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Dominion®

May 17, 2004

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Serial No. 04-170
ESP/JDH
Docket No. 52-008

DOMINION NUCLEAR NORTH ANNA, LLC
NORTH ANNA EARLY SITE PERMIT APPLICATION
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION
REGARDING ENVIRONMENTAL PORTION OF ESP APPLICATION

In its March 12, 2004 letter titled "Request for Additional Information (RAI) Regarding the Environmental Portion of the Early Site Permit (ESP) Application for the North Anna Site (TAC No. MC1128)," the NRC requested additional information regarding certain aspects of Dominion Nuclear North Anna, LLC's (Dominion) Early Site Permit application. This letter contains our response to the following requests for additional information:

E3.1-1, E3.1-2, E3.5-1, E3.6.1-1, E3.8-1, E3.8-2, E3.8-3, E3.8-4, E3.8-5, E3.8-6, E3.8-7, E3.8-8, E3.8-9, E3.8-10, E3.8-11, E3.8-13, E3.8-14, E3.8-15, E3.8-16, E3.8-17, E3.8-18, E3.8-19, E4.2.2-1, E4.2.2-2, E4.2.2-3, E4.2.2-4, E4.2.2-5, E4.4.2-1, E4.5-1, E4.5-2, E4.5-3, E4.5-4, E4.5-5, E4.5-6, E4.5-7, E5.4.2-1, E5.4.2-3, E5.4.4-1, E5.7-1, E5.7-2, E7.1-2, E7.1-3, E7.2-2, E7.2-3, E7.2-4, E7.2-5

Responses to the following requests for additional information contained in the NRC's March 12, 2004 letter will be submitted at a later date:

E3.8-12, E5.4.2-2, E5.4.3-1, E7.1-1, E7.2-1

It is our intent to revise the North Anna ESP application to reflect our responses to these and other RAIs to support issuance of the NRC staff's draft safety and environmental evaluations scheduled for later this year. Planned changes to the application are identified following the response to each RAI.

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If you have any questions or require additional information, please contact Mr. Tony Banks at 804-273-2170.

Very truly yours,

Eugene S. Grecheck
Vice President-Nuclear Support Services

Enclosures:

1. Response to March 12, 2004 Environmental RAIs
2. CD containing response to RAIs E4.2.2-4 and E7.2-4(h)
3. Topological maps in response to RAI E4.2.2-3

Commitments made in this letter:

1. Revise North Anna ESP application to reflect RAI responses.
2. Submit responses to remaining requests for additional information contained in March 12, 2004 NRC letter.

cc: (with Enclosure 1)

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COMMONWEALTH OF VIRGINIA

COUNTY OF HENRICO

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Eugene S. Grecheck, who is Vice President, Nuclear Support Services, of Dominion Nuclear North Anna, LLC. He has affirmed before me that he is duly authorized to execute and file the foregoing document on behalf of Dominion Nuclear North Anna, LLC, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 17TH day of May, 2004.

My Commission expires: May 31, 2006

Vicki L. Hull
Notary Public

(SEAL)

Enclosure 1

Responses to March 12, 2004 NRC Request for Additional Information Regarding Environmental Portion of North Anna ESP Application

RAI E3.1-1

Table 3.1-1 - Section 9.1 of the table, "Atmospheric Dispersion," lists bounding χ/Q values for various time periods for the exclusion area boundary and low population zone. These bounding χ/Q values are referenced to the Advanced Pressurized Water Reactor (AP-1000), Advanced Boiling Water Reactor/ Economic Simplified Boiling Water Reactor (ABWR/ESBWR), and Advanced CANDU Reactor (ACR-700) reactor design criteria. The bounding χ/Q values for the AP-1000 and the ABWR in Table 3.1-1 do not appear to match the χ/Q values provided in Table 7.1-1, "Design Certification χ/Q Values" for the AP-1000 and the ABWR. Please explain any differences. In addition, provide the basis and reference for ESBWR and ACR-700 bounding χ/Q values provided for the 0 to 8 and 8 to 24 hour periods in the table.

Response

Table 1 lists the χ/Q values from ER Tables 3.1-1 and 7.1-1.

Table 1. ER χ/Q Values

	ER Table 3.1-1		ER Table 7.1-1	
	χ/Q (sec/m^3)	Limiting Design	AP1000 χ/Q (sec/m^3)	ABWR χ/Q (sec/m^3)
0-2 hr @ EAB	0.61 E-03	AP1000	6.00 E-04	1.37 E-03
0-8 hr @ LPZ	1.30 E-04	ACR-700	1.35 E-04	1.56 E-04
8-24 hr @ LPZ	1.0 E-04	AP1000/ACR-700	1.00 E-04	9.61 E-05
1-4 day @ LPZ	4.18 E-05	ABWR/ESBWR	5.40 E-05	3.36 E-05
4-30 day @ LPZ	9.24 E-06	ABWR/ESBWR	2.20 E-05	7.42 E-06

The χ/Q values in Table 7.1-1 come from the design certification documentation for the referenced design. The χ/Q values in Table 3.1-1 come from Plant Parameter Envelope (PPE) data provided by the reactor vendors.

The PPE tables were developed by requesting a selected set of plant data from each of the reactor vendors. The data was expected to encompass the plant data or be typical of the required data needed for the plant. The information was provided in a written form by the vendors and then compiled to determine the limiting values for each parameter. It is from this data submission that all χ/Q data was derived.

For the data in Table 3.1-1, the 1-4 day and 4-30 day χ/Q limiting values are incorrect. The values listed in the PPE tables are for the ESBWR and have been identified as less conservative than those for the ABWR. The ABWR values listed above for 1-4 day and

4-30 day χ/Q (from Table 7.1-1) are correct and are the limiting values. These items will be corrected in the application.

As part of the PPE data submission, Westinghouse identified the 0-2hr χ/Q at EAB for the AP1000 as 0.61E-3 sec/m^3. This value differs slightly from the design certification χ/Q value of 0.60 E-3 sec/m^3. Discussions with Westinghouse indicate that this difference is insignificant, as neither χ/Q, when combined with the AP1000 gaseous release fractions, exceeds the regulatory maximum dose limits to the public, and therefore need not be revised.

Application Revision

Table 1.3-1 of the SSAR and Table 3.1-1 of the ER, which contain the PPE tables, will be revised. Specifically, Section 9.1.4 will be revised to reflect a bounding value of 3.36 E-5 sec/m^3 for the 1-4 day χ/Q value, and Section 9.1.5 will be revised to reflect a bounding value of 7.42 E-6 sec/m^3 for the 4-30 day χ/Q value.

RAI E3.1-2

Table 3.1-1 - Sections 9.3.3 and 9.4.4 reference plant parameter envelope bounding values for both severe accidents and the minimum distance to the site boundary to the International Reactor Innovative and Secure (IRIS) and ESBWR design criteria (in addition to the AP-1000 and the ABWR design criteria). Provide the bases and references for the bounding values for the ESBWR and IRIS design criteria provided.

Response

The PPE tables were developed by requesting a selected set of plant data from each of the reactor vendors. The data was expected to encompass the plant data or be typical of the required data needed for the plant. Written input was provided by the vendors and then compiled to determine the limiting values for each parameter.

The IRIS PPE data was provided by Westinghouse in Reference 1. For Section 9.3.3, the IRIS data is based on the AP-600 design envelope. The IRIS design, which incorporates the entire RCS within a single pressure vessel, is intended by design to eliminate most severe accidents. However, the state of design maturity for the IRIS is such that specific calculational data is not available. For this reason, the AP-600 value was assumed as a bounding value. For Section 9.4.4, a site boundary distance of 0.5 miles was assumed for the IRIS design.

The ESBWR PPE data was provided by General Electric in Reference 2. The values provided for the ESBWR for Sections 9.3.3 and 9.4.4 are identical to those for the ABWR and are thus bounded by the ABWR design.

References:

1. STD-ES-03-10, "IRIS (International Reactor, Innovative and Secure) Plant Parameter Envelope (PPE) for Early Site Permit Applications," Westinghouse, Rev. 0, March 2003 (Westinghouse Proprietary).
2. NEDO-33103, "GE Nuclear Energy ABWR and ESBWR Plant Parameters Envelope," General Electric, Rev. C, April 2003.

Application Revision

None.

RAI E3.5-1

<u>**Section 3.5 of ER (Radioactive Waste Management)**</u> - The ER states that light water reactor (LWR) gaseous and liquid effluents bounded effluent releases from gas-cooled reactor designs. Provide references to support this statement. Has the impact of the multiple modules (reactors) for the gas-cooled reactor designs been considered in this determination?

Response

The PPE tables were developed by requesting a selected set of plant data from each of the reactor vendors. The data was expected to encompass the plant data or be typical of the required data needed for the plant. The information was provided in a written form by the vendors and then compiled to determine the limiting values for each parameter.

The data compiled for the proposed reactor designs were based on a reactor configuration that equaled approximately 4300 MWth per identified unit. For the gas reactors in particular, four GT-MHR modules and eight PBMR modules were combined to meet the 4300 MWth criteria. This process is further described in Section 3.1.2.2. The total for each PPE parameter for all of the units needed to meet this total thermal megawatt value was used to determine the bounding design for each PPE parameter for that reactor type.

During the process to compile the liquid and gaseous waste limiting parameters, it was clear that the radioactive release estimates for the gas reactors were not as developed as for the light water reactors. General Atomics and PBMR, Pty. Ltd. did provide radioactive release data in their PPE submittals. This release data for an equivalent size unit (about 4300 MWth) was in all cases the same or lower than other reactor designs. Where it was the same, the basis was not a design feature, but a maximum regulatory limit that would not be exceeded by the design and was not bounding.

Application Revision

None.

RAI E3.6.1-1

Section 3.6.1 of ER (Effluents Containing Chemicals or Biocides) - Provide projected average and maximum concentrations for chemicals that would be expected in the plant effluents and the average and maximum levels of these substances in the receiving waters.

