U.S. NUCLEAR REGULATORY COMMISSION

ENVIRONMENTAL STANDARD REVIEW PLAN

5.7.1 URANIUM FUEL CYCLE IMPACTS

REVIEW RESPONSIBILITIES

Primary— Organization responsible for review of uranium fuel cycle information

Secondary— None

I. AREAS OF REVIEW

This environmental standard review plan (ESRP) directs the staff's review to comply with 10 CFR 51.51,[a] "Uranium fuel cycle environmental data - Table S–3," as the basis for the staff's evaluation of the environmental effects of the uranium fuel cycle.

Review Interfaces

The reviewers for this ESRP should obtain input from and provide input to reviewers for the following ESRP:

- ESRP 10.4.2. Provide a statement, if appropriate, that the environmental impacts of the uranium fuel cycle, as shown in Table 5.7-A-1 and in relationship to the proposed project, appear to have little significance and would not alter the overall benefit-cost balance.

(a) The table has been further updated to reflect the changes contained in Attachment A to the Fuel Cycle Rulemaking Hearing Board's Conclusions and Recommendations of the Hearing Board Regarding the Environmental Effects of the Uranium Fuel Cycle, Docket No. RM 50-3, dated October 26, 1978 (NRC 1996).

Data and Information Needs

The type of data and information needed will be affected by site- and station-specific factors, and the degree of detail should be modified according to the anticipated magnitude of the potential impacts. The following data or information should be obtained.

- Table S–3 of Paragraph (a) of 10 CFR 51.51. The current amendment (as given in 49 FR 9381, March 12, 1984 and 49 FR 10922, March 23, 1984) is included in Appendix A to this ESRP as Table 5.7-A-1.[a]

The reviewer should ensure that the most recent amendment of Table S–3 has been provided as input to the EIS and should update the staff analysis given in Appendix A to this ESRP when necessary. The reviewer should also ensure that all conclusions given in Appendix A are appropriate for the proposed project.

II. ACCEPTANCE CRITERIA

Acceptance criteria for the evaluation of the impacts of the uranium fuel cycle for light-water reactor designs are based on the relevant requirements of the following:

- Paragraph (a) of 10 CFR 51.51, "Uranium fuel cycle environmental data—Table S–3" (*Federal Register* Notices 49 FR 9381, March 12, 1984, and 49 FR 10922, March 23, 1984) with respect to the impacts to the environment from the hazards associated with the fuel cycle.

Technical Rationale

Appendix A provides a summary of the technical rationale for evaluating the applicant's potential uranium fuel cycle impacts for both light-water reactor designs and non-light-water reactor designs. NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (NRC 1996) provides a more detailed analysis of the environmental impacts from the uranium fuel cycle for light-water reactor designs. Although NUREG-1437 is specific to the impacts as they relate to license renewal, most of the information can also be applied to this ESRP review.

III. REVIEW PROCEDURES

No analysis of these data is required.

(a) The table has been further updated to reflect the changes contained in Attachment A to the Fuel Cycle Rulemaking Hearing Board's Conclusions and Recommendations of the Hearing Board Regarding the Environmental Effects of the Uranium Fuel Cycle, Docket No. RM 50-3, dated October 26, 1978 (NRC 1996).

IV. EVALUATION FINDINGS

Appendix A to this plan provides the input from this ESRP to be used in the environmental impact statement (EIS). In addition, the reviewer should ensure that, if appropriate, a statement similar to the following is included as input to ESRP 10.4.2:

> The staff evaluated the environmental impacts of the uranium fuel cycle as given in Table 5.7-A-1. The staff found these impacts to be sufficiently small so that when they are added to the other environmental impacts predicted for the proposed project, the fuel cycle impacts would not alter the overall benefit-cost balance.

V. IMPLEMENTATION

The method described in this ESRP should be used by the staff in evaluating conformance with NRC requirements, except in those cases in which the applicant proposes an acceptable alternative for complying with specified portions of the requirements.

VI. REFERENCES

10 CFR 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulator Functions.

10 CFR 51.20, "Criteria for and identification of licensing and regulatory actions requiring environmental impact statements."

10 CFR 51.51, "Uranium fuel cycle environmental data."

42 FR 13803. March 14, 1984. "Interim rule regarding the environmental considerations of the uranium fuel cycle." *Federal Register.*

43 FR 15613. April 14, 1978. Table S–3 of Paragraph (e) of 10 CFR 51.20 was amended. *Federal Register.*

49 FR 9381. March 12, 1984. Notice. *Federal Register.*

49 FR 10922. March 23, 1984. Notice. *Federal Register.*

Council on Environmental Quality (CEQ). 1976. *The Seventh Annual Report of the Council on Environmental Quality*. Executive Office of the President, Administrative Operations Branch. Washington, D.C.

Evans, J. S., S. Abrahamson, M. A. Bender, B. B. Boecker, E. S. Gilbert, and B. R. Scott. 1993. *Health Effects Models for Nuclear Power Plant Accident Consequence Analysis.* Part I. Rev. 2. Introduction, Integration, and Summary. NUREG/CR-4214. Office of Nuclear Regulatory Research, Washington, D.C.

International Commission on Radiological Protection (ICRP). 1991. *1990 Recommendations of the International Commission on Radiological Protection*. ICRP Publication 60, Pergamon Press, Oxford, United Kingdom.

National Academy of Sciences (NAS). 1995. *Technical Bases for Yucca Mountain Standards*. National Academy Press, Washington, D.C.

