.50E+09	405254	20-Nov	70.2	1.04E+01	36.00	138.00	933	2.50E+09	405254
Laos	None									None								None							
Mongolia	21-Apr	5	1.5	2.33E-06	47.00	120.00	1042	2.11E+09	33341	21-Apr	1.5	1.77E-06	47.00	120.00	1042	2.11E+09	33341	21-Apr	0.9	2.33E-06	47.00	120.00	1042	2.11E+09	33341
N. Korea	20-Aug	150	45.6	3.93E+01	42.00	129.00	270	2.30E+09	200822	20-Aug	45.6	2.65E+01	42.00	129.00	270	2.30E+09	200822	20-Aug	35.6	3.51E+01	42.00	129.00	270	2.30E+09	200822
Russia	12-Jun	324	98.5	2.10E+02	43.50	133.50	134	2.25E+09	34008	12-Jun	98.5	1.59E+02	43.50	133.50	134	2.25E+09	34008	12-Jun	97.9	2.10E+02	43.50	133.50	134	2.25E+09	34008
S. Korea	11-Jan	89	27.1	4.55E+00	37.50	129.00	662	2.45E+09	155901	11-Jan	27.1	3.72E+00	37.50	129.00	662	2.45E+09	155901	11-Jan	18.8	4.55E+00	37.50	129.00	662	2.45E+09	155901
Taiwan	None									None								None							
Thailand	None									None								None							
Aleutians (U.S.)	07-Mar	25	7.6	2.62E-02	52.00	177.00	3464	1.91E+09	0	07-Mar	7.6	2.21E-02	52.00	177.00	3464	1.91E+09	0	07-Nov	0.3	6.36E-11	52.00	177.00	3464	1.91E+09	0
Alaska (U.S.)	14-Nov	5	1.5	2.13E-14	55.00	198.00	4801	1.78E+09	46	14-Nov	1.5	1.79E-14	55.00	198.00	4801	1.78E+09	46	None							
Vietnam	None									None								None							

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all areas, including ocean, outside of Russia.

Table 89. PRS Worst-Case Cs-137 Maximum Total Dose Commitment per Maximum Individual (i.e., Teen) Estimates and Breakdown by Type

Region	Date	N	N (%)	MaxTot (mSv)	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Ingest (mSv)	Ingest (%)	Inhalat (mSv)	Inhalat (%)	ExtExp (mSv)	ExtExp (%)
Regional	21-Mar-00	326	100.0	1.08E+02	52.50	157.50	87	1.89E+09	1944	4.64E+01	43.0	2.07E-01	0.2	6.13E+01	56.8
Transboundary**	18-Feb-00	316	96.9	4.98E+00	58.50	198.00	2507	1.62E+09	22	2.14E+00	43.0	9.55E-03	0.2	2.83E+00	56.8
Burma	None														
China	05-Jan-00	58	17.8	7.56E-01	52.50	126.00	2169	1.89E+09	7721	3.25E-01	43.0	1.45E-03	0.2	4.29E-01	56.8
Hong Kong	None														
Japan	26-Apr-00	82	25.2	1.07E+00	43.50	142.50	1581	2.25E+09	155808	4.61E-01	43.0	2.06E-03	0.2	6.09E-01	56.8
Laos	None														
Mongolia	04-Jan-00	13	4.0	4.22E-02	46.50	119.50	2855	2.13E+09	1835	1.81E-02	43.0	8.09E-05	0.2	2.40E-02	56.8
N. Korea	07-Jan-00	18	5.5	2.11E-01	43.00	130.00	2372	2.26E+09	175327	9.07E-02	43.0	4.04E-04	0.2	1.20E-01	56.8
Russia	21-Mar-00	326	100.0	1.08E+02	52.50	157.50	87	1.89E+09	1944	4.64E+01	43.0	2.07E-01	0.2	6.13E+01	56.8
S. Korea	05-Jan-00	5	1.5	1.59E-02	37.50	126.50	3001	2.45E+09	2006368	6.84E-03	43.0	3.05E-05	0.2	9.03E-03	56.8
Taiwan	None														
Thailand	None														
Aleutians (U.S.)	24-Jan-00	273	83.7	3.33E+00	52.50	185.50	1807	1.89E+09	63	1.43E+00	43.0	6.38E-03	0.2	1.89E+00	56.8
Alaska (U.S.)	18-Feb-00	229	70.2	4.98E+00	58.50	198.00	2507	1.62E+09	22	2.14E+00	43.0	9.55E-03	0.2	2.83E+00	56.8
Vietnam	None														

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 90. PRS Worst-Case Cs-137 Maximum Total Dose Commitment per Adult Estimates and Breakdown by Type

Region	Date	N	N (%)	MaxTot (mSv)	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Ingest (mSv)	Ingest (%)	Inhalat (mSv)	Inhalat (%)	ExtExp (mSv)	ExtExp (%)
Regional	21-Mar-00	326	100.0	9.73E+01	52.50	157.50	87	1.89E+09	1944	3.58E+01	36.8	2.10E-01	0.2	6.13E+01	63.0
Transboundary**	18-Feb-00	316	96.9	4.49E+00	58.50	198.00	2507	1.62E+09	22	1.65E+00	36.8	9.68E-03	0.2	2.83E+00	63.0
Burma	None														
China	05-Jan-00	58	17.8	6.82E-01	52.50	126.00	2169	1.89E+09	7721	2.51E-01	36.8	1.47E-03	0.2	4.29E-01	63.0
Hong Kong	None														
Japan	26-Apr-00	82	25.2	9.67E-01	43.50	142.50	1581	2.25E+09	155808	3.56E-01	36.8	2.08E-03	0.2	6.09E-01	63.0
Laos	None														
Mongolia	04-Jan-00	13	4.0	3.80E-02	46.50	119.50	2855	2.13E+09	1835	1.40E-02	36.8	8.20E-05	0.2	2.40E-02	63.0
N. Korea	07-Jan-00	18	5.5	1.90E-01	43.00	130.00	2372	2.26E+09	175327	7.00E-02	36.8	4.10E-04	0.2	1.20E-01	63.0
Russia	21-Mar-00	326	100.0	9.73E+01	52.50	157.50	87	1.89E+09	1944	3.58E+01	36.8	2.10E-01	0.2	6.13E+01	63.0
S. Korea	05-Jan-00	5	1.5	1.43E-02	37.50	126.50	3001	2.45E+09	2006368	5.28E-03	36.8	3.09E-05	0.2	9.03E-03	63.0
Taiwan	None														
Thailand	None														
Aleutians (U.S.)	24-Jan-00	273	83.7	3.00E+00	52.50	185.50	1807	1.89E+09	63	1.10E+00	36.8	6.46E-03	0.2	1.89E+00	63.0
Alaska (U.S.)	18-Feb-00	229	70.2	4.49E+00	58.50	198.00	2507	1.62E+09	22	1.65E+00	36.8	9.68E-03	0.2	2.83E+00	63.0
Vietnam	None														

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 91. PRS Worst-Case Sr-90 Maximum Total Dose Commitment per Maximum Individual (i.e., Infant) Estimates and Breakdown by Type

Region	Date	N	N (%)	MaxTot (mSv)	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Ingest (mSv)	Ingest (%)	Inhalat (mSv)	Inhalat (%)	ExtExp (mSv)	ExtExp (%)
Regional	21-Mar-00	326	100.0	1.47E+01	52.50	157.50	87	1.89E+09	1944	1.44E+01	97.8	3.16E-01	2.2	3.09E-03	0.02
Transboundary**	18-Feb-00	215	66.0	7.09E-01	58.50	198.00	2507	1.62E+09	22	6.94E-01	97.8	1.53E-02	2.2	1.49E-04	0.02
Burma	None														
China	05-Jan-00	50	15.3	1.01E-01	52.50	126.00	2169	1.89E+09	7721	9.84E-02	97.8	2.16E-03	2.2	2.12E-05	0.02
Hong Kong	None			0.00E+00											
Japan	26-Apr-00	76	23.3	1.66E-01	43.50	142.50	1581	2.25E+09	155808	1.62E-01	97.8	3.57E-03	2.2	3.49E-05	0.02
Laos	None														
Mongolia	04-Jan-00	11	3.4	5.78E-03	46.50	119.50	2855	2.13E+09	1835	5.65E-03	97.8	1.24E-04	2.2	1.22E-06	0.02
N. Korea	07-Jan-00	14	4.3	3.14E-02	43.00	130.00	2372	2.26E+09	175327	3.07E-02	97.8	6.76E-04	2.2	6.62E-06	0.02
Russia	21-Mar-00	326	100.0	1.47E+01	52.50	157.50	87	1.89E+09	1944	1.44E+01	97.8	3.16E-01	2.2	3.09E-03	0.02
S. Korea	05-Jan-00	5	1.5	1.11E-03	37.50	126.50	3001	2.45E+09	2006368	1.09E-03	97.8	2.39E-05	2.2	2.34E-07	0.02
Taiwan	None														
Thailand	None														
Aleutians (U.S.)	24-Jan-00	269	82.5	4.42E-01	52.50	185.50	1807	1.89E+09	63	4.32E-01	97.8	9.50E-03	2.2	9.30E-05	0.02
Alaska (U.S.)	18-Feb-00	215	66.0	7.09E-01	58.50	198.00	2507	1.62E+09	22	6.94E-01	97.8	1.53E-02	2.2	1.49E-04	0.02
Vietnam	None														

