APPENDIX B

RADIATION DOSE CALCULATION METHODS AND ASSUMPTIONS FOR NORMAL L-REACTOR OPERATION

The normal operation of L-Reactor and its support facilities will result in releases of radioactive materials. This appendix describes the methods and assumptions used to determine the radiological impacts expected from these normal releases.

Radioactive materials released to the environment generally become involved in a complex series of physical, chemical, and biological processes. The principal pathways by which radioactivity released from a facility can reach people are (1) exposure to nuclides in the air, in the water, or on the ground, (2) the inhalation of radioactivity, and (3) the ingestion of radioactivity in food and water. Figure B-1 shows these pathways.

The calculations of radiological doses to members of the public from these various pathways are based on methods recommended by the U.S. Nuclear Regulatory Commission (NRC) for licensing power reactors. The estimates of doses are based on detailed analyses of the sources and rates of radioactive releases, and the pathways by which dispersed radioactive materials can result in exposure to people. The NRC methods are adopted to the specific Savannah River Plant (SRP) conditions.

Radiation doses are calculated for the maximally exposed individual, for the regional population within 80 kilometers of the Savannah River Plant, and to the population being served by the Beaufort-Jasper County and Cherokee Hill (Port Wentworth) water-treatment plants. To determine the expected L-Reactor impacts, the calculations were made for both the first and tenth years of L-Reactor operation. The first year was considered because the doses from remobilized cesium-137 are highest in that year; the tenth year was considered because it will take approximately 10 years before the tritium inventory in the reactor, and the resulting releases, reach equilibrium. Also, radioactive liquid releases from the migration of radionuclides from seepage basins to surface streams via ground water will not occur until 4.4 years after L-Reactor operations are resumed. The calculations were made on the basis of continuous exposure to the radionuclides released from the L-Reactor and its support facilities during these years.

The radiation doses have been calculated for a set of reference-case alternatives that consist of once-through cooling with and without seepage basins. A number of other alternatives with different cooling systems that operate with and without seepage basins have been evaluated in the main text of this EIS. TC
The doses associated with these additional alternatives, including the preferred alternative, have been derived from the reference-case analysis presented in this appendix.

B.1 ATMOSPHERIC RELEASES

For airborne releases, annual average air concentration and ground deposition per unit release (χ/Q and D/Q, respectively) were calculated for each of 160 segments (16 wind direction sectors at 10 distances) within an 80-kilometer radius of the site and for the site boundaries, using the methods implemented in the NRC computer program XOQDOQ (Sagendorf and Gall, 1976). Site-specific meteorological data were used to generate joint-frequency distributions (JFDs) of wind speed, stability, and direction for input to XOQDOQ (Table B-1). These stability windrose statistics were derived by 1-hour averaging of data collected at the 61-meter level of the SRP H-Area meteorological tower during the 5-year period from 1975 to 1979. Stability class was determined from the observed azimuthal and vertical standard deviations (σ_θ and σ_ϕ). Values of χ/Q and D/Q by compass sector and radial increment from both elevated (61-meter) stack releases and ground-level releases (using the windspeed measured at a height of 61 meters) were calculated and are presented in Tables B-2 and B-3, respectively. Flat terrain was assumed; no credit was taken for plume rise induced by momentum or thermal effects. TC

The meteorological dispersion parameters obtained by running the XOQDOQ code are used as input to the NRC GASPAR code (Eckerman et al., 1980), which implements the radiological exposure models of Regulatory Guide 1.109 (NRC, 1977) to estimate doses from atmospheric exposure pathways. Population distribution data and milk, meat, and vegetable production distribution data (Table B-4) for the 16 wind direction sectors are also used as input to GASPAR for calculating the dose to the regional population; the term "regional population" refers to those individuals residing within 80 kilometers of the Savannah River Plant. Population projections for the year 2000 are used in this analysis.

Source terms input to the GASPAR code, and used in the calculation of doses to the maximally exposed individual and the regional population, are given in Table 4-8 for the L-Reactor only, and Table 5-11 for L-Reactor support facilities. Source terms are presented for the first and tenth years of L-Reactor operation.