National Cancer Institute (NCI). 1990. *Cancer in Populations Living Near Nuclear Facilities*. NIH Publication 90-874. National Institutes of Health, Washington, D.C.

National Council on Radiation Protection and Measurements (NCRP). 1987. *Ionizing Radiation Exposure of the Population of the United States*. NCRP Report No. 93, Bethesda, Maryland.

National Environmental Policy Act of 1969, as amended (NEPA). 2 USC 4321, et. seq.

National Research Council. 2006. *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII - Phase 2*. Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation, National Research Council, National Academy Press, Washington, D.C.

U.S. Atomic Energy Commission (AEC). 1974. *Environmental Survey of the Uranium Fuel Cycle*. WASH-1248, Washington, D.C.

U.S. Court of Appeals. 2004. Nuclear Energy Institute v. EPA, 373 F.3d 1251 9th Cir. 2004).

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

U.S. Nuclear Regulatory Commission (NRC). 1977. *Public Comments and Task Force Responses Regarding the Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle*, NUREG-0216 (Supplement 2 to WASH-1248), Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1978. Attachment A to the Fuel Cycle Rulemaking Hearing Board's Conclusions and Recommendations of the Hearing Board Regarding the Environmental Effects of the Uranium Fuel Cycle, Docket No. RM 50-3.

U.S. Nuclear Regulatory Commission (NRC). 1996. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants.* NUREG-1437, Vol. 1, Washington, D.C.

U. S. Nuclear Regulatory Commission (NRC). 2003. July 21, 2003 Letter Report from James E. Lyons to Dr. Ronald L. Simard entitled *Early Site Permit Topic 8 (ESP-8), Fuel Cycle and Transportation Impacts*.

White House Press Release. 2002. "Yucca Mountain Statement."

PAPERWORK REDUCTION ACT STATEMENT

The information collections contained in the Environmental Standard Review Plan are covered by the requirements of 10 CFR Part 51, and were approved by the Office of Management and Budget, approval number 3150-0021.

PUBLIC PROTECTION NOTIFICATION

The NRC may not conduct or sponsor, and a person is not required to respond to, a request for information or an information collection requirement unless the requesting document displays a currently valid OMB control number.

APPENDIX A

INPUT TO THE ENVIRONMENTAL IMPACT STATEMENT

On March 14, 1977, the Commission issued an interim rule in the *Federal Register* (42 FR 13803) an interim rule regarding the environmental considerations of the uranium fuel cycle. It was effective through September 13, 1978, and revised Table S–3 of Paragraph (e) of 10 CFR 51.20. In a subsequent rule issued on April 14, 1978 (43 FR 15613), the Commission further amended Table S–3 to delete the numerical entry for the estimate of radon releases and to clarify *that the table does not cover health effects*. Further revision to 10 CFR 51 was made in 1984. The current requirement for Table S–3 is in 10 CFR 51.51 (49 FR 9381, March 12, 1984, and 49 FR 10922, March 23, 1984). The revised table is shown here as Table 5.7-A-1. The current rule reflects information on reprocessing spent fuel and radioactive-waste management as discussed in NUREG-0116, *Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle* (NRC 1976) and NUREG-0216, *Public Comments and Task Force Responses Regarding the Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle* (NRC 1977) which presents staff responses to comments on NUREG-0116. The rule also considers other environmental factors of the uranium fuel cycle, including aspects of mining and milling, isotopic enrichment, fuel fabrication, and management of low- and high-level wastes. These are described in the AEC report WASH-1248 (AEC 1974).

The regulations in 10 CFR 51.51(a) state that

> Every environmental report prepared for the construction permit stage of a light-water-cooled nuclear power reactor, and submitted on or after September 4, 1979, shall take Table S–3, *Table of Uranium Fuel Cycle Environmental Data*, as the basis for evaluating the contribution of the environmental effects of uranium mining and milling, the production of uranium hexafluoride, isotopic enrichment, fuel fabrication, reprocessing of irradiated fuel, transportation of radioactive materials, and management of low level wastes and high level wastes related to uranium fuel cycle activities to the environmental costs of licensing the nuclear power plant. Table S–3 shall be included in the environmental report and may be supplemented by a discussion of the environmental significance of the data set forth in the table as weighed in the analysis for the proposed facility.

Light-water reactor (LWR) designs use uranium dioxide fuel; therefore, the values in Table S–3 can be used to assess environmental impacts. Table S–3 values are normalized for a reference 1000-MW(e) LWR at an 80 percent capacity factor. Table S–3 values are not appropriate reference sources for analyzing fuel cycle impacts for applications that reference non-LWR designs. Applicants proposing non-LWR designs will need to fully address fuel cycle impacts using appropriate references. WASH-1248 (AEC 1974) may be used in determining the impacts; however, the applicant bears the burden of demonstrating that the impacts, and the methods used to determine those impacts, are accurate and appropriate for the proposed non-LWR reactor design. Applicants should comprehensively address impacts of the non-LWR reactor design and should not just address impacts of earlier technology that are lessened by the new technology.

Specific categories of natural resource use are included in Table S–3 of the rule. These categories relate to land use, water consumption and thermal effluents, radioactive releases, burial of transuranic and high- and low-level wastes, and radiation doses from transportation and occupational exposures. In developing Table S–3 (Table 5.7-A-1), the staff considered two fuel cycle options – no recycle and uranium-only recycle – which differed in the treatment of spent fuel removed from a reactor. "No recycle" treats all spent fuel as waste to be stored at a Federal waste repository; "uranium only recycle" involves reprocessing of spent fuel to recover unused uranium and return it to the system. Neither cycle involves the recovery of plutonium. The contributions in Table S–3 for reprocessing, waste management, and transportation of wastes are maximized for either of the two fuel cycles (uranium only and no recycle); that is, the identified environmental impacts are based on the cycle that results in the greater impact. The uranium fuel cycle is defined as the total of those operations and processes associated with provision, utilization, and ultimate disposition of fuel for nuclearpower reactors.