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 92. PRS Worst-Case Sr-90 Maximum Total Dose Commitment per Adult Estimates and Breakdown by Type

Region	Date	N	N (%)	MaxTot (mSv)	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Ingest (mSv)	Ingest (%)	Inhalat (mSv)	Inhalat (%)	ExtExp (mSv)	ExtExp (%)
Regional	21-Mar-00	326	100.0	3.53E+00	52.50	157.50	87	1.89E+09	1944	3.16E+00	89.5	3.67E-01	10.4	3.09E-03	0.09
Transboundary**	18-Feb-00	215	66.0	1.70E-01	58.50	198.00	2507	1.62E+09	22	1.52E-01	89.5	1.77E-02	10.4	1.49E-04	0.09
Burma	None														
China	05-Jan-00	50	15.3	2.42E-02	52.50	126.00	2169	1.89E+09	7721	2.16E-02	89.5	2.51E-03	10.4	2.12E-05	0.09
Hong Kong	None														
Japan	26-Apr-00	76	23.3	3.99E-02	43.50	142.50	1581	2.25E+09	155808	3.57E-02	89.5	4.14E-03	10.4	3.49E-05	0.09
Laos	None														
Mongolia	04-Jan-00	11	3.4	1.39E-03	46.50	119.50	2855	2.13E+09	1835	1.24E-03	89.5	1.44E-04	10.4	1.22E-06	0.09
N. Korea	07-Jan-00	14	4.3	7.55E-03	43.00	130.00	2372	2.26E+09	175327	6.76E-03	89.5	7.85E-04	10.4	6.62E-06	0.09
Russia	21-Mar-00	326	100.0	3.53E+00	52.50	157.50	87	1.89E+09	1944	3.16E+00	89.5	3.67E-01	10.4	3.09E-03	0.09
S. Korea	05-Jan-00	5	1.5	2.67E-04	37.50	126.50	3001	2.45E+09	2006368	2.39E-04	89.5	2.78E-05	10.4	2.34E-07	0.09
Taiwan	None														
Thailand	None														
Aleutians (U.S.)	24-Jan-00	269	82.5	1.06E-01	52.50	185.50	1807	1.89E+09	63	9.50E-02	89.5	1.10E-02	10.4	9.30E-05	0.09
Alaska (U.S.)	18-Feb-00	215	66.0	1.70E-01	58.50	198.00	2507	1.62E+09	22	1.52E-01	89.5	1.77E-02	10.4	1.49E-04	0.09
Vietnam	None														

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 93. PRS Worst-Case I-131 Maximum Total Dose Commitment per Maximum Individual (i.e., Infant) Estimates and Breakdown by Type

Region	Date	N	N (%)	MaxTot (mSv)	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Ingest (mSv)	Ingest (%)	Inhalat (mSv)	Inhalat (%)	ExtExp (mSv)	ExtExp (%)
Regional	09-Feb-00	326	100.0	2.64E-02	52.50	157.50	87	1.89E+09	1944	2.62E-02	99.2	1.52E-04	0.6	6.02E-05	0.2
Transboundary**	18-Jan-00	98	30.1	3.53E-04	52.50	174.00	1043	1.89E+09	0	3.50E-04	99.2	2.04E-06	0.6	8.05E-07	0.2
Burma	None														
China	04-Dec-00	4	1.2	4.32E-11	52.50	123.00	2365	1.89E+09	5976	4.28E-11	99.2	2.49E-13	0.6	9.84E-14	0.2
Hong Kong	None														
Japan	03-Jan-00	10	3.1	2.68E-05	44.50	145.50	1338	2.21E+09	2136	2.66E-05	99.2	1.54E-07	0.6	6.10E-08	0.2
Laos	None														
Mongolia	None														
N. Korea	None														
Russia	09-Feb-00	326	100.0	2.64E-02	52.50	157.50	87	1.89E+09	1944	2.62E-02	99.2	1.52E-04	0.6	6.02E-05	0.2
S. Korea	None														
Taiwan	None														
Thailand	None														
Aleutians (U.S.)	18-Jan-00	86	26.4	3.53E-04	52.50	174.00	1043	1.89E+09	0	3.50E-04	99.2	2.04E-06	0.6	8.05E-07	0.2
Alaska (U.S.)	20-Jan-00	7	2.1	2.38E-05	54.50	195.00	2379	1.80E+09	38	2.36E-05	99.2	1.37E-07	0.6	5.43E-08	0.2
Vietnam	None														

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 94. PRS Worst-Case I-131 Maximum Total Dose Commitment per Age-Weighted Individual Estimates and Breakdown by Type

Region	Date	N	N (%)	MaxTot (mSv)	Lat	Lon	Dist* (km)	Area* (m^2)	Pop	Ingest (mSv)	Ingest (%)	Inhalat (mSv)	Inhalat (%)	ExtExp (mSv)	ExtExp (%)
Regional	09-Feb-00	326	100.0	3.09E-03	52.50	157.50	87	1.89E+09	1944	2.90E-03	93.8	1.32E-04	4.3	6.02E-05	1.9
Transboundary**	18-Jan-00	98	30.1	4.13E-05	52.50	174.00	1043	1.89E+09	0	3.87E-05	93.8	1.76E-06	4.3	8.05E-07	1.9
Burma	None														
China	04-Dec-00	4	1.2	5.05E-12	52.50	123.00	2365	1.89E+09	5976	4.74E-12	93.8	2.15E-13	4.3	9.84E-14	1.9
Hong Kong	None														
Japan	03-Jan-00	10	3.1	3.13E-06	44.50	145.50	1338	2.21E+09	2136	2.94E-06	93.8	1.33E-07	4.3	6.10E-08	1.9
Laos	None														
Mongolia	None														
N. Korea	None														
Russia	09-Feb-00	326	100.0	3.09E-03	52.50	157.50	87	1.89E+09	1944	2.90E-03	93.8	1.32E-04	4.3	6.02E-05	1.9
S. Korea	None														
Taiwan	None														
Thailand	None														
Aleutians (U.S.)	18-Jan-00	86	26.4	4.13E-05	52.50	174.00	1043	1.89E+09	0	3.87E-05	93.8	1.76E-06	4.3	8.05E-07	1.9
Alaska (U.S.)	20-Jan-00	7	2.1	2.78E-06	54.50	195.00	2379	1.80E+09	38	2.61E-06	93.8	1.19E-07	4.3	5.43E-08	1.9
Vietnam	None														

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 95. VRS Worst-Case Cs-137 Maximum Total Dose Commitment per Maximum Individual (i.e., Teen) Estimates and Breakdown by Type