Response

The existing plant's effluent discharges are permitted in accordance with EPA's Steam Electric Power Generating Effluent Guidelines, the Clean Water Act, Virginia's Water Quality Standards, State Water Control Law, and Virginia's VPDES regulation. The Virginia Department of Environmental Quality (VDEQ) enforces effluent limitations through the VPDES permit. Generally the limitations are based on the degree of effluent reduction attainable. Any additional chemicals or biocides in effluents from new unit operation would also have to meet the criteria specified by the applicable rules and guidelines.

Intake samples collected in the past have shown background levels of certain constituents in Lake Anna and are compared to the existing units' effluent in Table 1.

Table 1. Comparison of Intake and Effluent Samples

	Intake Water (Background) ppm	Existing Units' Effluent (Outfall 001) ppm
Iron	0.14	0.27
Ammonia	0.04	0.06
Sulfates	7.45	5.53
Phenols	0.06	Not Detectable
Copper	0.003	0.004
Lead	0.002	0.001
Bromide	0.29	0.28
Fluoride	0.052	0.039
Aluminum	0.094	0.252
Barium	0.027	0.039
Magnesium	1.79	1.70
Manganese	0.22	0.162
Nitrate	0.13	0.15
Phosphorus	0.02	0.02

Increases in these parameters from any new unit operation would be negligible because chemicals are used sparingly and releases to the environment are managed carefully and are tightly controlled.

New unit operation would be expected to use products (and applications) similar to those currently in use. Examples may include a liquid oxidant system utilizing a 40% sodium bromide and sodium hypochlorite (15% active). The feed rates would be on the order of 3.5 gallons and 11.3 gallons, respectively, during 30-minute periods up to four times a day for no more than 2 hours per day.

A small residual of chlorine must be maintained in the bearing cooling tower to control biological growth. A continuous or near continuous feed of chlorine is necessary and is maintained at a level below the discharge limit of 0.2 mg/l monthly average. The discharge of chlorinated blowdown has a negligible impact on the environment. The estimated flowrate for the blowdown is 150 gpm to 200 gpm. Engineering calculations have demonstrated that the 126 priority pollutants are not detectable in the receiving waters as a result of the bearing cooling system blowdown. The VPDES permit allows the discharge of reverse osmosis reject water directly to the lake with a total chlorine residual of up to 4.0 mg/l. Another microbiocide that could be utilized may be an amine salt of endothall. This would be added to the unit 3 to 4 times a year at the rate of 100-150 pounds per treatment to produce a concentration of 1.5 ppm to 3.0 ppm. Blowdown for this treatment is held for at least 72 hours to provide time for natural decomposition.

Hydrazine (hydrazine hydrate) could be used as an oxygen scavenger in boiler water to reduce oxidation in both low- and high-pressure steam systems. It rapidly degrades in air, water and soil. VDEQ has not established Water Quality Standards for hydrazine. Typical usage of this product in the steam generator secondary system or the auxiliary heating boiler would result in maximum concentration below 1.0 ppm. This discharge would be routed internally into the circulating water tunnel and mixed with lake water prior to the discharge canal and cooling lagoons.

Application Revision

None.

RAI E3.8-1

Radionuclide content of advanced design irradiated fuel. Provide each irradiated fuel type with a detailed listing of all radionuclides and their inventories (e.g., Curies per metric ton uranium (Ci/MTU) or other suitable unit that can be used to calculate the inventories of each radionuclide in advanced reactor irradiated fuel shipments). Explain the technical basis for the data (how the information was obtained) and the accuracy of the data.

Response

ABWR, AP1000, IRIS, ESBWR, ACR-700

As discussed in Section 3.8.1, these LWR designs satisfy the 10 CFR 51.52(a) conditions for use of Table S-4 or have impacts shown by sensitivity analysis to be bounded by Table S-4. The environmental impacts of transportation of fuel and radioactive wastes are represented by the values given in 10 CFR 51.52(c), Table 4. For this reason, no further detail on the fuel characteristics for these LWRs is provided.

GT-MHR

Information on the GT-MHR is provided in Reference 1. The General Atomics (GA) methodology for computing the GT-MHR radionuclide inventories and resulting decay heat was the same as that used for the 350 MWt MHTGR submitted to the NRC in Reference 2, the MHTGR Preliminary Safety Information Document. This methodology uses a point-depletion model with 1100 nuclides including 123 heavy metal isotopes, 112 structural or impurity isotopes, and 862 fission product nuclides using cross section data from ENDF/B-V files. The model provides up to four decay and four capture parents for each nuclide, plus two (n,2n) parents, with fractional yields possible for all.

The GT-MHR model includes burnout effects for all fission products. GA expects a standard deviation of approximately 4% in the decay heat calculation consistent with the ENDF/B-IV data uncertainties in ANSI/ANS-5.1-1979.

The NRC and Oak Ridge National Laboratory reviewed the GA methodology as part of the PSID pre-application licensing activities. The review concluded that the calculated decay-heat rates were acceptable for use in conceptual design and analysis (Reference 3).

PBMR

The methodology used to generate the PBMR values is described in Reference 4 as follows.

The fission product and actinide activities have been calculated for different fuel spheres and different burn-up values. Using ORIGEN-S with the 302 MW 6 pass ORIGEN-S library, the activities were calculated for the following parameters:

Table 1. PBMR Parameters

Parameter	Case 1	Case 2
Reactor Power (MW)	400	400
Burn-up (GWD/TU)	92	133
Reactor Fuel Spheres	451545	451545
Full Power Days	~935	~1351
Fuel Sphere U Mass (g)	9	9
Enrichment (%)	9.6	12.9
Reactor Flux <0.5 eV ($n.cm^{-2}.s^{-1}$)	6.82×10^{13}	6.35×10^{13}

Note that the ORIGEN-S cross section library was generated with the reactor spectrum calculated for the following conditions:

- Dynamic central column PBMR model.
- Equilibrium core based on 8.46% enriched fuel spheres and 80 WD/T(U) burn-up.

Therefore, this ORIGEN-S cross-section library is not directly applicable for the conditions in Cases 1 and 2, but was used for scoping purposes. The neutron flux was chosen such that the spent fuel burn-up was reached.

References:

1. PC-000507, GT-MHR Plant Parameter Envelope Supporting Early Site Permitting, General Atomics, April 2003. Contained in Idaho National Engineering & Environmental Laboratory Engineering Design File 3747, May 2003 (NRC Accession Number ML040580285).
2. Preliminary Safety Information Document for the Standard Modular High Temperature Gas-Cooled Reactor, DOE-HTGR-86-024, General Atomics, February 1992.

3. NUREG-1338, Draft Preapplication Safety Evaluation Report for the Modular High-Temperature Gas-Cooled Reactor, U.S. Nuclear Regulatory Commission, March 1989.
4. Calculational Record MF100-016344-2053, "Scoping Calculation: Spent Fuel Activities After 5 Years Decay," PBMR, 6/03/2003. Enclosure to April 13, 2004 Letter from Marilyn C. Kray, Exelon Nuclear, to Document Control Desk, U. S. Nuclear Regulatory Commission, "Submission of Requested Information" (NRC Accession Number ML041110024).

Application Revision

None.

RAI E3.8-2

Detailed information about the advanced fuel designs. Provide information to support a preliminary comparative evaluation of the abilities of the advanced fuel designs to withstand structural and thermal accident conditions relative to current design fuel assemblies. In particular, provide the following information on the advanced fuels:

a. Detailed drawings of the fuel elements
b. For the fuel
    i. Fuel material form/manufacturing processes
    ii. Fuel physical dimensions and mass
    iii. Fuel mechanical and thermal properties
c. For the cladding
    i. Material(s) used and form/manufacturing processes
    ii. Physical dimensions
    iii. Mechanical and thermal properties
d. Investigation/analysis of fission product transport within and out of the fuel matrix
e. Irradiation and temperature effects on the mechanical and thermal properties discussed above
f. Assumptions about packagings that would be used as inner containers (i.e., overpack) inside a conceptual shipping cask
g. Expected release fractions from the fuel during accident conditions - if this information is given as a comparison to LWR fuels release fractions, provide the basis for the comparison

Response

ABWR, AP1000, IRIS, ESBWR, ACR-700

As discussed in Section 3.8.1, these LWR designs satisfy the 10 CFR 51.52(a) conditions for use of Table S-4 or have impacts shown by sensitivity analysis to be bounded by Table S-4. The environmental impacts of transportation of fuel and radioactive wastes are represented by the values given in 10 CFR 51.52(c), Table 4. For this reason, no further detail on the fuel characteristics for these LWRs is provided.

GT-MHR

References 1 and 2 provide information on the GT-MHR. Spent fuel cask modeling assumptions are discussed in the response to RAI E3.8-3. Due to the high temperature capability of the GT-MHR fuel, General Atomics anticipates that the fission product release characteristics during credible transportation accidents would be less than LWR fuels. Additional information on the release characteristics during normal operation of the MHTGR can be found in the MHTGR PSID (Reference 2).

PBMR

Reference 3 provides information on the PBMR.

References:

1. PC-000507, GT-MHR Plant Parameter Envelope Supporting Early Site Permitting, General Atomics, April 2003. Contained in Idaho National Engineering & Environmental Laboratory Engineering Design File 3747, May 2003 (NRC Accession Number ML040580285).
2. Preliminary Safety Information Document for the Standard Modular High Temperature Gas-Cooled Reactor, DOE-HTGR-86-024, General Atomics, February 1992.
3. November 29, 2002 Letter from A.P. George and F. Curtolo, Pebble Bed Modular Reactor (Pty) Ltd., to Michael J. Cambria, Parsons Energy and Chemicals, "ESP-8: Reactor Vendor Questionnaire." Contained in Idaho National Engineering & Environmental Laboratory Engineering Design File 3747, May 2003 (NRC Accession Number ML040580285).

Application Revision

None.