The Nuclear Nonproliferation Act of 1978, Pub. L. No. 95-242 (22 USC 3201 et seq.) significantly impacted the disposition of spent nuclear fuel by deferring indefinitely the commercial reprocessing and recycling of spent fuel produced in the U.S. commercial nuclear power program. While the ban on the reprocessing of spent fuel was lifted during the Reagan administration, economic circumstances changed, reserves of uranium ore increased, and the stagnation of the nuclear power industry provided little incentive for industry to resume reprocessing. The Energy Policy Act of 2005, Pub. L. No. 109-58 (119 Stat. 594 [2005]) authorized DOE to conduct an advanced fuel recycling technology research and development program to evaluate proliferation-resistant fuel recycling and transmutation technologies that minimize environmental or public health and safety impacts. Consequently, while Federal policy does not prohibit reprocessing, additional DOE efforts would be required before commercial reprocessing and recycling of spent fuel produced in the U.S. commercial nuclear power plants could commence.

The no-recycle option is presented schematically in Figure 5.7-A-1. Natural uranium is mined in either open-pit or underground mines or by an in situ mining process. In situ leach mining, the primary form of mining in the United States today, involves injecting a lixiviant solution into the uranium ore body to dissolve uranium and then pumping the solution to the surface for further processing. The ore or in situ leach solution is transferred to mills where it is processed to produce"yellow-cake" (U_3O_8). A conversion facility prepares the uranium oxide by converting it to uranium hexafluoride (UF_6), which is then processed by an enrichment facility to increase the percentage of the more fissile isotope uranium-235 and decrease the percentage of the nonfissile isotope uranium-238. At a fuel-fabrication facility, the enriched uranium, approximately 5 percent uranium-235, is then converted to UO_2. The UO_2 is pelletized, sintered, and inserted into tubes to form fuel assemblies. The fuel assemblies are placed in the reactor to produce power. When the content of the uranium-235 reaches a point where the nuclear reactor has become inefficient with respect to neutron economy, the fuel assemblies are withdrawn from the reactor. After onsite storage for sufficient time to allow for short-lived fission product decay and to reduce the heat generation rate, the fuel assemblies would be transferred to a Federal repository for internment. Disposal of spent fuel elements in a repository constitutes the final step in the no-recycle option.

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 and the staff's analysis of the radiological impact from radon-222 and technicium-99 releases. In NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (GEIS) (NRC 1996),[a] the staff provides a detailed analysis of the environmental impacts from the uranium fuel cycle. Although NUREG-1437 is specific

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(a) The GEIS was originally issued in 1996. Addendum 1 to the GEIS was issued in 1999. Hereafter, all references to the "GEIS" include the GEIS and its Addendum 1.

to the impacts related to license renewal, the information is relevant to this review because the advanced LWR designs considered here use the same type of fuel; the staff's analyses in Section 6.2.3 of NUREG-1437 are summarized and set forth here. The fuel cycle impacts in Table S–3 are based on a reference 1000-MW(e) LWR operating at an annual capacity factor of 80 percent for a net electric output of 800 MW(e).

In the following review and evaluation of environmental impacts of the fuel cycle, the staff assumed the fuel cycle impacts for the reference 1000-MW(e) LWR in Table S-3. When evaluating the proposed reactor design, the staff needs to scale the impacts in Table S-3 to the net electric output for the proposed design. For example, the Early Site Permit application for the North Anna site proposed reactor designs with a net electric output of 3200 MW(e). This was termed the 1000 MW(e) LWR scaled model and resulted in a factor approximately four times (i.e., 3200/800) the impacts in Table S–3.

Recent changes in the fuel cycle may have some bearing on environmental impacts; however, as discussed below, the staff is confident that the contemporary fuel cycle impacts are less than those identified in Table S–3.

The values in Table S–3 were calculated from industry averages for the performance of each type of facility or operation within the fuel cycle. Recognizing that this approach would result in a range of reasonable values for each estimate, the staff followed the policy of choosing the assumptions or factors to be applied so the calculated values would not be underestimated. This approach was intended to ensure that the actual environmental impacts would be less than the quantities shown in Tables S–3 for all LWR nuclear power plants within the widest range of operating conditions. Many subtle fuel cycle parameters and interactions were recognized by the staff as being less precise than the estimates and were not considered or were considered but had no effect on the Table S–3 calculations. For example, to determine the quantity of fuel required for a year's operation of a nuclear power plant in Table S–3, the staff defined the model reactor as a 1000-MW(e) light-water-cooled reactor operating at 80 percent capacity with a 12-month fuel reloading cycle and an average fuel burnup of 33,000 MWd/MTU. This is a "reactor reference year" or "reference reactor year" depending on the source document (either Table S–3 or NUREG-1437), but it has the same meaning. The sum of the initial fuel loading plus all of the reloads for the lifetime of the reactor can be divided by the now more likely 60-year (40-year initial license term and 20-year renewal license term) lifetime to obtain an average annual fuel requirement. The quantity of fuel was determined in NUREG-1437 for both boiling-water reactors (BWRs) and pressurized-water reactors (PWRs); the higher annual requirement, 35 metric tonnes (MT) of uranium made into fuel for a BWR, was chosen in NUREG-1437 as the basis for the reference reactor year. A number of fuel management improvements have been adopted by nuclear power plants to achieve higher performance and to reduce fuel and separative work (enrichment) requirements. Since Table S–3 was promulgated, these improvements have reduced the annual fuel requirement.