Region	Date	N	N (%)	MaxTot (mSv)	Lat	Lon	Dist (km)	Area (m^2)	Pop	Ingest (mSv)	Ingest (%)	Inhalat (mSv)	Inhalat (%)	ExtExp (mSv)	ExtExp (%)
Regional	02-Aug-00	329	100.0	1.02E+02	43.50	133.50	134	2.25E+09	34008	4.41E+01	43.0	1.96E-01	0.2	5.82E+01	56.8
Transboundary**	07-Jun-00	329	100.0	2.69E+01	43.50	131.50	69	2.25E+09	42463	1.16E+01	43.0	5.16E-02	0.2	1.53E+01	56.8
Burma	None														
China	07-Jun-00	262	79.6	2.69E+01	43.50	131.50	69	2.25E+09	42463	1.16E+01	43.0	5.16E-02	0.2	1.53E+01	56.8
Hong Kong	12-Sep-00	9	2.7	2.17E-02	22.50	114.50	2794	2.85E+09	125994	9.32E-03	43.0	4.15E-05	0.2	1.23E-02	56.8
Japan	16-Dec-00	317	96.4	1.49E+01	40.50	141.00	796	2.35E+09	358298	6.43E+00	43.0	2.87E-02	0.2	8.49E+00	56.8
Laos	None														
Mongolia	10-May-00	40	12.2	2.60E-01	47.00	120.00	1042	2.11E+09	33341	1.12E-01	43.0	4.99E-04	0.2	1.48E-01	56.8
N. Korea	20-Aug-00	202	61.4	1.66E+01	42.00	129.00	270	2.30E+09	200822	7.13E+00	43.0	3.18E-02	0.2	9.41E+00	56.8
Russia	02-Aug-00	324	98.5	1.02E+02	43.50	133.50	134	2.25E+09	34008	4.41E+01	43.0	1.96E-01	0.2	5.82E+01	56.8
S. Korea	11-Jan-00	156	47.4	4.02E+00	38.50	127.50	628	2.42E+09	292252	1.73E+00	43.0	7.71E-03	0.2	2.28E+00	56.8
Taiwan	29-Nov-00	32	9.7	7.44E-01	24.00	121.50	2322	2.82E+09	152461	3.20E-01	43.0	1.43E-03	0.2	4.22E-01	56.8
Thailand	None														
Aleutians (U.S.)	23-Apr-00	172	52.3	2.28E-01	52.00	177.00	3464	1.91E+09	0	9.80E-02	43.0	4.37E-04	0.2	1.29E-01	56.8
Alaska (U.S.)	24-Mar-00	140	42.6	4.37E-01	60.00	210.00	5359	1.55E+09	1314	1.88E-01	43.0	8.38E-04	0.2	2.48E-01	56.8
Vietnam	29-Nov-00	1	0.3	1.12E-08	20.50	107.00	3416	2.89E+09	13869	4.81E-09	43.0	2.15E-11	0.2	6.35E-09	56.8

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 96. VRS Worst-Case Cs-137 Maximum Total Dose Commitment per Adult Estimates and Breakdown by Type

Region	Date	N	N (%)	MaxTot (mSv)	Lat	Lon	Dist (km)	Area (m^2)	Pop	Ingest (mSv)	Ingest (%)	Inhalat (mSv)	Inhalat (%)	ExtExp (mSv)	ExtExp (%)
Regional	02-Aug-00	329	100.0	9.24E+01	43.50	133.50	134	2.25E+09	34008	3.40E+01	36.8	1.99E-01	0.2	5.82E+01	63.0
Transboundary**	07-Jun-00	329	100.0	2.43E+01	43.50	131.50	69	2.25E+09	42463	8.94E+00	36.8	5.23E-02	0.2	1.53E+01	63.0
Burma	None														
China	07-Jun-00	262	79.6	2.43E+01	43.50	131.50	69	2.25E+09	42463	8.94E+00	36.8	5.23E-02	0.2	1.53E+01	63.0
Hong Kong	12-Sep-00	9	2.7	1.95E-02	22.50	114.50	2794	2.85E+09	125994	7.19E-03	36.8	4.21E-05	0.2	1.23E-02	63.0
Japan	16-Dec-00	317	96.4	1.35E+01	40.50	141.00	796	2.35E+09	358298	4.96E+00	36.8	2.91E-02	0.2	8.49E+00	63.0
Laos	None														
Mongolia	10-May-00	40	12.2	2.35E-01	47.00	120.00	1042	2.11E+09	33341	8.64E-02	36.8	5.06E-04	0.2	1.48E-01	63.0
N. Korea	20-Aug-00	202	61.4	1.49E+01	42.00	129.00	270	2.30E+09	200822	5.50E+00	36.8	3.22E-02	0.2	9.41E+00	63.0
Russia	02-Aug-00	324	98.5	9.24E+01	43.50	133.50	134	2.25E+09	34008	3.40E+01	36.8	1.99E-01	0.2	5.82E+01	63.0
S. Korea	11-Jan-00	156	47.4	3.63E+00	38.50	127.50	628	2.42E+09	292252	1.34E+00	36.8	7.81E-03	0.2	2.28E+00	63.0
Taiwan	29-Nov-00	32	9.7	6.71E-01	24.00	121.50	2322	2.82E+09	152461	2.47E-01	36.8	1.45E-03	0.2	4.22E-01	63.0
Thailand	None														
Aleutians (U.S.)	23-Apr-00	172	52.3	2.05E-01	52.00	177.00	3464	1.91E+09	0	7.56E-02	36.8	4.43E-04	0.2	1.29E-01	63.0
Alaska (U.S.)	24-Mar-00	140	42.6	3.94E-01	60.00	210.00	5359	1.55E+09	1314	1.45E-01	36.8	8.49E-04	0.2	2.48E-01	63.0
Vietnam	29-Nov-00	1	0.3	1.01E-08	20.50	107.00	3416	2.89E+09	13869	3.72E-09	36.8	2.17E-11	0.2	6.35E-09	63.0

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 97. VRS Worst-Case Sr-90 Maximum Total Dose Commitment per Maximum Individual (i.e., Infant) Estimates and Breakdown by Type

Region	Date	N	N (%)	MaxTot (mSv)	Lat	Lon	Dist (km)	Area (m^2)	Pop	Ingest (mSv)	Ingest (%)	Inhalat (mSv)	Inhalat (%)	ExtExp (mSv)	ExtExp (%)
Regional	12-Jun-00	329	100.0	1.55E+01	43.50	133.50	134	2.25E+09	34008	1.52E+01	97.8	3.34E-01	2.2	3.27E-03	0.02
Transboundary**	07-Jun-00	329	100.0	4.08E+00	43.50	131.50	69	2.25E+09	42463	3.99E+00	97.8	8.77E-02	2.2	8.59E-04	0.02
Burma	None														
China	07-Jun-00	259	78.7	4.08E+00	43.50	131.50	69	2.25E+09	42463	3.99E+00	97.8	8.77E-02	2.2	8.59E-04	0.02
Hong Kong	29-Nov-00	4	1.2	1.18E-06	22.50	114.50	2794	2.85E+09	125994	1.15E-06	97.8	2.53E-08	2.2	2.48E-10	0.02
Japan	16-Dec-00	316	96.0	2.25E+00	40.50	141.00	796	2.35E+09	358298	2.20E+00	97.8	4.84E-02	2.2	4.74E-04	0.02
Laos	None														
Mongolia	10-May-00	36	10.9	3.91E-02	47.00	120.00	1042	2.11E+09	33341	3.83E-02	97.8	8.42E-04	2.2	8.24E-06	0.02
N. Korea	20-Aug-00	199	60.5	2.46E+00	42.00	129.00	270	2.30E+09	200822	2.41E+00	97.8	5.29E-02	2.2	5.18E-04	0.02
Russia	12-Jun-00	324	98.5	1.55E+01	43.50	133.50	134	2.25E+09	34008	1.52E+01	97.8	3.34E-01	2.2	3.27E-03	0.02
S. Korea	11-Jan-00	151	45.9	6.04E-01	38.50	127.50	628	2.42E+09	292252	5.90E-01	97.8	1.30E-02	2.2	1.27E-04	0.02
Taiwan	29-Nov-00	21	6.4	1.13E-01	24.00	121.50	2322	2.82E+09	152461	1.11E-01	97.8	2.43E-03	2.2	2.38E-05	0.02
Thailand	None														
Aleutians (U.S.)	23-Apr-00	154	46.8	3.15E-02	52.00	177.00	3464	1.91E+09	0	3.08E-02	97.8	6.77E-04	2.2	6.63E-06	0.02
Alaska (U.S.)	25-Mar-00	119	36.2	2.17E-02	58.50	202.50	4986	1.62E+09	15	2.12E-02	97.8	4.66E-04	2.2	4.56E-06	0.02
Vietnam	29-Nov-00	1	0.3	2.29E-13	20.50	107.00	3416	2.89E+09	13869	2.24E-13	97.8	4.93E-15	2.2	4.83E-17	0.02

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 98. VRS Worst-Case Sr-90 Maximum Total Dose Commitment per Adult Estimates and Breakdown by Type