To calculate doses to the population within 80 kilometers, compass-sector average values of χ/Q and D/Q are used. All atmospheric releases are assumed to occur at the center of the site; the population and agricultural production distributions were centered at the same points. These are reasonable assumptions, given the absence of high population densities near either L-Reactor or Separations (F and H) Areas release points. Population doses for each year of operation were calculated as the sum of the doses during that year of operation plus residual doses from radioactivity released during that year, for 100 years into the future. The calculated population dose is referred to as a 100-year environmental dose commitment (EDC) per year of operation. (The EDC concept is discussed later in this appendix.) The total dose received by the exposed offsite population as a result of releases from L-Reactor and its support facilities is calculated by adding the individual dose commitments in the population. Parameters used in calculating doses to the 80-kilometer population are summarized in Table B-5. TC

For the doses to the maximally exposed individual, the XOQDOQ code and the GASPAR code are combined into a computer procedure to determine the doses at the location of the maximum total-body dose rate (millirem per year of operation) to the age-specific individuals along the SRP buffer-zone boundary (the nearest possible approach of the residential population). Boundary locations are selected for each of the four support facilities (i.e., the 200-F and 200-H separations areas, the 300-M fuel fabrication area, and the 400-D heavy-water rework area) in each cardinal direction. For each location the doses from releases from L-Reactor and its support facilities are added to arrive at the total dose for that location. This method is used to determine the location at which a member of the public would receive the highest individual dose.

The maximally exposed individual is assumed to reside continuously at the location of highest potential exposure. All individual doses are 50-year dose commitments. Parameters used in calculating doses to maximally exposed individuals are summarized in Table B-6.

The response to radiation will vary with the age of the individual, or group of individuals, receiving the dose. Also, the stage of an individual's physical development and the chemical form of any radioactive material ingested will contribute to differences in its rate of uptake and internal deposition. For this reason, age-specific dose commitment factors were used to calculate dose. The age groups considered were infant (0 to 1 year old), child (1 to 11 years old), teen (11 to 17 years old), and adult (17 years and older). The dose factors used for exposure to noble gases are the factors in Table B-1 of Regulatory Guide 1.109 (NRC, 1977), plus lung exposure factors contained in the GASPAR code. The remainder of the dose factor library is that described in Appendix C of NUREG/CR-1276 (Simpson and McGill, 1980); for the inhalation and ingestion pathways, this incorporates the age-specific 50-year dose commitment factors of Hoenes and Soldat (1977) with NRC-approved corrections in actinide factors.

The following pathways and their descriptions were considered for the atmospheric dose assessment:

1. Plume--External dose from radioactive materials transported by the atmosphere.

2. Ground--External dose from radioactive material deposited on the ground.

3. Inhalation--Internal dose from inhalation of radioactive materials transported by the atmosphere.

4. Vegetation--Internal dose from consumption of vegetable food crops that are contaminated by radioactive material deposited from the atmosphere.

5. Milk--Internal dose from consumption of milk that is contaminated by radioactive material deposited from the atmosphere on vegetation.

6. Meat--Internal dose from consumption of meat products that are contaminated by radioactive material deposited from the atmosphere on vegetation.

The results of dose calculations to the maximally exposed individual and to the population within 80 kilometers of Savannah River Plant from atmospheric releases are contained in Tables B-7 through B-17. For releases from L-Reactor only, results are shown for the first- and tenth-year operation, as well as for operation with and without the use of the L-Area seepage basin. For support facility doses, maximum-individual doses are shown for the first and tenth year; the population dose will not change significantly between the first and tenth year.

Atmospheric releases containing tritium, carbon-14, krypton-85, and iodine-129 that will be released from L-Reactor and its support facilities will persist in the environment for long periods, and will be transported long distances. The population beyond 80 kilometers from the Savannah River Plant can receive radiation doses from these nuclides. Environmental transport and dose models have been adapted for each of these nuclides for this analysis. For each nuclide, the 100-year environmental dose commitment has been calculated. A constant U.S. population of 250 million for the year 2000 has been assumed (NCRP, 1975, 1979; Kocher, 1979; Killough, 1980). Table B-18 lists the results of these calculations. |TC

B.2 LIQUID RELEASES

The LADTAP II computer code (Simpson and McGill, 1980) was used to calculate radiation exposures due to liquid releases; LADTAP II implements the dose models recommended in NRC Regulatory Guide 1.109 (NRC, 1977). Both maximum-individual and population doses were calculated as functions of age group and pathway for the total body and appropriate body organs. Age-specific dose conversion factors were used for converting internal exposures to doses. The dose conversion factors are based on NUREG-0172 (Hoenes and Soldat, 1977), with revisions for some radionuclides (Simpson and McGill, 1980); the age groups considered were the same as those used for the atmospheric release calculations. The exposure to external radiation is the same for all age groups.