Another change considered is the elimination of the U.S. restrictions on importation of foreign uranium. The economic conditions of the uranium market currently favor utilization of foreign uranium at the expense of the domestic uranium industry. These market conditions have led to the closing of most U.S. uranium mines and mills, substantially reducing the environmental impacts in the United States from these activities. Factoring in changes to the fuel cycle suggests that the environmental impacts of mining and milling could drop levels below those given in Table S–3; however, for the purposes of this analysis, Table S–3 estimates have not been reduced.

Section 6.2 of NUREG-1437 discusses the sensitivity to recent changes in the fuel cycle on the environmental impacts in greater detail.

[Note: Regarding unit conversion of units in the next sections, generally, if the source of the number is in English units, keep the English units. If the source is in metric units, do not add the English unit conversion.]

[Note: In the following sections the environmental effects presented are those found Table S–3 for the reference 1000 MW(e) LWR operating at a net electric output of 800 MW(e). Impact values that need to be scaled to the net electric output for the proposed application are in brackets.]

A. Land Use

A discussion of land-use impacts can be found in Section 6.2.2.6 of NUREG 1437. The total annual land requirement for the fuel cycle supporting the 1000-MW(e) LWR scaled model is about [46 hectares (113 acres)]. Approximately [5 hectares (13 acres)] are permanently committed land, and [41 hectares (100 acres)] 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). Following decommissioning, such land can be used for unrestricted use. "Permanent" commitments represent land that may not be released for use after plant shutdown and/or decommissioning because decommissioning activities do not result in removal of sufficient radioactive material to meet the limits in 10 CFR Part 20, Subpart E, for release of land for unrestricted use. Of the 41 hectares (100 acres) per year of temporarily committed land, 32 hectares (79 acres) are undisturbed and 9 hectares (22 acres) are disturbed. In comparison, a coal-fired power plant with the same output as the LWR scaled model and that uses using strip-mined coal requires the disturbance of about 81 hectares (200 acres) per year for fuel alone. The staff concludes that the impacts on land use to support the 1000-MW(e) LWR scaled model would be [IMPACT LEVEL].

B. Water Use

A discussion of water-use impacts can be found in Section 6.2.2.7 of NUREG-1437. The principal water use for the fuel cycle supporting a 1000-MW(e) LWR scaled model is that required to remove waste heat from the power stations supplying electrical energy to the enrichment step of this cycle. The total annual water use [43×10^6 m^3 (11.4×10^9 gal), about 42×10^6 m^3] required for the removal of waste heat, assuming that these plants use once-through cooling, must be scaled based on the net capacity ratio. Other water uses involve the discharge to air (e.g., evaporation losses in process cooling) of about [0.6×10^6 m^3] per year and water discharged to ground (e.g., mine drainage) of about [0.5×10^6 m^3] per year.

Regarding thermal effects, annual discharges from the nuclear fuel cycle are about 4 percent of the 1000-MW(e) LWR scaled model using once-through cooling. The consumptive water use of [0.6×10^6 m^3] per year is about 2 percent of the 1000 MW(e) LWR scaled model 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 percent of the 1000-MWe LWR scaled model using cooling towers. Under this condition, thermal effluents would be negligible. The staff concludes that the impacts on water use for these combinations of thermal loadings and water consumption would be [IMPACT LEVEL] relative to the water use and thermal discharges of the proposed project.

C. Fossil Fuel Impacts

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 percent of the annual electrical power production of the reference 1000-MW(e) LWR. Process heat is primarily generated by the combustion of natural gas. This gas consumption, if used to generate electricity, would be less than 0.4 percent of the electrical output from the model plant. The staff concludes that the fossil fuel impacts from the direct and indirect consumption of electrical energy for fuel cycle operations would be [IMPACT LEVEL] relative to the net power production of the proposed project.

D. Chemical Effluents

The quantities of chemical, gaseous, and particulate effluents with fuel cycle processes are given in Table S–3 for the reference 1000-MW(e) LWR. The site-wide quantities of effluents would be approximately [INSERT VALUE] times that of the reference 1000-MW(e) LWR model. The principal effluents are SO_x, NO_x, and particulates. Based on data in the *Seventh Annual Report of the Council on Environmental Quality Report* (CEQ 1976), these emissions constitute a SMALL additional atmospheric loading in comparison with these emissions from the stationary fuel combustion and transportation sectors in the United States, which is about [0.02] percent of the annual national releases for each of these species.

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 amount 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 by an appropriate Federal, State, regional, local, or affected Native American tribal regulatory agency.

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. The staff determined that the impact of these chemical effluents would be [IMPACT LEVEL].

Additional details relating to the environmental impacts from chemical effluents can be found in Section 6.2.2.9 of NUREG-1437.