RAI E3.8-3

Information about the designs of shipping casks for advanced reactor irradiated fuels. Provide capacities and dimensions of the shipping casks being modeled. It is assumed that the advanced LWR irradiated fuels would be shipped in casks similar to the current generation. For advanced non-LWR irradiated fuels, provide information about irradiated fuel handling, fuel behavior regarding failure and release fractions, and shipping cask concepts. Include all references and provide the basis for all assumptions made.

Response

ABWR, AP1000, IRIS, ESBWR, ACR-700

As discussed in Section 3.8.1, these LWR designs satisfy the 10 CFR 51.52(a) conditions for use of Table S-4 or have impacts shown by sensitivity analysis to be bounded by Table S-4. The environmental impacts of transportation of fuel and radioactive wastes are represented by the values given in 10 CFR 51.52(c), Table 4. For this reason, no further detail on the fuel characteristics for these LWRs is provided.

GT-MHR

The GT-MHR spent fuel was modeled as being shipped in a 42-element shipping cask by rail. A preliminary design of a multi-purpose canister (MPC) was initially performed for the Plutonium Consumption-Modular Helium Reactor (PC-MHR) in FY-95 for the DOE. Reference 1 is the MPC preliminary design report. The application of the MPC design to the GT-MHR spent fuel was evaluated for DOE in Reference 2.

PBMR

The PBMR was modeled based on shipping 24,000 fuel spheres per container with two 6-m long containers per truck. The total mass of one container with fuel is 15,900 kg. This information was provided in Reference 3.

References:

1. GA/DOE-082-95, letter report from D. A. Alberstein to Howard R. Canter, "PC-MHR Spent Fuel Disposal Multipurpose Canister Preliminary Design Report, October 1995.
2. PC-000502/0, Assessment of GT-MHR Spent Fuel Characteristics and Repository Performance, General Atomics, April 2002.
3. November 29, 2002 Letter from A.P. George and F. Curtolo, Pebble Bed Modular Reactor (Pty) Ltd., to Michael J. Cambria, Parsons Energy and Chemicals, "ESP-8: Reactor Vendor Questionnaire." Contained in Idaho National Engineering & Environmental Laboratory Engineering Design File 3747, May 2003 (NRC Accession Number ML040580285).

Application Revision

None.

RAI E3.8-4

Table 3.8-2 (p. 3-3-87) - This table provides data on fission product inventory, actinide inventory, and Krypton-85 inventory for gas-cooled reactors. What was the source for this information?

Response

The GT-MHR and PBMR information is from References 1 and 2, respectively.

References:

1. PC-000507, GT-MHR Plant Parameter Envelope Supporting Early Site Permitting, General Atomics, April 2003. Contained in Idaho National Engineering & Environmental Laboratory Engineering Design File 3747, May 2003 (NRC Accession Number ML040580285).
2. Calculational Record MF100-016344-2053, "Scoping Calculation: Spent Fuel Activities After 5 Years Decay," PBMR, 6/03/2003. Enclosure to April 13, 2004 Letter from Marilyn C. Kray, Exelon Nuclear, to Document Control Desk, U. S. Nuclear Regulatory Commission, "Submission of Requested Information" (NRC Accession Number ML041110024).

Application Revision

None.

RAI E3.8-5

p. 3-3-78 (Section 3.8.2.3, second paragraph) - What are the initial core loadings and annual fuel reloadings for the gas-cooled reactor designs (pebble bed modular reactor - PBMR and the gas turbine modular helium reactor - GT-MHR)?

Response

The initial core fuel loading for the GT-MHR is 5.650 MTU with an annual average fuel loading based on 40 years of operation of 1.711 MTU. The GT-MHR information is from Reference 1.

The initial core fuel loading for the PBMR is 20.0 MTU (2.5 MTU per reactor module). The annual average fuel loading is 6.32 MTU/1000 MWe. The PBMR information is from Reference 2.

References:

1. PC-000507, GT-MHR Plant Parameter Envelope Supporting Early Site Permitting, General Atomics, April 2003. Contained in Idaho National Engineering & Environmental Laboratory Engineering Design File 3747, May 2003 (NRC Accession Number ML040580285).
2. November 29, 2002 Letter from A.P. George and F. Curtolo, Pebble Bed Modular Reactor (Pty) Ltd., to Michael J. Cambria, Parsons Energy and Chemicals, "ESP-8: Reactor Vendor Questionnaire." Contained in Idaho National Engineering & Environmental Laboratory Engineering Design File 3747, May 2003 (NRC Accession Number ML040580285).

Application Revision

None.

RAI E3.8-6

p. 3-3-78 (Section 3.8.2.3, seventh paragraph) - The ER states that low-level radioactive waste shipments would be less for gas-cooled reactor technologies (i.e., 6-9 shipments annually compared to 46 shipments for the reference LWR). What is the basis (reference) for the smaller waste volumes for gas-cooled reactors? Provide the radionuclide inventory estimates and the basis for the low-level radioactive waste shipments.

Response

General Atomics estimated 98 m^3/yr of solid LLW (38 m^3/yr of general solid wastes and 60 m^3/yr of irradiated replaceable reflector blocks) for the GT-MHR. The GT-MHR information is from Reference 1.

The vendor estimate for the PBMR is 800 drums (100 drums per module) per year. The vendor also estimated that the main radionuclide contributors would be 0.064 Ci/yr of Ag-110m; 15.2 Ci/yr of Cs-134; 50 Ci/yr of Cs-137; and 0.16 Ci/yr of Sr-90. The PBMR information is from Reference 2.

As described in Section 3.8.2.3, to convert these volumes into shipments, it was assumed that 90 percent of the LLW can be shipped at 1000 ft^3 per truck and the remaining 10 percent can be shipped at 200 ft^3 per truck.

References:

1. PC-000507, GT-MHR Plant Parameter Envelope Supporting Early Site Permitting, General Atomics, April 2003. Contained in Idaho National Engineering & Environmental Laboratory Engineering Design File 3747, May 2003 (NRC Accession Number ML040580285).
2. November 29, 2002 Letter from A.P. George and F. Curtolo, Pebble Bed Modular Reactor (Pty) Ltd., to Michael J. Cambria, Parsons Energy and Chemicals, "ESP-8: Reactor Vendor Questionnaire." Contained in Idaho National Engineering & Environmental Laboratory Engineering Design File 3747, May 2003 (NRC Accession Number ML040580285).

Application Revision

None.

RAI E3.8-7

p. 3-3-79 (Section 3.8.2.3, first paragraph) - The ER provides an annual value of truck shipments for the reference LWR (110 shipments), the PBMR (18 shipments), and GT-MHR (41 shipments). When adding up the individual values for unirradiated fuel shipments, spent fuel shipments, and low level waste shipments within that same section, we obtained different totals – reference LWR (112 shipments); PBMR (22 shipments); and GT-MHR (58 shipments). Explain the differences.

Response

Table 1 provides an estimate of truck shipments based on the following assumptions:

- 40 years of operation
- 1 initial core load
- 39 annual core reloads
- 39 annual spent fuel shipments for the LWR; 35 annual spent fuel shipments for the gas-cooled reactors to achieve the much higher burnup
- 39 years of LLW generation

The estimate was normalized to an equivalent electrical generation (i.e., the GTMHR shipments were reduced by 12% and the PBMR shipments were reduced by 30%). The calculated numbers of shipments were then rounded to the next whole number.

Table 1

	Number of Assemblies		
	LWR	GT-MHR	PBMR
Initial core load	18	51	44
Annual reload	6	20	3
Annual spent fuel	60	38	16
LLW	46	6	9
40 year total	4386	2395	1072
Yearly average	110	60	27
Adjusted yearly average	110	53	19

These values for the gas-cooled reactors do not match the RAI numbers because the total number of unnormalized shipments are calculated first and then adjusted for the electrical generation. Doing it this way, there is no annual rounding up of the number of shipments. This is a more representative estimate because the plant operator would likely wait until a full shipment was available and not just ship because the year is drawing to a close.

Application Revision

The 8th paragraph of ER Section 3.8.2.3 will be revised to read as follows:

> The Table S-4 value, traffic density in trucks per day, for the reference LWR is given as less than one per day. Both the gas-cooled reactor technologies would also have less than one per day. In fact, the new gas-cooled reactor technologies would have far fewer shipments per year. The reference LWR bounding annual value for truck shipments is 110 based on a 40-year period, while the normalized number of truck shipments for the gas-cooled reactor technologies would require as few as 19 for the PBMR and only 53 for the GT-MHR.

RAI E3.8-8

<u>p. 3-3-80 (second paragraph)</u> - What is the reference for the decay heat estimates for gas-cooled reactor technologies (i.e., 6.36 kilowatts (kW)/MTU for GT-MHR and 3.91 kW/MTU for PBMR)?

Response

The decay heat estimates for the GT-MHR and PBMR are from References 1 and 2, respectively.

References:

1. PC-000507, GT-MHR Plant Parameter Envelope Supporting Early Site Permitting, General Atomics, April 2003. Contained in Idaho National Engineering & Environmental Laboratory Engineering Design File 3747, May 2003 (NRC Accession Number ML040580285).
2. November 29, 2002 Letter from A.P. George and F. Curtolo, Pebble Bed Modular Reactor (Pty) Ltd., to Michael J. Cambria, Parsons Energy and Chemicals, "ESP-8: Reactor Vendor Questionnaire." Contained in Idaho National Engineering & Environmental Laboratory Engineering Design File 3747, May 2003 (NRC Accession Number ML040580285).

Application Revision

None.

RAI E3.8-9

p. 3-3-81 (first paragraph) - For each gas cooled reactor technology proposed, demonstrate/quantify how the increased actinide activity in the fuel impacts neutron dose.

Response

The second paragraph of Section 3.8.2.5 discusses the increased actinide activity and corresponding requirement for increased neutron shielding. It also quotes NUREG/CR-6703 "because neutrons are effectively attenuated by low-density materials such as plastics and water, it is believed that minor modifications can be made to the shipping casks to allow them to transport the higher burnup fuel at full load."

The neutron dose is dependent not only on the source term (cask loading) but also the cask design itself. At this time, since the cask has not been designed, quantification is not possible. The casks would be certified by the NRC prior to use and would meet applicable regulations.