Region	Date	N	N (%)	MaxTot (mSv)	Lat	Lon	Dist (km)	Area (m^2)	Pop	Ingest (mSv)	Ingest (%)	Inhalat (mSv)	Inhalat (%)	ExtExp (mSv)	ExtExp (%)
Regional	12-Jun-00	329	100.0	3.73E+00	43.50	133.50	134	2.25E+09	34008	3.34E+00	89.5	3.87E-01	10.4	3.27E-03	0.09
Transboundary**	07-Jun-00	329	100.0	9.80E-01	43.50	131.50	69	2.25E+09	42463	8.77E-01	89.5	1.02E-01	10.4	8.59E-04	0.09
Burma	None														
China	07-Jun-00	259	78.7	9.80E-01	43.50	131.50	69	2.25E+09	42463	8.77E-01	89.5	1.02E-01	10.4	8.59E-04	0.09
Hong Kong	29-Nov-00	4	1.2	2.83E-07	22.50	114.50	2794	2.85E+09	125994	2.53E-07	89.5	2.94E-08	10.4	2.48E-10	0.09
Japan	16-Dec-00	316	96.0	5.41E-01	40.50	141.00	796	2.35E+09	358298	4.84E-01	89.5	5.62E-02	10.4	4.74E-04	0.09
Laos	None														
Mongolia	10-May-00	36	10.9	9.40E-03	47.00	120.00	1042	2.11E+09	33341	8.41E-03	89.5	9.77E-04	10.4	8.24E-06	0.09
N. Korea	20-Aug-00	199	60.5	5.91E-01	42.00	129.00	270	2.30E+09	200822	5.29E-01	89.5	6.14E-02	10.4	5.18E-04	0.09
Russia	12-Jun-00	324	98.5	3.73E+00	43.50	133.50	134	2.25E+09	34008	3.34E+00	89.5	3.87E-01	10.4	3.27E-03	0.09
S. Korea	11-Jan-00	151	45.9	1.45E-01	38.50	127.50	628	2.42E+09	292252	1.30E-01	89.5	1.51E-02	10.4	1.27E-04	0.09
Taiwan	29-Nov-00	21	6.4	2.72E-02	24.00	121.50	2322	2.82E+09	152461	2.43E-02	89.5	2.82E-03	10.4	2.38E-05	0.09
Thailand	None														
Aleutians (U.S.)	23-Apr-00	154	46.8	7.56E-03	52.00	177.00	3464	1.91E+09	0	6.77E-03	89.5	7.86E-04	10.4	6.63E-06	0.09
Alaska (U.S.)	25-Mar-00	119	36.2	5.21E-03	58.50	202.50	4986	1.62E+09	15	4.66E-03	89.5	5.41E-04	10.4	4.56E-06	0.09
Vietnam	29-Nov-00	1	0.3	5.51E-14	20.50	107.00	3416	2.89E+09	13869	4.93E-14	89.5	5.72E-15	10.4	4.83E-17	0.09

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 99. VRS Worst-Case I-131 Maximum Total Dose Commitment per Maximum Individual (i.e., Infant) Estimates and Breakdown by Type

Region	Date	N	N (%)	MaxTot (mSv)	Lat	Lon	Dist (km)	Area (m^2)	Pop	Ingest (mSv)	Ingest (%)	Inhalat (mSv)	Inhalat (%)	ExtExp (mSv)	ExtExp (%)
Regional	12-Jun-00	329	100.0	3.76E-02	43.50	133.50	134	2.25E+09	34008	3.73E-02	99.2	2.17E-04	0.6	8.56E-05	0.2
Transboundary**	07-Jun-00	329	100.0	9.78E-03	43.50	131.50	69	2.25E+09	42463	9.70E-03	99.2	5.64E-05	0.6	2.23E-05	0.2
Burma	None														
China	07-Jun-00	245	74.5	9.78E-03	43.50	131.50	69	2.25E+09	42463	9.70E-03	99.2	5.64E-05	0.6	2.23E-05	0.2
Hong Kong	None														
Japan	20-Nov-00	270	82.1	1.86E-03	36.00	138.00	933	2.50E+09	405254	1.84E-03	99.2	1.07E-05	0.6	4.24E-06	0.2
Laos	None														
Mongolia	21-Apr-00	5	1.5	4.17E-10	47.00	120.00	1042	2.11E+09	33341	4.14E-10	99.2	2.40E-12	0.6	9.50E-13	0.2
N. Korea	20-Aug-00	150	45.6	6.27E-03	42.00	129.00	270	2.30E+09	200822	6.22E-03	99.2	3.61E-05	0.6	1.43E-05	0.2
Russia	12-Jun-00	324	98.5	3.76E-02	43.50	133.50	134	2.25E+09	34008	3.73E-02	99.2	2.17E-04	0.6	8.56E-05	0.2
S. Korea	11-Jan-00	89	27.1	8.78E-04	37.50	129.00	662	2.45E+09	155901	8.71E-04	99.2	5.06E-06	0.6	2.00E-06	0.2
Taiwan	None														
Thailand	None														
Aleutians (U.S.)	07-Mar-00	25	7.6	5.27E-06	52.00	177.00	3464	1.91E+09	0	5.23E-06	99.2	3.04E-08	0.6	1.20E-08	0.2
Alaska (U.S.)	14-Nov-00	5	1.5	4.29E-18	55.00	198.00	4801	1.78E+09	46	4.25E-18	99.2	2.47E-20	0.6	9.76E-21	0.2
Vietnam	None														

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 100. VRS Worst-Case I-131 Maximum Total Dose Commitment per Age-Weighted Individual Estimates and Breakdown by Type

Region	Date	N	N (%)	MaxTot (mSv)	Lat	Lon	Dist (km)	Area (m^2)	Pop	Ingest (mSv)	Ingest (%)	Inhalat (mSv)	Inhalat (%)	ExtExp (mSv)	ExtExp (%)
Regional	12-Jun-00	329	100.0	4.39E-03	43.50	133.50	134	2.25E+09	34008	4.12E-03	93.8	1.87E-04	4.3	8.56E-05	1.9
Transboundary**	07-Jun-00	329	100.0	1.14E-03	43.50	131.50	69	2.25E+09	42463	1.07E-03	93.8	4.87E-05	4.3	2.23E-05	1.9
Burma	None														
China	07-Jun-00	245	74.5	1.14E-03	43.50	131.50	69	2.25E+09	42463	1.07E-03	93.8	4.87E-05	4.3	2.23E-05	1.9
Hong Kong	None														
Japan	20-Nov-00	270	82.1	2.17E-04	36.00	138.00	933	2.50E+09	405254	2.04E-04	93.8	9.26E-06	4.3	4.24E-06	1.9
Laos	None														
Mongolia	21-Apr-00	5	1.5	4.88E-11	47.00	120.00	1042	2.11E+09	33341	4.57E-11	93.8	2.08E-12	4.3	9.50E-13	1.9
N. Korea	20-Aug-00	150	45.6	7.33E-04	42.00	129.00	270	2.30E+09	200822	6.88E-04	93.8	3.12E-05	4.3	1.43E-05	1.9
Russia	12-Jun-00	324	98.5	4.39E-03	43.50	133.50	134	2.25E+09	34008	4.12E-03	93.8	1.87E-04	4.3	8.56E-05	1.9
S. Korea	11-Jan-00	89	27.1	1.03E-04	37.50	129.00	662	2.45E+09	155901	9.63E-05	93.8	4.37E-06	4.3	2.00E-06	1.9
Taiwan	None														
Thailand	None														
Aleutians (U.S.)	07-Mar-00	25	7.6	6.17E-07	52.00	177.00	3464	1.91E+09	0	5.78E-07	93.8	2.62E-08	4.3	1.20E-08	1.9
Alaska (U.S.)	14-Nov-00	5	1.5	5.01E-19	55.00	198.00	4801	1.78E+09	46	4.70E-19	93.8	2.13E-20	4.3	9.76E-21	1.9
Vietnam	None														

* Dist and Area represent the distance from the risk site to the maximum deposition and area impacted by the maximum deposition, respectively.
** The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 101. Maximum, Worst-Case Regional Dose Commitments for the Maximum Individual Compared to Reference Limits [17]

	PRS*							VRS*					
	Cs-137 (Teen)		Sr-90 (Infant)		I-131 (Infant)			Cs-137 (Teen)		Sr-90 (Infant)		I-131 (Infant)	
Criterion	Count	Percent	Count	Percent	Count	Percent		Count	Percent	Count	Percent	Count	Percent
<0.15 mSv	2	0.6	47	14.4	323	100.0		1	0.3	20	6.1	329	100.0
<1.0 mSv	46	14.1	139	42.6	3	0.0		19	5.8	172	52.3	0	0.0
<10.0 mSv	180	55.2	135	41.4	0	0.0		209	63.5	133	40.4	0	0.0
<100.0 mSv	97	29.8	5	1.5	0	0.0		98	29.8	4	1.2	0	0.0
>100.0 mSv	1	0.3	0	0.0	0	0.0		2	0.6	0	0.0	0	0.0
Total	326	100.0	326	100.0	326	100.0		329	100.0	329	100.0	329	100.0

* As stated above, there were complete data (i.e., all 144 hours) for 326 and 329 out of 366 days of CY2000 for the PRS and VRS, respectively.

