3/8/82

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
LOUISIANA POWER AND LIGHT COMPANY	)	Docket No. 50-382 OL
	)	
	)	
Waterford Steam Electric Station, Unit 3)	)	

NRC STAFF TESTIMONY OF
EDWARD F. BRANAGAN, JR. REGARDING CONTENTION 8/9

Q.1. Please state your name and occupation.

A.1. My name is Edward F. Branagan, Jr. I am a Radiological Physicist with the Radiological Assessment Branch in the Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission.

Q.2. Have you prepared a statement of your professional qualifications?

A.2. Yes. A copy is attached to this testimony.

Q.3. Please describe the nature of your responsibilities.

A.3. I am responsible for evaluating the environmental radiological impacts from nuclear power reactors and, in particular, for evaluating radiological models for use in reactor licensing.

Q.4. What is the purpose of this testimony?

A.4. This testimony is designed to address the dose estimates presented in the NRC Staff's Final Environmental Statement Related to the Operation of Waterford Steam Electric Station, Unit 3 (FES) (NUREG-0779, September 1981), to the extent that those dose estimates

relate to Contention 8/9 in this proceeding. As utilized in this testimony, "dose" refers to the "dose equivalent" for an individual and the "dose commitment" for a population.

Q.5. Have you reviewed Section 5.9.1 entitled "Radiological Impacts from Routine Operation" and Appendices H, I and J of the FES related to the operation of Waterford Unit 3?

A.5. Yes. A copy of Section 5.9.1, as relevant, and Appendices H, I and J to the FES is attached to this testimony.

Q.6. To the best of your knowledge and belief, are the statements set forth in Section 5.9.1 and Appendices H, I and J to the FES true and correct?

A.6. Yes.

Q.7. Has the NRC Staff calculated the amount of radioactive materials in liquid effluents to be released from Waterford Unit 3?

A.7. Yes. The radioactive effluent releases calculated for the facility are listed in Table J-8 (p. J-10) of the FES.

Q.8. Has the Staff calculated doses to the public resulting from exposure to radioactive liquid releases?

A.8. Yes. The radioactive liquid releases in Table J-8 (p. J-10) and the hydrological transport and dispersion factors in Table J-9 (p. J-11) of the FES were used to estimate doses (1) to a hypothetical maximally exposed individual, (2) to the population within 80 km of the plant, and (3) to the general U.S. population. These dose estimates are presented in Table J-5 (p. J-7) and Table J-7 (p. J-9) of the FES.

Q.9. What is the Staff's estimate of the doses to a hypothetical maximally exposed individual resulting from exposure to radioactive liquid releases?

A.9. The total body dose to the maximally exposed individual resulting from exposure to radioactive liquid effluents from one year of reactor operation is about 0.1 millirem (Table J-5). This dose is a small fraction of the annual dose resulting from exposure to natural background radiation (i.e., about 84 millirems for persons in the State of Louisiana).

Q.10. What is the Staff's estimate of the dose to the population resulting from exposure to radioactive liquid releases?

A.10. The dose to the total body of the population within 80 km of the site resulting from exposure to radioactive liquid releases is about 6 person-rems (Table J-5). This dose is a small fraction of the annual dose resulting from exposure of the population to natural background radiation (i.e., about 180,000 person-rems within 80 km of the site).

Q.11. Has the Staff calculated the amount of radioactive materials in gaseous effluents to be released from Waterford Unit 3?

A.11. Yes. The Staff's estimates of the quantities of radioactive gaseous effluents are presented in Table J-1 (p. J-4) of the FES. The values in Table J-1 were used with the atmospheric dispersion factors in Table J-2 to estimate doses to a hypothetical maximally exposed individual resulting from exposure to noble gases, and radioiodines and particulates. The doses to the maximally exposed individual are presented in Tables J-4 and J-5.

Q.12. What is the Staff's estimation of the dose to a hypothetical maximally exposed individual resulting from exposure to radioactive gaseous releases?

A.12. The dose to the total body of the maximally exposed individual resulting from exposure to noble gases, or radioiodines and particulates,

is estimated to be less than 5 millirems. The highest dose to any organ (i.e., the bone of a child) was estimated to be about 12 millirems. These doses are a fraction of the annual dose from exposure to natural background radiation (i.e., about 84 millirems for Louisiana).

Q.13. What is the Staff's estimate of the dose to the population resulting from exposure to radioactive gaseous releases?

A.13. The Staff estimated that the dose to the total body of the population within 80 km of the site from exposure to radioactive gases (i.e., noble gases, radioiodines and particulates) would be about 6 person-rems (Table J-5). This dose is a small fraction of the annual dose resulting from exposure of the population to natural background radiation (i.e., about 180,000 person-rems).

Q.14. How do the doses to the hypothetical maximally exposed individual resulting from exposure to liquid and gaseous radioactive releases estimated by the Staff compare with the annual dose design objectives set forth in 10 C.F.R. Part 50 Appendix I?

A.14. The Staff's dose estimates to the hypothetical maximally exposed individual resulting from exposure to liquid and gaseous radioactive releases from the facility are lower than the annual dose design objectives set forth in 10 C.F.R. Part 50 Appendix I (see, e.g., FES Table J-5 (p. J-7)). In addition, the dose design objectives set forth in 10 C.F.R. Part 50 Appendix I are about two orders of magnitude below the dose limits for the public health and safety which can be derived from 10 C.F.R. Part 20.

Q.15. Please describe the environmental transport and dose models used by the Staff in estimating the doses referred to in your testimony.

A.15. In licensing commercial nuclear power reactors, the Staff uses mathematical models that characterize radionuclide movement in the environment to determine the radiolocial impact resulting from nuclear power plant operations. These models are described in several NRC Regulatory Guides. Regulatory Guide 1.109, entitled "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 C.F.R. Part 50, Appendix I," Revision 1 (October 1977), provides models for calculating doses to both the hypothetical maximally exposed individual and the general population resulting from exposure to radioactive liquid and airborne releases. Other regulatory guides relating to this subject are Regulatory Guide 1.111, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Reactors", Revision 1 (July 1977); Regulatory Guide 1.112, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Power Reactors," Revision 0-R (April 1976); and Regulatory Guide 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I," Revision 1 (April 1977).

The models employed by the NRC Staff were developed by members of the Staff having backgrounds and training in the field of radiological protection, and by experts at national laboratories such as Oak Ridge and Argonne under contract with the NRC. NRC models are subject to continuing peer review and verification by other Federal agencies such as the Environmental Protection Agency (EPA) and the Bureau of Radiological Health (BRH).

EDWARD F. BRANAGAN, JR.
OFFICE OF NUCLEAR REACTOR REGULATION

PROFESSIONAL QUALIFICATIONS

From April 1979 to the present, I have been employed as a Radiological Physicist with the Radiological Assessment Branch in the Office of Nuclear Reactor Regulation of the U.S. Nuclear Regulatory Commission (NRC). Currently, I am responsible for evaluating the environmental radiological impacts resulting from the operation of nuclear power reactors. In particular, I am responsible for evaluating radio-ecological models and health effect models for use in reactor licensing.

In addition to my duties involving the evaluation of radiological impacts from nuclear reactors, my duties in the Radiological Assessment Branch have included the following: (1) I managed and was the principal author of a report entitled "Staff Review of 'Radioecological Assessment of the Wyhl Nuclear Power Plant'" (NUREG-0668); (2) I served as a technical contact on an NRC contract with Argonne National Laboratory involving development of a computer program to calculate health effects from radiation; (3) I served as the project manager on an NRC contract with Idaho National Engineering Laboratory involving estimated and measured concentrations of radionuclides in the environment; (4) I served as the project manager on an NRC contract with Lawrence Livermore Laboratory concerning a literature review of values for parameters in terrestrial radionuclide transport models; and (5) I served as the project manager

on an NRC contract with Oak Ridge National Laboratory concerning a statistical analysis of dose estimates via food pathways.

From 1976 to April 1979, I was employed by the NRC's Office of Nuclear Materials Safety and Safeguards, where I was involved in project management and technical work. I served as the project manager for the NRC in connection with the NRC's estimation of radiation doses from radon-222 and radium-226 releases from uranium mills, in coordination with Oak Ridge National Laboratory which served as the NRC contractor. As part of my work on NRC's Generic Environmental Impact Statement on Uranium Milling (GEIS), I estimated health effects from uranium mill tailings. Upon publication of the GEIS, I presented a paper entitled "Health Effects of Uranium Mining and Milling for Commercial Nuclear Power" at a Conference on Health Implications of New Energy Technologies.

I received a B.A. in Physics from Catholic University in 1969, a M.A. in Science Teaching from Catholic University in 1970, and a Ph.D. in Radiation Biophysics from Kansas University in 1976. While completing my course work for my Ph.D., I was an instructor of Radiation Technology at Haskell Junior College in Lawrence, Kansas. My doctoral research work was in the area of DNA base damage, and was supported by a U.S. Public Health Service traineeship; my doctoral dissertation was entitled "Nuclear Magnetic Resonance Spectroscopy of Gamma-Irradiated DNA Bases."

I am a member of the Health Physics Society.