E. 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 effluents in NUREG-1437 (NRC 1996) data, the staff has calculated the 100-year involuntary environmental dose commitment to the U.S. population from the LWR-supporting fuel cycle for one year of operation of the model 1000-MW(e) LWR. These calculations estimate that the overall whole body gaseous dose commitment to the U.S. population from the fuel cycle (excluding reactor releases and the dose commitment from radon-222 and technicium-99) would be approximately [4 person-sievert (400 person-rem)] per year of operation of the 1000-MW(e) LWR scaled model; this reference reactor year is scaled to reflect the total electric power rating for the site for a year (based on net capacity ratio). The additional whole body dose commitment to the U.S. population from radioactive liquid effluents due to all fuel cycle operations other than reactor operation would be approximately [2 person-sievert (200 person -rem)] per year of operation. Thus, the estimated 100-year environmental dose commitment to the U.S. population from radioactive gaseous and liquid releases due to [resulting from] these portions of the fuel cycle is approximately [6 person-sievert (600 person -rem)] (whole body) for the 1000-MW(e) LWR scaled model.

Currently, the radiological impacts associated with radon-222 releases and technetium-99 releases are not addressed in Table S–3. (NUREG-1437, Section 6.2.2.1, provides an analysis of the environmental impacts from these two radionuclides as they pertain to the uranium fuel cycle, including a detailed discussion of predicted health effects and the technical basis for the health effects.)

In Section 6.2 of NUREG-1437, the staff estimated the radon-222 releases from mining and milling operation, and from mill tailings for each year of operations of the reference 1000-MW(e) LWR. The estimated releases of radon-222 for the reference reactor year for the 1000-MW(e) LWR scaled model, or for the total electric power rating for the site for a year, is approximately [1.9×10^{14} Bq (5200 Ci)]. Of this total, about 78 percent would be from mining, 15 percent from milling operations, 7 percent from inactive tails prior to stabilization. For radon releases from stabilized tailings, the staff assumed that the scaled model would result in an emission of [3.8×10^{10} Bq (1 Ci)] per site year (i.e., [INSERT VALUE] times the NUREG-1437 estimate for the reference reactor year). The major risks from radon-222 are from exposure to the bone and the lung, although there is a small risk from exposure to the whole body. The organ-specific dose weighting factors from 10 CFR Part 20 were applied to the bone and lung doses to estimate the 100-year dose commitment from radon-222 to the whole body. The estimated population dose commitment from mining, milling, and tailings before stabilization for each year of operation for the 1000 MW(e) LWR scaled model (assuming the 1000 MW(e) LWR scaled model) would be approximately [9.2 person-Sv (920 person-rem)] to the whole body. From stabilized tailings piles, the estimated 100-year environmental dose commitment would be approximately [0.18 person-Sv (18 person-rem)] to the whole body. Additional insights regarding national policy/resource perspectives regarding institutional controls comparisons with routine radon-222 exposure and risk, and long-term releases from stabilized tailings piles are discussed in NUREG-1437.

Also in NUREG-1437, the staff considered the potential health effects associated with the releases of technetium-99. The estimated releases of technetium-99 for the reference reactor year for the 1000 MW(e) LWR scaled model, or the total electric power rating for the site for a year is [2.8×10^{8} Bq (0.007 Ci)] from chemical processing of recycled UF_6 before it enters the isotope enrichment cascade and [1.9×10^{8} Bq (0.005 Ci]) into the groundwater from a candidate repository. The major risks from technetium-99 are from exposure of the gastrointestinal tract and kidney, although there is a small risk from exposure to the whole body. Applying the organ-specific dose weighting factors from 10 CFR Part 20 to the gastrointestinal tract and kidney doses, the total-body 100-year dose commitment from technetium-99 was estimated to be [1person-Sv (100 person-rem)] for the 1000-MW(e) LWR scaled model.

Although radiation may cause cancers at high doses and high dose rates, currently there are no data that unequivocally establish the occurrence of cancer following exposure to low doses and dose rates, below about 100 mSv (10,000 mrem). However, radiation protection experts conservatively assume that any amount of radiation may pose some risk of causing cancer or a severe hereditary effect and that the risk is higher for higher radiation exposures. Therefore, a linear, no-threshold dose response model is used to describe the relationship between radiation dose and detriments such as cancer induction. A recent report by the National Research Council (2006), the BEIR VII report, supports the linear, no-threshold dose response model. Simply stated, any increase in dose, no matter how small, results in an incremental increase in health risk. This theory is accepted by the NRC as a conservative model for estimating health risks from radiation exposure, recognizing that the model probably overestimates those risks.

Based on this model, the staff estimated the risk to the public from radiation exposure using the nominal probability coefficient for total detriment (730 fatal cancers, nonfatal cancers, and severe hereditary effects per 10,000 person-Sv (1,000,000 person-rem)) from International Commission on Radiation Protection (ICRP) Publication 60 (ICRP 1991). This coefficient was multiplied by the sum of the estimated whole body population doses discussed above, approximately [16 person-Sv/yr (1640 person-rem/yr),] to calculate that the U.S. population would incur a total of approximately [1.2] fatal cancers, nonfatal cancers, and severe hereditary effects annually. This risk is quite small compared to the number of fatal cancers, nonfatal cancers, and severe hereditary effects that would be estimated to the U.S. population annually from exposure to natural sources of radiation using the same risk estimation method.

Radon releases from tailings are indistinguishable from background radiation levels at a few kilometers from the tailings pile (at less than 1 km in some cases) (NRC Docket 50-488 1986). The public dose limit specified by U.S. Environmental Protection Agency's (EPA) regulation in 40 CFR Part 190, is 0.25 mSv/yr (25 mrem/yr) to the whole body from the entire fuel cycle, but most NRC licensees have airborne effluents resulting in doses of less than 0.01 mSv/yr (1 mrem/yr) (61 FR 65120).