Table 102. Maximum, Worst-Case Regional Dose Commitments for Adults Compared to Reference Limits [17]

	PRS*							VRS*					
	Cs-137 (Adult)		Sr-90 (Adult)		I-131 (Weighted)			Cs-137 (Adult)		Sr-90 (Adult)		I-131 (Weighted)	
Criterion	Count	Percent	Count	Percent	Count	Percent		Count	Percent	Count	Percent	Count	Percent
<0.15 mSv	3	0.9	142	43.6	326	100.0		1	0.3	135	41.0	329	100.0
<1.0 mSv	47	14.4	152	46.6	0	0.0		20	6.1	169	51.4	0	0.0
<10.0 mSv	190	58.3	32	9.8	0	0.0		215	65.3	25	7.6	0	0.0
<100.0 mSv	86	26.4	0	0.0	0	0.0		93	28.3	0	0.0	0	0.0
>100.0 mSv	0	0.0	0	0.0	0	0.0		0	0.0	0	0.0	0	0.0
Total	326	100.0	326	100.0	326	100.0		329	100.0	329	100.0	329	100.0

* As stated above, there were complete data (i.e., all 144 hours) for 326 and 329 out of 366 days of CY2000 for the PRS and VRS, respectively.

Table 103. Maximum, Worst-Case Transboundary Dose Commitments for the Maximum Individual Compared to Reference Limits [17]

	PRS*							VRS*					
	Cs-137 (Teen)		Sr-90 (Infant)		I-131 (Infant)			Cs-137 (Teen)		Sr-90 (Infant)		I-131 (Infant)	
Criterion	Count	Percent	Count	Percent	Count	Percent		Count	Percent	Count	Percent	Count	Percent
<0.15 mSv	168	51.5	303	92.9	326	100.0		1	0.3	67	20.4	329	100.0
<1.0 mSv	135	41.4	23	7.1	0	0.0		65	19.8	199	60.5	0	0.0
<10.0 mSv	23	7.1	0	0.0	0	0.0		234	71.1	63	19.1	0	0.0
<100.0 mSv	0	0.0	0	0.0	0	0.0		29	8.8	0	0.0	0	0.0
>100.0 mSv	0	0.0	0	0.0	0	0.0		0	0.0	0	0.0	0	0.0
Total	326	100.0	326	100.0	326	100.0		329	100.0	329	100.0	329	100.0

* As stated above, there were complete data (i.e., all 144 hours) for 326 and 329 out of 366 days of CY2000 for the PRS and VRS, respectively.

Table 104. Maximum, Worst-Case Transboundary Dose Commitments for Adults Compared to Reference Limits [17]

	PRS*							VRS*					
	Cs-137 (Adult)		Sr-90 (Adult)		I-131 (Weighted)			Cs-137 (Adult)		Sr-90 (Adult)		I-131 (Weighted)	
Criterion	Count	Percent	Count	Percent	Count	Percent		Count	Percent	Count	Percent	Count	Percent
<0.15 mSv	172	52.8	325	99.7	326	100.0		1	0.3	216	65.7	329	100.0
<1.0 mSv	138	42.3	1	0.3	0	0.0		75	22.8	113	34.3	0	0.0
<10.0 mSv	16	4.9	0	0.0	0	0.0		229	69.6	0	0.0	0	0.0
<100.0 mSv	0	0.0	0	0.0	0	0.0		24	7.3	0	0.0	0	0.0
>100.0 mSv	0	0.0	0	0.0	0	0.0		0	0.0	0	0.0	0	0.0
Total	326	100.0	326	100.0	326	100.0		329	100.0	329	100.0	329	100.0

* As stated above, there were complete data (i.e., all 144 hours) for 326 and 329 out of 366 days of CY2000 for the PRS and VRS, respectively.

Table 105. PRS Maximum Weighted Cs-137 Collective Dose Estimates for Threshold Values of 0.0, 0.1 and 0.15 mSv

	No Threshold						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	1-Jan	7.09E+03	2.75E+03	1.42E+01	4.33E+03	1.89E+12	1.38E+08
Transboundary*	1-Jan	6.57E+03	2.55E+03	1.31E+01	4.01E+03	1.02E+12	1.34E+08
Burma	None						
China	4-Jan	1.66E+03	6.43E+02	3.31E+00	1.01E+03	1.48E+12	1.13E+08
Hong Kong	None						
Japan	1-Jan	6.57E+03	2.55E+03	1.31E+01	4.01E+03	4.28E+11	9.75E+07
Laos	None						
Mongolia	4-Jan	3.79E+00	1.47E+00	7.58E-03	2.31E+00	3.11E+11	3.43E+05
N. Korea	7-Jan	2.02E+02	7.82E+01	4.03E-01	1.23E+02	1.72E+11	2.63E+07
Russia	14-Jun	2.05E+03	7.96E+02	4.11E+00	1.25E+03	1.76E+12	9.98E+05
S. Korea	5-Jan	2.32E+02	9.00E+01	4.64E-01	1.41E+02	1.52E+11	4.48E+07
Taiwan	None						
Thailand	None						
Aleutians (U.S.)	24-Jan	5.26E+00	2.04E+00	1.05E-02	3.21E+00	5.29E+10	5.47E+03
Alaska (U.S.)	13-Oct	3.53E+02	1.37E+02	7.06E-01	2.15E+02	9.93E+11	4.61E+05
Vietnam	None						

	Threshold of 0.1 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	1-Jan	4.44E+03	1.72E+03	8.89E+00	2.71E+03	3.76E+11	2.70E+07
Transboundary*	1-Jan	3.98E+03	1.55E+03	7.97E+00	2.43E+03	2.20E+11	2.63E+07
Burma	None						
China	7-Jan	8.05E+02	3.12E+02	1.61E+00	4.91E+02	7.78E+10	4.90E+06
Hong Kong	None						
Japan	1-Jan	3.98E+03	1.55E+03	7.97E+00	2.43E+03	2.20E+11	2.63E+07
Laos	None						
Mongolia	None						
N. Korea	7-Jan	1.54E+02	5.98E+01	3.09E-01	9.41E+01	9.09E+09	1.03E+06
Russia	14-Jun	2.04E+03	7.93E+02	4.09E+00	1.25E+03	2.84E+11	2.48E+05
S. Korea	None						
Taiwan	None						
Thailand	None						
Aleutians (U.S.)	24-Jan	5.17E+00	2.01E+00	1.04E-02	3.16E+00	4.19E+10	2.37E+03
Alaska (U.S.)	13-Oct	3.50E+02	1.36E+02	6.99E-01	2.13E+02	2.58E+11	3.08E+05
Vietnam	None						

	Threshold of 0.15 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	26-Apr	2.47E+03	9.56E+02	4.93E+00	1.50E+03	2.61E+11	4.89E+06
Transboundary*	26-Apr	2.37E+03	9.18E+02	4.73E+00	1.44E+03	1.50E+11	4.61E+06
Burma	None						
China	7-Jan	5.49E+02	2.13E+02	1.10E+00	3.35E+02	4.46E+10	2.83E+06
Hong Kong	None						
Japan	26-Apr	2.37E+03	9.18E+02	4.73E+00	1.44E+03	1.01E+11	4.61E+06
Laos	None						
Mongolia	None						
N. Korea	7-Jan	8.67E+01	3.36E+01	1.73E-01	5.29E+01	4.53E+09	5.10E+05
Russia	14-Jun	2.04E+03	7.92E+02	4.08E+00	1.25E+03	2.63E+11	2.32E+05
S. Korea	None						
Taiwan	None						
Thailand	None						
Aleutians (U.S.)	24-Jan	5.17E+00	2.01E+00	1.04E-02	3.16E+00	4.19E+10	2.37E+03
Alaska (U.S.)	13-Oct	3.48E+02	1.35E+02	6.97E-01	2.12E+02	2.26E+11	2.98E+05
Vietnam	None						

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 106. PRS Maximum Weighted Cs-137 Collective Dose Estimates for Threshold Values of 1.0 and 10.0 mSv