NUREG-0779

Final Environmental Statement

related to the operation of
Waterford Steam Electric Station,
Unit No. 3

Docket No. 50-382

Louisiana Power and Light Company

U.S. Nuclear Regulatory Commission

Office of Nuclear Reactor Regulation

September 1981

5.9 RADIOLOGICAL IMPACTS

(1) Regulatory Requirements

Nuclear power reactors in the United States must comply with certain regulatory requirements in order to operate. The permissible levels of radiation in unrestricted areas and the radioactivity in effluents to unrestricted areas are spelled out in 10 CFR Part 20, Standards for Protection Against Radiation.[38] These regulations specify limits on levels of radiation and limits on concentrations of radionuclides in the station's effluent releases to the air and water (above natural background), under which the reactor must operate. These regulations state that no member of the general public in unrestricted areas shall receive a radiation dose, due to Station operation, of more than 0.5 rems/yr (or 2 mrems/hr or 100 mrems/7 days) to the total body. These radiation dose limits are established to be consistent with considerations of the health and safety of the public.

In addition to the Radiation Protection Standards of 10 CFR Part 20, there are spelled out in 10 CFR Part 50.36a[39] license requirements that are to be imposed on licensees in the form of Technical Specifications on Effluents from Nuclear Power Reactors to keep releases of radioactive materials to unrestricted areas during normal operations, including expected operational occurrences, as low as is reasonably achievable (ALARA). Appendix I of 10 CFR Part 50 provides numerical guidance on design objectives and limiting conditions for operation of LWRs to meet this ALARA requirement. Applicants for permits to construct and licenses to operate an LWR shall provide reasonable assurance that the following dose design objectives will be met: 3 mrems/yr to the total body or 10 mrems/yr to any organ from liquid effluents; 10 mrads/yr gamma radiation or 20 mrads/yr beta radiation from gaseous effluents--and/or 5 mrems/yr to the total body or 15 mrems/yr to the skin from gaseous effluents; and 15 mrems/yr to any organ from the airborne effluents that include the radioiodines, carbon-14, tritium, and the particulates.

Experience with the design, construction and operation of nuclear power reactors indicates that compliance with such design objectives will keep average annual releases of radioactive material in effluents at small percentages of the limits specified in 10 CFR Part 20, and in fact, generally below the design objective values of Appendix I. At the same time, the licensee is permitted the flexibility of operation, compatible with considerations of health and safety, to assure that the public is provided a dependable source of power even under unusual operating conditions which may temporarily result in releases higher than such small percentages, but still well within the limits specified in 10 CFR Part 20.

In addition to the impact created by station radioactive effluents as discussed above, within the NRC policy and procedures for environmental protection spelled out in 10 CFR Part 51 there are generic treatments of environmental effects of all aspects of the Uranium Fuel Cycle. These environmental data have been summarized in Table S-3 (Table 5.13) and are discussed later in this report in Section 5.9.3 In the same manner the environmental impact of transportation of fuel and waste to and from an LWR is summarized in Table S-4 (Table 5.6) of Section 5.9.1.

Recently an additional operational requirement for Uranium Fuel Cycle Facilities including nuclear power plants has been established by the EPA in 40 CFR Part 190.[40] This regulation limits annual doses (excluding radon and daughters) for members of the public to 25 mrems total body, 75 mrems thyroid, and 25 mrems other organs from all fuel cycle facility contributions that may impact a specific individual in the public.

(2) Operational Overview

During normal operation of Waterford 3, small quantities of fission products and induced radioactivities will be released to the environment. As required by NEPA, the staff has determined the dose estimated to members of the public outside of the plant boundaries due to the radiation from these radioisotope releases and relative to natural background radiation dose levels.

These station-generated environmental dose levels are estimated to be very small due to plant design and the development of a conscious program which will be implemented at the station to contain and control all radioactive emissions and effluents. As mentioned above, highly efficient radioactive-waste management systems are incorporated into the plant design and are specified in detail in the Technical Specifications for the station. The effectiveness of these systems will be measured by process and effluent radiological monitoring systems that permanently record the amounts of radioactive constitutents remaining in the various airborne and waterborne process and effluent streams. The amounts of radioactivity released through vents and discharge points to be further dispersed and diluted to points outside the plant boundaries are to be recorded and published semiannually in the Radioactive Effluent Release Reports of each facility.

The small amounts of airborne effluents that are released will diffuse in the atmosphere in a fashion determined by the prevalent meteorological conditions and are thus much dispersed and diluted by the time they reach unrestricted areas that are open to the public. Similarly, the small amounts of waterborne effluents released will be diluted with plant waste water and then further diluted as they are discharged into the Mississippi River beyond the plant boundaries.

Any radioisotopes in the station's effluents that finally enter unrestricted areas will produce dose effects through their radiations on members of the general public similar to the dose effects from background radiations (i.e., cosmic/terrestrial and internal radiations), which also include radiation from nuclear weapons fallout. These radiation dose effects can be calculated for the many potential radiological exposure pathways specific to the environment around the station, such as direct radiation doses from the airborne or waterborne effluent streams outside of the plant boundaries, or internal radiation

dose commitments from radioactive contaminants that might have been deposited on vegetation, or in meat and fish products eaten by people, or that might be present in drinking water outside the plant, or incorporated into milk from cows at nearby farms.

These doses, calculated for the "maximally exposed" individual (i.e., the hypothetical individual potentially subject to maximum exposure), form the basis of the NRC staff's evaluation of impacts. These estimates are for a fictitious or "maximally exposed" person, since assumptions are made that tend to overestimate the dose that would actually accrue to members of the public outside the plant boundaries. For example, if this "maximally exposed" individual were to receive the dose calculated at the plant boundary, he/she is assumed to be physically at that boundary for 100% of the year, and outside (unshielded from gamma radiation) 50% of the year, an unlikely occurrence.

Site specific values for the various parameters involved in each dose pathway are used in the calculations. These include calculated or observed values for the amounts of radioisotopes released in the gaseous and liquid effluents, meteorological information (e.g., wind speed and direction) specific to the site topography and effluent release points, and hydrological information relative to dilution and "flushing" of the liquid effluents as they are discharged.

A periodic land census, to be required by the Radiological Technical Specifications of the operating license, will require that as use of the land surrounding the site boundary changes, revised calculations be made to ensure that this dose estimate for gaseous effluents always represents the highest dose for any individual member of the public for each applicable foodchain pathway. The estimate considers, for example, where people live, where vegetable gardens are located, where cows are pastured, etc.

For Waterford 3, in addition to the direct effluent monitoring, measurements will be made on a number of types of samples from the surrounding area to determine the possible presence of radioactive contaminants which, for example, might be deposited on vegetation, or be present in drinking water outside the plant, or incorporated into cow's milk from nearby farms.

5.9.1 Radiological Impacts from Routine Operations

5.9.1.1 Radiation Exposure Pathways: Dose Commitments

There are many environmental pathways through which persons may be exposed to radiation originating in a nuclear power reactor. All of the potentially meaningful exposure pathways are shown schematically in Figure 5.7. When an individual is exposed via one of these pathways, his dose is determined in part by the amount of time he is in the vicinity of the source, or the amount of time the radioactivity is retained in his body. The actual effect of the radiation or radioactivity is determined by calculating the dose commitment. This dose commitment represents the total dose that would be received over a 50-yr period, following the intake of radioactivity for 1 yr under the conditions existing 15 yrs after the station begins operation (i.e., the mid-point of station operation).

