5.4 RADIOLOGICAL IMPACTS OF NORMAL OPERATION

This section describes the radiological impacts of normal operations of the Clinch River (CR) Small Modular Reactor (SMR) Project on members of the public and the biota of terrestrial and aquatic ecosystems. As discussed in Section 3.9, the SMRs would be manufactured in a factory and shipped to the Clinch River Nuclear (CRN) Site. The number of SMR units would vary depending on the SMR design selected. In most SMR designs, the reactor containment vessel is underground. Because a final SMR design has not yet been selected, a plant parameter envelope, described in Section 3.1, was developed for use in evaluating potential environmental impacts from normal operations of the CR SMR Project.

Subsection 5.4.1 describes the environmental pathways by which radiation and radiological effluents from the facility may be transmitted to living organisms in and around the CRN Site. Subsection 5.4.2 estimates individual and collective doses to members of the public from gaseous and liquid effluents from normal SMR operations, as well as from increased ambient background radiation levels from the facility. Subsection 5.4.3 evaluates the impacts of these doses by comparing them to regulatory limits. Subsection 5.4.4 evaluates the impact to non-human biota.

5.4.1 Exposure Pathways

Living organisms in the vicinity of the CR SMR Project may be exposed to radiological releases from normal facility operations. Small quantities of radioactive gases and liquids are expected to be released to the environment during normal operation of SMRs at the CRN Site. Radiological exposure due to operation of the SMRs is highly dependent on the pathways by which a receptor may become exposed to radiological releases from the facility. The major pathways of concern are those that could result in the highest offsite radiological dose. The relative importance of a pathway depends on the type and amount of radioactivity released, its environmental transport mechanism, and usage of the land surrounding the CRN Site (e.g., residence, gardens, etc.). Factors such as the relative location of homes and the local production of milk cattle and vegetable gardens are taken into consideration when evaluating pathways of radiological exposure. In addition, the environmental transport mechanisms for gaseous effluents are dependent on the meteorological characteristics of the area.

Radioactive gaseous effluent pathways include direct radiation, deposition on plants and soil, and inhalation by humans and animals. Radioactive liquid effluent pathways include consumption of fish, drinking of water from downstream sources, and direct exposure from radionuclides that may be deposited in the Clinch River arm of Watts Bar Reservoir. An additional exposure pathway is direct radiation from the SMRs during normal operation.

Radiation doses to humans from the potential release of radionuclides during operation of the SMRs have been evaluated for gaseous emissions released to the atmosphere and for liquid effluents released into the Clinch River arm of the Watts Bar Reservoir. The critical pathways to humans for routine releases at the CRN Site are radiation exposure from submersion in air,

inhalation of contaminated air, drinking milk from an animal that feeds on open pasture near the CRN Site, eating vegetables and meat raised near the CRN Site, eating fish caught in the Clinch River arm of Watts Bar Reservoir, and drinking water from downstream sources. Other less significant pathways considered include: external irradiation from radionuclides deposited on the ground surface, activities on the shoreline of the Clinch River arm of the Watts Bar Reservoir, and direct radiation from the SMRs. The relative importance of the potential pathways to humans has been evaluated by calculating the doses from routine operations for each pathway. Calculation assumptions, methodology, results, and conclusions are presented in the following subsections.

The release of small amounts of radioactive effluents is permitted as long as releases comply with the requirements in Title 10 of the Code of Federal Regulations (10 CFR) Part 20 and 40 CFR Part 190. The design and operation of the SMRs at the CRN Site will also limit gaseous and liquid effluent releases such that doses to the public would be as low as reasonably achievable (ALARA) in accordance with the objectives of 10 CFR 50, Appendix I.

The exposure pathways considered and the calculation methods used to estimate doses to the maximally exposed individual (MEI) and to the population surrounding the CRN Site were based on U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide (RG) 1.109, *Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR 50*, Appendix I and on NRC RG 1.111, *Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors*. The MEI is defined as a member of the general public at an assumed location that results in the maximum possible calculated dose. The exposure pathway parameters are provided in Tables 5.4-1, 5.4-2, and 5.4-3 for the liquid pathways and Table 5.4-4 for the gaseous pathways. The projected population distribution in the year 2067 within 50 mile (mi) of the CRN Site is provided in Table 5.4-5. The source terms used in estimating exposure pathway doses were based on the total projected bounding site release activity levels provided in Tables 3.5-1 and 3.5-2 releases for all units and individual units, respectively. The source terms for gaseous releases are provided in Tables 3.5-3 and 3.5-4 for all units and individual units, respectively. There are no unusual animals, plants, agricultural practices, game harvests, or food processing operations within the surrounding region requiring special consideration.

5.4.1.1 Liquid Pathways

The pathways evaluated for exposure to liquid effluents from normal facility operations include ingestion of contaminated fish or invertebrates and ingestion of contaminated drinking water. Exposure to liquid effluents from normal operations also may occur through shoreline, swimming, and boating activities occurring downstream of the facility discharge location on the Clinch River arm of the Watts Bar Reservoir.

Liquid effluent discharge is assumed to be fully mixed with the flow in the Clinch River arm of the Watts Bar Reservoir. As described in Subsection 5.2.1.1.1, the overall average release from

Melton Hill Dam for 2004 through 2013, and consequently the expected approximate average river flow past the CRN Site during operations, is approximately 4670 cubic feet per second (cfs). For the purpose of this analysis, the mean flow rate over the course of a year is assumed to be 4000 cfs. The use of this flow is conservative because mixing the discharge into a smaller volume yields higher activity concentrations. In addition, transit time from liquid discharge to receptor is conservatively assumed to be zero. Thus, other than the distribution times built into the LADTAP II computer code, no decay time is applied to reduce the activity of the radioactive liquid effluent between discharge and exposure.

5.4.1.2 Gaseous Pathways

The exposure pathways evaluated for gaseous effluents from normal facility operations include external exposure to (submersion in) gases in the air, external exposure to ground contaminated by gaseous deposition, and inhalation of airborne activity. Exposure to gaseous effluents also may occur through ingestion of contaminated milk, meat, and vegetables.

5.4.1.3 Direct Radiation from SMRs

An NRC evaluation of operating nuclear plants in NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, Rev. 1, states:

> "Direct radiation from sources within a light water reactor (LWR) plant is due primarily to nitrogen-16, a radionuclide produced in the reactor core by neutron activation of oxygen-16 from the water. Because the primary coolant of an LWR is contained in a heavily shielded area, dose rates in the vicinity of LWRs are generally undetectable and less than 1 mrem/year at the site boundary."

Thus, data from operating reactors indicate that direct radiation doses from large operating pressurized water reactors are negligible. The statement from NUREG-1437, Rev. 1 can be extrapolated to conclude that direct radiation doses from multiple SMRs with a total electric power generation not greater than 1000 megawatts electric are also expected to be less than 1 millirem per year (mrem/yr). Similarly, based on dose rate modeling results for the AP1000, a reactor much larger in size than the SMRs, direct radiation from the containment and other buildings would be negligible at the site boundary (Reference 5.4-1).