In addition, at the request of the U.S. Congress, the National Cancer Institute (NCI) conducted a study and published *Cancer in Populations Living Near Nuclear Facilities* in 1990 (NCI 1990). This report included an evaluation of health statistics around all nuclear power plants, as well as several other nuclear fuel cycle facilities, in operation in the U.S. in 1981 and found "no evidence that an excess occurrence of cancer has resulted from living near nuclear facilities" (NCI 1990). The contribution to the annual average dose received by an individual from the fuel cycle-related radiation and other sources as reported in National Council on Radiation Protection and Measurements (NCRP) Report 93 (NCRP 1987) is shown in Table 5.7-A-2. The nuclear fuel cycle contribution to an individual's annual average radiation dose is extremely small (less than 0.01 mSv (1 mrem) per year).

Based on the analyses presented above, the staff concludes that the environmental impacts of radioactive effluents from the fuel cycle are [IMPACT LEVEL].

F. Radioactive Wastes

The quantities of buried radioactive waste material (low-level, highlevel, 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. For high-level and transuranic wastes, the Commission notes that these are to be buried at a repository and that no release to the environment is expected to be associated with such disposal because the gaseous and volatile radionuclides contained in the spent fuel would have been released and monitored before the disposal. NUREG-0116 (NRC 1976), 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 environment.

On February 15, 2002, subsequent to receipt of a recommendation by the Secretary of Energy, the President recommended the Yucca Mountain site for the development of a repository for the geologic disposal of spent nuclear fuel and high-level nuclear waste (White House Press Release 2002).

The EPA developed Yucca Mountain-specific repository standards, which were subsequently adopted by the NRC in 10 CFR Part 63. In an opinion, issued July 9, 2004, the U.S. Court of Appeals for the District of Columbia Circuit (the Court) vacated EPA's radiation protection standards for the candidate repository, which required compliance with certain dose limits over a 10,000 year period (U.S. Courts of Appeals 2004). The Court's decision also vacated the compliance period in NRC's licensing criteria for the candidate repository in 10 CFR Part 63. In response to the Court's decision, EPA issued proposed revised standards on August 22, 2005, that would revise the radiation protection standards for the candidate repository (70 FR 49014). As required by the Nuclear Waste Policy Act of 1982 (42 USC 10101 et seq.) in order to be consistent with EPA's revised standards, NRC proposed revisions to 10 CFR Part 63 on September 8, 2005 (70 FR 53313). The proposed standards are 0.15 mSv (15 mrem) per year for 10,000 years following disposal and 3.5 mSv (350 mrem) per year, after 10,000 years through 1 million years after disposal. [Note: Update after the NRC's Part 63 rulemaking is completed.]

Therefore, for the high-level waste and spent-fuel disposal component of the fuel cycle, there is some uncertainty with respect to regulatory limits for offsite releases of radioactive nuclides for the current candidate repository site. However, before promulgation of the affected provisions of the Commission's regulations, the staff assumed that limits would be developed along the lines of the 1995 National Academy of Sciences report, *Technical Bases for Yucca Mountain Standards*, and that in accordance with the Commission's Waste Confidence Decision, 10 CFR 51.23, a repository can and likely will be developed at some site that will comply with such limits, with peak doses to virtually all individuals of 100 mrem (1 mSv) per year or less (NAS 1995; NRC 1996).

Despite the current uncertainty with respect to these rules, some judgment as to the National Environmental Policy Act of 1969 (NEPA) implications of offsite radiological impacts of spent fuel and high-level waste disposal should be made. The staff concludes that these impacts are acceptable because the impacts would not be sufficiently great to require the NEPA conclusion that the construction and operation of new units at the [PROPOSED] site should be denied. For the reasons stated above, the staff concludes that the environmental impacts of radioactive waste disposal are [IMPACT LEVEL].

G. Occupational Dose

In the review and evaluation of the environmental impacts of the fuel cycle, the staff considered a total net electrical output of [LEVEL] MW(e) for the [ESP/COL] site. This case is referred to as the 1000-MW(e) LWR scaled model. The annual occupational dose attributable to all phases of the fuel cycle for the 1000-MWe LWR scaled model is about [6 person-sievert (600 person-rem)][remember to scale numbers in this section based on net capacity ratio]. This is based on the 6 person-Sv (600 person-rem) occupational dose estimate attributed to all phases of the fuel cycle for the model 1000 MW(e) LWR (NRC 1996). Occupational doses would be maintained to meet the dose limit of 0.05 Sv/yr (5 rem/hr) in 10 CFR Part 20. On this basis, the staff concludes that this occupational dose would be [IMPACT LEVEL].

H. Transportation

The transportation dose to workers and the public totals about 0.025 person-Sv (2.5 person-rem) annually for the reference 1000-MW(e) LWR per Table S–3. This corresponds to dose of [INSERT VALUE person-Sv (INSERT VALUE person-rem)] for the 1000-MW(e) LWR scaled model. For comparative purposes, the estimated collective dose from natural background radiation to the population within 80 km (50 mi) of the [ESP/COL] site is [INSERT VALUE person-Sv/yr (INSERT VALUE person-rem/yr) (reference)]. On this basis, the staff concludes that environmental impacts of transportation would be [IMPACT LEVEL].

I. Fuel Cycle

The staff evaluated the environmental impacts of the uranium fuel cycle as given in Table S–3 (see Table 6-1); considered the effects of radon-222 and technetium-99; and appropriately scaled for the 1000-MW(e) LWR scaled model. On the basis of this comparison, the staff concludes that the impacts would be [IMPACT LEVEL, and mitigation is/is not warranted.]