Application Revision

None.

RAI E3.8-10

p. 3-3-81 (last paragraph) - The ER states that the accident rate for large trucks has steadily declined for more than the past 25 years and is less than half the rate in 1975. Provide the basis (reference) for this statement.

Response

The statement was based on information from Reference 1, which shows the following:

	1975	2001
Large Truck Involvement Rate per 100 Million Vehicle Miles Traveled	4.89	2.31

Reference:

1. Table 3 of the National Center for Statistics and Analysis of the National Highway Traffic Safety Administration report, "Traffic Safety Facts 2001" (http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/TSFAnn/TSF2001.pdf).

Application Revision

None.

RAI E3.8-11

General question - For the light water reactor designs, what is the bounding value for 1) the number of truck shipments of irradiated fuel annually per unit, and 2) MTU of spent fuel per truck cask?

Response

The bounding value for the number of truck shipments of irradiated fuel annually is 33 for the ESBWR based on 1 MTU (7 assemblies) per truck cask.

Application Revision

None.

RAI E3.8-13

p. 3-3-75 (Section 3.8.1, top of page) - Provide justification for the statement that the Department of Energy (rather than licensees) would make the decision on transport mode.

Response

As part of its obligations under the Nuclear Waste Policy Act [Section 302(a)(1)] and per 10 CFR 961, DOE will take title to, transport, and dispose of spent nuclear fuel. Thus, DOE is responsible for determining the transport mode.

Application Revision

None.

RAI E3.8-14

p. 3-3-77 (Section 3.8.2.2, last paragraph) - The ER states that adjustments have been made on the basis of electrical output, but on p. 3-3-89, the note to Table 3.8-2 states that results were not adjusted. Describe all adjustments or normalizations that have been made (e.g., decay time, shipment, electrical generation, etc.).

Response

Table 3.8-2 was generated based on the standard configuration for each of the reactor technologies.

Section 3.8.2.2 describes the adjustment made to normalize the new designs to 880 MWe for comparison with the reference LWR.

The normalization to 880-MWe was the only adjustment made.

Application Revision

None.

RAI E3.8-15

<u>**p. 3-3-79 (Section 3.8.2.4, first paragraph)**</u> - The ER states that the reference LWR used a 90-day decay time, but on p. 3-3-87, 150 days is entered for decay time prior to shipment in the Reference LWR column of Table 3.8-2. What reference LWR decay time was used for the impact evaluation? In addition, what gas-cooled reactor radionuclide inventory was used for the impact evaluation?

Response

As was done in the WASH-1238, Table 3.8-2 uses 150 days for the reference LWR when calculating impacts. The 90-day decay time is the minimum decay time specified in 10 CFR 51.52.

The gas-cooled reactor radionuclide inventory is based on a five-year decay time.

Application Revision

None.

RAI E3.8-16

p. 3-3-79 (Section 3.8.2.4, first paragraph) - Justify the applicability of the depletion code used to calculate the isotopic content of spent fuel for the new reactor designs.

Explain the in-core differences between a commercial LWR and the new reactor designs and how these differences affect the performance of the depletion calculation. These differences may include: initial enrichment, fuel configuration, type of moderator, specific power, fuel temperature, moderator temperature, and the presence of soluble, burnable and integral poisons.

Response

ABWR, AP1000, IRIS, ESBWR, ACR-700

As discussed in Section 3.8.1, these LWR designs satisfy the 10 CFR 51.52(a) conditions for use of Table S-4 or have impacts shown by sensitivity analysis to be bounded by Table S-4. The environmental impacts of transportation of fuel and radioactive wastes are represented by the values given in 10 CFR 51.52(c), Table 4. For this reason, no further detail on the fuel characteristics for these LWRs is provided.

GT-MHR, PBMR

The depletion code methodologies for the GT-MHR and PBMR are explained in the response to RAI E3.8-1.

In-core differences between new reactor designs and various LWR designs have the same effects. These differences affect the neutron spectrum and resulting actinide production and fission rates between various fissile and fertile isotopes.

Application Revision

None.

RAI E3.8-17

p. 3-3-79 (Section 3.8.2.4, third paragraph) - The ER provides a comparison of reference LWR actinide and gas-cooled fuel inventories that states that the actinide inventory in Ci/MTU for the gas-cooled fuel exceeds that of the reference LWR, and that the pebble bed modular reactor (PBMR) would have essentially the same MTU per cask as the reference LWR. Provide the basis for the total actinide inventory per gas-cooled fuel truck cask. Does the increased actinide inventory call for additional cask shielding relative to that needed for reference LWR fuel? If so, does the added shielding affect cask payload and the number of shipments by truck, as shown in Table 3.8-2 on page 3-3-88?

Response

ABWR, AP1000, IRIS, ESBWR, ACR-700

As discussed in Section 3.8.1, these LWR designs satisfy the 10 CFR 51.52(a) conditions for use of Table S-4 or have impacts shown by sensitivity analysis to be bounded by Table S-4. The environmental impacts of transportation of fuel and radioactive wastes are represented by the values given in 10 CFR 51.52(c), Table 4. For this reason, no further detail on the fuel characteristics for these LWRs is provided.

GT-MHR, PBMR

The basis for the actinide inventory for both gas-cooled reactors is provided in the response to RAI E3.8-1.

As stated in Section 3.8.2.4, the MTU per cask for the GT-MHR is 0.16044 MTU. This is one third of the LWR shipment capacity of 0.5 MTU per cask. Based on this comparison, the actinide inventory per shipment is about half (53 percent) for the GT-MHR versus the reference LWR and there should be no need for additional cask shielding relative to the LWR.

The PBMR information is provided in Reference 1. The need for any additional shielding has not been determined at this time.

Reference:

1. November 29, 2002 Letter from A.P. George and F. Curtolo, Pebble Bed Modular Reactor (Pty) Ltd., to Michael J. Cambria, Parsons Energy and Chemicals, "ESP-8: Reactor Vendor Questionnaire." Contained in Idaho National Engineering & Environmental Laboratory Engineering Design File 3747, May 2003 (NRC Accession Number ML040580285).

Application Revision

None.

RAI E3.8-18

p. 3-3-81 (Section 3.8.2.5, second paragraph) - The ER quotes NUREG/CR-6703, *Environmental Effects of Extending Fuel Burnup Above 60 Gwd/MTU* [giga-watt days/MTU], (p. 3), regarding actinide dose contribution, however, the quoted text relates to pressurized water reactor (PWR) fuels burned in the presence of burnable poison rod assemblies. Describe the relevance of this information to the type of gas-cooled reactor spent fuel shipments contemplated in the ER.

Response

The information from NUREG/CR-6073 was intended to clarify that the issue that needs to be evaluated is the cask isotopic inventory and not how the fuel was used in the reactor. What is important for the transport is the identity of the nuclides and their quantity.

Application Revision

None.

RAI E3.8-19

p. 3-3-81 (Section 3.8.2.5, second paragraph) - Justify the representation that only minor modifications to the amount of neutron shielding on the transportation packages will allow them to be used for fuel with a significantly higher neutron source term.

Address the effect of additional neutron shielding on other design aspects of the package performance such as the ability to reject the thermal heat load, the method for attaching the shielding, and the size of the impact limiter which affects the package's performance during a drop accident. Address the effect of additional shielding on package diameter, impact limiter size, rail or truck bed width, package weight, cask capacity, and number of shipments needed.

Address how the neutron source term for gas-cooled reactor fuel will be distributed when the fuel is shipped, and how that distribution might affect the shielding design of the transportation cask.

Response

The justification for only minor modifications arises from statements made in NUREG/CR-6703, which are captured in Section 3.8.2.5 as follows:

> "From NUREG/CR-6703 'Environmental Effects of Extending Fuel Burnup Above 60 GWd/MTU,' we learn that 'none of the actinides contributes more than one percent of the external dose from an iron transportation cask, and as a group, the actinides do not contribute significantly to the dose from transportation accidents. In fact, increasing the activities of Pu-238, Pu-239, Pu-240, Pu-241, Am-241, Cm-242 and Cm-244 by more than a factor of 1000 only increased the cumulative dose for a transportation accident during shipment of 43 GWd/MTU spent fuel from the northeast to Clark County, NV from 0.0358 to 0.0359 person-mSv/shipment (3.58×10^{-3} to 3.59×10^{-3} person-rem/shipment).' "

> "NUREG/CR-6703 states 'because neutrons are effectively attenuated by low-density materials such as plastics and water, it is believed that minor modifications can be made to shipping casks to allow them to transport the higher burnup fuel at full load.' "

As discussed in the response to RAI E3.8-17, the actinide inventory per shipment will be less for the GT-MHR than the reference LWR.

Details of a final cask design for PBMR fuel are not available.

Application Revision

None.

RAI E4.2.2-1

Section 4.2 of ER (Water Related Impacts) - Provide the stage-storage relationship for Lake Anna. This is a table of lake storages over the range of feasible lake elevations. Provide a description of the method and data used to construct the stage-storage table. Storages for lake elevations down to at least 219 feet should be included.

Response

The stage storage curve of Lake Anna for water surface elevations ranging from 200 ft MSL to 270 ft MSL were derived from the 1"=200 ' contour drawings constructed from aerial photogrammetry of the proposed lake area before the dam was built. Surface areas at elevations 200 ft, 220ft, 240 ft, 250 ft, 260 ft and 270 ft MSL were measured from the contour drawings (referred to as photo science sheets) using a planimeter, and the incremental volume between two successive contours was determined by assuming a truncated square pyramid. The stage storage curves were checked for accuracy in two ways: (1) spot checking of surface areas of the photo sheets under various elevation contours using a planimeter; and (2) checking of the area enclosed by the 250 ft MSL contour of a USGS topographic map by a planimeter.

The stage-storage computed values are:

Elevation (feet)	Cumulative Volume (Acre-feet)
200	10,497.20
220	62,815.30
240	195,201.70
250	305,118.55
260	458,057.90
270*	665,147.40

* Note that the North Anna Dam crest elevation is 265 feet. Therefore, actual stage-storage volume would be limited to that elevation.