5.4.2 Radiation Dose Modeling

This subsection describes the methodology, data, and results of the evaluation of radiation doses to members of the public. LADTAP II and GASPAR II are the computer models used to evaluate doses to members of the public from liquid and gaseous effluents, respectively, released from normal operations of the SMRs at the CRN Site. The annual consumption and usage rates for the average individual and the MEI were taken from NRC RG 1.109 Tables E-4 and E-5, respectively. LADTAP II and GASPAR II use the maximum rates in calculating individual doses and the average rates in calculating population doses.

Production rates for agricultural commodities within 50 mi of the CRN Site were determined for use in the LADTAP II and GASPAR II models. Vegetable production rates within 50 mi of the CRN Site are assumed to be equal to the state production rates multiplied by the fraction of the state harvested land area that falls within the 50-mi radius. Similarly, milk and meat production rates within 50 mi of the CRN Site are assumed to be equal to the state production rates multiplied by the respective fractions of the state milk and meat animals that reside within the 50-mi radius. Food production rates are assumed to increase proportionally with population increases within 50 mi of the CRN Site. This is conservative because the guidance in NUREG-1555, Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan, requires the use of only present production rates for calculating population doses. Table 5.4-6 shows the annual production rate of foods in Tennessee, and Table 5.4-7 shows the vegetable, milk and meat production rates within 50 mi of the facility.

No dose modeling was conducted to evaluate the dose from the direct radiation pathway. As discussed in Subsection 5.4.1.3, the direct radiation doses from the SMRs are expected to be negligible. However, it was conservatively assumed that the total direct radiation dose from all SMR units on the CRN Site would be 1 mrem/yr at the site boundary.

5.4.2.1 Liquid Pathways

The LADTAP II computer program, as described in NUREG/CR-4013, LADTAP II – Technical Reference and User Guide, was used to calculate doses to the MEI and to the general population surrounding the CRN Site from normal operations of the SMRs at the CRN Site. This program implements the radiological exposure models described in NRC RG 1.109 to estimate the dose resulting from radioactive releases in liquid effluents.

LADTAP II was used to evaluate both internal and external doses to the MEI and the general population from radionuclides in liquid effluents based on the following pathways:

- Internal exposure from ingestion of aquatic foods
- Internal exposure from ingestion of drinking water
- Internal exposure from ingestion of milk and meat from livestock consuming water and pasture feed from farms irrigated by contaminated water
- Internal exposure from ingestion of vegetables and fruits from farms irrigated by contaminated water
- External exposure to shoreline sediments
- External exposure from boating and swimming

Input parameters for LADTAP II are detailed in Tables 5.4-1 through 5.4-3. Table 5.4-1 presents the fish and invertebrate consumption rates and aquatic recreation usage rates used for the

average individual and the MEI. The values are taken from NRC RG 1.109 Tables E-4 and E-5, respectively.

Table 5.4-2 provides population consumption rates of aquatic food obtained from the Clinch River arm of Watts Bar Reservoir for the projected 2067 population within 50 mi of the CRN Site. These consumption rates are based on the assumption that 50 percent of the fish and invertebrate consumed by the population within 50 mi comes from the Clinch River arm of Watts Bar Reservoir. Table 5.4-2 identifies the portion of the consumption that represents aquatic food obtained by sport fishers and the portion that represents commercially caught aquatic food, and it provides details on how these values were calculated.

Table 5.4-3 identifies the primary liquid pathway parameters used in the LADTAP II program to estimate radioactive exposures due to liquid effluents from the SMRs at the CRN Site. An explanation of each of the parameters is provided in the table footnotes.

5.4.2.2 Gaseous Pathways

The GASPAR II computer program was used to calculate doses from gaseous pathways to offsite receptors from normal operations of the SMRs at the CRN Site. This program, described in NUREG/CR-4653, *GASPAR II – Technical Reference and User Guide,* implements the radiological exposure models described in NRC RG 1.109 for radioactivity releases in gaseous effluents. As discussed in Subsection 2.7.6, routine dilution and deposition estimates were calculated using the XOQDOQ-82 modeling program, which is the dispersion model for evaluating routine releases recommended by NRC in NUREG/CR-2919, *XOQDOQ: Computer Program for the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations*. Site-specific, validated meteorological data for June 2011 through May 2013 were used as input to the model. The site-specific dilution and deposition estimates were used by the GASPAR II computer program to calculate radiation doses.

By using projections of food production and consumption rates coupled with the projected population within a 50-mi radius of the CRN Site, GASPAR II evaluated both external and internal exposures to gaseous effluents from the operation of SMRs at the CRN Site based on the following pathways:

- External exposure to gases
- External exposure to ground contaminated by gases
- Inhalation of gases
- Ingestion of milk contaminated from the grass-to-cow-to-milk pathway
- Ingestion of contaminated vegetables and meats

Table 5.4-4 identifies the gaseous pathway parameters used in the GASPAR II computer program, including current and projected milk, meat, and vegetable production within 50 mi of

the CRN Site. Annual consumption rates for the average individual and the MEI were obtained from NRC RG 1.109 Tables E-4 and E-5, respectively. Table 5.4-5 presents the projected total 2067 population within a 50-mi radius of the CRN Site as a function of direction and distance.

5.4.3 Impacts to Members of the Public

This subsection summarizes the impacts to individuals from radioactive effluents released in the course of normal operation of the SMRs at the CRN Site. Impacts to the public are evaluated by comparing estimated dose to regulatory acceptance criteria. Doses to the MEI and collective doses to the public were evaluated.

Doses to the MEI from liquid effluent from all units are shown in Table 5.4-8 (per SMR unit) and 5.4-9 (all units), and doses from gaseous effluent are shown in Tables 5.4-10 (per SMR unit) and 5.4-11 (all units). Collective doses to the population from liquid and gaseous effluents are shown in Tables 5.4-12 and 5.4-13, respectively. Gaseous effluent doses to the thyroid of the MEI from iodines and particulates are shown in Table 5.4-14.

Table 5.4-15 summarizes the estimated doses to the MEI per operating unit of the CR SMR Project and compares them to the ALARA design objectives from 10 CFR Part 50, Appendix I to determine compliance with dose rates protective of the general public. All of the doses are less than or equal to the corresponding regulatory dose limits in 10 CFR Part 50, Appendix I; thus, the criteria are met.