	Threshold of 1.0 mSv per person							Threshold of 10.0 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	14-Jun	1.99E+03	7.74E+02	3.99E+00	1.22E+03	1.37E+11	1.32E+05	14-Jun	1.67E+03	6.49E+02	3.35E+00	1.02E+03	7.05E+10	6.60E+04
Transboundary*	13-Oct	2.94E+02	1.14E+02	5.87E-01	1.79E+02	5.33E+10	1.99E+05	None						
Burma	None							None						
China	None							None						
Hong Kong	None							None						
Japan	None							None						
Laos	None							None						
Mongolia	None							None						
N. Korea	None							None						
Russia	14-Jun	1.99E+03	7.74E+02	3.99E+00	1.22E+03	1.37E+11	1.32E+05	14-Jun	1.67E+03	6.49E+02	3.35E+00	1.02E+03	7.05E+10	6.60E+04
S. Korea	None							None						
Taiwan	None							None						
Thailand	None							None						
Aleutians (U.S.)	24-Jan	5.05E+00	1.96E+00	1.01E-02	3.08E+00	1.53E+10	2.21E+03	None						
Alaska (U.S.)	13-Oct	2.94E+02	1.14E+02	5.87E-01	1.79E+02	5.33E+10	1.99E+05	None						
Vietnam	None							None						

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 107. PRS Maximum Weighted Sr-90 Collective Dose Estimates for Threshold Values of 0.0, 0.1 and 0.15 mSv

	No Threshold						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	1-Jan	3.69E+02	3.36E+02	3.35E+01	2.46E-01	1.23E+12	1.19E+08
Transboundary*	1-Jan	3.45E+02	3.13E+02	3.13E+01	2.29E-01	7.23E+11	1.16E+08
Burma	None						
China	7-Jan	8.10E+01	7.36E+01	7.35E+00	5.39E-02	1.03E+12	7.61E+07
Hong Kong	None						
Japan	1-Jan	3.45E+02	3.13E+02	3.13E+01	2.29E-01	4.28E+11	9.75E+07
Laos	None						
Mongolia	4-Jan	1.74E-01	1.58E-01	1.58E-02	1.16E-04	3.11E+11	3.43E+05
N. Korea	7-Jan	9.82E+00	8.92E+00	8.91E-01	6.53E-03	1.27E+11	1.42E+07
Russia	14-Jun	1.09E+02	9.94E+01	9.92E+00	7.28E-02	1.73E+12	9.94E+05
S. Korea	5-Jan	5.18E+00	4.70E+00	4.70E-01	3.44E-03	1.49E+11	4.48E+07
Taiwan	None						
Thailand	None						
Aleutians (U.S.)	24-Jan	2.37E-01	2.16E-01	2.15E-02	1.58E-04	5.29E+10	5.47E+03
Alaska (U.S.)	13-Oct	1.51E+01	1.37E+01	1.37E+00	1.01E-02	8.69E+11	4.54E+05
Vietnam	None						

	Threshold of 0.1 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	14-Jun	1.06E+02	9.61E+01	9.59E+00	7.03E-02	1.29E+11	1.23E+05
Transboundary*	13-Oct	7.33E-01	6.66E-01	6.65E-02	4.88E-04	7.42E+09	7.19E+03
Burma	None						
China	None						
Hong Kong	None						
Japan	None						
Laos	None						
Mongolia	None						
N. Korea	None						
Russia	14-Jun	1.06E+02	9.61E+01	9.59E+00	7.03E-02	1.29E+11	1.23E+05
S. Korea	None						
Taiwan	None						
Thailand	None						
Aleutians (U.S.)	24-Jan	2.00E-01	1.82E-01	1.82E-02	1.33E-04	1.14E+10	1.79E+03
Alaska (U.S.)	13-Oct	7.33E-01	6.66E-01	6.65E-02	4.88E-04	7.42E+09	7.19E+03
Vietnam	None						

	Threshold of 0.15 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	14-Jun	1.05E+02	9.52E+01	9.51E+00	6.97E-02	1.20E+11	1.15E+05
Transboundary*	18-Feb	5.72E-02	5.20E-02	5.19E-03	3.81E-05	8.03E+09	3.45E+02
Burma	None						
China	None						
Hong Kong	None						
Japan	None						
Laos	None						
Mongolia	None						
N. Korea	None						
Russia	14-Jun	1.05E+02	9.52E+01	9.51E+00	6.97E-02	1.20E+11	1.15E+05
S. Korea	None						
Taiwan	None						
Thailand	None						
Aleutians (U.S.)	None						
Alaska (U.S.)	18-Feb	5.72E-02	5.20E-02	5.19E-03	3.81E-05	8.03E+09	3.45E+02
Vietnam	None						

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 108. PRS Maximum Weighted Sr-90 Collective Dose Estimates for Threshold Values of 1.0 and 10.0 mSv

	Threshold of 1.0 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	21-Mar	7.16E+01	6.51E+01	6.50E+00	4.76E-02	3.97E+10	3.33E+04
Transboundary*	None						
Burma	None						
China	None						
Hong Kong	None						
Japan	None						
Laos	None						
Mongolia	None						
N. Korea	None						
Russia	21-Mar	7.16E+01	6.51E+01	6.50E+00	4.76E-02	3.97E+10	3.33E+04
S. Korea	None						
Taiwan	None						
Thailand	None						
Aleutians (U.S.)	None						
Alaska (U.S.)	None						
Vietnam	None						

Threshold of 10.0 mSv per person						
Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
No dose commitments at this threshold value						

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 109. PRS Maximum Weighted I-131 Collective Dose Estimates for Threshold Values of 0.0, 0.1 and 0.15 mSv

	No Threshold							Threshold of 0.1 mSv per person							Threshold of 0.15 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	14-Jun	6.54E-02	6.14E-02	2.78E-03	1.27E-03	2.99E+11	2.54E+05														
Transboundary*	1-Jan	1.29E-03	1.21E-03	5.49E-05	2.51E-05	8.04E+10	3.63E+06														
Burma	None																				
China	4-Dec	7.05E-10	6.61E-10	3.00E-11	1.37E-11	5.62E+11	2.16E+07														
Hong Kong	None																				
Japan	1-Jan	1.29E-03	1.21E-03	5.49E-05	2.51E-05	8.04E+10	3.63E+06														
Laos	None																				
Mongolia	None							No dose commitments at this threshold value							No dose commitments at this threshold value						
N. Korea	None																				
Russia	14-Jun	6.54E-02	6.14E-02	2.78E-03	1.27E-03	2.99E+11	2.54E+05														
S. Korea	None																				
Taiwan	None																				
Thailand	None																				
Aleutians (U.S.)	20-Jan	4.31E-05	4.04E-05	1.83E-06	8.39E-07	5.29E+10	5.47E+03														
Alaska (U.S.)	12-Oct	1.23E-06	1.15E-06	5.23E-08	2.39E-08	5.47E+10	3.10E+03														
Vietnam	None																				

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 110. PRS Maximum Weighted I-131 Collective Dose Estimates for Threshold Values of 1.0 and 10.0 mSv

	Threshold of 1.0 mSv per person							Threshold of 10.0 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional														
Transboundary*														
Burma														
China														
Hong Kong														
Japan														
Laos														
Mongolia	No dose commitments at this threshold value							No dose commitments at this threshold value						
N. Korea														
Russia														
S. Korea														
Taiwan														
Thailand														
Aleutians (U.S.)														
Alaska (U.S.)														
Vietnam														

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 111. VRS Maximum Weighted Cs-137 Collective Dose Estimates for Threshold Values of 0.0, 0.1 and 0.15 mSv