During routine operation of L-Reactor and its support facilities, radioactive materials will be discharged both to surface streams and to seepage basins. In this analysis, two alternatives have been considered for the discharge of L-Reactor liquid radioactive effluent. The first alternative is discharge both to Steel Creek and to the existing L-Reactor seepage basin and the second alternative is discharge directly to Steel Creek. All radioactive materials discharged from facility operations to surface streams ultimately discharge into the Savannah River. Radioactive materials discharged to seepage basins will move down to the ground water; gradually they will be transported laterally to outcrop areas along surface streams. After ground water containing radionuclides emerges at these outcrops, it is discharged to the Savannah River. Table B-19 lists ground-water velocities and the distances between the various seepage basins and their respective outcrops for operations associated with L-Reactor. The model for radionuclide transport in ground water uses a one-dimensional analytic solution for the mass transport of radionuclides and their decay products (Burkholder and Rosinger, 1979). Dispersion in the direction of travel was assumed to be zero. Some radioactive decay will occur during transit, thereby reducing the dose. The transport of nuclides can also be impeded by chemical interactions and the adsorptive and absorptive properties of the geologic media through which ground water flows. Radionuclide activities at the outcrops were simulated for periods as long as 39,000 years. This period was

Table B-18. 100-year environmental dose commitment to the U.S. population beyond 80 kilometers of Savannah River Plant from gaseous effluents from L-Reactor and its support facilities

Nuclide	Curies released per year of operation	Person-rem per year of operation	Organ
	L-REACTOR WITH SEEPAGE BASIN (FIRST YEAR)		
H-3	5,490	2.57	Total body
C-14	12	8.40	Total body
Kr-85	138	2.76×10^{-3}	Total body
I-129	0	0	Thyroid
	L-REACTOR WITH SEEPAGE BASIN (TENTH YEAR)		
H-3	54,900	25.7	Total body
C-14	12	8.40	Total body
Kr-85	138	2.76×10^{-3}	Total body
I-129	0	0	Thyroid
	L-REACTOR WITHOUT SEEPAGE BASIN (FIRST YEAR)		
H-3	5,170	2.42	Total body
C-14	12	8.40	Total body
Kr-85	138	2.76×10^{-3}	Total body
I-129	0	0	Thyroid
	L-REACTOR WITHOUT SEEPAGE BASIN (TENTH YEAR)		
H-3	51,700	24.2	Total body
C-14	12	8.40	Total body
Kr-85	138	2.76×10^{-3}	Total body
I-129	0	0	Thyroid
	SUPPORT FACILITIES		
H-3	9,390	4.39	Total body
C-14	8	5.60	Total body
Kr-85	201,800	4.04	Total body
I-129	0.07	1.73	Thyroid

Table B-19. Ground-water migration data for seepage basins

Parameter	L-Area (100-L)	Central shops (690-G)	Fuel fabrication (300-M)	Separations areas 200-F	Separations areas 200-H
Ground-water velocity (m/day)[a]	0.3[b]	0.3	0.3	0.2	0.3
Distance to outcrop (m)	490	365	1220	490	120-425
Ground-water travel time (yr)	4.4	3.3	[b]	6.7[c]	1.1-3.8[c]

[a]Based on Du Pont, 1983b.

[b]Assumed lateral ground-water velocity of 0.3 meter per day used in dose calculations; based on Root (1983) and Section F.2.10, a more realistic ground-water velocity is calculated to be 0.075 to 0.057 meter per day.

[c]3.8 years has been assumed for both the 200-F and 200-H areas.

TC

chosen so all nuclides (even those with retarded movement) emerged at the outcrop. However, liquid radioactive releases from this pathway reduce to insignificant levels after the L-Reactor operation period.

Liquid radioactive release source terms for L-Reactor are given in Table 4-9 for both first- and tenth-year operation. Source terms for the support facilities are given as annual average quantities discharged directly to surface streams, and to surface streams from seepage-basin/ground-water migration (Tables 5-8 through 5-10). TC

The following pathways and their descriptions were considered in the liquid dose assessments:

1. Drinking water--Internal dose from consumption of drinking water from the Savannah River and containing radioactive materials transported by the river.

2. Sport and commercial fish--Internal dose from consumption of fish of Savannah River origin.

3. Salt-water invertebrates--Internal dose from consumption of shellfish from estuaries of the Savannah River.

4. Recreation--External dose from recreational activities on and along the Savannah River; that is, shoreline activities, boating, and swimming.