Annual doses to the MEI from the SMRs at the CRN Site are summarized in Table 5.4-16. The sum of the direct radiation dose, liquid effluent dose, and gaseous effluent dose yields an annual total body dose of 11.0 mrem/yr. (As discussed in Subsections 5.4.1.3 and 5.4.2, the direct radiation dose would be negligible but is assumed to be 1 mrem/yr.) Similarly, the sum of direct, liquid, and gaseous contributions for the thyroid and the bone pathways yields a total dose of 25 mrem/yr and 24 mrem/yr respectively. The U.S. Environmental Protection Agency (EPA) radiation protection standards in 40 CFR Part 190 provide criteria that apply to the annual dose equivalent received by members of the general public exposed to planned discharges of radioactive materials from the operation of nuclear power plants. The most restrictive portion of the standards specified in this regulation states that the annual dose equivalent shall not exceed 25 mrem/yr to the whole body. The regulation also provides standards limiting the annual dose equivalent to the thyroid (75 mrem/yr) and any other organ (25 mrem/yr). As shown in Table 5.4-16, the total body annual dose, estimated to be 11.0 mrem/yr, is below the limit of 25 mrem/yr. Similarly, total doses to the thyroid and bone also are below their respective limits. This annual dose was compared to EPA's environmental radiation protection standards for individual members of the public from 40 CFR 190.10 to determine compliance. All of the doses are less than the corresponding regulatory dose limits; thus the criteria are met. As indicated in NUREG-1555, demonstration of compliance with the limits of 40 CFR 190 is considered to also indicate compliance with the 100 mrem limit in 10 CFR 20.1301.

Annual collective doses to the public based on the population within 50 mi of the CRN Site also were estimated based on the operation of all SMR units. Table 5.4-17 shows the total body and thyroid doses from all liquid and gaseous pathways expressed in units of person-rems per year (person-rem/yr). For comparison, Table 5.4-17 also includes the annual collective background radiation dose calculated from the estimated population within 50 mi of the CRN Site in 2067 and the average natural background dose in the United States of approximately 311 mrem/yr. The total of the doses to the population for the total body (68 person-rem/yr) and thyroid (100 person-rem/yr) are negligible compared to the background dose of 820,000 person-rem/yr.

Because the doses to members of the public from operation of the SMRs at the CRN Site are calculated to be within the regulatory limits for protection of the MEI and the contribution to the collective population dose is estimated to be negligible compared to background, the radiological impacts to members of the public from normal operation of the CR SMR Project would be SMALL.

5.4.4 Impacts to Biota Other than Members of the Public

This subsection examines radiation exposure pathways to biota other than members of the public to determine if these pathways could result in doses to biota greater than the doses predicted for humans. This assessment uses surrogate biota species that provide representative information on the various dose pathways potentially affecting broader classes of living organisms, including the important terrestrial and aquatic species identified in Section 2.4. Surrogates are used because important attributes are well defined and are accepted as a method for judging doses to biota. As described in NUREG/CR-4013 the use of surrogate biota in this analysis includes the use of algae as a surrogate for aquatic plants and the use of invertebrates as a surrogate for freshwater mollusks and crayfish. Other surrogates used in this analysis include fish, muskrat, raccoon, heron, and duck. There are no unusual plants, animals, or pathways in the vicinity of the CRN Site that would require specific evaluation.

Doses to surrogate biota from liquid effluents were calculated using the LADTAP II program and the parameters included in the computer program. As described in NUREG-CR/4013, pathways evaluated for aquatic biota include internal exposure from bioaccumulation and external exposure from swimming and the shoreline. Exposure pathways for terrestrial biota include ingestion of aquatic biota and external exposure from swimming and the shoreline. Liquid effluent doses to biota from the operation of SMRs at the CRN Site are shown in Table 5.4-18. Doses range from 1.3 millirad per year (mrad/yr) for the raccoon to 8.9 mrad/yr for the heron.

Because the GASPAR II program does not perform biota dose calculations, the human doses calculated for the gaseous pathway were assumed to be applicable to biota. Because biota are closer to the ground than are humans, the ground deposition doses calculated by the GASPAR II computer program were doubled. This is consistent with the approach used for biota in LADTAP II. The nearest terrestrial biota were assumed to be exposed to gaseous effluents at a distance of 0.25 mi from the SMR release point. It was also assumed that the internal dose and the external plume dose received by the biota are the same as the doses received by humans.

This is reasonable because the plume dose is independent of the size of the receptor, and it is conservative because the internal dose for humans is based on a much longer retention period than would be expected for biota. As shown in Table 5.4-19, the highest of the total body doses for the child, teen, and adult was identified as the biota dose for the inhalation, vegetable consumption, plume immersion, and ground deposition pathways. The total biota dose from all four pathways is 84 millirads per year (mrad/yr).

The total doses to surrogate biota from liquid and gaseous effluents released from normal operations of the SMRs at the CRN Site are shown in Table 5.4-20. The total dose to each of the biota was calculated by summing the annual doses from gaseous and liquid pathways in mrad/yr. The total doses also were converted to units of mrad/day for comparison to criteria for the protection of biota.

Use of exposure guidelines, such as 40 CFR Part 190, which apply to members of the public in unrestricted areas, is considered very conservative when evaluating calculated doses to biota. As noted in NUREG-1555, Subsection 5.4.4, the International Council on Radiation Protection states "… if man is adequately protected then other living things are also likely to be sufficiently protected" and uses human protection to infer environmental protection from the effects of ionizing radiation.

As stated in NUREG-1555, "species in most ecosystems experience rather high mortality rates from natural causes." From an ecological viewpoint, population stability is considered more important to the survival of a species than individual mortality. In addition, no biota have been discovered that show significant changes in morbidity or mortality due to radiation exposures predicted for nuclear power plants.

The National Academy of Sciences-National Research Council's Committee on the Biological Effects of Ionizing Radiation concludes that the evidence indicates that no other living organisms have been identified that are likely to be significantly more radiosensitive than members of the public (Reference 5.4-2). The Department of Energy (DOE) Order 458.1, Radiation Protection of the Public and the Environment, identifies dose rate criteria to protect aquatic and terrestrial biota from adverse effects due to radiation released from DOE operations (Reference 5.4-3). These criteria, provided in DOE Standard 1153-2002, are 1 rad/day for aquatic animals and 0.1 rad/day for terrestrial animals. Existing effects data support the application of these dose limits to representative individuals within the population of animals (Reference 5.4-4). As shown in Table 5.4-20, total doses to the surrogate aquatic animals are 0.0045 mrad/day for fish and 0.021 mrad/day for invertebrates. For surrogate terrestrial biota, total body doses range from 0.23 mrad/day for the raccoon to 0.25 mrad/day for the heron. The highest of these doses (0.021 mrad/day for aquatic biota and 0.25 mrad/day for terrestrial biota) are significantly less than their respective dose rate criteria (1 rad/day and 0.1 rad/day). The permissible dose rates given in 40 CFR Part 190 are considered screening levels and higher species-specific dose rates could be acceptable with additional study or data. Because the doses to surrogate biota presented in Table 5.4-20 are significantly below the dose rate criteria

specified by DOE, the impact to biota other than members of the public due to operation of the CR SMR Project would be SMALL.