Application Revision

None.

RAI E4.2.2-2

Section 4.2 of ER (Water Related Impacts) - Based on available county and/or State growth management plans, provide a description of likely upstream land-use changes and changes in downstream water demand. From this information, describe both the direct and indirect effects of these changes on the flow of water into the lake and on low water conditions in the lake and in the river downstream of the lake.

Response

As shown in ER Figure 2.3-9, the watershed draining to Lake Anna upstream of the North Anna Dam, referred to as the "upstream watershed", lies within three counties: Louisa, Spotsylvania and Orange Counties. Downstream of the North Anna Dam, the North Anna River becomes part of the Pamunkey River Basin, which lies within the land of Hanover County, Caroline County, New Kent County and King William County. Further downstream, the Pamunkey River joins with the Mattaponi River to form the York River, which is tidal and its flow availability will not be affected by the inflow from the North Anna River and the Pamunkey River.

In the consideration of regional water use and water budget, future growth and development will impact a watershed in three ways:

(1) Increase withdrawal from surface water and/or groundwater resources to meet the rising water demand from population, commercial and industrial growth.

(2) Increase impervious area due to urbanization and land development will reduce groundwater recharge and affect the local and regional water budget.

(3) Increase impervious area due to urbanization and land development will increase runoff volume and/or peak runoff intensity.

Anticipated changes in the upstream land-use and downstream water demand are described below.

Future Upstream Land-Use Changes

The upstream watershed lies in three counties in Virginia: Louisa, Spotsylvania and Orange. The watershed is predominantly rural with residential areas in the immediate surrounding of Lake Anna. Of the acreage in the Lake Anna watershed, 57% is forest, 38% is covered with cropland and pasture. Only 3% of the land is developed for residential use (Reference 1). The comprehensive plan for each county (References 2, 4, and 6) indicates that future growth and land use changes are expected in all three counties.

The following examines the projected growth and impact in each of the three upstream counties:

Louisa County

Louisa County has projected a population increase of about 36% over the 20-year period from 2000 to 2020. The Comprehensive Plan proposes the designation of growth centers to guide future growth and development to preserve and protect the rural character of the county as well as provide for efficient delivery of public services. Most of the growth will center around existing towns in the county. Of these towns, parts of Louisa, Mineral, and Gordonsville lie within the Lake Anna watershed. The town of Gordonsville is actually located in Orange County, but portions of the growth area for this town are located in Louisa County. Most of the area adjacent to Lake Anna has been designated as low density residential with smaller portions designated as village residential (see Map 24 of Comprehensive Plan). (Reference 2)

The Plan recognizes that water resources in Louisa County are somewhat limited, and careful planning for allocation of scarce and costly water resources is required to support the projected growth. Historically, Louisa has been a county of individual well and septic systems with 89% of the county's residents relying on groundwater for their drinking water. Public water and sewer are provided for the towns of Louisa and Mineral and the adjoining areas. The Northeast Creek Reservoir just north of Route 33 between the towns of Louisa and Mineral, outside the Lake Anna watershed, serves the water needs of the two towns and would provide water for the future development in that area. Future growth and development in the areas not supported by the reservoir would increase groundwater withdrawal rate. However, impact to both the groundwater and surface water resources in the Lake Anna watershed is not expected to be extensive since future land use outside the towns is planned to be low density development.

According to Louisa County website (Reference 3), about 71% of County's land is in natural and planted forest land, 16% in crop, pasture and open land, 10% developed as urban, residential and industrial, and 3% in water bodies. With growth projected for these areas, the percentage of developed land is expected to increase slightly in future years leading to more impervious areas. To minimize the impacts of this growth on storm water runoff and downstream water resources, the Comprehensive Plan recommends the implementation of policies to encourage the use of storm water management measures that promote infiltration and discourage the use of impervious surfaces. Since the majority of the Lake Anna watershed within Louisa County is not designated as growth centers and future development is expected to be primarily of the low-density residential type, the impact to groundwater recharge and surface runoff are expected to be small.

Spotsylvania County

Spotsylvania County's population has increased rapidly at an annual growth rate of 4.5% from 1990 to 2000. The rapid growth in the county has been primarily concentrated in the northern and central portions of the county in a concentric pattern around the City of Fredericksburg as well as along Route 3, Route 17, and Route 208, outside of the Lake Anna watershed. There has also been significant growth around Lake Anna, primarily recreational and retirement living. In the remainder of Spotsylvania County, a rural settlement pattern predominates even though growth is occurring. One of the goals of the 2002 Comprehensive Plan of Spotsylvania County (Reference 4) is to implement policies to limit the growth rate to 2% annually and achieve a 70/30 mix of residential to commercial/industrial development. The Plan recommends that the residential growth continue within the settlement areas of the county in proportion to existing development patterns. Most of the county's residential, commercial, office and industrial development has occurred and will continue in the "Primary Settlement District" near Fredericksburg. To discourage growth outside the designated areas, a Primary Development Boundary has been established to define the area within which public utilities would be provided. Both the Primary Settlement District and the Primary Development Boundary are located outside the Lake Anna watershed. In the Lake Anna District, there is plan to allow for the development of a village center and allow public water and sewer services within the boundaries of the village center. The rest of the Lake Anna watershed in Spotsylvania County would remain largely low-density residential area and would rely on private groundwater wells. (Reference 4)

Water supply for the county mainly comes from surface water. The county's water supply system consists of the Ni Reservoir, the Motts Run Reservoir, an intake on the Rappahannock River, and the Hunting Run Side-Stream Storage Reservoir with an intake on the Rapidan River, all of which are located outside the Lake Anna watershed.

Groundwater is not considered a viable public water source for Spotsylvannia County. Currently, approximately one-third of Spotsylvania County residents use small private wells withdrawing from the Piedmont aquifers, which are generally low yielding and highly variable in thickness and hydrologic characteristics. Because of this, groundwater is dedicated for residential use only, and withdrawals for commercial and industrial purposes are denied. (Reference 5)

Several alternatives have been considered to meet future water supply demands including expanding existing reservoirs and adding new impoundments. The Rappahannock River is considered a promising source of water for domestic and industrial consumption. It has been determined that Lake Anna, on the other hand, would be unavailable as a significant water resource for Spotsylvania County (Reference 5). Future growth in the County is therefore not expected to impact the water budget of the Lake Anna watershed.

The Plan recommends implementation of land use and best management practices to limit the increase of impervious areas created due to future growth to reduce their impact on groundwater recharge and runoff increases.

Orange County

Orange County is a rural community whose economic base is primarily agricultural. The future land-use plan is built around the goal of striving to protect the farm and forest land. In the next decade (2000-2010), the population growth is projected at 2.25% per year, which is somewhat above the normally accepted highest level for orderly growth rate of 2%. The Comprehensive Plan (Reference 6) advises that the County should limit growth to those areas that can support it: places where water supply, sewage disposal, transportation and other public facilities and services can be provided at low cost. Development is encouraged in the existing growth areas: the Towns of Orange, Gordonsville, Unionville and Rhoadesville, the area around the Orange County Airport and the Germanna Highway Corridor. Among these areas, parts of the towns of Orange, Gordonsville, Unionville and Rhoadesville border on the Lake Anna watershed. According to the future land use map 2000-2020, a majority of the county lying within the Lake Anna watershed would remain agricultural. (Reference 6)

The county lies between the headwaters of York and Rappahannock Rivers, with its northern limit bounded by the Rapidan River and the southern limit bounded by the North Anna River. The primary sources of water for the near term are the Rapidan River and domestic wells. Impoundments have yet to be exploited as a source of water except on a few farms. In most parts of the county, an adequate supply of water is obtained from springs, streams and wells. Farm ponds are used to supply water for livestock. A total of 300 to 370 farm ponds have been inventoried in the county. The North Anna River and its tributaries are small and supply only a small amount of water. As the county's population continues to grow, new development would be encouraged where it can be supplied from surface water sources. The flow of the Rapidan River is limited, but the water supply can be augmented through impoundments. The Comprehensive Plan recommends that the county should look well into the future when planning for impoundments due to the lengthy permitting processes. (Reference 6)

Under the current Riparian Rule, Orange County has little control over how much water is withdrawn upstream on the Rapidan River. Construction of impoundments in the county has been considered for several decades. It does not appear that North Anna River and its tributaries would be considered as future water source for the county due to their small flow. Groundwater offers several advantages compared to river withdrawal and surface reservoirs. The Plan recommends investigating groundwater conjunctively or independently, with surface water sources. The area of the county appearing most suited for groundwater resource is the northern tip of the Triassic Barboursville Basin. (Reference 6)

Over 58% of Orange County's 355 square miles land area is in commercial farms and forestland, areas that are critical to groundwater recharge. Residential, commercial, industrial and public uses occupy about 5%. The Plan also recognizes that the location of new development has an impact on groundwater. It is a goal of the Comprehensive Plan to protect the groundwater resources by implementing policies to identify and protect groundwater recharge areas as well as to minimize impact on surface runoff. (Reference 6)

Future Downstream Water Withdrawal Changes

The North Anna and Pamunkey River are both potential water sources for industrial and potable use in the downstream counties. These rivers pass through Hanover, Caroline, King William, and New Kent Counties in Virginia. Counties located downstream along the York River will not be discussed further since the river is tidal and inflows from the Pamunkey River would not affect the availability of the York River water.

The comprehensive plan for each of these counties (References 7, 8, 9, and 10) indicates that growth is anticipated and that additional water resources would be needed. The Hanover County Comprehensive Plan (Reference 7) describes an alternative that includes water withdrawal from the North Anna River. Additionally, the Comprehensive Plan for Caroline County (Reference 8) and New Kent County (Reference 9) list the Pamunkey River as a possible source for future water needs. The King William County plan, while indicating future water needs, does not list the Pamunkey River as a possible source.

Use of the North Anna/Pamunkey River by the downstream counties for future water use would further reduce the overall water volume in the Pamunkey River in addition to the reduction from the addition of the new units at North Anna Power Station.