All individual and population doses were based on the assumption that liquids discharged from L-Reactor and its support facilities are mixed completely in the river before reaching the potential exposure pathways. This assumption is supported by measurements that indicate complete mixing occurs prior to reaching the Highway 301 bridge. A dilution factor of 3 was applied to the shellfish dose calculation because a significant portion of the harvest would be from estuarine or ocean waters.

Individual and site parameters used in the calculations are summarized in Tables B-20 and B-21, respectively. The data on fish consumption, swimming, and boating are based on data from the region.

The individual who would receive the maximum potential dose from liquid releases was assumed to live near the Savannah River, downstream from the Savannah River Plant. This individual was assumed to use river water regularly for drinking, to consume river fish, and to receive external exposure from shoreline activities, swimming, and boating.

The total dose received by the offsite population as a result of liquid releases from L-Reactor and its support facilities is estimated by summing the doses to the individuals in the population. The population within an 80-kilometer radius uses no river water for domestic purposes downstream from Savannah River Plant; this population is assumed to use the river for recreational purposes and to consume fish and shellfish from the river and its estuary.

There is no known use of Savannah River water for human consumption to a distance of about 160 kilometers downstream from Savannah River Plant. At this distance, Beaufort and Jasper Counties, South Carolina, will pump water from the river for treatment and service to a population of about 117,000 people in the year 2000. Several kilometers farther downstream, the Cherokee Hill Water Treatment Plant draws water from the river to supply a business-industrial complex near Savannah, Georgia. This water is not used at present for normal domestic service, but it is assumed that about 200,000 people will use this water during the year 2000. Although these population groups are beyond the 80-kilometer radius, drinking-water doses for these groups have been included in this document. All population doses are 100-year environmental dose commitments.

The results of the calculations of doses to the maximally exposed individual and to populations from liquid radioactive releases from L-Reactor and its support facilities are presented in Tables B-22 through B-33. Maximum individual and population doses due to L-Reactor liquid radioactive releases for the first year, and after the tenth year, are presented in Tables B-22 through B-25 for the seepage-basin alternative. Similar results are presented in Tables B-26 through B-29 for the no-seepage-basin alternative. Results for the support facilities are presented in Tables B-30 through B-33. These results are not affected by the seepage-basin alternative used; they are presented as releases directly to surface streams and to streams by the seepage-basin/ground-water pathway.

B.3 RADIOACTIVE CESIUM AND COBALT REDISTRIBUTION

The reactivation of L-Reactor will cause a portion of the radioactive cesium and cobalt in the Steel Creek channel and floodplain to be resuspended and transported for both the reference case (defined in this appendix) and the

Table B-20. Individual parameters used in dose calculations

Parameters	Child	Teen	Adult
AVERAGE INDIVIDUAL			
Water consumption (ℓ/year)	260	260	370
Fish consumption (kg/yr)	3.6	8.5	11.3
Other seafood consumption (kg/yr)	0.33	0.75	1.0
Shoreline recreation (hr/yr)	9.5	47	8.3
Boating (person-hours)[a]	--	--	700,000
Swimming (person-hours)[a]	--	--	100,000
Shoreline recreation (person-hours)[a]	--	--	200,000
MAXIMUM INDIVIDUAL			
Water consumption (ℓ/yr)[b]	510	510	730
Fish consumption (kg/yr)	11.2	25.9	34
Other seafood consumption (kg/yr)	1.7	3.8	5
Shoreline recreation (hr/yr)	14	67	20
Swimming (hr/yr)	10	10	10
Boating (hr/yr)	60	60	60

[a]For population dose calculations.
[b]Drinking water consumption for an infant equals 330 liters per year.

Table B-21. Site parameters used in dose calculations

Parameters	Values
River flow rate (average m^3/s)	294
(low flow m^3/s)	173
River dilution in estuary	3
Transit time, L-Area to river (hr)	24
Transit time, SRP to water treatment plants (hr)	72
Water treatment time (hr)	24
Aquatic food harvest (kg/yr)	
Fish - sport	90,700
Fish - commercial	31,800
Invertebrates - salt water	299,000
Irrigation	None
Shore width factor	0.2
Population in year 2000[a]	
Beaufort-Jasper water consumers	117,000
Port Wentworth water consumers	200,000
80-kilometer-radius population	852,000

[a]Age distribution of population: Beaufort-Jasper--21 percent child, 10 percent teen, 69 percent adult; Port Wentworth--100 percent adult; and 80-kilometer radius--21 percent child, 11 percent teen, 68 percent adult.