5.4.5 Occupational Doses

The annual occupational dose to operational workers, including outage activities, is dependent on the specific plant design chosen, and is determined in accordance with applicable criteria in 10 CFR 20 and 10 CFR 50 Appendix I. The occupational dose is provided at COLA once the design has been selected.

5.4.6 References

Reference 5.4-1. U.S. Nuclear Regulatory Commission, Westinghouse AP1000 Design Control Document Rev. 19 (Chapter 12), Website: http://pbadupws.nrc.gov/docs/ML1117/ML11171A500.html, June 21, 2011.

Reference 5.4-2. National Research Council, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation. Report of the Advisory Committee on the Biological Effects of Ionizing Radiation," INIS-XA-N--248, Washington, DC, November, 1972.

Reference 5.4-3. U.S. Department of Energy, "Radiation Protection of the Public and the Environment," DOE O 458.1, February 11, 2011.

Reference 5.4-4. U.S. Department of Energy, "DOE Standard: A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota," DOE-STD-1153-2002, Washington, DC, 2002.

Table 5.4-1
Liquid Pathway Parameters – Aquatic Food and Activities

Parameter	MEI			Average			
	Child	Teen	Adult	Child	Teen	Adult	Average Rate
Fish consumption[1] (kg/yr)	6.9	16	21	2.2	5.2	6.9	5.9[2]
Invertebrate consumption[1] (kg/yr)	1.7	3.8	5	0.33	0.75	1.0	0.85[2]
Shoreline recreation[3] (hr/yr)	14	67	12	9.5	47	8.3	12.8[4]
Swimming recreation[3] (hr/yr)	14	67	12	9.5	47	8.3	12.8[4]
Boating recreation[3] (hr/yr)	14	67	12	9.5	47	8.3	12.8[4]
Population distribution[5]	NA	NA	NA	0.18	0.11	0.71	NA

[1] MEI rates from NRC RG 1.109 Table E-5. Average individual rates from NRC RG 1.109 Table E-4.
[2] Average rate of fish and invertebrate consumption calculated by weighting age-specific consumption by population distribution and summing across the age groups.
[3] Water recreation from NRC RG 1.109 Tables E-4 and E-5 as listed for shoreline activities. Time spent swimming and boating is assumed for each to be identical to time spent on shoreline activities.
[4] Average rate of recreational shoreline, swimming, and boating activities calculated by weighting age-specific recreational rates by population distribution and summing across the age groups.
[5] NRC RG 1.109 Page 1.109-33.

Notes:
hr/yr = hours per year
kg/yr = kilograms per year
MEI = maximum exposed individual
NA = not applicable

Table 5.4-2
Aquatic Food Consumption from Clinch River arm of Watts Bar Reservoir for 2067 Population within 50 Miles (kg/yr)

Parameter	Fish	Invertebrate
Average person[1]	5.9[1]	0.85[1]
50-mi population - total[2]	7,800,000	1,130,000
50-mi population - sport[3]	1,870,000	271,000
50-mi population - commercial[4]	5,930,000	861,000

[1] Aquatic food consumption for the average person from NRC RG 1.109 Table E-4. Average rate of fish and invertebrate consumption calculated by weighting age-specific consumption by population distribution and summing across the age groups.

[2] Total consumption of fish by the 2067 population within 50 mi of the CRN Site. As source of 50% of fish and invertebrate consumed by the population within 50 mi of the site is Clinch River arm of the Watts Bar Reservoir, the total population consumption is determined by multiplying the average person rate (5.9 and 0.85) by the 2067 50-mi population and by 50%.

[3] Population consumption of food obtained by sport is determined by multiplying the total consumption by the percentage of the population that eats sport food, estimated at 24 percent.

[4] Commercial population consumption is the remaining consumption rate (total minus sport population value).

Notes:
kg/yr = kilograms per year

Table 5.4-3
Liquid Pathway Parameters

Parameter	Value
Release source terms	Tables 3.5-1 and 3.5-2
Discharge rate (Clinch River flow)[1]	4000 cfs[1]
Dilution factor for discharge	1[1]
Transit time to receptor	0[2]
Impoundment reconcentration model	None[3]
50-mi population in 2010	1,723,327[4]
50-mi population in 2067[5]	2,658,157[4]
50-mi shoreline usage	34,000,000 person-hours/yr[6]
50-mi swimming usage	34,000,000 person-hours/yr[6]
50-mi boating usage	34,000,000 person-hours/yr[6]
Fish and invertebrate consumption	Table 5.4-2
Drinking water consumption	730 liters per year[7]
Current – 50-mi drinking water population	162,000[8]
2067 – 50-mi drinking water population	249,000[8]
2067 – milk production using Clinch River as Irrigation	30,800 kilograms per year[9]
2067 – meat production using Clinch River as Irrigation	26,200 kilograms per year[9]
2067 – produce production using Clinch River as Irrigation	113,000 kilograms per year[9]

[1] Liquid discharge from the surrogate plant is assumed to be fully mixed with Clinch River arm of Watts Bar Reservoir. A conservative mean flow rate of 4000 cfs is assumed. It is conservative because it is lower than the flow data collected over 47 years for the Clinch River arm of Watts Bar Reservoir near Oak Ridge and at Melton Hill Dam.

[2] Transit time to the liquid effluent receptor is conservatively assumed to be zero; no decay is assumed other than the distribution times built into LADTAP II.

[3] Liquid effluent is released directly into Clinch River Arm of the Watts Bar Reservoir. Effluent is assumed to be immediately, completely mixed.

[4] The total population within 50 mi of the CRN Site is projected to increase from the current 1,723,327 to 2,658,157 in 2067. This is a projected increase of 54 percent.

[5] Permanent population is projected to 40 years beyond the projected 2027 commencement of operation date for the last unit.

[6] Time spent by the average individual on shoreline activities taken from NRC RG 1.109 Table E-4. The time spent boating and swimming each is assumed identical to that spent on shoreline activities. Person-hours per year was determined by multiplying the average rate of 12.8 hours per year (hr/yr) by the projected 2067 population of 2,658,157.

[7] Adult maximum exposed individual annual drinking water consumption from NRC RG 1.109 Table E-5.

[8] Current and 2067 drinking water populations determined by multiplying the 50-mi population by the percentage of persons served by Clinch River arm of Watts Bar Reservoir (9.4 percent).

[9] Irrigated food production within 50 mi determined by multiplying the projected 2067 food production within 50 mi by the percentage of irrigated state land within 50 mi (2.41 percent) and by the percentage of irrigation occurring with water from the Clinch River arm of Watts Bar Reservoir within 50 mi (0.67 percent).