	No Threshold							Threshold of 0.1 mSv per person							Threshold of 0.15 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	21-Nov	1.96E+05	7.59E+04	3.91E+02	1.19E+05	2.10E+12	2.70E+08	21-Nov	1.95E+05	7.57E+04	3.90E+02	1.19E+05	6.49E+11	1.39E+08	21-Nov	1.95E+05	7.56E+04	3.90E+02	1.19E+05	6.08E+11	1.36E+08
Transboundary*	21-Nov	1.95E+05	7.58E+04	3.91E+02	1.19E+05	1.21E+12	2.69E+08	21-Nov	1.95E+05	7.56E+04	3.90E+02	1.19E+05	6.26E+11	1.38E+08	21-Nov	1.95E+05	7.55E+04	3.89E+02	1.19E+05	5.94E+11	1.36E+08
Burma	None							None							None						
China	9-May	1.72E+05	6.65E+04	3.43E+02	1.05E+05	1.71E+12	2.17E+08	9-May	1.71E+05	6.63E+04	3.42E+02	1.04E+05	7.09E+11	9.67E+07	9-May	1.71E+05	6.62E+04	3.41E+02	1.04E+05	6.35E+11	9.43E+07
Hong Kong	12-Sep	3.78E+01	1.47E+01	7.57E-02	2.31E+01	5.70E+09	5.42E+06	None							None						
Japan	21-Nov	1.90E+05	7.37E+04	3.80E+02	1.16E+05	6.37E+11	1.25E+08	21-Nov	1.90E+05	7.36E+04	3.80E+02	1.16E+05	5.70E+11	1.17E+08	21-Nov	1.89E+05	7.35E+04	3.79E+02	1.16E+05	5.41E+11	1.15E+08
Laos	None							None							None						
Mongolia	10-May	3.21E+01	1.24E+01	6.42E-02	1.96E+01	4.06E+11	4.77E+05	10-May	2.88E+01	1.12E+01	5.75E-02	1.75E+01	1.24E+11	1.61E+05	10-May	2.22E+01	8.63E+00	4.45E-02	1.36E+01	8.05E+10	1.07E+05
N. Korea	12-Sep	4.97E+04	1.93E+04	9.94E+01	3.03E+04	1.84E+11	2.76E+07	12-Sep	4.95E+04	1.92E+04	9.91E+01	3.02E+04	1.80E+11	2.56E+07	12-Sep	4.95E+04	1.92E+04	9.91E+01	3.02E+04	1.77E+11	2.56E+07
Russia	2-Aug	3.23E+04	1.25E+04	6.46E+01	1.97E+04	6.64E+11	6.09E+06	2-Aug	3.23E+04	1.25E+04	6.45E+01	1.97E+04	3.70E+11	4.58E+06	2-Aug	3.22E+04	1.25E+04	6.44E+01	1.96E+04	3.56E+11	3.99E+06
S. Korea	27-Sep	4.87E+04	1.89E+04	9.75E+01	2.97E+04	1.52E+11	4.48E+07	27-Sep	4.87E+04	1.89E+04	9.75E+01	2.97E+04	1.49E+11	4.48E+07	27-Sep	4.87E+04	1.89E+04	9.75E+01	2.97E+04	1.49E+11	4.48E+07
Taiwan	29-Nov	6.35E+03	2.46E+03	1.27E+01	3.88E+03	6.49E+10	2.17E+07	29-Nov	6.35E+03	2.46E+03	1.27E+01	3.88E+03	6.49E+10	2.17E+07	29-Nov	6.35E+03	2.46E+03	1.27E+01	3.88E+03	6.49E+10	2.17E+07
Thailand	None							None							None						
Aleutians (U.S.)	6-Mar	3.31E-01	1.29E-01	6.63E-04	2.02E-01	5.29E+10	5.47E+03	7-Mar	5.84E-02	2.27E-02	1.17E-04	3.56E-02	1.14E+10	5.29E+02	None						
Alaska (U.S.)	24-Mar	3.67E+01	1.42E+01	7.34E-02	2.24E+01	1.01E+12	4.66E+05	24-Mar	2.82E+01	1.09E+01	5.64E-02	1.72E+01	5.80E+10	2.01E+05	24-Mar	5.17E+00	2.01E+00	1.03E-02	3.15E+00	2.67E+10	2.54E+04
Vietnam	29-Nov	1.44E-07	5.60E-08	2.89E-10	8.81E-08	2.89E+09	1.39E+04	None							None						

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 112. VRS Maximum Weighted Cs-137 Collective Dose Estimates for Threshold Values of 1.0 and 10.0 mSv

	Threshold of 1.0 mSv per person							Threshold of 10.0 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	21-Nov	1.69E+05	6.54E+04	3.37E+02	1.03E+05	2.32E+11	7.80E+07	2-Aug	2.55E+04	9.90E+03	5.10E+01	1.56E+04	4.48E+10	6.19E+05
Transboundary*	21-Nov	1.68E+05	6.54E+04	3.37E+02	1.03E+05	2.23E+11	7.79E+07	7-Jun	1.25E+04	4.86E+03	2.51E+01	7.65E+03	2.03E+10	9.30E+05
Burma	None							None						
China	9-May	1.58E+05	6.12E+04	3.16E+02	9.62E+04	3.78E+11	6.91E+07	1-Jan	9.72E+03	3.77E+03	1.94E+01	5.93E+03	1.80E+10	7.21E+05
Hong Kong	None							None						
Japan	21-Nov	1.68E+05	6.54E+04	3.37E+02	1.03E+05	2.23E+11	7.79E+07	16-Dec	1.10E+04	4.27E+03	2.20E+01	6.71E+03	7.08E+09	9.41E+05
Laos	None							None						
Mongolia	None							None						
N. Korea	7-Jun	4.16E+04	1.61E+04	8.31E+01	2.53E+04	9.55E+10	8.97E+06	20-Aug	9.85E+03	3.82E+03	1.97E+01	6.01E+03	9.22E+09	8.47E+05
Russia	2-Aug	3.14E+04	1.22E+04	6.29E+01	1.92E+04	2.31E+11	2.57E+06	2-Aug	2.55E+04	9.90E+03	5.10E+01	1.56E+04	4.48E+10	6.19E+05
S. Korea	15-Nov	3.37E+04	1.31E+04	6.75E+01	2.06E+04	5.64E+10	2.29E+07	None						
Taiwan	None							None						
Thailand	None							None						
Aleutians (U.S.)	None							None						
Alaska (U.S.)	None							None						
Vietnam	None							None						

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 113. VRS Maximum Weighted Sr-90 Collective Dose Estimates for Threshold Values of 0.0, 0.1 and 0.15 mSv

No Threshold

	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	21-Nov	9.68E+03	8.80E+03	8.78E+02	6.44E+00	1.84E+12	2.40E+08
Transboundary*	21-Nov	9.67E+03	8.78E+03	8.77E+02	6.43E+00	1.10E+12	2.39E+08
Burma	None						
China	9-May	8.53E+03	7.75E+03	7.73E+02	5.67E+00	1.55E+12	1.91E+08
Hong Kong	29-Nov	1.08E-03	9.84E-04	9.82E-05	7.20E-07	5.70E+09	5.42E+06
Japan	21-Nov	9.55E+03	8.67E+03	8.66E+02	6.35E+00	6.28E+11	1.25E+08
Laos	None						
Mongolia	10-May	1.38E+00	1.25E+00	1.25E-01	9.18E-04	3.86E+11	4.43E+05
N. Korea	12-Sep	2.53E+03	2.29E+03	2.29E+02	1.68E+00	1.84E+11	2.76E+07
Russia	2-Aug	1.64E+03	1.49E+03	1.49E+02	1.09E+00	6.64E+11	6.09E+06
S. Korea	27-Sep	2.48E+03	2.25E+03	2.25E+02	1.65E+00	1.52E+11	4.48E+07
Taiwan	29-Nov	3.28E+02	2.98E+02	2.98E+01	2.18E-01	6.49E+10	2.17E+07
Thailand	None						
Aleutians (U.S.)	6-Mar	9.57E-03	8.69E-03	8.68E-04	6.36E-06	5.29E+10	5.47E+03
Alaska (U.S.)	25-Mar	2.52E-01	2.29E-01	2.29E-02	1.68E-04	8.62E+11	3.78E+05
Vietnam	29-Nov	1.01E-12	9.15E-13	9.13E-14	6.70E-16	2.89E+09	1.39E+04

Threshold of 0.1 mSv per person

	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	30-Jan	6.22E+03	5.65E+03	5.64E+02	4.14E+00	7.26E+10	3.70E+07
Transboundary*	30-Jan	6.22E+03	5.65E+03	5.64E+02	4.14E+00	7.26E+10	3.70E+07
Burma	None						
China	9-May	5.23E+03	4.76E+03	4.75E+02	3.48E+00	1.97E+11	3.57E+07
Hong Kong	None						
Japan	30-Jan	6.22E+03	5.65E+03	5.64E+02	4.14E+00	7.26E+10	3.70E+07
Laos	None						
Mongolia	None						
N. Korea	12-Sep	1.92E+03	1.74E+03	1.74E+02	1.28E+00	9.08E+10	8.71E+06
Russia	2-Aug	1.55E+03	1.41E+03	1.41E+02	1.03E+00	1.62E+11	1.93E+06
S. Korea	11-Jan	3.67E+02	3.34E+02	3.33E+01	2.44E-01	2.93E+10	2.64E+06
Taiwan	None						
Thailand	None						
Aleutians (U.S.)	None						
Alaska (U.S.)	None						
Vietnam	None						