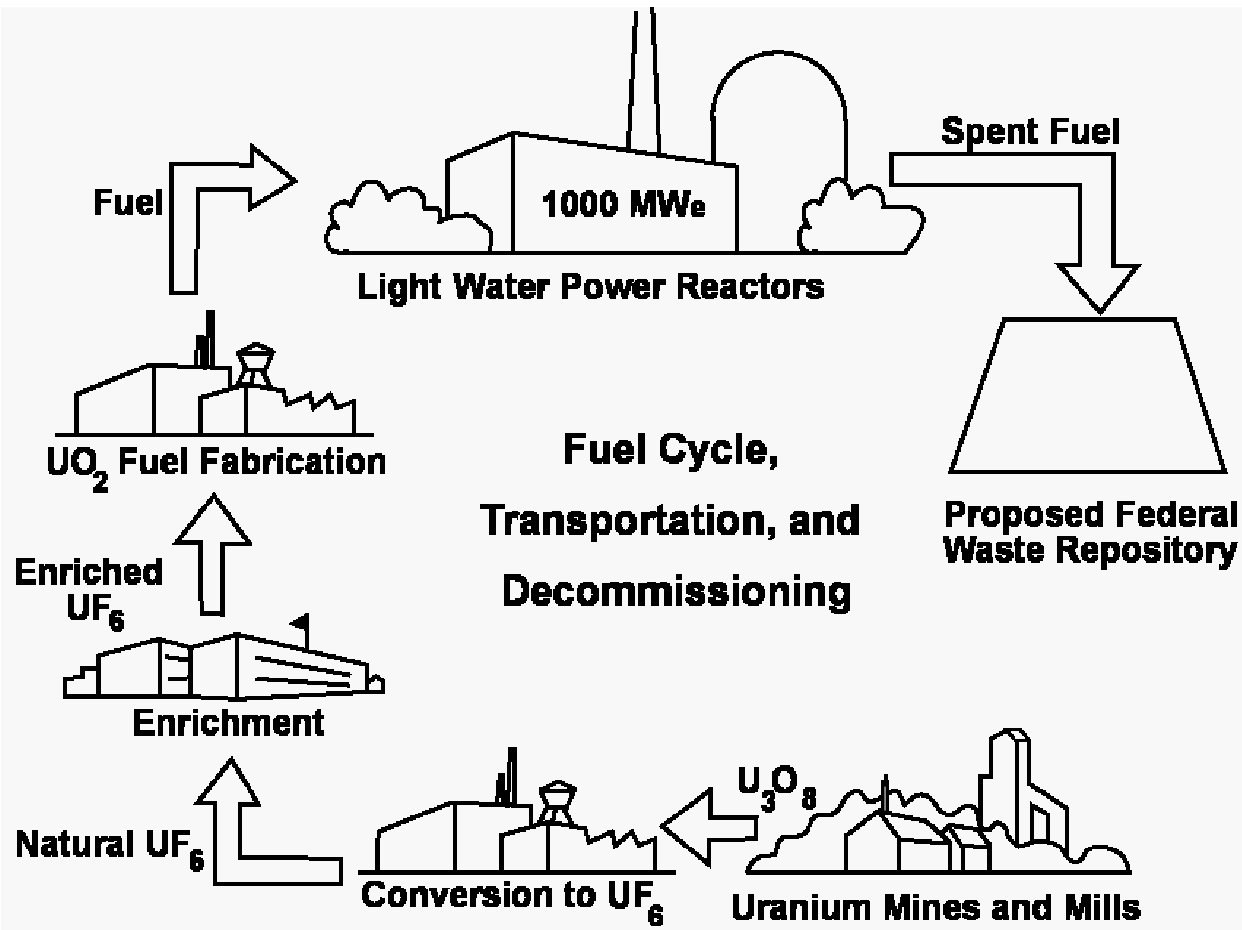

Figure 5.7-A-1. The Uranium Fuel Cycle: No-Recycle Option

Table 5.7-A-1. Summary of Environmental Considerations for Uranium Fuel Cycle[(a)]
(Normalized to Model LWR Annual Fuel Requirement
[WASH-1248] or Reference Reactor Year [NUREG-0116])

Environmental Considerations	Total	Maximum effect per annual fuel total requirement or reference reactor year of model 1000 MWe LWR
NATURAL RESOURCE USE		
Land (acres):		
Temporarily committed[(b)]	100	
Undisturbed area	79	
Disturbed area	22	Equivalent to 110 MWe coal-fired power plant
Permanently committed	13	
Overburden moved (millions of MT)	2.8	Equivalent to 95 MWe coal-fired power plant
Water (millions of gallons):		
Discharged to air	160	= 2 percent of model 1000 MWe LWR with cooling tower.
Discharged to water bodies	11,090	
Discharged to ground	127	
Total	11,377	< 4 percent of model 1000 MWe LWR with once-through cooling
Fossil fuel:		
Electrical energy (thousands of MW-hour)	323	< 5 percent of model 1000 MWe LWR output
Equivalent coal (thousands of MT)	118	Equivalent to the consumption of a 45-MWe coal-fired power plant
Natural gas (millions of scf)	135	< 0.4 percent of model 1000 MWe energy output
EFFLUENTS - CHEMICAL (MT):		
Gases (including entrainment):[(c)]		
SO_x	4,400	
NO_x[(d)]	1,190	Equivalent to emissions from 45-MWe coal-fired plant for a year
Hydrocarbons	14	
CO	29.6	

Table 5.7-A-1. (contd)