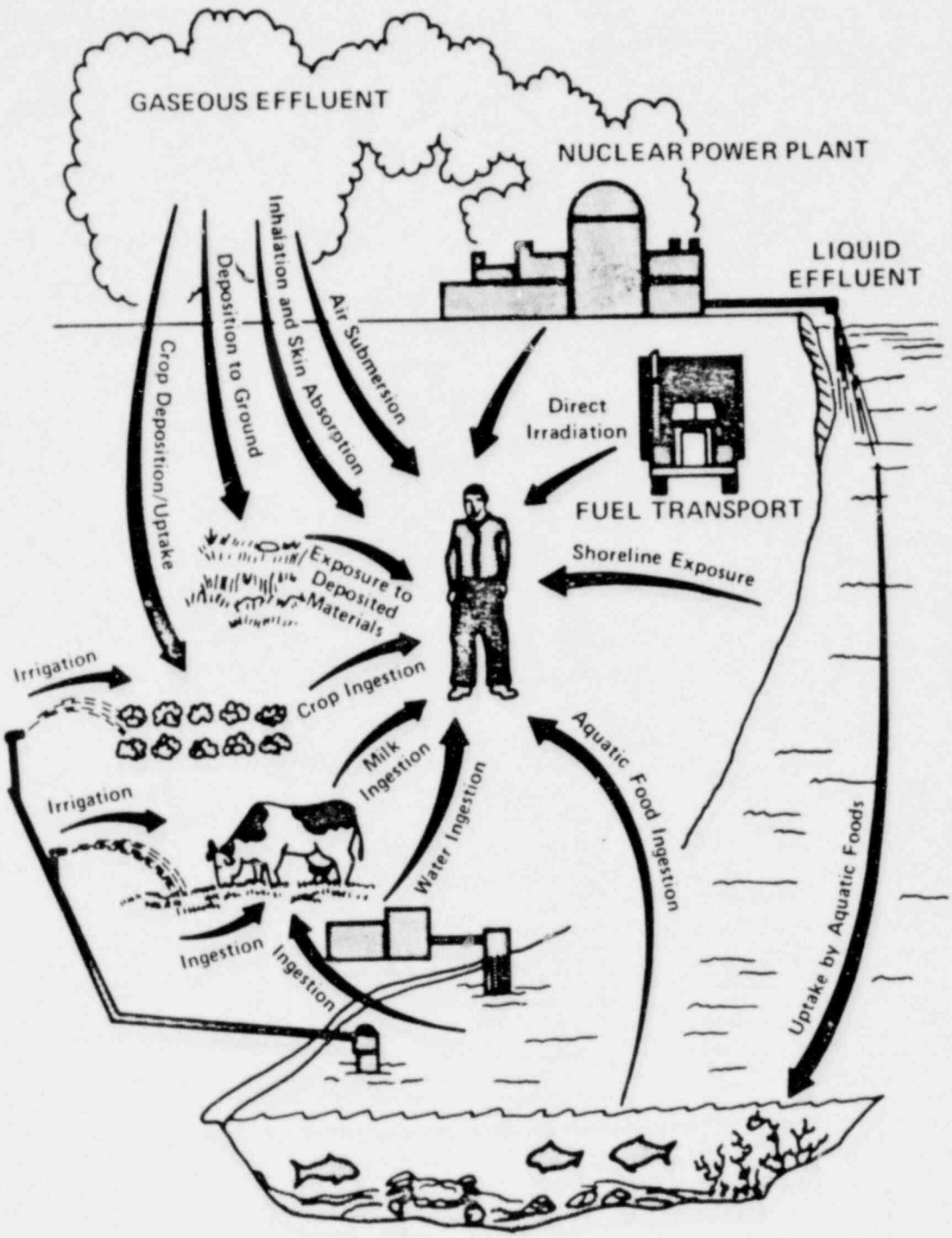

Figure 5.7 Potentially Meaningful Exposure Pathways to Humans

There are a number of possible exposure pathways to man that can be studied to determine whether the routine releases at the Waterford site are likely to have any significant impact on members of the general public living and working outside of the site boundaries, and whether the releases will in fact meet regulatory requirements. A detailed listing of these possibilities would include external radiation exposure from the gaseous effluents, inhalation of iodines and particulate contaminants in the air, drinking milk from a cow or eating meat from an animal that feeds on open pasture near the site on which iodines or particulates may have deposited, eating vegetables from a garden near the site that may be contaminated by similar deposits, drinking water and eating fish caught near the point of discharge of liquid effluents.

Other less significant pathways include: external irradiation from radionuclides deposited on the ground surface, eating animals and food crops raised near the site using irrigation water that may contain liquid effluents, shoreline activities near lakes or streams that may be contaminated by effluents, and direct radiation from within the plant itself.

Calculations of the effects for most pathways are limited to a radius of 80 km (50 miles). This limitation is based on several facts. Experience has shown that all significant dose commitments (>0.1 mrems/yr) for radioactive effluents are accounted for within a radius of 80 km from the plant. Beyond 80 km the doses are smaller than 0.1 mrems/yr, which is far below natural background doses, and the doses are subject to substantial uncertainty because of limitations of predictive mathematical models.

The NRC staff has made a detailed study of all of the above significant pathways and has evaluated the radiation dose commitments both to the plant workers and the general public for these pathways resulting from routine operation of the Station. A discussion of these evaluations follows.

5.9.1.1.1 Occupational Radiation Exposure

5.9.1.1.2 Public Radiation Exposure

(1) Transportation of Radioactive Materials

The transportation of "cold" (unirradiated) nuclear fuel to the reactor, of spent irradiated fuel from the reactor to a fuel reprocessing plant, and of solid radioactive wastes from the reactor to waste burial grounds is considered in 10 CFR Section 51.20.[76] The contribution of the environmental effects of such transportation to the environmental costs of licensing the nuclear power reactor is set forth in Summary Table S-4 from 10 CFR Section 51.20, reproduced herein as Table 5.6. The cumulative dose to the exposed population as summarized in Table S-4 is very small when compared to the annual dose of 26,000,000 person-rems to this same population from background radiation.

(2) Direct Radiation

Radiation fields are produced around nuclear plants as a result of radioactivity within the reactor and its associated components, as well as a result of small radioactive effluent releases. Direct radiation from sources within the plant are due primarily to nitrogen-16, a radionuclide produced in the reactor core.

Table 5.5 Incidence of Job-Related Fatalities

Table 5.6 Environmental Impact of Transportation of Fuel and Waste To and From One Light-Water-Cooled Nuclear Power Reactor[1]

NORMAL CONDITIONS OF TRANSPORT

	Environmental impact
Heat (perirradiated fuel cask in transit)	250,000 Btu/hr.
Weight (governed by Federal or State restrictions)	73,000 lbs per truck; 100 tons per cask per rail car.
Traffic density:	
Truck	Less than 1 per day.
Rail	Less than 3 per month.

Exposed population	Estimated number of persons exposed	Range of doses to exposed individuals[2] (per reactor year)	Cumulative dose to exposed population (per reactor year)[3]
Transportation workers	200	0.01 to 300 millirem	4 person-rem
General public:			
Onlookers	1,100	0.003 to 1.3 millirem	3 person-rem
Along Route	600,000	0.0001 to 0.06 millirem.	

ACCIDENTS IN TRANSPORT

	Environmental risk
Radiological effects	Small[4]
Common (nonradiological causes)	1 fatal injury in 100 reactor years; 1 nonfatal injury in 10 reactor years; $475 property damage per reactor year.

[1]Data supporting this table are given in the Commission's "Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants," WASH-1238, December 1972, and Supp. 1, NUREG-75/038, April 1975. Both documents are available for inspection and copying at the Commission's Public Document Room, 1717 H Street, NW., Washington, D.C., and may be obtained from National Technical Information Service, Springfield, VA 22161. WASH-1238 is available from NTIS at a cost of $5.45 (microfiche, $2.25) and NUREG-75/038 is available at a cost of $3.25 (microfiche, $2.25).

[2]The Federal Radiation Council has recommended that the radiation doses from all sources of radiation other than natural background and medical exposures should be limited to 5,000 millirem per year for individuals as a result of occupational exposure and should be limited to 500 millirem per year for individuals in the general population. The dose to individuals due to average natural background radiation is about 130 millirem per year.

[3]Person-rem is an expression for the summation of whole body doses to individuals in a group. Thus, if each member of a population group of 1,000 people were to receive a dose of 0.001 rem (1 millirem), or if 2 people were to receive a dose of 0.5 rem (500 millirem) each, the total person-rem dose in each case would be 1 person-rem.

[4]Although the environmental risk of radiological effects stemming from transportation accidents is currently incapable of being numerically quantified, the risk remains small regardless of whether it is being applied to a single reactor or a multireactor site.

Because the primary coolant of a PWR is contained in a heavily shielded area, dose rates in the vicinity of PWRs are generally undetectable (less than 5 mrems/yr).

Low-level radioactivity storage containers outside the plant are estimated to make a dose contribution at the site boundary of less than 0.1% of that due to the direct radiation described above.

(3) Radioactive Effluent Releases: Air and Water

As pointed out in section 4.2.3, all effluents from the station will be subject to extensive decontamination, but small controlled quantities of radioactive effluents will be released to the atmosphere and to the hydrosphere during normal operations. Estimates of site-specific radioisotope release values have been developed on the basis of the description of operational and radwaste systems in the applicant's ER and FSAR and by using the calculational model and parameters developed in NUREG-0017.[45] This has been supplemented by extensive use of the applicant's site and environmental data in the ER and in subsequent answers to NRC staff questions, to obtain a complete picture of airborne and waterborne releases from the station.

These small amounts of effluents are then highly diluted by the air and water into which they are released before they reach areas in which they interact with activities of the general public.

Radioactive effluents can be divided into several groups. Among the airborne effluents the radioisotopes of the noble gases--krypton, xenon, and argon--do not deposit on the ground or interact with living organisms; therefore, the noble gas effluents act primarily as a source of direct external radiation emanating from the effluent plume. Dose calculations are performed for the site boundary where the highest external radiation doses to a member of the public as a result of gaseous effluents have been estimated to occur; these include the annual beta and gamma air doses as well as the total body and skin doses from the plume at that boundary location.

Another group of airborne radioactive effluents--the radioiodines, carbon-14, and tritium--are also gaseous but tend to be deposited on the ground and/or absorbed into the body during inhalation. For this class of effluents, estimates of direct external radiation doses from deposits on the ground, and of internal radiation doses to total body, thyroid, bone, and other organs from inhalation, from vegetable consumption, from milk consumption, and from meat consumption are made. Concentrations of iodine in the thyroid and of carbon-14 in bone are of particular significance here.

A third group of airborne effluents, consisting of particulates that remain after filtration of the effluents, could include fission products such as cesium and barium and corrosion products such as cobalt and chromium. The calculational model determines the direct external radiation dose and the internal radiation doses for these contaminants through the same pathways as described above for the radioiodines, carbon-14, and tritium. Doses from the particulates are combined with those of the radioiodines, carbon-14, and tritium for comparison to one of the design objectives of Appendix I to 10 CFR Part 50.

The waterborne radioactive effluent constituents could include fission products such as strontium and iodine; corrosion and activation products, such as sodium and manganese; and tritium as tritiated water. Calculations estimate the internal doses (if any) from fish consumption, from water ingestion (as drinking water), and from eating of meat or vegetables raised near the site on irrigation water, as well as any direct external radiation from recreational use of the water past the point of discharge.

The release values for each group of effluents along with site-specific meteorological and hydrological data, serve as input to computerized radiation-dose models that estimate the maximum radiation dose that would be received outside the facility via a number of pathways for individual members of the public and for the general public as a whole. These models and the radiation dose calculations are discussed in Regulatory Guide 1.109[16] and in Appendix H of this statement.