TC | preferred cooling-water alternative (doses derived from the reference-case analysis described in this appendix and presented in Appendix L). The methods used to calculate dose commitments from this source were the same as those used for other liquid releases, except a bioaccumulation factor of 3000 was used for cesium in freshwater fish rather than the value of 2000 recommended in NRC Regulatory Guide 1.109 (NRC, 1977). This higher bioaccumulation factor reflects the results of studies of fish from the Savannah River and Steel Creek performed by the Savannah River Laboratory and the Savannah River Ecology Laboratory (Du Pont, 1982; Smith et al., 1982).

Tables B-34 through B-37 list the results of dose calculations (for both average and low river flow) to maximally exposed individuals and to regional populations due to the first year (maximum) radioactive cesium and cobalt transport that results from the resumption of L-Reactor operation.

B.4 *CUMULATIVE EFFECTS*

The evaluation of the radiological impacts associated with the restart of L-Reactor also has considered the cumulative effects of all nuclear facilities in the affected region. These cumulative effects are summarized in Section 5.2.6 of the main text and the details of the calculated results are presented below.

Nuclear facilities, in addition to L-Reactor and its support facilities, whose impacts have been considered in the cumulative effects, include the following:

- Three production reactors (P, K, and C) onsite at Savannah River Plant and associated support facilities
- The Vogtle Nuclear Generating Station (VNGS) under construction across the Savannah River from the southwest boundary of Savannah River Plant
- The Defense Waste Processing Facility (DWPF) under construction at S-Area on the Savannah River Plant
- The Fuels Material Facility (FMF) under construction at F-Area on the Savannah River Plant

The maximum individual dose and population doses associated with each of these facilities have been calculated. Information necessary for these dose calculations was derived from supporting environmental documentation available for each facility (DOE, 1982a,b; Du Pont, 1983; and Georgia Power Company, 1973).

The results of the dose calculations are presented in Tables B-38 through B-48. The maximum individual and population doses due to the three production reactors and their support facilities presently operating at Savannah River Plant are given in Tables B-38 through B-41. The same information predicted for the VNGS is given in Tables B-42 through B-45. Projected doses for the DWPF and the FMF are included in Tables B-46 through B-48. These latter three tables also present the cumulative doses associated with L-Reactor and its support facilities, current SRP operations with three reactors and their support facilities, and the other nuclear facilities being built in the affected region (VNGS, DWPF, and FMF).

B.5 ENVIRONMENTAL DOSE COMMITMENT CONCEPT

Man can receive doses externally from radioactive materials outside the body or internally from the intake of radioactive material by inhalation or ingestion. Radionuclides that enter the body are distributed to various organs and are removed by normal biological processes and radioactive decay. The rate at which each radionuclide is removed from the body depends on its chemical, physical, and radiological properties. Historically, dose calculations have included an accounting of doses resulting from the fraction of radionuclides retained in the body for 50 years following the year of intake. This 50-year "integrating period" is included in the dose commitment factors used in these dose calculations.

Similarly, radioactive material released in any year remains in the environment for varying lengths of time, depending on many environmental factors and on the decay rate of each radionuclide. The environmental dose commitment (EDC) concept is employed to account for this residual activity.

The EDC concept has been developed by the U.S. Environmental Protection Agency (EPA, 1974). EPA has defined the environmental dose commitment as "... the sum of all doses to individuals over the entire time period the material persists in the environment in a state available for interaction with humans." The EPA report describes how this concept is implemented and presents some sample calculations. These calculations integrate doses for 100 years following radionuclide release rather than "the entire time period." This 100-year integrating period is distinct from the 50-year integrating period discussed above because it deals with the accumulation of doses from residual radioactivity in the environment rather than in the body.

The 100-year integrating period was used in this analysis; in other words, all population dose calculations will include an accounting of population doses caused by environmental radioactivity levels for 100 years following each year's release. The 100-year period provides results that are meaningful by accounting for impacts over a period of time about equal to the maximum lifetime of an individual; thus, it provides a measure of risk to an individual. Longer integrating periods or an infinite time integral would require extremely speculative predictions about man's environment for thousands of years into the future.

For all EDC calculations, no attempt was made to predict changes in environmental characteristics. Population size and distribution were based on the latest estimates. Historic meteorology was assumed to continue into the future. Food production and consumption patterns were assumed to be static.