Environmental Considerations	Total	Maximum effect per annual fuel total requirement or reference reactor year of model 1000 MWe LWR
Particulates	1,154	
Other gases:		Principally from UF_6 production, enrichment, and reprocessing. Concentration within range of State standards—below level that has effects on human health
F	0.67	
HCl	0.014	
Liquids:		From enrichment, fuel fabrication, and reprocessing steps. Components that constitute a potential for adverse environmental effect are present in dilute concentrations and receive additional dilution by receiving bodies of water to levels below permissible standards. The constituents that require dilution and the flow of dilution water are: NH_3—600 cfs., NO_3—20 cfs., Fluoride—70 cfs.
$SO_4^{=}$	9.9	
NO_3^-	25.8	
Fluoride	12.9	
Ca^{++}	5.4	
Cl^-	8.5	
Na^+	12.1	
NH_3	10.0	
Fe	0.4	
Tailings solutions (thousands of MT)	240	From mills only—no significant effluents to environment
Solids	91,000	Principally from mills—no significant effluents to environment
EFFLUENTS—RADIOLOGICAL (CURIES):		
Gases (including entrainment):		
Rn-222	.....	Presently under reconsideration by the Commission
Ra-226	0.02	
Th-230	0.02	
Uranium	0.034	
Tritium (thousands)	18.1	
C-14	24	
Kr-85 (thousands)	400	Principally from fuel-reprocessing plants
Ru-106	0.14	
I-129	1.3	
I-131	0.83	
Tc-99	....	Presently under consideration by the Commission

Table 5.7-A-1. (contd)

Environmental Considerations	Total	Maximum effect per annual fuel total requirement or reference reactor year of model 1000 MWe LWR
Fission products and transuranics	0.203	
Liquids:		
Uranium and daughters	2.1	Principally from milling—included in tailings liquor and returned to ground—no effluents; therefore, no effect on environment
Ra-226	0.0034	From UF_6 production
Th-230	0.0015	
Th-234	0.01	From fuel fabrication plants — concentration 10 percent of 10 CFR 20 for total processing 26 annual fuel requirements for model LWR
Fission and activation products	5.9×10^{-6}	
Solids (buried onsite):		
Other than high level (shallow)	11,300	9100 Ci comes from lowlevel reactor wastes and 1500 Ci comes from reactor decontamination and decommissioning—buried at land burial facilities. 600 Ci comes from mills—included in tailings returned to ground. Approximately 60 Ci comes from conversion and spent-fuel storage. No significant effluent to the environment.
TRU and HLW (deep)	1.1×10^{7}	Buried at Federal Repository
Effluents—thermal (billions of British thermal units)	4063	< 5 percent of model 1,000 MWe LWR
Transportation (person-rem):		
Exposure of workers and general public	2.5	
Occupational exposure (person-rem)	22.6	From reprocessing and waste management

Table 5.7-A-1. (contd)

Environmental Considerations	Total	Maximum effect per annual fuel total requirement or reference reactor year of model 1000 MWe LWR

Notes:

(a) In some cases where no entry appears, it is clear from the background documents that the matter was addressed and that, in effect, the Table should be read as if a specific zero entry had been made. However, there are other areas that are not addressed at all in the Table. Table S–3 does not include health effects from the effluents described in the Table, or estimates of releases of radon-222 from the uranium fuel cycle or estimates of technetium-99 released from waste-management or reprocessing activities. These issues may be the subject of litigation in the individual licensing procedures.
Data supporting this table are given in the "Environmental Survey of the Uranium Fuel Cycle," WASH-1248, April 1974; the "Environmental Survey of the Reprocessing and Waste Management Portion of the LWR Fuel Cycle," NUREG-0116 (Supp. 1 to WASH-1248); the " Public Comments and Task Force Responses Regarding the Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle," NUREG-0216 (Supp. 2 to WASH-1248); and in the record of the final rulemaking pertaining to Uranium Fuel Cycle Impacts from Spent Fuel Reprocessing and Radioactive Waste Management, Docket RM-50-3 (NRC 1996). The contributions from reprocessing, waste management, and transportation of wastes are maximized for either of the two fuel cycles (uranium only and no recycle). The contribution from transportation excludes transportation of cold fuel to a reactor and of irradiated fuel and radioactive wastes from a reactor, which are considered in Table S–4 of 51.20(g). The contributions from the other steps of the fuel cycle are given in columns A-E of Table S–3A of WASH-1248.

(b) The contributions to temporarily committed land from reprocessing are not prorated over 30 years since the complete temporary impact accrues regardless of whether the plant services one reactor for one year or 57 reactors for 30 years.

(c) Estimated effluents based upon combustion of equivalent coal for power generation.

(d) 1.2 percent from natural gas use and process.

Table 5.7-A-2. Comparison of Annual Average Dose Received by an Individual from All Sources

Source	Dose (mSv/yr)[(a)]	Percent of Total
Natural		
Radon	2	55
Cosmic	0.27	8
Terrestrial	0.28	8
Internal (body)	0.39	11
Total natural sources	3	82
Artificial		
Medical x-ray	0.39	11
Nuclear medicine	0.14	4
Consumer products	0.10	3
Total artificial sources	0.63	18
Other		
Occupational	0.009	<0.30
Nuclear fuel cycle	<0.01	<0.03
Fallout	<0.01	<0.03
Miscellaneous sources	<0.01	<0.03

(a) To convert mSv/yr to mrem/yr, multiply by 100.
Source: NCRP Report 93, Ionizing Radiation Exposure of the Population in the United States (NCRP 1987)