The following examines the projected growth and impact in each of the four downstream counties that will affect the flow in the North Anna River or Pamunkey River:

Hanover County

The Hanover County Comprehensive Plan adopted in June 2003 (Reference 7) states that the long-range population growth should be maintained at an average rate of 2.5%, and that suburban development should be concentrated in those sections of the county with an existing infrastructure so that suburban services can be most economically provided within the 2022 suburban boundary.

The need for future water supplies has been recognized since the 1970's. The findings of numerous studies agree that the groundwater resources of Hanover

County are restricted by quantity and quality and are not viable for meeting the county's long-term water resource requirements.

Currently, the county provides water service from 11 wells and 2 surface water treatment plants. In addition, the county has water supply contracts to purchase water from Henrico County and from the City of Richmond. Of the two water treatment plants, Doswell Water Treatment Plant has a capacity of 4 million gallon per day (MGD) (6.1 cfs) and utilizes the North Anna River as its source. Through its contract with the City of Richmond, the county would have 20 MGD of water available to it through 2010. Currently, 10 MGD of water is available from Richmond. It is estimated that the 20 MGD capacity of this contract, when combined with other supply sources available to the county, would meet the county's average and peak day demands to sometime during 2020 – 2025 period, depending on growth within the Suburban Service Area (Reference 7).

Among the various water supply alternatives proposed, two are being retained for incorporation into the Comprehensive Plan, one of which would require a new river intake of 30 MGD (46 cfs) estimated capacity at the North Anna River. The minimum instantaneous release from the North Anna Dam under normal conditions is 25.8 MGD (40 cfs) when lake level is at or above 248 ft MSL in accordance with the Lake Level Contingency Plan operating rules (Reference 11). During drought condition, when the lake level reaches 248 ft above MSL, the Lake Level Contingency Plan operating rules requires a minimum instantaneous release limit of 12.9 MGD (20 cfs). Although the Hanover County Comprehensive Plan does not specify the location of the North Anna River intake, it does not appear feasible to plan for a new intake at the North Anna River with a capacity of 30 MGD as the river may not be able to support this flow in addition to the existing Doswell WTP intake with a 4 MGD of capacity given the Lake Level Contingency Plan operating rules as defined for the North Anna dam. The addition of Unit 3 at the North Anna site would have no impact on these operating rules and there would be no changes in the minimum instantaneous release values.

Caroline County

During the period of 2000 to 2010, the population of Caroline County is projected to grow by 14% to 36%, depending on the growth scenario. The Comprehensive Plan (Reference 8) recognizes the need to conduct a long range water supply planning for the county as a whole to sustain anticipated growth, inclusive of surface water, groundwater, flood hazards, and regular potable water quality. Currently, groundwater is the primary source of potable water in Caroline County. Only Lake Caroline is served by surface water withdrawal for its water requirements. The county anticipates that groundwater supplies are probably sufficient to meet the water needs in the near future. To avoid depletion of the groundwater supply, the Virginia Water Control Board regulates withdrawals from wells in the Groundwater Management Area. The county also has an abundant supply of surface water resources available. The Rappahannock, Mattaponi, and Pamunkey Rivers are considered as potential water supply sources for the county, however, no definite plan or study has yet been developed. (Reference 8)

<u>New Kent County</u>

The New Kent County Planning Department projects continued population growth of 33.7% during the period of 2000 to 2010, and another 30.6% from 2010 to 2020 (Reference 9). The county's residents have relied primarily on groundwater to provide their potable water needs. The continued withdrawal of groundwater has caused a lowering of the water levels throughout the aquifer system creating problems for existing shallow wells and raising concerns about the long-term viability of groundwater as a dependable, safe source of water. The county lies within two major river basins: the York in the northeast and the James in the south. Approximately one-third of the county lies in the Pamunkey River basin, which is part of the York basin. The county's rivers, streams, and water bodies provide opportunities for a variety of surface water users, but difficulties in federal and state permitting severely restrict the county's ability to develop its own surface water resources. Although permitting issues would need to be evaluated, considerations have been given to develop a future reservoir or reservoirs to be utilized for the collection of both surface runoff and as a storage site for pump-over from the upper, freshwater portion of Pamunkey River. Future water resource plans for New Kent County would be developed based on the preliminary state water resource plan which would include criteria for development of local and regional plans. No defined study or plan has yet been developed. (Reference 9)

<u>King William County</u>

The 2003 Comprehensive Plan Update of King William County (Reference 10) on population projections indicates that the county would continue to experience accelerated population growth during the planning period. It is estimated that the county's population would grow from 2000 to 2010 by over 20%, twice the rate projected for Virginia as a whole. The vast majority of King William County residents are served by private wells, though the county does have three small water systems that have specific service areas. Within Virginia, King William ranks in the second highest category for groundwater withdrawal. A reservoir is being planned by damming Cohoke Creek near its confluence with the Pamunkey River. However, water would be taken from the Mattaponi River at Scotland Landing and pumped to the proposed Cohoke Reservoir. It would provide the county with an alternate surface water supply. There is no plan of using North Anna or Pamunkey Rivers or their tributaries as future water sources. (Reference 10)

Impacts of Future Development on Inflow and on Low Water Condition of the Lake

Most of the upstream counties do not rely on the North Anna River or its tributaries for their current or future water supply. Groundwater withdrawal would increase with the rising demand from the projected growth of the counties, but impact on the inflow to the lake is expected to be small due to the relatively low percentage of overall development and the low density of the projected development in the majority of the watershed.

Due to the increase in impervious area, increased growth and urbanization in the watershed would generally increase runoff volume and peak discharges in local streams and rivers, and reduce groundwater recharge. Through storm water management measures that promote stormwater retention and infiltration, these impacts can be reduced significantly. The growth and development projected for the upstream counties would tend to increase the runoff volume into Lake Anna. Increased flow into the lake could reduce the impacts of increased evaporation that would result from the operation of Unit 3. However, current development in the counties located in the watershed is small relative to the size of the watershed and even with the projected growth, the increase in the runoff to the lake is expected to be small.

During periods of low runoff, the lake could receive less inflow because of the higher groundwater withdrawal and the potentially lower groundwater recharge as a result of increased impervious area from future development. But the effect should be small due to the relatively small percentage of current and projected future development relative to the size of the watershed.

Impact of Future Development on Downstream River Flow

The future growth in the upstream counties is not likely to have a significant impact on the watershed's surface and groundwater resources, and on the inflow to Lake Anna. Consequently, the impact of future development of the upstream counties would have small impact on the release from the North Anna Dam to the downstream river.

Three of the counties downstream of the dam are considering using the North Anna River or Pamunkey River as future water sources to support their projected growth. No firm estimate or definite water use plans have been developed to this date, but detailed state water resource studies would be required to demonstrate the feasibility of using these downstream rivers as potential water sources for the downstream counties. The operation of Unit 3 would have no effect on the instantaneous minimum releases from Lake Anna and would not affect the minimum flows available for any future downstream development. The duration of the minimum flow release rates would increase with the addition of Unit 3 as discussed in Section 5.2.2.2 of the ER.

References:

1. Lake Anna Special Plan Committee, "Lake Anna Special Area Plan," March, 2000.
2. County of Louisa, Virginia, " Louisa County Comprehensive Plan," September 4, 2001.
3. Website of County of Louisa, Virginia, "Louisa County At a Glance," http://www.louisacounty.com/glance.htm, accessed on April 15, 2004
4. County of Spotsylvania, Virginia, "Comprehensive Plan," 2002.
5. County of Spotsylvania, Virginia, "Water and Sewer Master Plan," Revisions 2002.
6. County of Orange, Virginia, "Comprehensive Plan," adopted on September 14, 1999.
7. County of Hanover, Virginia, " Hanover County Comprehensive Plan – Vision 2022," adopted June 2003.
8. County of Caroline, Virginia, "2001 – 2004 Caroline County Comprehensive Plan," adopted on February 27, 2001.
9. New Kent County, Virginia, "Vision 2020, New Kent County Comprehensive Plan," adopted August 4, 2003.
10. King William County, Virginia, "2003 Comprehensive Plan Update," adopted June 23, 2003

<u>Application Revision</u>

The ER will be revised to incorporate the information contained in this RAI response.

RAI E4.2.2-3

Section 4.2 of ER (Water Related Impacts) – Provide topographic maps of land surface elevation below the lake surface.

Response

The following U.S. Department of the Interior Geological Survey topographic maps are provided as a separate enclosure:

- Lake Anna West Quadrangle, Virginia, 7.5 Minute Series (Topographic)
- Lake Anna East Quadrangle, Virginia, 7.5 Minute Series (Topographic)
- Lahore Quadrangle, Virginia, 7.5 Minute Series (Topographic)
- Belmont Quadrangle, Virginia, 7.5 Minute Series (Topographic)
- Beaverdam Quadrangle, Virginia, 7.5 Minute Series (Topographic)
- Buckner Quadrangle, Virginia – Louisa County, 7.5 Minute Series (Topographic)
- Mineral Quadrangle, Virginia, 7.5 Minute Series (Topographic)

Application Revision

None.

RAI E4.2.2-4

Section 4.2 of ER (Water Related Impacts) – Provide in electronic format all lake physical monitoring data (including velocity) in both the lake and waste heat treatment facility (WHTF).

Response

Lake physical monitoring data is provided in electronic format on the enclosed CD. The data included on the CD is listed in Table 1.