Examples of site-specific dose assessment calculations and discussions of parameters involved are given in Appendix J. Doses from all airborne effluents except the noble gases are calculated for the location (e.g., site boundary, garden, residence, milk cow, meat animal) where the highest radiation dose to a member of the public from all applicable pathways has been established. Only those pathways associated with airborne effluents that are known to exist at a single location, are combined to calculate the total maximum exposure to an exposed individual. Pathways associated with liquid effluents are combined without regard to location, but they are assumed to be associated with maximum exposure to an individual other than through gaseous-effluent pathways.

5.9.1.2 Radiological Impact on Humans

Although the doses calculated in Appendix J are based on radioactive-waste treatment system capability, the actual radiological impact associated with the operation of the station will depend, in part, on the manner in which the radioactive waste treatment system is operated. Based on its evaluation of the potential performance of the ventilation and radwaste treatment systems, the NRC staff has concluded that the systems as now proposed are capable of controlling effluent releases to meet the dose design objectives of Appendix I to 10 CFR Part 50.[39]

The Station's operation will be governed by operating license Technical Specifications which will be based on the dose design objectives of Appendix I to 10 CFR Part 50.[39] Since these design objective values were chosen to permit flexibility of operation while still ensuring that plant operations are ALARA, the actual radiological impact of plant operation may result in doses close to the dose design objectives. Even if this situation exists, the individual doses for the member of the public subject to maximum exposure will still be very small when compared to natural background doses (~100 mrems/yr) or the dose limits specified in 10 CFR Part 20 (500 mrems/yr - whole body). As a result, the staff concluded that there will be no measurable radiological impact on members of the public from routine operation of the station.

Operating standards of 40 CFR Part 190, the Environmental Protection Agency's Environmental Radiation Protection Standards for Nuclear Power Operations,[40] specify that the annual dose equivalent must not exceed 25 mrems to the whole

body, 75 mrems to the thyroid, and 25 mrems to any other organ of any member of the public as the result of exposures to planned discharges of radioactive materials (radon and its daughters excepted) to the general environment from all uranium-fuel-cycle operations and radiation from these operations that can be expected to affect a given individual. The NRC staff concludes that under normal operations Waterford 3 is capable of operating within these standards.

The radiological effects of a nuclear power plant are well known and documented. Accurate measurements of radiation and radioactive contaminants can be made with very high sensitivity so that much smaller amounts of radioisotopes can be recorded than can be associated with any possible known ill effects. Furthermore, the effects of radiation on living systems have for decades been subject to intensive investigation and consideration by individual scientists as well as by select committees, occasionally constituted to objectively and independently assess radiation dose effects. Although, as in the case of chemical contaminants, there is debate about the exact extent of the effects of very low levels of radiation, the limits of deleterious effects are well established and amenable to standard methods of risk analysis. Thus the risks to the maximally exposed member of the public outside of the site boundaries can be readily quantified. Further, the impacts on, and risks to, the total population outside of the boundaries can also be readily calculated and recorded.

5.9.1.3 Radiological Impacts on Biota Other Than Humans

Depending on the pathway and radiation source, terrestrial and aquatic biota will receive doses that are approximately the same or somewhat higher than humans receive. Although guidelines have not been established for acceptable limits for radiation exposure to species other than human, it is generally agreed that the limits established for humans are conservative for other species. Experience has shown that it is the maintenance of population stability that is crucial to the survival of a species, and species in most ecosystems suffer rather high mortality rates from natural causes.

While the existence of extremely radiosensitive biota is possible, and while increased radiosensitivity in organisms may result from environmental interactions with other stresses (for example, heat or biocides), no biota have yet been discovered that show a sensitivity (in terms of increased morbidity or mortality) to radiation exposures as low as those expected in the area surrounding the station. Furthermore, at all nuclear plants for which radiation exposure to biota other than humans has been analyzed,[47] there have been no cases of exposure that can be considered significant in terms of harm to the species, or that approach the limits for exposure to members of the public that are permitted by 10 CFR Part 20.[38] The 1972 BEIR Report[48] concluded that the evidence to date indicates that no other living organisms are very much more radiosensitive than humans; therefore, no measurable radiological impact on populations of biota is expected as a result of the routine operation of this station.

5.9.1.4 Radiological Monitoring

Radiological environmental monitoring programs are established to provide data on measurable levels of radiation and radioactive materials in the site

environs. Such monitoring programs are conducted to verify the effectiveness of in-plant systems used to control the release of radioactive materials and to ensure that unanticipated buildups of radioactivity will not occur in the environment. Secondarily, the monitoring programs could identify the highly unlikely existence of previously undetected releases of radioactivity. A surveillance (Land Census) program is established to identify changes in the use of unrestricted areas to provide a basis for modifications of the monitoring programs.

These programs are discussed in greater detail in NRC Regulatory Guide 4.1, Rev. 1, "Programs for Monitoring Radioactivity in the Environs of Nuclear Power Plants,"[49] and the Radiological Assessment Branch Technical Position, Rev. 1, November 1979, "An Acceptable Radiological Environmental Monitoring Program."[50]

5.9.1.4.1 Preoperational

The preoperational phase of the monitoring program should provide for the measurement of background levels of radioactivity and radiation and their variations along the anticipated important pathways in the areas surrounding the station, the training of personnel and the evaluation of procedures, equipment and techniques. The applicant proposed a radiological environmental-monitoring program to meet these objectives in the ER-CP and it was discussed in the FES-CP. This early program has been updated and expanded; it is presented in Section 6.1.5 of the applicant's ER-OL and is summarized here in Table 5.7.

The applicant states that the preoperational program has been implemented, at least two years prior to initial criticality of Waterford 3, to document background levels of direct radiation and concentrations of radionuclides that exist in the environment. The preoperational program will continue up to the initial criticality of Waterford 3 at which time the operational radiological monitoring program will commence.

The staff has reviewed the preoperational environmental monitoring plan of the applicant and finds that it is acceptable as presented.

5.9.1.4.2 Operational

The operational, offsite radiological-monitoring program is conducted to measure radiation levels and radioactivity in plant environs. It assists and provides backup support to the effluent-monitoring program as recommended in NRC Regulatory Guide 1.21, "Measuring, Evaluating and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Materials in Liquid and Gaseous Effluents from Light-Water Cooled Nuclear Power Plants."[51]

The applicant states that the operational program will in essence be a continuation of the preoperational program described above with some adjustment of sampling frequencies in expected critical exposure pathways, such as increasing milk sampling frequency and deletion of fruit, vegetable, soil, and gamma radiation survey samples. The proposed operational program will be reviewed prior to plant operation. Modification will be based upon anomalies and/or exposure pathway variations observed during the preoperational program.

Table 5.7 Radiological Environmental Monitoring Program for Waterford

Exposure pathway and/or sample type	Number of samples[a] and locations	Sampling and collection frequency	Type of frequency of analysis
AIRBORNE			
Radioiodine and particulates	3 offsite locations (in different sectors) of the highest calculated annual average ground level D/Q (A8-N, A16-S, A17-NW)[b] 1 sample from the vicinity of Killona, a community having the highest calculated annual average ground level D/Q. 1 sample from the vicinity of Norco (A13) and 1 sample from LaPlace (A14) · 1 sample from Desallemond (A12, SSE) · 1 sample from Luling (A11-E), a control location 10-20 miles distant and in a least prevalent wind direction[e]	Continuous sampler operation with sample collection weekly or as required by dust loading, whichever is more frequent	Radioiodine cartridge: Analyze weekly for I-131 Particulate sampler: Gross beta radioactivity following filter change, composite (by location) for gamma isotopic quarterly
DIRECT RADIATION			
TLD	· 4 stations at ~500 ft in W, WNW, S, and NW sectors. · 8 stations 1 mile from plant in SSE, S, SSW, WSW, W, NW, N, and NE sectors · Norco (W) · LaPlace · Luling (E) · Desallemond (SSE) · 4 stations located in special interest areas.	Quarterly, semi-annually	Gamma dose quarterly
WATERBORNE			
Surface[a]	· 1 upstream sample (~2 miles)[g] · 1 downstream sample (~1000 meters) · 1 sample from intake structure	Composite sample over 1 month period[h]	Gamma isotopic analysis monthly. Composite for tritium analysis quarterly
Ground	· Riverside of plant (G1) · Lakeside of plant (G2)	Quarterly	Gamma isotopic and tritium analysis quarterly
Drinking	· 1 sample from Union Carbide (W7) · 1 sample from St. Charles Parish (W8)	Monthly composite taken at each municipal facility	Gross beta and gamma isotopic isotopic analysis monthly. Composition for tritium analysis quarterly
Rooted aquatic plants & shoreline sediments	· 1 sample 1000 meters downstream · 1 sample 2 miles upstream	Semiannual	Gamma isotopic analysis semiannually
Bottom sediments	· 1 sample 1000 meters downstream · 1 sample 2 miles upstream	Semiannual	Gamma isotopic analysis semiannually

Table 5.7 Continued

Exposure pathway and/or sample type	Number of samples[a] and locations	Sampling and collection frequency	Type of frequency of analysis
INGESTION			
Fish and invertebrates	• 1 sample 1000 meters downstream • 1 sample 2 mi upstream	Semiannual	Gamma isotopic analysis of edible portions
Fruits and vegetables	Samples from following locations • 1 mile NW (A15) • 1 mile NE (A19) • 1 mile N (A20) • 1.7 mile N (A20) • 1.3 mile W(A21) • Luling • Desallemond	At time of harvest[k]	Gamma isotopic analysis of edible portions
Milk	Samples from following locations: • 1 mile NW (A15) • 1.7 mile N (A20) • 1.3 mile W (A21) • Luling • Desallemond	Semimonthly when animals are on pasture, monthly at other times	Gamma isotopic and I-131 analyses semimonthly when animals are on pasture, monthly otherwise
Meat animals	Samples from following locations: • 1 mile NE (A19) • Luling • Desallemond	Semiannually for wildlife.	Gamma isotopic analysis on edible sections semiannually

[a]The number, media, frequency, and location of samples may vary. It is recognized that, at times, it may not be possible or practical to obtain samples of the media of choice at the most desired location or time. In these instances suitable alternative media and locations may be chosen for the particular pathway in question and submitted for acceptance.