Table 5.4-4
Gaseous Pathway Parameters – GASPAR II Information

Parameter	Value
Release source terms	Tables 3.5-3 and 3.5-4
Population distribution - current	Tables 2.5.1-2 and 2.5.1-4
Population distribution – projected 2067	Table 5.4-5
Dispersion and deposition factors	Section 2.7
Meteorology	Section 2.7
Maximum dispersion direction	WNW
Current - 50-mi milk production[1] (kg/yr)	124,000,000
Current - 50-mi meat production[1] (kg/yr)	106,000,000
Current - 50-mi vegetable/fruit production[1] (kg/yr)	454,000,000
Projected 2067 - 50-mi milk production[2,3] (kg/yr)	191,000,000
Projected 2067 - 50-mi meat production[2,3] (kg/yr)	163,000,000
Projected 2067 - 50-mi vegetable/fruit production[2,3] (kg/yr)	700,000,000

[1] Current production: Production in Tennessee multiplied by percent of Tennessee food produced within 50 mi.
[2] Permanent population is projected to 40 years beyond the projected 2027 commencement of operation date for the last unit.
[3] Projected 2067 production: Current production within 50 mi multiplied by the population ratio of 1.54 (ratio of 2067 population/current population).

Notes:
kg/yr = kilograms per year
WNW = west northwest

Table 5.4-5
Total Population Distribution Within 50 Miles of the CRN Site in 2067[1,2]

Direction	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
N	0	0	0	0	110	2850	2594	570	5499	12,272
NNE	0	0	0	0	0	8678	10,509	12,234	35,396	11,082
NE	5	0	0	0	0	1555	51,540	30,575	25,463	12,290
ENE	8	9	1	0	0	1670	104,860	711,355	81,037	31,999
E	8	14	130	57	116	9101	130,456	207,087	67,225	108,807
ESE	6	39	112	203	475	12,098	26,220	229,719	32,360	14,583
SE	8	42	85	307	357	22,492	11,132	21,153	4038	10,641
SSE	7	59	67	234	396	3916	35,921	17,961	2693	707
S	13	29	38	150	213	2446	14,716	24,197	19,100	10,242
SSW	14	31	41	150	147	1242	5357	26,006	49,143	21,631
SW	13	51	69	132	265	965	3895	5502	12,679	44,254
WSW	16	68	172	151	373	7989	4829	7185	7015	9876
W	18	107	161	183	742	18,819	15,343	5587	52,483	12,930
WNW	21	89	248	87	220	5303	6069	8407	11,606	13,108
NW	20	25	50	14	84	1771	7498	4907	3914	24,543
NNW	0	1	0	0	156	2077	8465	840	11,546	35,117
Total	157	564	1174	1668	3654	102,972	439,404	1,313,285	421,197	374,082
								Grand Total	2,658,157	

[1] Projected total 2067 population distribution; sum of transient and permanent projected populations.
[2] Permanent population is projected to 40 years beyond the projected 2027 commencement of operation date for the last unit.

Notes:
E = East
N = North
S = South
W = West

Table 5.4-6
Food Production in Tennessee

Food	State Production	Max Year
Red Meat	6.76E+08 lbm	2012
Broilers	1.02E+09 lbm	2008
Milk	9.48E-08 lbm	2008
Tomatoes	8.50E+05 cwt	2012
Snap Beans	1.95E+05 cwt	2012
Soybeans	4.67E+07 bu	2012
Corn	1.28E+08 bu	2012
Wheat	2.14E+07 bu	2012
Apples	6.40E+06 lbm	2012

Table 5.4-7
Vegetable, Milk, and Meat Production within 50 Miles in 2067

Food	Production in TN (kg/yr)[1]	Percent of TN Food Produced within 50 mi		Production within 50 mi (Kg/yr)		
				Present	2067	Irrig 2067[2]
Milk	4.30E+08	Milk Cows	28.81%	1.24E+08	1.91E+08	3.08E+04
Red Meat	3.06E+08	Beef Cows	12.75%	3.91E+07	-	-
Broilers	4.62E+08	Broilers	41.39%	6.65E+07	-	-
Meat Total	-	-	-	1.06E+08	1.63E+08	2.62E+04
Vegetables/Fruit[3]	5.17E+09	Harvested Land	8.79%	4.54E+08	7.00E+08	1.13E+05

[1] Production in TN –State values are from Table 5.4-1.

[2] Production within 50 mi (Irrig 2067) – the percentage of state irrigation occurring within 50 mi and by 0.67%, the percentage of irrigation occurring with water from the Clinch River.

[3] Vegetable production rates are for non-leafy vegetables only. Although there is no significant production of leafy vegetables, the same production rates are conservatively assumed to be applicable to leafy vegetables.

Table 5.4-8
Liquid Effluent Doses per Unit Units to MEI (mrem/yr)

Pathway	Total Body	GI-LLI	Liver	Kidney	Lung	Skin	Thyroid	Bone
Fish	8.5E-03	1.3E-02	1.1E-02	7.0E-03	1.1E-03	0	3.0E-03	2.2E-02
Invertebrate	2.6E-03	4.6E-02	5.4E-03	1.5E-02	1.8E-04	0	1.9E-03	6.5E-03
Drinking	2.9E-03	4.3E-03	4.2E-03	4.6E-03	3.7E-03	0	1.8E-02	2.0E-03
Shoreline activities	1.2E-05	1.2E-05	1.4E-05	1.4E-05	1.4E-05	7.9E-05	1.4E-05	1.4E-05
Swimming	1.4E-06	1.4E-06	1.7E-06	1.7E-06	1.7E-06	0	1.7E-06	1.7E-06
Boating	7.2E-07	7.2E-07	8.4E-07	8.4E-07	8.4E-07	0	8.4E-07	8.4E-07
Irrigated Vegetables	3.4E-03	7.2E-03	8.5E-03	8.3E-03	4.5E-03	0	1.8E-02	1.9E-02
Irrigated Milk	2.0E-03	2.1E-03	6.0E-03	4.0E-03	2.8E-03	0	2.3E-02	9.1E-03
Irrigated Meat	6.5E-04	2.5E-04	6.8E-04	2.9E-03	3.4E-04	0	7.6E-04	2.0E-03
Total Dose	2.0E-02	9.7E-02	3.5E-02	4.2E-02	1.3E-02	7.9E-05	6.4E-02	6.0E-02
Age group[1]	Adult	Adult	Child	Child	Child	Teen	Child	Child

[1] The age group receiving the maximum dose for each organ shown.