Table 1. Lake Anna and WHTF Data Sets

No.	File Name	Description
Lake Anna Water Temperatures		
1	NORTH ANNA GPS READINGS.xls	List of Lake Anna temperature survey sites (name, longitude, latitude, location).
2	North Anna Lake temps 1983 through 2001.csv	Observed Lake Anna surface temperatures (10/1/1983-12/31/2001) at four locations (NALBRPT, NALINT, NAWHTF3, NADISC1).
3	NA Temps and Unit info.csv	Data set includes the following values for 07/26/1978-09/30/1983: date, observed surface temperatures at seven sites (NALBRPT, NALINT, NAWHTF3, NADISC1, TAILRACE, INTAKADJ, DISCADJ), percent load per unit 1&2 (PCTU1, PCTU2), lake water level, number of operating pumps for Units 1 and 2 (PUMPSU1, PUMPSU2), average load of PCTU1 and PCTU2 (POWLEV).
4	North Anna Lake Temp Transects.csv	Data set includes observed Lake Anna temperatures (02/21/1984 – 11/27/2001) for specified dates and locations (depth, station, transects). Coordinates of stations are listed in "plume gps.doc".
5	plume gps.doc	Coordinates of stations mentioned in North Anna Lake Temp Transects.csv.
6	North Anna Lake Surface Isotherms	27 gif files with isotherm plots of the Lake Anna surface temperatures for time period of 1984-1987.
7	BechtelRFI61.xls	Observed lake surface temperatures (1/1/2002-4/10/2003) at four locations (NALBRPTT, NALINT, NAWHTF3, NADISC1); observed lake transect temperatures (3/19/2002 – 3/21/2003) for specified dates and locations (depth, station, transects); observed lake surface temperatures

Table 1. Lake Anna and WHTF Data Sets		
No.	File Name	Description
		(1/1/1978-4/10/2003) at five locations (NALST10, NAL208T, NAL719NT, NAL719ST, NARIV601).
8	na_cont_monitors update090302.csv	The file shows the number of records (thermal monitoring data) per month.
Lake Anna Water Levels		
9	Lake Levels 1996 to 2001.xls	Daily lake level readings and monthly values for 1996-2001.
10	Lake Level Data 79-82.xls	Daily lake level readings 7/26/1978-12/31/1982.
11	NA-WL1983-1985.xls, NA-WL1986.xls, NA-WL1987&1990.xls, NA-WL1988-1989.xls, NA-WL1991-1992.xls, NA-WL1993-1995.xls	Hourly lake level readings, daily and monthly values for 1983-1995.
Stream Gage Data		
12	Doswell.csv	Daily mean flow values in CFS from the discontinued USGS gaging station located on the North Anna River upstream of the Rt. 1 bridge. The gage is on the North Anna River near Doswell, VA.
13	Monthly Average North Anna River flows at Partlow.xls	Monthly average flows recorded at USGS gauging station near Partlow, VA, No. 01670400. The gauge operated from 1978 through 1995.
14	North Anna River flows at Partlow.csv	Daily average flows recorded at USGS gauging station near Partlow, VA, No. 01670400. The gauge operated from 1978 through 1995.

Application Revision

None.

E4.2.2-5

Section 4.2 of ER (Water Related Impacts) – Provide a description of the quality assurance protocol followed in the lake modeling analyses.

Response

Dominion's Quality Assurance Manual (QAM) for development of the Early Site Permit Application is contained in Chapter 17 of the SSAR. The QAM establishes the quality assurance plan for the development of the ESP application to assure that the application is developed in a quality manner and, where appropriate, in accordance with 10 CFR 50 Appendix B.

The lake modeling analyses were performed by Bechtel Power Corporation to support Dominion for the ESP project. Dominion contractually required that Bechtel implement a quality assurance program that complied with the requirements of 10 CFR 50, Appendix B, and ANSI N45.2. Bechtel's QA Program Plan was approved by Dominion. Bechtel's work on the ESP project is governed by its Quality Assurance Program Plan and implementing procedures. These documents as well as Bechtel's Project Engineering Procedures Manual (PEPM) were approved by Dominion. The lake modeling analyses described in the SSAR and ER were performed in accordance with the PEPM.

In late 2003, the NRC performed an audit of the Dominion and Bechtel quality assurance programs for the North Anna ESP, including the documents identified above. The results of that inspection are presented in Inspection Report 05200008/2003001 dated January 12, 2004.

Application Revision

None.

E4.4.2-1

<u>Section 4.4 of ER (Social and Economic Impacts)</u> – During its December 8, 2003 site visit, the NRC was made aware of a study that had been undertaken (source unknown) on the availability of construction workers for the proposed Units 3 and 4 at North Anna. Please provide a copy of the study.

Response

The study identified is: "Study of Potential Sites for the Deployment of New Nuclear Plants in the United States," U.S. Department of Energy Cooperative Agreement No. DE-FC07-02ID14313, Prepared by Dominion Energy, Inc. and Bechtel Power Corporation, September 2002.

A copy of the study is available on DOE's website at:

ne.doe.gov/NucPwr2010/ESP_Study/ESP_Study_Dominion.pdf

Part 3, Section 3.5, of the study addresses construction labor and associated issues.

Application Revision

None.

RAI E4.5-1

General - Provide a bounding estimate of the number of construction hours per year and the number of years it will take to complete construction for each unit.

Response

As stated in Section 4.5.4, the peak loading is 5000 construction workers per year at 2080 hours per construction worker, resulting in a total of 10.4 million hours per year. As stated in Section 4.4.2, the construction of a new unit is estimated to take 5 years.

Application Revision

None.

RAI E4.5-2

<u>Section 4.5.4.2 and 4.5.4.3</u> In the ER, the annual gaseous and liquid effluent doses resulting from the operation of the existing nuclear units was multiplied by a factor of 10 (to cover uncertainty regarding the location of a construction worker at a new unit compared to the maximally exposed member of the public) in arriving at the estimated worker doses from gaseous and liquid effluents. Justify the use of this factor in arriving at the annual construction worker doses from gaseous and liquid effluents.

<u>Response</u>

The doses to the maximally exposed member of the public (MEMP) were calculated based on the methodology provided in the Offsite Dose Calculation Manual (ODCM). According to the ODCM, gaseous effluent dose to the MEMP is calculated at or beyond the site boundary.

The dose to the construction worker was assumed to be 10 times higher than to the MEMP. The construction worker and the MEMP would be subjected to the same effluent releases from the existing units, with the only difference being the atmospheric dispersion of the released activity, which is location-dependent. The atmospheric dispersion factor (χ/Q) for routine releases from the existing units is 3.3E-6 sec/m^3 at the exclusion distance of 4430 ft (North Anna UFSAR, Section 2.3.5). It increases to as much as 1.0E-5 sec/m^3 at a distance of about one-fourth of a mile to the west of the existing units (North Anna UFSAR, Figure 2.3-31). Since the distance from the existing units to the construction site is about one-fourth of a mile, it is reasonable to assume that the gaseous effluent dose to the construction worker would be no more than 10 times higher than to the MEMP at the site boundary.

As indicated in Section 4.5.4.3, the liquid effluent dose to the construction worker would be expected to be no higher than to the MEMP because both would be drinking from the same water supply. However, for conservatism and consistency with the gaseous effluent approach, the liquid effluent doses for the MEMP were also multiplied by a factor of 10 in estimating the construction worker dose.

<u>Application Revision</u>

Section 4.5.4.2 will be revised to read as follows. (Note that this section includes other changes based on the response to RAI E4.5-7.)

4.5.4.2 **Gaseous Effluents**

The annual gaseous effluent doses to the maximally exposed member of the public (Section 4.5.3.2) are based on continuous occupancy. Adjusted for an exposure time of 2080 hr/yr and multiplying by a factor of 10 to account for the fact that the worker is located closer to the effluent release point than is the maximally exposed member of the public, the estimated worker doses are 1.1E-1 mrem for the total body, 2.7E-1 mrem for the skin, and 3.5E-1 mrem for the critical organ. Applying a weighting factor of 0.3 to the critical organ dose (Reference 5) and adding to the total body dose, a TEDE of 2.1E-1 mrem is estimated.

RAI E4.5-3

Table 4.5-1 – The ER provides thermo-luminescent dosimeter (TLD) dose measurements for each of the years 1996 to 2002. Provide the locations of the TLDs used to obtain these measurements and explain why these TLD locations were chosen as the representative locations for the direct shine dose.

Response

As the title of Table 4.5-1 indicates, the TLD measurements were taken at the west protected area fence of the existing units. As stated in Section 4.5.1, the new units would be located west of the existing units. This represents the closest approach to the existing units for construction workers working on the new units. Hence, it is conservative to use the dose measurements at this location to estimate the doses to the construction workers working on the new units.

Application Revision

ER Table 4.5-1 will be revised to add the following at the bottom of the table:

Note: The west protected area fence represents the closest approach to the existing units for construction workers working on the new units; see Section 4.5.1.

RAI E4.5-4

Section 4.5.4.1 The calculated annual total effective dose equivalent (TEDE) dose to construction workers from direct radiation of 18 millirem (mrem) is based on the maximum TLD reading measured at the west protected area fence of the existing units. Since construction workers working in the southern portion of the ESP construction site will also be receiving direct radiation from the nearby independent spent fuel storage installation, state whether the annual dose to these construction workers will be bounded by the same calculated 18 mrem TEDE annual dose and explain the basis for the conclusion.

Response

The TLD reading at the west protected area fence included the ISFSI dose contribution based on the ISFSI loading at the time of the measurement. A more conservative estimate would include a dose contribution from a fully loaded ISFSI.

The average distance from the ISFSI pads to the construction area for the new units is about 1600 feet. The dose at a distance of 1600 feet from a fully loaded ISFSI has been previously calculated using the MCNP computer program as 4.7E-3 mrem/hr. With an occupancy rate of 2080 hours per year, this is equivalent to an annual dose of 9.8 mrem.

The average annual TLD reading from 1996 to 2002 was 56 mrem (Table 4.5-1), which equates to an annual dose of 13 mrem based on an occupancy rate of 2080 hours per year. Although the center of the construction area for the new units is several hundred feet west of the fence, it is conservatively assumed that the average dose rate at the west protected area fence applies to the entire construction area. When this dose of 13 mrem is added to the ISFSI dose of 9.8 mrem, a total dose of 23 mrem is obtained.

In summary, a conservative annual dose of 23 mrem is estimated for construction workers based on a fully loaded ISFSI and the average TLD reading at the west protected area fence.