[b]The parenthetical symbols correspond to the location identification specified in Figures 6.1.5-2 and 6.1.5-3 of the applicant's Environmental Report.

[c]Particulate sample filters are analyzed for gross beta radioactivity 24 hours or more after sampling to allow for radon and thoron daughter decay. If gross beta activity in air or water is greater than ten times the yearly mean of control samples for any medium, gamma isotopic analysis will be performed on the individual samples.

[d]Gamma isotopic analysis means the identification and quantification of gamma-emitting radionuclides that may be attributable to the effluents from the facility.

[e]The purpose of this sample is to obtain background information.

[f]Regulatory Guide 4.13 provides minimum acceptable performance criteria for TLD systems used for environmental monitoring. One or more instruments, such as a pressurized ion chamber, for measuring and recording dose rate continuously, may be used in place of, or in addition to, integrating dosimeters. For the purpose of this table, a thermoluminescent dosimeter may be considered to be one phosphorus and two or more phosors in a packet may be considered as two or more dosimters. The 40 stations are not an absolute number.

[g]The "upstream sample" will be taken at a distance beyond significant influence of the discharge. The "downstream" sample will be taken in an area beyond but near the mixing zone.

[h]Composite samples will be collected with equipment (or equivalent) which is capable of collecting an aliquot at time intervals which are very short (e.g., hourly) relative to the compositing period (e.g., monthly).

[i]Groundwater samples will be taken when this source is tapped for drinking or irrigation purposes in areas where the hydraulic gradient or recharge properties are suitable for contamination.

[j]The dose will be calculated for the maximum organ and age group, using the methodology contained in Regulatory Guide 1.109, and the actual parameters particular to the site.

[k]If harvest occurs more than once a year, sampling will be performed during each discrete harvest. If harvest occurs continuously, sampling will be monthly. Attention will be paid to including samples of tuborous and root food products.

The final operational-monitoring program proposed by the applicant will be reviewed in detail by the NRC staff, and the specifics of the required monitoring program will be incorporated into the Operating License Radiological Technical Specifications.

APPENDIX H

NEPA POPULATION-DOSE ASSESSMENT

Population-dose commitments are calculated for all individuals living within 80 km (50 miles) of Waterford 3, employing the same models used for individual doses (see Regulatory Guide 1.109, Rev. 1)[1], for the purpose of meeting the "as low as reasonably achievable" (ALARA) requirements of 10 CFR, Part 50, Appendix I.[2] In addition, dose commitments to the population residing beyond the 80-km region, associated with the export of food crops produced within the 80-km region and with the atmospheric and hydrospheric transport of the more mobile effluent species, such as noble gases, tritium, and carbon-14, are taken into consideration for the purpose of meeting the requirements of the National Environmental Policy Act, 1969 (NEPA). This appendix describes the methods used to make these NEPA population dose estimates.

1. Iodines and Particulates Released to the Atmosphere

Effluent nuclides in this category deposit on the ground as the effluent moves downwind, thus the concentration of these nuclides remaining in the plume is continuously being reduced. Within 80 km of the facility, the deposition model in Regulatory Guide 1.111, Rev. 1,[3] is used in conjunction with the dose models in Regulatory Guide 1.109, Rev. 1.[1] Site specific data concerning production and consumption of foods within 80 km of the reactor are used. For estimates of population doses beyond 80 km it is assumed that excess food not consumed within the 80-km area will be consumed by the population beyond 80 km. It is further assumed that none, or very few, of the particulates released from the facility will be transported beyond the 80-km distance; thus they will make no contribution to the population dose outside the 80-km region. This assumption was tested and found to be reasonable for Waterford 3.

2. Noble Gases, Carbon-14, and Tritium Released to the Atmosphere

For locations within 80 km (50 miles) of the reactor facility, exposures to these effluents are calculated with a constant mean wind-direction model according to the guidance provided in Regulatory Guide 1.111, Rev. 1, and the dose models described in Regulatory Guide 1.109, Rev. 1. For estimating the dose commitment from these radionuclides to the U.S. population residing beyond the 80-km region, two dispersion regimes are considered. These are referred to as the first-pass dispersion regime and the world-wide dispersion regime. The model for the first-pass dispersion regime estimates the dose commitment to the population from the radioactive plume as it leaves the facility and drifts across the continental United States to the northeastern corner of the U.S. The model for the world-wide dispersion regime estimates the dose commitment to the U.S. population after the released radionuclides mix uniformly in the world's atmosphere or oceans.

a. First-Pass Dispersion

For estimating the dose commitment to the U.S. population residing beyond the 80-km region due to the first pass of radioactive pollutants, it is assumed that the pollutants disperse in the lateral and vertical directions along the plume path. The direction of movement of the plume is assumed to be from the facility toward the northeast corner of the U.S. The extent of vertical dispersion is assumed to be limited by the ground plane and the stable atmospheric layer aloft, the height of which determines the mixing depth. The

shape of such a plume geometry can be visualized as a right cylindrical wedge whose height is equal to the mixing depth. Under the assumption of constant population density, the population dose associated with such a plume geometry is independent of the extent of lateral dispersion, and is only dependent upon the mixing depth and other nongeometrical related factors.[4] The mixing depth is estimated to be 1000m, and a uniform population density of 62 persons/km^2 is assumed along the plume path, with an average plume transport velocity of 2 m/s.

The total-body population dose commitment from the first-pass of radioactive effluents is due principally to external exposure from gamma-emitting noble gases, and to internal exposure from inhalation of air containing tritium and from ingestion of food containing carbon-14 and tritium.

b. World-Wide Dispersion

For estimating the dose commitment to the U.S. population after the first-pass, world-wide dispersion is assumed. Nondepositing radionuclides with half-lives greater than one year are considered. Noble gases and carbon-14 are assumed to mix uniformly in the world's atmosphere (3.8×10^{18} m^3), and radioactive decay is taken into consideration. The world-wide dispersion model estimates the activity of each nuclide at the end of a 15-year release period (midpoint of reactor life) and estimates the annual population dose commitment at that point in time, taking into consideration radioactive decay.

The total-body population dose commitment from the noble gases is due mainly to external exposure from gamma-emitting nuclides, while from carbon-14 it is due mainly to internal exposure from ingestion of food containing carbon-14.

The population dose commitment due to tritium releases is estimated in a manner similar to that for carbon-14, except that after the first-pass, all of the tritium is assumed to be absorbed by the world's oceans (2.7×10^{16} m^3). The concentration of tritium in the world's oceans is estimated at the point in time after 15 years of releases have occurred, taking into consideration radioactive decay; the population dose commitment estimates are based on the incremental concentration at that point in time. The total-body population dose commitment from tritium is due mainly to internal exposure from the consumption of food grown with irrigation water.

3. Liquid Effluents

Population dose commitments due to effluents in the receiving water within 80 km (50 miles) of the facility are calculated as described in Regulatory Guide 1.109. It is assumed that no depletion by sedimentation of the nuclides present in the receiving water occurs within 80 km. It also is assumed that aquatic biota concentrate radioactivity in the same manner as was assumed for the ALARA maximumally exposed individual evaluation. However, food consumption values appropriate for the average, rather than the maximum, individual are used. It is further assumed that all the sport and commercial fish and shellfish caught within the 80-km area are eaten by the U.S. population.

Beyond 80 km, it is assumed that all the liquid-effluent nuclides except tritium have deposited on the sediments so that they make no further contribution to population exposures. The tritium is assumed to mix uniformly in the hydrosphere and to result in an exposure to the U.S. population in the same manner as discussed for tritium in gaseous effluents.

REFERENCES FOR APPENDIX H

(1) U.S. Nuclear Regulatory Commission, "Regulatory Guide 1.109: Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I," Revision 1, October 1977.

(2) Title 10 Code of Federal Regulations Part 50, "Domestic Licensing of Production and Utilization Facilities," January 1981.

(3) U.S. Nuclear Regulatory Commission, "Regulatory Guide 1.111: Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Reactors," Revision 1, July 1977.

(4) K. F. Eckerman, et. al., "User's Guide to GASPAR Code," U.S. Nuclear Regulatory Commission report NUREG-0597, June 1980.

APPENDIX I

IMPACT OF THE URANIUM FUEL CYCLE

The following assessment of the environmental impacts of the fuel cycle as related to the operation of the proposed project is based on the values given in Table S-3 (Section 5.9) and the NRC staff's analysis of the radiological impact from radon releases. For the sake of consistency, the analysis of fuel cycle impacts has been cast in terms of a model 1000-MWe light-water-cooled reactor (LWR) operating at an annual capacity factor of 80%. In the following review and evaluation of the environmental impacts of the fuel cycle, the staff's analysis and conclusions would not be altered if the analysis were to be based on the net electrical power output of Waterford 3.