Notes:
GI-LLI = Gastrointestinal – Lower Large Intestine
mrem/yr = millirems per year
MEI = maximum exposed individual

Table 5.4-9
Liquid Effluent Doses from All Units to MEI (mrem/yr)

Pathway	Total Body	GI-LLI	Liver	Kidney	Lung	Skin	Thyroid	Bone
Fish	9.2E-02	4.5E-02	1.1E-01	3.2E-02	1.2E-02	0	3.2E-02	1.6E-01
Invertebrate	2.3E-02	2.3E-01	5.2E-02	7.7E-03	2.0E-03	0	7.7E-03	3.4E-02
Drinking	1.3E-02	1.7E-02	2.1E-02	1.8E-01	1.5E-02	0	1.8E-01	1.9E-02
Shoreline activities	1.1E-04	1.1E-04	1.3E-04	1.3E-04	1.3E-04	7.0E-04	1.3E-04	1.3E-04
Swimming	8.8E-06	8.8E-06	1.0E-05	1.0E-05	1.0E-05	0	1.0E-05	1.0E-05
Boating	4.4E-06	4.4E-06	5.1E-06	5.1E-06	5.1E-06	0	5.1E-06	5.1E-06
Irrigated Vegetables	2.2E-02	3.2E-02	6.8E-02	1.8E-01	2.2E-02	0	1.8E-01	2.1E-01
Irrigated Milk	1.4E-03	1.5E-02	5.1E-02	2.5E-01	1.4E-02	0	2.5E-03	1.1E-02
Irrigated Meat	3.5E-02	9.9E-02	4.2E-02	5.0E-03	1.7E-03	0	5.0E-01	1.4E-01
Total Dose	1.7E-01	4.4E-01	3.1E-01	6.6E-01	6.8E-02	7.0E-04	6.6E-01	5.4E-01
Age group[1]	Adult	Adult	Child	Child	Child	Teen	Child	Child

[1] The age group receiving the maximum dose for each organ shown.

Notes:
GI-LLI = Gastrointestinal – Lower Large Intestine
mrem/yr = millirems per year
MEI = maximum exposed individual

Table 5.4-10 (Sheet 1 of 2)
Gaseous Effluent Doses per Unit to MEI

Location	Pathway		Dose per Unit (mrem/yr)							
			Total Body	GI-Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
Site Boundary (0.21 mi WNW)	External	Plume	6.2E+00	6.2E+00	6.2E+00	6.2E+00	6.2E+00	6.2E+00	6.3E+00	1.4E+01
		Ground	8.5E-01	8.5E-01	8.5E-01	8.5E-01	8.5E-01	8.5E-01	8.5E-01	1.0E+00
		Total	7.1E+00	7.1E+00	7.1E+00	7.1E+00	7.1E+00	7.1E+00	7.2E+00	1.5E+01
	Inhalation	Adult	1.5E+00	1.5E+00	2.9E-01	1.5E+00	1.5E+00	1.2E+01	2.0E+00	0
		Teen	1.5E+00	1.5E+00	3.5E-01	1.6E+00	1.6E+00	1.5E+01	2.4E+00	0
		Child	1.3E+00	1.3E+00	4.3E-01	1.4E+00	1.4E+00	1.8E+01	2.1E+00	0
		Infant	7.6E-01	7.5E-01	2.1E-01	8.5E-01	8.3E-01	1.6E+01	1.3E+00	0
	All	Adult	8.5E+00	8.6E+00	7.3E+00	8.6E+00	8.6E+00	1.9E+01	9.2E+00	1.5E+01
		Teen	8.5E+00	8.6E+00	7.4E+00	8.6E+00	8.7E+00	2.2E+01	9.5E+00	1.5E+01
		Child	8.4E+00	8.4E+00	7.5E+00	8.5E+00	8.5E+00	2.5E+01	9.2E+00	1.5E+01
		Infant	7.8E+00	7.8E+00	7.3E+00	7.9E+00	7.9E+00	2.3E+01	8.5E+00	1.5E+01
Residence (0.66 mi WNW)	External	Plume	7.8E-01	7.8E-01	7.8E-01	7.8E-01	7.8E-01	7.8E-01	7.9E-01	1.8E+00
		Ground	1.3E-01	1.3E-01	1.3E-01	1.3E-01	1.3E-01	1.3E-01	1.3E-01	1.5E-01
		Total	9.0E-01	9.0E-01	9.0E-01	9.0E-01	9.0E-01	9.0E-01	9.2E-01	1.9E+00
	Inhalation	Adult	1.8E-01	1.9E-01	3.5E-02	1.9E-01	1.9E-01	1.5E+00	2.5E-01	0
		Teen	1.9E-01	1.9E-01	4.2E-02	2.0E-01	2.0E-01	1.8E+00	2.9E-01	0
		Child	1.6E-01	1.6E-01	5.2E-02	1.8E-01	1.8E-01	2.2E+00	2.5E-01	0
		Infant	9.5E-02	9.4E-02	2.6E-02	1.1E-01	1.0E-01	1.9E+00	1.6E-01	0
Vegetable Garden (1.15 mi WNW)	Veg	Adult	5.7E-01	5.7E-01	2.3E+00	5.8E-01	5.6E-01	1.5E+00	5.5E-01	0
		Teen	8.5E-01	8.5E-01	3.7E+00	8.7E-01	8.5E-01	2.1E+00	8.3E-01	0
		Child	1.9E+00	1.9E+00	8.9E+00	1.9E+00	1.9E+00	4.2E+00	1.9E+00	0
Meat Animal (0.70 mi WNW)	Meat	Adult	4.4E-01	4.6E-01	2.0E+00	4.4E-01	4.4E-01	5.1E-01	4.4E-01	0
		Teen	3.6E-01	3.7E-01	1.6E+00	3.6E-01	3.6E-01	4.1E-01	3.6E-01	0
		Child	6.5E-01	6.6E-01	3.1E+00	6.6E-01	6.5E-01	7.3E-01	6.5E-01	0

Table 5.4-10 (Sheet 2 of 2)
Gaseous Effluent Doses per Unit to MEI

Location	Pathway		Dose per Unit (mrem/yr)							
			Total Body	GI-Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
MEI	All	Adult	2.1E+00	2.1E+00	5.2E+00	2.1E+00	2.1E+00	4.4E+00	2.2E+00	1.9E+00
		Teen	2.3E+00	2.3E+00	6.3E+00	2.3E+00	2.3E+00	5.2E+00	2.4E+00	1.9E+00
		Child	3.6E+00	3.6E+00	1.3E+01	3.7E+00	3.6E+00	8.0E+00	3.7E+00	1.9E+00
		Infant	1.0E+00	1.0E+00	9.3E-01	1.0E+00	1.0E+00	2.8E+00	1.1E+00	1.9E+00
		Max	3.6E+00	3.6E+00	1.3E+01	3.7E+00	3.6E+00	8.0E+00	3.7E+00	1.9E+00
		Group	Child	Child	Child	Child	Child	Child	Child	All

Note: In the first four rows for the MEI, MEI doses are obtained by conservatively summing the residence total external dose with the residence inhalation, vegetable, and meat maximum doses even though they are not all at the same location.