Threshold of 0.15 mSv per person

	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	30-Jan	3.92E+03	3.56E+03	3.56E+02	2.61E+00	4.77E+10	1.91E+07
Transboundary*	30-Jan	3.92E+03	3.56E+03	3.56E+02	2.61E+00	4.77E+10	1.91E+07
Burma	None						
China	30-Aug	2.74E+03	2.49E+03	2.48E+02	1.82E+00	1.21E+11	1.30E+07
Hong Kong	None						
Japan	30-Jan	3.92E+03	3.56E+03	3.56E+02	2.61E+00	4.77E+10	1.91E+07
Laos	None						
Mongolia	None						
N. Korea	7-Jun	1.72E+03	1.56E+03	1.56E+02	1.14E+00	5.55E+10	4.66E+06
Russia	2-Aug	1.49E+03	1.36E+03	1.36E+02	9.94E-01	1.13E+11	1.45E+06
S. Korea	11-Jan	1.32E+02	1.20E+02	1.20E+01	8.78E-02	7.30E+09	7.37E+05
Taiwan	None						
Thailand	None						
Aleutians (U.S.)	None						
Alaska (U.S.)	None						
Vietnam	None						

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 114. VRS Maximum Weighted Sr-90 Collective Dose Estimates for Threshold Values of 1.0 and 10.0 mSv

Threshold of 1.0 mSv per person

	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	2-Aug	1.27E+03	1.15E+03	1.15E+02	8.42E-01	4.03E+10	5.52E+05
Transboundary*	14-Jun	1.30E+02	1.18E+02	1.18E+01	8.64E-02	4.36E+09	1.25E+05
Burma	None						
China	14-Jun	1.30E+02	1.18E+02	1.18E+01	8.64E-02	4.36E+09	1.25E+05
Hong Kong	None						
Japan	None						
Laos	None						
Mongolia	None						
N. Korea	None						
Russia	2-Aug	1.27E+03	1.15E+03	1.15E+02	8.42E-01	4.03E+10	5.52E+05
S. Korea	None						
Taiwan	None						
Thailand	None						
Aleutians (U.S.)	None						
Alaska (U.S.)	None						
Vietnam	None						

Threshold of 10.0 mSv per person

Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
No dose commitments at this threshold value						

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 115. VRS Maximum Weighted I-131 Collective Dose Estimates for Threshold Values of 0.0, 0.1 and 0.15 mSv

	No Threshold						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional	30-Jan	3.56E+00	3.34E+00	1.51E-01	6.93E-02	2.37E+11	8.58E+07
Transboundary*	30-Jan	3.56E+00	3.34E+00	1.51E-01	6.93E-02	2.25E+11	8.57E+07
Burma	None						
China	10-May	3.05E+00	2.86E+00	1.30E-01	5.94E-02	8.68E+11	1.04E+08
Hong Kong	None						
Japan	30-Jan	3.56E+00	3.34E+00	1.51E-01	6.93E-02	2.25E+11	8.57E+07
Laos	None						
Mongolia	21-Apr	1.96E-09	1.84E-09	8.35E-11	3.82E-11	1.48E+10	4.92E+04
N. Korea	14-Sep	1.58E+00	1.48E+00	6.72E-02	3.07E-02	1.84E+11	2.76E+07
Russia	12-Jun	1.15E+00	1.08E+00	4.91E-02	2.25E-02	3.06E+11	4.29E+06
S. Korea	15-Sep	1.70E+00	1.59E+00	7.22E-02	3.31E-02	1.47E+11	4.48E+07
Taiwan	None						
Thailand	None						
Aleutians (U.S.)	14-Nov	8.20E-09	7.69E-09	3.49E-10	1.60E-10	4.73E+10	5.47E+03
Alaska (U.S.)	14-Nov	8.57E-20	8.03E-20	3.65E-21	1.67E-21	3.66E+10	2.16E+03
Vietnam	None						

	Threshold of 0.1 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional through Vietnam	**No dose commitments at this threshold value**						

	Threshold of 0.15 mSv per person						
	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional through Vietnam	**No dose commitments at this threshold value**						

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

Table 116. VRS Maximum Weighted I-131 Collective Dose Estimates for Threshold Values of 1.0 and 10.0 mSv

	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop	Date	Total (per-Sv)	Ingest (per-Sv)	Inhalat (per-Sv)	ExtExp (per-Sv)	Area (m^2)	Pop
Regional, Transboundary*, Burma, China, Hong Kong, Japan, Laos, Mongolia, N. Korea, Russia, S. Korea, Taiwan, Thailand, Aleutians (U.S.), Alaska (U.S.), Vietnam	**No dose commitments at this threshold value**							**No dose commitments at this threshold value**						

* The transboundary region includes all land areas (i.e., excluding ocean) outside of Russia.

10 List of Symbols

Symbol	Definition
A_0	Environmental input
$A_{j,td}$	Least-squares parameter from linear regression
AREA	Area of contaminated zone (m**2)
BRDL	Basic radiation dose limit (mSv/yr)
COVER0	Cover depth (m)
$Cs137_j(t_p)$	Value of the corresponding Cs-137 parameter at either the same or previous time (or $t_p \leq t_d$) that provides the best least-squares fit
D_c	UNSCEAR dose commitment for a specific radionuclide
DENSCZ	Density of contaminated zone (g/cm**3)
DIET(1)	Fruits, vegetables and grain consumption (kg/yr)
DIET(2)	Leafy vegetable consumption (kg/yr)
DIET(3)	Milk consumption (L/yr)
DIET(4)	Meat and poultry consumption (kg/yr)
DIET(5)	Fish consumption (kg/yr)
DIET(6)	Other seafood consumption (kg/yr)
DWI	Drinking water intake (L/yr)
ED	Exposure duration
FIND	Fraction of time spent indoors
FOTD	Fraction of time spent outdoors (on site)
INHALR	Inhalation rate (m**3/yr)
P_{01}	The integrated concentration of a radionuclide in the air at a given location or averaged for a broader region divided by the amount released, A_0
P_{12}	Ground deposition velocity
P_{14}	Average breathing rate
P_{23}	Transfer from deposition to diet
P_{234}	$P_{23}P_{34}$ for ingestion of I-131
P_{2345}	$P_{23}P_{34}P_{45}$ for ingestion
P_{245}	$(P_{14}P_{45})/P_{12}$ for inhalation
P_{25}	Transfer coefficients for external irradiation due to ground contamination to effective committed dose
P_{34}	Coefficient linking the concentrations of radionuclides in diet to those in the body
P_{45}	Effective committed dose per unit intake for the ingestion of a given radinuclide
p_i	Fractional population
R_i	Indoor occupancy rate
S1(1)	Initial principal radionuclide (Bq/g): Cs-137
S_f	$(1-R_i) + (R_i)(S_h)$

Symbol	Definition
S_h	Shielding factor
SHF1	Shielding factor, external gamma
SHF3	Shielding factor, inhalation
SOIL	Soil ingestion rate (g/yr)
$t_{1/2}$	Half-life
THICK0	Thickness of contaminated zone (m)
VCZ	Contaminated zone erosion rate (m/yr)
$X_j(t_d)$	Value of the parameter represented by j (i.e., j = wdep, ddep, or integrated concentration) at the desired time, t_d

11 List of Acronyms

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CY2000	Calendar Year 2000
ddep	Dry deposition
DERMA	Danish Emergency Response Model of the Atmosphere
DMI	Danish Meterological Institute
DOE	U.S. Department of Energy
ECMWF	European Center for Medium-Range Weather Forecasts
EPA	Environmental Protection Agency
FARECS	Assessment of Impact of Russian Nuclear Fleet Operations on Russian Far East Coastal Regions
FGR	Federal Guidance Report
GPW	Gridded Population of the World
ICRP	International Commission on Radiological Protection
IIASA	International Institute forApplied Systems Analysis
NARP	Nordic Arctic Research Programme
NATO	North Atlantic Treaty Organisation
NRC	U.S. Nuclear Regulatory Commission
NRS	Nuclear Risk Site
NS	Nuclear Submarine
PRS	Petropavlovsk Risk Site
RAD	Radiation Safety of the Biosphere
RESRAD	RESidual RADioactivity
SFA	Spent Fuel Assembly
SFA	Spent Fuel Assembly
tdep	Total deposition
UNFAO	Food and Agricultural Organization of the United Nations
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
VRS	Vladivostok Risk Site
wdep	Wet deposition