1. Land Use

The total annual land requirement for the fuel cycle supporting a model 1000-MWe LWR is about 460,000 m^2 (113 acres). Approximately 53,000 m^2 (13 acres) per year are permanently committed land, and 405,000 m^2 (100 acres) per year are temporarily committed. (A "temporary" land commitment is a commitment for the life of the specific fuel cycle plant, e.g., mill, enrichment plant, or succeeding plants. On abandonment or decommissioning, such land can be used for any purpose. "Permanent" commitments represent land that may not be released for use after plant shutdown and/or decommissioning.) Of the 405,000 m^2 per year of temporarily committed land, 320,000 m^2 are undisturbed and 90,000 m^2 are disturbed. Considering common classes of land use in the United States,* fuel cycle land use requirements to support the model 1000-MWe LWR do not represent a significant impact.

2. Water Use

The principal water use requirement for the fuel cycle supporting a model 1000-MWe LWR is that required to remove waste heat from the power stations supplying electrical energy to the enrichment step of this cycle. Of the total annual requirement of 43×10^6 m^3 (11.4×10^9 gal), about 42×10^6 m^3 are required for this purpose, assuming that these plants use once-through cooling. Other water uses involve the discharge to air (e.g., evaporation losses in process cooling) of about 0.6×10^6 m^3 (16×10^7 gal) per year and water discharged to the ground (e.g., mine drainage) of about 0.5×10^6 m^3 per year.

On a thermal effluent basis, annual discharges from the nuclear fuel cycle are about 4% of the model 1000-MWe LWR using once-through cooling. The consumptive water use of 0.6×10^6 m^3 per year is about 2% of the model 1000-MWe LWR using cooling towers. The maximum consumptive water use (assuming that all plants supplying electrical energy to the nuclear fuel cycle used cooling towers) would be about 6% of the model 1000-MWe LWR using cooling towers. Under this condition, thermal effluents would be negligible. The staff finds that these combinations of thermal loadings and water consumption are acceptable relative to the water use and thermal discharges of the station.

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* A coal-fired plant of 1000-MWe capacity using strip-mined coal requires the disturbance of about 810,000 m^2 (200 acres) per year for fuel alone.

3. Fossil Fuel Consumption

Electrical energy and process heat are required during various phases of the fuel cycle process. The electrical energy is usually produced by the combustion of fossil fuel at conventional power plants. Electrical energy associated with the fuel cycle represents about 5% of the annual electrical power production of the model 1000-MWe LWR. Process heat is primarily generated by the combustion of natural gas. This gas consumption, if used to generate electricity, would be less than 0.3% of the electrical output from the model plant. The staff finds that the direct and indirect consumptions of electrical energy for fuel cycle operations are small and acceptable relative to the net power production of the station.

4. Chemical Effluents

The quantities of chemical, gaseous, and particulate effluents associated with fuel cycle processes are given in Table S-3. The principal species are SOx NO_x, and the particulates. Judging from data in a Council on Environmental Quality report,[1] the NRC staff finds that these emissions constitute an extremely small additional atmospheric loading in comparison with these emissions from the stationery fuel-combustion and transportation sectors in the United States, that is, about 0.02% of the annual national releases for each of these species. The staff believes such small increases in releases of these pollutants are acceptable.

Liquid chemical effluents produced in fuel cycle processes are related to fuel enrichment, fabrication, and reprocessing operations and may be released to receiving waters. These effluents are usually present in dilute concentrations such that only small amounts of dilution water are required to reach levels of concentration that are within established standards. Table S-3 specifies the flow of dilution water required for specific constituents. Additionally, all liquid discharges into the navigable waters of the United States from plants associated with the fuel cycle operations will be subject to requirements and limitations set forth in the NPDES permit.

Tailings solutions and solids are generated during the milling process. These solutions and solids are not released in quantities sufficient to have a significant impact on the environment.

5. Radioactive Effluents

Radioactive effluents estimated to be released to the environment from reprocessing and waste management activities and certain other phases of the fuel cycle process are set forth in Table S-3. Using these data, the staff has calculated the 100-year involuntary environmental dose commitment* to the U.S. population.

These calculations estimate that the overall involuntary total-body gaseous dose commitment to the U.S. population from the fuel cycle (excluding reactor releases and the dose commitment due to radon-222) would be approximately

* The environmental dose commitment (EDC) is the integrated population dose for 100 years; that is, it represents the sum of the annual population doses for a total of 100 years. The population dose varies with time, and it is not practical to calculate this dose for every year.

400 person-rems per year of operation of the model 1000-MWe LWR. Based on Table S-3 values, the additional involuntary total body-dose commitments to the U.S. population from radioactive liquid effluents due to all fuel cycle operations other than reactor operation would be approximately 100 person-rems per year of operation. Thus the estimated involuntary 100-year environmental dose commitment to the U.S. population from radioactive gaseous and liquid releases due to these portions of the fuel cycle is approximately 500 person-rems (whole-body) per year of operation of the model 1000-MWe LWR.

At this time Table S-3 does not address the radiological impacts associated with radon-222 releases. Principal radon releases occur during mining and milling operations and as emissions from mill tailings. The staff has determined that releases from these operations for each year of operation of the model 1000-MWe LWR are as given in Table I-1.

The staff has calculated population dose commitments for these sources of radon-222 using the RABGAD computer code described in Appendix A of Chap. IV, Sec. J, of NUREG-002.[2] The results of these calculations for mining and milling activities prior to tailings stabilization are listed in Table I-2.

When added to the 500 person-rems total-body dose commitment for the balance of the fuel cycle, the overall estimated total-body involuntary 100-year environmental dose commitment to the U.S. population from the fuel cycle for the model 1000-MWe LWR is approximately 640 person-rems. Over this period of dose is equivalent to 0.00002% of the natural background dose of about 3 billion person-rems to the U.S. population.*

The staff has considered the health effects associated with the releases of radon-222, including both the short-term effects of mining and milling, and active tailings, and the potential long-term effects from unreclaimed open-pit mines and stabilized tailings. The staff has assumed that after completion of active mining underground mines will be sealed, returning releases of radon-222 to background levels. For purposes of providing an upper-bound impact assessment, the staff has assumed that open-pit mines will be unreclaimed and has calculated that if all ore were produced from open-pit mines, releases from them would be 110 Ci per year per reference reactor year (RRY). However, because the distribution of uranium ore reserves available by conventional mining methods is 66.8% underground and 32.2% open pit,[3] the staff has further assumed that uranium to fuel LWRs will be produced by conventional mining methods in these proportions. This means that long-term releases from unreclaimed open-pit mines will be 0.332 x 110 or 37 Ci per year per RRY.

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* Based on an annual average natural background individual dose commitment of 100 millirems and a stabilized U.S. population of 300 million.

Table I-1 Radon releases for each year of operation of the model 1000-MWe LWR*

Radon source	Quantity released	Source
Mining	4060 Ci	a
Milling and tailings (during active mining)	780 Ci	b
Inactive tailings (prior to stabilization)	350 Ci	b
Stabilized tailings (several hundred years)	1 to 10 Ci/year	b
Stabilized tailings (after several hundred years)	110 Ci/year	b

[a]R. Wilde, U.S. Nuclear Regulatory Commission transcript of direct testimony given "In the Matter of Duke Power Company Company (Perkins Nuclear Station), Docket No. 50-488, April 17, 1978.

[b]P. Magno, U.S. Nuclear Regulatory Commission transcript of direct testimony given "In the Matter of Duke Power Company (Perkins Nuclear Station)," Docket No. 50-448, April 17, 1978.

*After three days of hearings before the Atomic Safety and Licensing Appeal Board (ASLAB) using the Perkins record in a "lead case" approach, the ASLAB issued a decision on May 13, 1981 (ALAB-640) on the radon-222 release source term for the Uranium Fuel Cycle. The decision, among other matters, produced new source term numbers based on the record developed at the hearings. These new numbers did not differ significantly from those in the Perkins record which are the values set forth in this Table. Any health effects relative to radon-222 are still under consideration before the ASLAB. Since the source term numbers in ALAB-640 do not differ significantly from those in the Perkins record, the staff continues to conclude that "both the dose commitments and health effects of the uranium fuel cycle are insignificant when compared to dose commitments and potential health effects to the U.S. population resulting from all natural background sources." (see page I-7)

Table I-2 Estimated 100-year environmental dose commitment per year of operation of the model 1000-MWe LWR

Radon Source	Releases (Ci)	Dosage (person-rems)		
		Total Body	Bone	Lung (Bronchial epithelium)
Mining	4100	110	2800	2300
Milling and active tailings	1100	29	750	620
Total		140	3600	2900

Based on the above, the radon released from unreclaimed open-pit mines over 100- and 1000-year periods would be about 3700 Ci and 37,000 Ci per RRY respectively. The total dose commitments for a 100 to 1000-year period would be as follows:

Time span (years)	Releases (Ci)	Population dose commitments (person-rems)		
		Total body	Bone	Lung (bronchial epithelium)
100	3,700	96	2,500	2,000
500	19,000	480	13,000	11,000
1,000	37,000	960	25,000	20,000

The above dose commitments represent a worst-case situation in that no mitigating circumstances are assumed. However, state and Federal laws currently require reclamation of strip and open-pit coal mines, and it is very probable that similar reclamation will be required for uranium open-pit mines. If so, long-term releases from such mines should approach background levels.