Table 5.4-11 (Sheet 1 of 2)
Gaseous Effluent Doses from All Units to MEI

Location	Pathway		Dose for All Units (mrem/yr)							
			Total Body	GI-Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
Site Boundary (0.21 mi WNW)	External	Plume	4.0E+01	4.0E+01	4.0E+01	4.0E+01	4.0E+01	4.0E+01	4.1E+01	8.4E+01
		Ground	2.9E+00	2.9E+00	2.9E+00	2.9E+00	2.9E+00	2.9E+00	2.9E+00	3.3E+00
		Total	4.3E+01	4.3E+01	4.3E+01	4.3E+01	4.3E+01	4.3E+01	4.3E+01	8.8E+01
	Inhalation	Adult	4.8E+00	5.0E+00	9.4E-01	5.0E+00	5.1E+00	4.1E+01	6.6E+00	0
		Teen	4.9E+00	5.0E+00	1.2E+00	5.2E+00	5.3E+00	5.2E+01	7.7E+00	0
		Child	4.3E+00	4.3E+00	1.4E+00	4.7E+00	4.7E+00	6.2E+01	6.7E+00	0
		Infant	2.5E+00	2.5E+00	7.3E-01	2.8E+00	2.8E+00	5.5E+01	4.2E+00	0
	All	Adult	4.8E+01	4.8E+01	4.4E+01	4.8E+01	4.8E+01	8.4E+01	5.0E+01	8.8E+01
		Teen	4.8E+01	4.8E+01	4.4E+01	4.8E+01	4.8E+01	9.5E+01	5.1E+01	8.8E+01
		Child	4.7E+01	4.7E+01	4.4E+01	4.8E+01	4.8E+01	1.0E+02	5.0E+01	8.8E+01
		Infant	4.5E+01	4.5E+01	4.4E+01	4.6E+01	4.6E+01	9.8E+01	4.8E+01	8.8E+01
Residence (0.66 mi WNW)	External	Plume	5.0E+00	5.0E+00	5.0E+00	5.0E+00	5.0E+00	5.0E+00	5.1E+00	1.1E+01
		Ground	4.3E-01	4.3E-01	4.3E-01	4.3E-01	4.3E-01	4.3E-01	4.3E-01	5.1E-01
		Total	5.4E+00	5.4E+00	5.4E+00	5.4E+00	5.4E+00	5.4E+00	5.4E+00	1.1E+01
	Inhalation	Adult	6.0E-01	6.2E-01	1.1E-01	6.3E-01	6.4E-01	5.1E+00	8.2E-01	0
		Teen	6.1E-01	6.3E-01	1.4E-01	6.5E-01	6.6E-01	6.4E+00	9.6E-01	0
		Child	5.4E-01	5.4E-01	1.7E-01	5.8E-01	5.9E-01	7.6E+00	8.2E-01	0
		Infant	3.1E-01	3.1E-01	8.9E-02	3.5E-01	3.4E-01	6.8E+00	5.2E-01	0
Vegetable Garden (1.15 mi WNW)	Veg	Adult	1.1E+00	1.1E+00	3.7E+00	1.1E+00	1.0E+00	4.0E+00	1.0E+00	0
		Teen	1.5E+00	1.5E+00	5.8E+00	1.6E+00	1.5E+00	5.2E+00	1.4E+00	0
		Child	3.1E+00	3.0E+00	1.4E+01	3.2E+00	3.1E+00	1.0E+01	3.0E+00	0
Meat Animal (0.70 mi WNW)	Meat	Adult	7.0E-01	7.5E-01	2.7E+00	7.0E-01	6.9E-01	9.0E-01	6.8E-01	0
		Teen	5.5E-01	5.8E-01	2.3E+00	5.6E-01	5.5E-01	7.0E-01	5.4E-01	0
		Child	9.6E+00	9.8E+00	4.3E+00	9.8E+00	9.6E+00	1.2E+00	9.6E-01	0

Table 5.4-11 (Sheet 2 of 2)
Gaseous Effluent Doses from All Units to MEI

Location	Pathway		Dose for All Units (mrem/yr)							
			Total Body	GI-Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
MEI	All	Adult	7.8E+00	7.9E+00	1.2E+01	7.9E+00	7.8E+00	1.5E+01	8.0E+00	1.1E+01
		Teen	8.1E+00	8.1E+00	1.4E+01	8.2E+00	8.1E+00	1.8E+01	8.4E+00	1.1E+01
		Child	1.0E+01	1.0E+01	2.3E+01	1.0E+01	1.0E+01	2.4E+01	1.0E+01	1.1E+01
		Infant	5.8E+00	5.8E+00	5.5E+00	5.8E+00	5.8E+00	1.2E+01	6.0E+00	1.1E+01
		Max	1.0E+01	1.0E+01	2.3E+01	1.0E+01	1.0E+01	2.4E+01	1.0E+01	1.1E+01
		Group	Child	Child	Child	Child	Child	Child	Child	All

Note: In the first four rows for the MEI, MEI doses are obtained by conservatively summing the residence total external dose with the residence inhalation, vegetable, and meat maximum doses even though they are not all at the same location.

Table 5.4-12
Liquid Effluent Doses Per Unit to Population Within 50 Miles[a] (person-rem/yr)

Pathway	Total Body	Thyroid
Sport fish	7.1E-01	1.7E-01
Commercial fish	7.8E-01	1.5E-01
Sport invertebrate	1.3E-01	6.3E-02
Commercial invertebrate	3.9E-01	1.7E-01
Drinking water	3.8E-01	1.2E+00
Shoreline activities	3.4E-02	3.4E-02
Swimming	4.1E-03	4.1E-03
Boating	2.0E-03	2.0E-03
Irrigated milk	2.2E-04	9.3E-04
Irrigated meat	1.7E-04	2.1E-04
Irrigated non-leafy vegetables	5.3E-04	4.0E-04
Irrigated leafy vegetables	6.7E-05	3.2E-04
Total Dose	2.4E+00	1.8E+00

[1] Annual liquid effluent dose for the 50-mi population determined by LADTAP II.

Notes:
person-rem/yr = person-rems per year

Table 5.4-13
Gaseous Effluent Dose per Unit to Population Within 50 Mi[1] (person-rem/yr)

Pathway	Total Body	Thyroid
Plume	8.0E-01	8.0E-01
Ground	5.7E-01	5.7E-01
Inhalation	1.4E+00	8.1E+00
Vegetable	7.7E+00	7.6E+00
Cow milk	1.8E+00	4.7E+00
Meat	2.6E+00	2.8E+00
Total Dose	1.5E+01	2.5E+01

[1] Annual gaseous effluent dose for the 50-mi population determined by GASPAR II.