B.6 RADIATION-INDUCED HEALTH EFFECTS

Radiation can affect human health by causing cancer, genetic disorders, and other health problems. The Committee on the Biological Effects of Ionizing Radiation (BEIR) of the National Academy of Sciences has published a detailed review of available data on radiation-induced health effects (BEIR, 1980). This report (BEIR III) uses a variety of methods and data to quantify the health impacts of low levels of radiation. Its estimates of health risk associated with radiation exposure have been used to quantify the possible radiation-induced health effects that might be caused by L-Reactor operation; these potential health effects are discussed in Sections 4.1.2.6, 5.1.2.5, 5.1.2.7, and 5.2.7.

The BEIR III report identifies three categories of radiation-induced human health effects: (1) cancer, (2) genetic disorders, and (3) somatic effects other than cancer. The committee believes cancer induction is the most important effect of low-dose radiation. In this context, "low dose" refers to doses as high as a few rads per person per year. Natural background radiation ranges from 0.1 to 0.2 rad per person per year. Genetic effects of low-level radiation have been well documented and are addressed in detail in the BEIR III report. Somatic effects other than cancer include such effects as cataract induction and the impairment of fertility. The BEIR III report concludes that low-dose exposure of human populations does not increase the risk of somatic effects other than cancer and developmental changes in unborn children. The report also indicates that developmental changes in unborn children are probably not caused by radiation at or below natural background levels. For these reasons, only cancer and genetic disorders are considered in this analysis.

Cancer data from the Japanese survivors of atomic bombs are used in most of the analyses in the BEIR III report. Individual dose rates of these individuals were very high compared to the dose rates associated with L-Reactor operation. A major question addressed by the BEIR III report is how to extrapolate the cancer risks observed at the relatively high dose rates down to the lower dose rates caused by most nuclear facilities. The BEIR III report adopted a parametric family of functions to accomplish this extrapolation. The linear model represents an upper limit or maximum risk; the linear-quadratic model, an intermediate or probable risk; and the quadratic model, a low limit or minimum risk. These functions have been suggested by the report for low linear energy transfer (LET) radiation. This type of radiation includes gamma and x-radiation and electrons (beta particles). High-LET radiation includes alpha particles, encountered in the decay of radionuclides in the natural uranium decay chain. The BEIR III report states that, for high-LET radiation ". . . the linear hypothesis is less likely to lead to overestimates of risk and may, in fact, lead to underestimates." The linear model would, therefore, represent the best estimate for probable risk from this type of radiation.

One characteristic of radiation-induced cancer is that it takes a long time to develop, a period referred to as the "latent period." Leukemia has a characteristically short latent period (less than 25 years), while other cancers can have latent periods as long as the life span of an individual. Because only about 30 years of cancer data have been collected on the survivors of the atomic bombs, the data do not account for all the cancers that might develop because of the bomb's radiation. Two projection models have been developed to account for these future cancer deaths: (1) the absolute-risk projection model assumes that the cancer rate (risk per year) observed since the atomic bomb blasts will continue throughout the lifespans of those exposed; (2) the relative-risk model assumes the excess radiation-induced risk is proportional to the natural incidence of cancer with age. The relative-risk model results in cancer-risk estimates greater than those predicted by the absolute model. However, the BEIR III report states that the absolute model is generally more applicable to most forms of cancer. The absolute model has been used in calculating the minimum risk, the relative model has been used for the maximum risk, and the arithmetic average of the two for the probable-risk estimates.

Health effects estimators for low-LET and high-LET radiation were derived for use in estimating health effects based on an evaluation of the data presented in the BEIR III report. The resulting health effects estimators used in this document are summarized in Table B-49. They total 120 fatalities per million person-rem for low-LET radiation and 285 fatalities per million person-rem for high-LET radiation. The health effects estimates for genetic effects used in this document is 257 genetic effects per million person-rem of whole-body gamma radiation.

Table B-49. Health effects estimators used in the evaluation of radiation health effects

Organ/cancer	Cancer fatalities per 10^6 person-rem	
	Low-LET radiation[a,b]	High-LET radiation[a,b]
Leukemia and bone cancer	20.0	45.0
Lung	34.0	66.0
Liver	7.9	16.0
Kidney	4.0	7.8
Gastrointestinal tract	6.4	13.0
Thyroid[c]	0.0	0.0
Other	48.0	137.0
Total	120.3	284.8

[a]LET = linear energy transfer.

[b]The arithmetic average of the absolute and relative model values have been used for both low- and high-LET radiation. In addition, the linear-quadratic model has been assumed for low-LET radiation and the linear model has been assumed for high-LET radiation (refer to Section B.6).

[c]Although thyroid cancer can be induced, it is rarely fatal (BEIR, 1980).

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