For long-term radon releases from stabilized tailings piles, the staff has assumed that these tailings would emit, per RRY, 1 Ci per year for 100 years, 10 Ci per year for the next 400 years and 100 Ci per year for periods beyond 500 years. With these assumptions, the cumulative radon-222 release from stabilized tailings piles per RRY would be 100 Ci in 100 years and 4090 Ci in 500 years and 53,800 Ci in 1000 years.[4] The total-body, bone, and bronchial epithelium dose commitments for these periods are as follows:

Time span (years)	Releases (Ci)	Population dose commitments (person-rems)		
		Total body	Bone	Lung (bronchial epithelium)
100	100	2.6	68	56
500	4,090	110	2,800	2,300
1,000	53,800	1,400	37,000	30,000

If risk estimators of 135, 6.9, and 22 cancer deaths per million person-rems for total-body, bone, and lung exposures, respectively, are used, the estimated risk of cancer mortality resulting from mining, milling, and active tailings emissions of radon-222 is about 0.11 cancer fatalities per RRY. When this risk from radon-222 emissions from stabilized tailings over a 100-year release period is added, the estimated risk of cancer mortality over a 100-year period is unchanged. Similarly, a risk of about 1.2 cancer fatalities is estimated over a 1000-year release period per RRY. When potential radon releases from reclaimed and unreclaimed open-pit mines are included, the overall risks of radon induced cancer fatalities per RRY range as follows: 0.11 to 0.19 fatalities for a 100-year period, 0.19 to 0.57 fatalities for a 500-year period, and 1.2 to 2.0 fatalities for a 1000-year period.

To illustrate: A single-model 1000-MWe LWR operating at an 80% capacity factor for 30 years would be predicted to induce between 3.3 and 5.7 cancer fatalities in 100 yr, 5.7 and 17 in 500 yr, and 36 and 60 in 1000 yr as a result of releases of radon-222.

These doses and predicted health effects have been compared with those that can be expected from natural-background emissions of radon-222. Calculated using data from the National Council on Radiation Protection (NCRP)[5] the average radon-222 concentration in air in the contiguous United States is about 150 pCi/m^3, which the NCRP estimates will result in an annual dose to the bronchial epithelium of 450 millirems. For a stabilized future U.S. population of 300 million, this represents a total lung dose commitment of 135 million person-rems per year. If the same risk estimator of 22.2 lung cancer fatalities per million person-lung-rems used to predict cancer fatalities for the model 1000 MWe LWR is used, estimated lung cancer fatalities alone from background radon-222 in the air can be calculated to be about 3000 per year, or 300,000 to 3,000,000 lung cancer deaths over periods of 100 to 1000 years respectively.

In addition to the radon-related potential health effects from the fuel cycle, other nuclides produced in the cycle, such as carbon-14, will contribute to population exposures. It is estimated that 0.08 to 0.12 additional cancer deaths may occur per RRY (assuming that no cure or prevention of cancer is ever developed) over the next 100 to 1000 years, respectively, from exposures to these other nuclides.

The latter exposures can also be compared with those from naturally occurring terrestrial and cosmic-ray sources. These average about 100 millirems. Therefore, for a stable future population of 300 million persons, the whole-body dose commitment would be about 30 million person-rems per year, or 3 billion person-rems and 30 billion person-rems for periods of 100 and 1000 years respectively. These dose commitments could produce about 400,000 and 4,000,000 cancer deaths during the same time periods. From the above analysis, the NRC staff concludes that both the dose commitments and health effects of the uranium fuel cycle are insignificant when compared to dose commitments and potential health effects to the U.S. population resulting from all natural-background sources.

6. Radioactive Wastes

The quantities of buried radioactive waste material (low-level, high-level, and transuranic wastes) are specified in Table S-3. For low-level waste disposal at land burial facilities, the Commission notes in Table S-3 that there will be no significant radioactive releases to the environment. The Commission notes that high-level and transuranic wastes are to be buried at a Federal Repository and that no release to the environment is associated with such disposal. NUREG-0116,[6] which provides background and context for the high-level and transuranic Table S-3 values established by the Commission, indicates that these high-level and transuranic wastes will be buried and will not be released to the biosphere. No radiological environmental impact is anticipated from such disposal.

7. Occupational Dose

The annual occupational dose attributable to all phases of the fuel cycle for the model 1000-MWe LWR is about 200 person-rems. The NRC staff concludes that this occupational dose will not have a significant environmental impact.

8. Transportation

The transportation dose to workers and the public is specified in Table S-3. This dose is small and not considered significant in comparison to the natural-background dose.

9. Fuel Cycle

The staff's analysis of the uranium fuel cycle did not depend on the selected fuel cycle (no recycle or uranium-only recycle), because the data provided in Table S-3 include maximum recycle option impact for each element of the fuel cycle. Thus the staff's conclusions as to acceptability of the environmental impacts of the fuel cycle are not affected by the specific fuel cycle selected.

REFERENCES FOR APPENDIX I

(1) Council on Environmental Quality, "The Seventh Annual Report of the Council on Environmental Quality," September 1976, Figs. 11-27 and 11-28, pp. 238-239.

(2) U.S. Nuclear Regulatory Commission, "Final Generic Environmental Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in Light-Water-Cooled Reactors, Report NUREG-0002,Washington, D.C., August 1976.

(3) U.S. Department of Energy, "Statistical Data of the Uranium Industry," Report GJO-100(8-78), January 1, 1978.

(4) R. Gotchy, U.S. Nuclear Regulatory Commission, transcript of direct testimony given "In the Matter of Duke Power Company" (Perkins Nuclear Station), Docket No. 50-448, April 17, 1978.

(5) National Council on Radiation Protection and Measurements "Natural Background Radiation in the United States," Publication No. 45, November 1975.

(6) U.S. Nuclear Regulatory Commission, "Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle," Report NUREG-0116 (Supplement 1 to WASH-1248), Washington, D.C., October 1976.

APPENDIX J

EXAMPLES OF SITE-SPECIFIC DOSE ASSESSMENT CALCULATIONS

1. Calculational Approach

As mentioned in the text the quantities of radioactive material that may be released annually from the Waterford 3 are estimated on the basis of the description of the radwaste systems in the applicant's ER and FSAR and by using the calculational model and parameters described in NUREG-0017.[1] These estimated effluent release values along with the applicant's site and environmental data in the ER and in subsequent answers to NRC staff questions are used in the calculation of radiation doses and dose commitments.

The models and considerations for environmental pathways that lead to estimates of radiation doses and dose commitments to individual members of the public near the plant and of cumulative doses and dose commitments to the entire population within an 80-km radius of the plant as a result of plant operations are discussed in detail in Regulatory Guide 1.109.[2] Use of these models with additional assumptions for environmental pathways that lead to exposure to the general population outside the 80-km (50 mile) radius are described in Appendix H of this Statement.

The calculations performed by the staff for the potentially contaminated atmosphere and hydrosphere provide total integrated dose commitments to the entire population within 80 km of the station based on the projected population distribution in the year 2000. The dose commitments represent the total dose that would be received over a 50-yr period, following the intake of radioactivity for 1 yr under the conditions existing 15 years after the station begins operation (i.e., the mid-point of station operation). For younger persons, changes in organ mass and metabolic parameters with age after the initial intake of radioactivity are accounted for.

2. Dose Commitments from Radioactive Effluent Releases

Radioactive effluents released to the atmosphere and to the hydrosphere from the Station will result in very small radiation dose commitments to individual members of the public and to the general population. The NRC staff estimates of the expected gaseous and particulate releases (listed in Table J-1) and the expected liquid releases (listed in Table J-8) along with the site meteorological and hydrological considerations (summarized in Tables J-2 and J-9 respectively) were used to estimate radiation doses and dose commitments.

Four years of meteorological data were used in the calculation of relative concentrations of effluents. The data were collected onsite from July 1972 to June 1975 and from February 1977 to February 1978. The long-term diffusion estimates were made using the procedure described in Regulatory Guide 1.111, Revision 1.[3] Open terrain recirculation factors were used by the staff in the computer model.

(a) Radiation Dose Commitments to Individual Members of the Public

As explained in the text, calculations are made for a hypothetical individual member of the public (i.e., the maximally exposed individual) who would be expected to receive the highest radiation dose from all appropriate pathways. This method tends to overestimate the doses since assumptions are made that would be difficult for a real individual to fulfill.

Individual receptor locations and pathway locations considered for the maximally exposed individual are listed in Table J-3. The estimated dose commitments to the individual who is subject to maximum exposure at selected offsite locations from airborne releases of radioiodine and particulates, and waterborn releases are listed in Tables J-4, J-5, and J-6. The maximum annual beta and gamma air dose and the maximum total body and skin dose to an individual, at the site boundary, also are presented in Tables J-4, J-5, and J-6.

The maximally exposed individual is assumed to consume well above average quantities of the potentially affected foods and to spend more time at potentially affected locations than the average person as indicated in Tables E-4 and E-5 of Regulatory Guide 1.109.[2] With regard to the doses calculated from the nearest farm (ESE 0.6m;) the staff assumed that 20% of the maximum individual's vegetable consumption is obtained from this location.

(b) Cumulative Dose Commitments to the General Population

Annual radiation dose commitments from airborne and waterborne radioactive releases from Waterford 3 are estimated for two populations in the year 2000: (1) all members of the general public within 80 km (50 miles) of the station (Table J-5) and (2) the entire U.S. population (Table J-7). Dose commitments beyond 80 km are based on the assumptions discussed in Appendix H. For perspective, annual background radiation doses are given in the tables for both populations.

REFERENCES FOR APPENDIX J

1. U.S. Nuclear Regulatory Commission, "Calculations of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Pressurized Water Reactors (PWR-GALE Code) NUREG-0017, U.S. Nuclear Regulatory Commission, April 1976.

2. "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I," Reg. Guide 1.109, Rev. 1, U.S. Nuclear Regulatory Commission, October 1977.

3. "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Reactors." Reg. Guide 1.111, Rev. 1, U.S. Nuclear Regulatory Commission, July 1977.