Notes:
person-rem/yr = person-rems per year

Table 5.4-14
Gaseous Effluent Thyroid Doses Per Unit to MEI from Iodines and Particulates[1] (mrem/yr)

Pathway	Adult	Teen	Child	Infant
Plume	0	0	0	0
Ground	1.3E-01	1.3E-01	1.3E-01	1.3E-01
Inhalation	1.3E+00	1.7E+00	2.0E+00	1.8E+00
Vegetable	9.9E-01	1.2E+00	2.3E+00	0
Meat	7.2E-02	5.3E-02	7.9E-02	0
Total Dose	2.5E+00	3.1E+00	4.5E+00	2.0E+00

[1] Annual gaseous effluent thyroid doses for the MEI determined by GASPAR II.

Notes:
mrem/yr = millirems per year
MEI = maximum exposed individual

Table 5.4-15
Compliance of MEI Annual Doses Per Unit with 10 CFR 50, Appendix I Criteria

Type of Dose	Location	Annual Dose	Limit[5]
Liquid Effluent[1]			
Total Body (mrem)	Clinch River	2.0E-02	3
Maximum Organ – GI-LLI (mrem)	Clinch River	9.7E-02	10
Gaseous Effluent			
Gamma Air[2] (mrad)	Site Boundary	9.5E+00	10
Beta Air[2] (mrad)	Site Boundary	1.2E+01	20
Total Body[3] (mrem)	Residence	9.0E-01	5
Skin[3] (mrem)	Residence	1.9E+00	15
Iodines and Particulates[4]			
Maximum Organ – Thyroid (mrem)	Residence/Garden/Meat	4.5E+00	15

[1] Annual liquid effluent doses for the MEI determined by LADTAP II; the MEI is the adult receptor.
[2] Annual gaseous effluent doses for the MEI determined by GASPAR II; dose for a receptor at the site boundary, near ground level.
[3] Annual gaseous effluent external doses for the MEI determined by GASPAR II.
[4] Annual gaseous effluent total thyroid doses from iodines and radioactive material in particulate form for the MEI determined by GASPAR II.
[5] Dose limits in 10 CFR 50, Appendix I.

Notes:
mrem = millirem
mrad = millirad
MEI = maximum exposed individual

Table 5.4-16
Compliance of MEI Doses from All Units with 40 CFR 190.10 Criteria (mrem/yr)

Pathway	Liquid[1]	Gaseous[2]	Direct[3]	Total[4]	Limit[5]
Total Body	1.7E-01	1.0E+01	1.0E+00	1.1E+01	25
Thyroid	6.6E-01	2.4E+01	0.0E+00	2.5E+01	75
Other Organ - Bone	5.4E-01	2.3E+01	0.0E+00	2.4E+01	25

[1] Annual liquid effluent doses for the MEI determined by LADTAP II; the MEI is the adult receptor for total body dose and the child for thyroid and bone dose.
[2] Annual gaseous effluent doses for the MEI determined by GASPAR II; the MEI is the child receptor.
[3] Annual direct dose is assumed to be 1 mrem per year.
[4] Site totals are summed across receptors and locations to provide a conservative site total.
[5] Dose limits in 40 CFR 190.10.

Notes:
mrem/yr = millirems per year
MEI = maximum exposed individual

Table 5.4-17
Doses from All Units to Population Within 50 Miles (person-rem/yr)[1]

Pathway	Total Body	Thyroid
Liquid	9.6E+00	7.2E+00
Gaseous		
Noble gases	3.2E+00	3.2E+00
Iodines	8.0E-02	4.0E+01
Particulates	2.9E+00	2.3E+00
C-14	4.0E+01	4.0E+01
H-3	1.3E+01	1.3E+01
Gaseous Total	6.0E+01	1.0E+02
Pathways Total	6.8E+01	1.0E+02
Background Radiation[2]	8.3E+05	

1 Doses per unit multiplied by 4 to approximate doses from all units

2 The background dose is obtained by multiplying the average natural background dose rate in the United States of 311 mrem/yr (0.311 rem/yr) by the 2067 population of2.66E6 persons.

Table 5.4-18
Liquid Effluent Doses from All Units to Biota

Biota	Dose for All Units (mrad/yr)
Fish	1.6E+00
Invertebrates	7.6E+00
Algae	2.5E+00
Muskrat	3.4E+00
Raccoon	1.3E+00
Heron	8.9E+00
Duck	3.2E+00

Notes:
mrad/yr = millirad per year

Table 5.4-19
Gaseous Effluent Doses from All Units to Biota

Pathway	Child TBD[1] (mrem/yr)	Teen TBD[1] (mrem/yr)	Adult TBD[1] (mrem/yr)	Biota Dose (mrad/yr)
Inhalation	3.2E+00	3.7E+00	3.6E+00	3.7E+00[2]
Vegetable consumption	4.6E+01	2.2E+01	1.6E+01	4.6E+01[2]
Plume immersion	3.0E+01	3.0E+01	3.0E+01	3.0E+01[2]
Ground deposition	2.2E+00	2.2E+00	2.2E+00	4.3E+00[3]
Total				8.4E+01[4]

[1] Total body dose (TBD) determined from GASPAR II for human receptors located 0.25 mi from the reactor release point was used as biota dose.

[2] Biota dose from gaseous effluent through inhalation, vegetable consumption, and plume immersion pathways is estimated as the maximum total body dose determined for human receptors located 0.25 mi of the SMR facility.

[3] Because biota are closer to the ground, biota dose from the ground deposition pathway is determined as twice the ground deposition dose determined for humans to compensate for the height differential.

[4] The total gaseous effluent dose to biota is estimated as the sum of inhalation, vegetable consumption, plume immersion, and ground deposition doses.

Notes:
mrad/yr = millirads per year
mrem/yr = millirems per year
TBD = total body dose

Table 5.4-20
Doses from All Units to Biota

Biota	Gaseous[1] (mrad/yr)	Liquid[2] (mrad/yr)	Total[3] (mrad/yr)	Total[4] (mrad/day)
Algae	0	2.5E+00	2.5E+00	6.7E-03
Invertebrate	0	7.6E+00	7.6E+00	2.1E-02
Fish	0	1.6E+00	1.6+00	4.5E-03
Muskrat	8.4E+01	3.4E+00	8.7E+01	2.4E-01
Raccoon	8.4E+01	1.3E+00	8.5E+01	2.3E-01
Heron	8.4E+01	8.9E+00	9.3E+01	2.5E-01
Duck	8.4E+01	3.2E+00	8.7E+01	2.4E-01

[1] Total body dose determined from GASPAR II for human receptors located 0.25 mi from the reactor release point was used to model biota dose.
[2] Biota dose from liquid effluent as modeled from LADTAP II.
[3] Annual total body dose for biota from gaseous and liquid effluent.
[4] Daily total body dose for biota from gaseous and liquid effluent as determined by dividing the annual dose by 365 days per year.

Notes:
mrad/yr = millirads per year
mrad/day = millirads per day