Table J-1 Calculated Releases of Radioactive Materials in Gaseous Effluents in Curies per year from Waterford 3

Nuclide	Plant Stack (continuous)	Plant Stack (intermittent)	Turbine Bldg (continuous)
Kr-85m	5.0	2.0	a
Kr-85	330	73	a
Kr-87	2.0	-	a
Kr-88	8.0	2.0	a
Xe-131m	8.0	52	a
Xe-133m	10	42	a
Xe-133	730	6400	a
Xe-135	15	12	a
Xe-138	1.0	a	a
		Total Noble Gases	7692
Mn-54	0.0047	0.000023	b
Fe-59	0.0016	0.0000079	b
Co-58	0.016	0.000079	b
CO-60	0.0073	0.000036	b
Sr-89	0.0034	0.0000018	b
Sr-90	0.00006	0.00000032	b
Cs-134	0.0047	0.000023	
Cs-137	0.0078	0.000049	b
		Total Particulates	0.04
I-131	0.013	0.0027	0.0041
I-133	0.016	0.00096	0.0035
H-3	940	a	a
C-14	7	1	a

a = less than 1.0 Ci/yr for noble gases and carbon-14 less than 10^{-4} Ci/yr for iodine

b = less than 1% of total for this nuclide

Table J-2 Summary of Atmospheric Dispersion Factors (x/Q) and Relative Deposition Values for Maximum Site Boundary and Receptor Locations Near Waterford 3

Location	X/Q (sec/m^3)	Relative Deposition (m^{-2})
Site boundary (ESE 0.6 mi)	1.4×10^{-5}	2.3×10^{-8}
Nearest** residence and milk cow (NW 0.9 mi)	7.9×10^{-6}	2.3×10^{-8}
Nearest farm (ESE 0.31 mi)	4.5×10^{-5}	6.5×10^{-8}
Nearest meat animal (NW 0.8 mi)	1.1×10^{-6}	3.2×10^{-8}

*The values presented in this table are corrected for radioactive decay and cloud depletion from deposition, where appropriate, in accordance with Regulatory Guide 1.111, Rev. 1, "Methods for Estimating Atomospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light Water Reactors," July 1977.[3]

**"Nearest" refers to that type of location where the highest radiation dose is expected to occur from all appropriate pathways.

Table J-3 Nearest Pathway Locations Used for Maximum Individual Dose Commitments for Waterford 3

Location	Sector	Distance (mi)
Site boundary*	ESE	0.6
Residence**	NW	0.9
Farm**	ESE	0.31
Milk cow	NW	0.9
Meat animal	NW	0.8

*Beta and gamma air doses, total body doses, and skin doses from noble gases are determined at site boundaries.

**Dose pathways including inhalation of atmospheric radioactivity, exposure to deposited radionuclides, and submersion in gaseous radioactivity are evaluated at residences.

Table J-4 Annual Dose Commitments to a Maximally Exposed Individual Near Waterford 3

Location	Pathway	Doses (mrem/yr per unit)			
		Noble Gases in Gaseous Effluents			
		Total Body	Skin	Gamma Air Dose (mrad/yr per unit)	Beta Air Dose (mrad/yr per unit)
Nearest site boundary[a] (ESE 0.6 km)	Direct radiation from plume	1.6	4.6	2.6	8.1
		Iodine and Particulates in Gaseous Effluents[b]			
		Total Body	Organ		
Nearest[c] site boundary (ESE 0.6 mi)	Ground deposit	0.29 (T)	0.29 (C) (bone)		
	Inhalation	0.04 (T)	0.006 (C) (bone)		
Nearest farm (ESE 0.31 mi)	Vegetable consumption	2.4 (C)	8.2 (C) (bone)		
Nearest milk cow (NW 0.9 mi)	Ground deposit	0.21 (C)	0.21 (C) (bone)		
	Inhalation	0.27 (C)	0.004 (C) (bone)		
	Vegetable consumption	2.10 (C)	7.4 (C) (bone)		
	Cow milk consumption	0.96 (C)	3.6 (C) (bone)		
	Meat consumption	0.25 (C)	1.1 (C) (bone)		
Nearest meat animal (NW 0.8 mi)	Meat consumption	0.40 (C)	1.7 (C) (bone)		
		Liquid Effluents (Adults)			
		Total Body	Organ		
Nearest Drinking Water (St. Charles Parish)	Ingestion	<0.01	0.03 (thyroid)		
Nearest fish (Discharge)	Fish ingestion	0.08	0.11 (liver)		

[a] "Nearest" refers to that site boundary location where the highest radiation doses as a result of gaseous effluents have been estimated to occur.

[b] Doses are for the age group that results in the highest dose: T=teen, C=child, I=infant.

[c] "Nearest" refers to the location where the highest radiation dose to an individual from all applicable pathways has been estimated.

Table J-5 Calculated Appendix I Dose Commitments to a Maximally Exposed Individual and to the Population from Operation of Waterford 3

	Annual Dose per Reactor Unit	
	Individual	
	Appendix I Design Objectives[a]	Calculated Doses
Liquid effluents		
Dose to total body from all pathways	3 mrem	0.1 mrem
Dose to any organ from all pathways	10 mrem	0.12 mrem
Noble-gas effluents (at site boundary)		
Gamma dose in air	10 mrad	2.6 mrad
Beta dose in air	20 mrad	8.1 mrad
Dose to total body of an individual	5 mrem	1.6 mrem
Dose to skin of an individual	15 mrem	4.6 mrem
Radioiodines and particulates[b]		
Dose to any organ from all pathways	15 mrem	12 mrem (bone-child)

	Population Within 80 km	
	Total Body	Organ
	(person-rem)	
Natural-background radiation[c]	180,000	
Liquid effluents	6.0	7.1 (thyroid)
Noble-gas effluents	0.23	0.23 (bone)
Radioiodine and particulates	5.5	8.7 (bone)

[a]Design Objectives from Sections II.A, II.B, II.C, and II.D of Appendix I, 10 CFR Part 50 consider doses to maximum individual and population per reactor unit.

[b]Carbon-14 and tritium have been added to this category.

[c]"Natural Radiation Exposure in the United States," U.S. Environmental Protection Agency, ORP-SID-72-1, June 1972; using the average background dose for Louisiana of 84 mrem/yr, and year-2000 projected population of 2,182,000.

Table J-6 Calculated RM-50-2 Dose Commitments to a Maximally Exposed Individual from Operation of Waterford 3[a]

	Annual Dose per Site	
	RM-50-2 Design Objectives[b]	Calculated Doses
Liquid effluents		
Dose to total body or any organ from all pathways	5 mrem	0.1 mrem
Activity-release estimate, excluding tritium (Ci/unit)	5	0.24
Noble-gas effluents (at site boundary)		
Gamma dose in air	10 mrad	2.6 mrad
Beta dose in air	20 mrad	8.1 mrad
Dose to total body of an individual	5 mrem	1.6 mrem
Radioiodine and particulates[c]		
Dose to any organ from all pathways	15 mrem	12 mrem (bone)
I-131 activity release (Ci)	1	0.4

[a]An optional method of demonstrating compliance with the cost-benefit Section (II.D) of Appendix I to 10 CFR Part 50.

[b]Annex to Appendix I to 10 CFR Part 50.

[c]Carbon-14 and tritium have been added to this category.

Table J-7 Annual Total-Body Population Dose Commitments, Year 2000

Category	U.S. Population Dose Commitment, person-rem/yr
Natural background radiation[a]	27,000,000[a]
Waterford Nuclear Station Unit 3 operation	
Plant workers	440
General public:	
Liquid effluents[b]	11.
Gaseous effluents	42
Transportation of fuel and waste	7

[a]Using the average U.S. background dose (100 mrem/yr) and year 2000 projected U.S. population from "Population Estimates and Projections," Series II, U.S. Department of Commerce, Bureau of the Census, Series P-25, No. 541 February 1975.

[b]80-km (50-mile) population dose

Table J-8 Calculated Release of Radioactive Materials in Liquid Effluents from Waterford 3

Nuclide	Ci/yr	Nuclide	Ci/yr
	Corrosion & Activation Products		
Cr-51	0.00007	I-130	0.00021
Mn-54	0.001	Te-131m	0.00005
Fe-55	0.00006	I-131	0.092
Fe-59	0.00004	Te-132	0.00072
Co-58	0.0046	I-132	0.0042
Co-60	0.0088	I-133	0.058
Zr-95	0.0014	I-134	0.00002
Nb-95	0.002	Cs-134	0.015
Np-239	0.003	I-135	0.0096
Te-129	0.00003		
	Fission Products		
Br-83	0.00004	Cs-136	0.0007
Sr-89	0.00001	Cs-173	0.026
Mo-99	0.0024	Bs-137m	0.0015
Tc-99m	0.0028	Ce-144	0.0052
Ru-103	0.00014	All others[a]	0.00006
Ru-106	0.0024	Total except tritium	0.24
Ag-110m	0.00044		
Te-127	0.00002		
Te-129m	0.00005	Tritium release	

[a]Nuclides whose release rates are less than 10^{-5} Ci/yr are not listed individually but are included in the category "All others."

Table J-9 Summary of Hydrologic Transport and Dispersion for Liquid Releases from Waterford 3

Location	Transit Time (hours)	Dilution Factor
Nearest drinking water intake (Union Carbide) (~2.6 mi, downstream)	1.0	5
Nearest sport fishing location (plant discharge)	0.01	1
Nearest shoreline (plant discharge)	0.01	1
Nearest irrigated crops (St. Charles)	0.1	5

[a]See Regulatory Guide 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I," April 1977.