Section 4.5.4.1 will be revised to bound the dose to construction workers from a fully loaded independent spent fuel storage installation (ISFSI) as described below.

Application Revision

Section 4.5.3.1 will be revised to read as follows:

4.5.3.1 **Direct Radiation**

Table 4.5-1 provides thermo-luminescent dosimeter (TLD) measurements at the west protected area fence of the existing units from 1996 to 2002. The average annual dose for this period is 56 mrem. It should be noted that the TLD measurements include background radiation. A radiological survey taken at the same location in April 2003 shows a dose rate of 0.02 mrem/hr.

The average distance from the ISFSI pads to the construction area for the new units is about 1600 feet. The dose rate at 1600 feet from a fully loaded ISFSI has been previously calculated using the MCNP computer program as 4.7E-3 mrem/hr.

Section 4.5.4.1 will be revised to read as follows:

4.5.4.1 **Direct Radiation**

At the west protected area fence, Section 4.5.3 indicates an average annual dose of 56 mrem based on TLD measurements and a dose rate of 0.02 mrem/hr based on a radiological survey. The latter reading reflects the sensitivity of the instrument in measuring such low instantaneous dose rates. TLD measurements, however, are more accurate as they reflect continuous exposures for long periods of time. The average measured dose rate over a seven-year period of 56 mrem/yr is based on continuous exposure at the protected area fence between the existing and new units. Since the construction workers would spend most of their time west of this fence, further away from the existing units, using this dose rate for the workers is conservative. Adjusting for an exposure time of 2080 hr/yr yields an annual worker whole body or total effective dose equivalent (TEDE) dose of 13 mrem.

Although the TLD reading includes the dose contribution from the ISFSI loading at the time of the measurement, the dose from a fully loaded ISFSI is conservatively added to the TLD dose. The ISFSI dose rate of 4.7E-3 mrem/hr with an exposure time of 2080 hr/yr is equivalent to an annual dose of 9.8 mrem. Adding the two contributions results in a total annual dose of 23 mrem.

The second paragraph of Section 4.5.4.4 will be revised to read as follows:

The maximum annual collective dose to the construction work force (5000 workers) is estimated to be 120 person-rem.

Tables 4.5-2, 4.5-3, and 4.5-4 will be revised to read as shown on the next page. Note that, in response to RAI E4.5-7, Table 4.5-2 also shows revised gaseous effluent doses and Table 4.5-4 also shows revised thyroid and other organ doses.

Table 4.5-2 Annual Construction Worker Doses

	Annual Dose (mrem)		
	Whole Body	Critical Organ	TEDE
Direct radiation	2.3E+01	-	2.3E+01
Gaseous effluents	1.1E-01	3.5E-01	2.1E-01
Liquid effluents	7.3E-01	8.4E-01	9.8E-01
Total	2.4E+01	1.2E+00	2.4E+01

Table 4.5-3 Comparison with 10 CFR 20.1301 Criteria for Doses to Members of the Public

Criteria	Dose Limit	Estimated Dose
Annual TEDE (mrem)	100	24
Unrestricted area dose rate (mrem/hr)	2	0.1

Table 4.5-4 Comparison with 40 CFR 190 Criteria for Doses to Members of the Public

Organ	Annual Dose (mrem)	
	Limit	Estimated
Whole body	25	24
Thyroid	75	1.2
Other organ	25	1.2

Note: The estimated whole body dose conservatively includes background radiation whereas the dose limit applies to exposures from plant operation only.

RAI E4.5-5

Section 4.5.2.1 The ER states that the boron recovery tanks and the low-level contaminated storage area are among the existing units' principal sources contributing to direct radiation exposure at the construction site. Provide layout maps showing the location of these sources with respect to the ESP construction site.

Response

A layout map of the existing units' protected area was provided to the NRC following the December 2003 NRC site audit (Reference 1). The map depicts the locations of the boron recovery tanks and the low-level contaminated storage area, relative to the ESP construction site.

References:

1. "Summary of Environmental Site Audit to Support Review of the North Anna Early Site Permit Application," Andrew J. Kugler, U. S. Nuclear Regulatory Commission, March 27, 2004 (NRC Accession Number ML040860222); Reference No. 14, "West Security Gate Survey Map from Dominion Technical Procedure C-HP-1032.010, 'Radiological Survey Records,' (NRC Accession Number ML040570378).

Application Revision

None.

RAI E4.5-6

Section 4.5.4.1 Provide the calculations that show how you modeled the existing direct radiation sources (such as the boron recovery tanks, the low-level contaminated storage area, and the independent spent fuel storage installation) to determine their contribution to construction worker dose.

Response

As described in Section 4.5.4.1, doses from direct radiation sources are based on TLD measurements, not calculations. However, as described in the response to RAI E4.5-4, Section 4.5.4.1 will be revised to include the calculated dose contribution from a fully loaded Independent Spent Fuel Storage Installation (ISFSI) facility. As explained in the response to RAI E4.5-4, the ISFSI doses were calculated using the MCNP computer program.

Application Revision

None.

RAI E4.5-7

Table 4.5-5 In addition to the 10 CFR Part 50, Appendix I Criteria Guidelines for doses from liquid and gaseous effluents, Appendix I (Section II.C) contains limits of 15 mrem to any organ of an individual in an unrestricted area from radioactive iodine and radioactive material in particulate form. Update Table 4.5-5 of the ER to include the comparison of the estimated dose to construction workers with this limit.

Response

The last entry of Table 4.5-5 will be revised to read "Organ dose from radioactive iodine and radioactive material in particulate form" instead of "Organ doses from all effluents."

Furthermore, the estimated doses in the last three rows of Table 4.5-5 will be revised along with Sections 4.5.3.2 and 4.5.4.2 and Tables 4.5-2 and 4.5-4 to reflect more accurate information found in the Annual Radioactive Effluent Release Report for 2001.

Application Revision

Sections 4.5.3.2 and 4.5.4.2 and Tables 4.5-2, 4.5-4, and 4.5-5 will be revised as shown below. Note that Tables 4.5-2 and 4.5-4 also reflect revised direct radiation total body doses in response to RAI E4.5-4.

4.5.3.2 **Gaseous Effluents**

The Annual Radioactive Effluent Release Report for 2001 (Reference 3) indicates a total body dose of 4.6E-2 mrem, a skin dose of 1.1E-1 mrem, and a critical organ dose of 1.5E-1 mrem to the maximally exposed member of the public due to the release of gaseous effluents from the existing units, calculated in accordance with the existing units' Offsite Dose Calculation Manual (Reference 4).

4.5.4.2 **Gaseous Effluents**

The annual gaseous effluent doses to the maximally exposed member of the public (Section 4.5.3.2) are based on continuous occupancy. Adjusted for an exposure time of 2080 hr/yr and multiplying by a factor of 10 to account for the fact that the worker is located closer to the effluent release point than is the maximally exposed member of the public, the estimated worker doses are 1.1E-1 mrem for the total body, 2.7E-1 mrem for the skin, and 3.5E-1 mrem for the critical organ. Applying a weighting factor of 0.3 to the critical organ dose (Reference 5) and adding to the total body dose, a TEDE of 2.1E-1 mrem is estimated.

Table 4.5-2 Annual Construction Worker Doses

	Annual Dose (mrem)		
	Total Body	Critical Organ	TEDE
Direct radiation	2.3E+01	-	2.3E+01
Gaseous effluents	1.1E-01	3.5E-01	2.1E-01
Liquid effluents	7.3E-01	8.4E-01	9.8E-01
Total	2.4E+01	1.2E+00	2.4E+01

Table 4.5-4 Comparison with 40 CFR 190 Criteria for Doses to Members of the Public

Organ	Annual Dose (mrem)	
	Limit	Estimated
Whole body	25	24
Thyroid	75	1.2
Other organ	25	1.2

Note: The estimated whole body dose conservatively includes background radiation whereas the dose limit applies to exposures from plant operation only.

Table 4.5-5 Comparison with 10 CFR 50, Appendix I Criteria for Effluent Doses

	Annual Dose (mrem)	
	Limit	Estimated
Total body dose from liquid effluents	3	0.73
Organ dose from liquid effluents	10	0.84
Total body dose from gaseous effluents	5	0.11
Skin dose from gaseous effluents	15	0.27
Organ dose from radioactive iodine and radioactive material in particulate form	15	1.2

RAI E5.4.2-1

Section 5.4.2 of ER (Radiation Doses to Member of the Public) - Provide any occupational dose estimates for the advanced reactor designs and information on which design would have the bounding occupational dose impacts.

Response

The following occupational dose estimates are available for the advanced reactor designs being considered:

Design	Dose (person-rem/year)
AP1000	67
ABWR	99
IRIS	67
GT-MHR	149

No dose estimates are available for the ACR-700, ESBWR, or PBMR.

Based on the above data, the maximum annual occupational dose at the site is estimated to be 150 person-rem. This maximum dose would be verified in the COL application when a reactor design has been selected.

Application Revision

Section 5.4.2 will be revised to read as follows:

5.4.2 Radiation Doses to Members of the Public

In this section, doses to MEIs from liquid and gaseous effluents from one new unit are estimated using the methodologies and parameters specified in Section 5.4.1. Additionally, based on the available data on the reactor designs being considered, the maximum annual occupational dose is estimated to be 150 person-rem. This maximum dose would be verified in the COL application when a reactor design is selected.

RAI 5.4.2-3

Section 5.4.2 of ER (Radiation Doses to Members of Public) – The ER states that the GASPAR II computer code was used to calculate dose estimates to the maximally exposed individual and the population from the gaseous effluent pathway. Provide the values of the following parameters that were used as inputs for the GASPAR II analysis:

- Distance (miles) from site to northeast corner of US
- Fraction of year leafy vegetables are grown
- Fraction of year that milk-cows are on pasture
- Fraction of the maximum individual's vegetable intake that is from his own garden
- Fraction of milk-cow feed intake that is from pasture while on pasture
- Average absolute humidity over the growing season
- Average temperature over the growing season
- Fraction of year that goats are on pasture
- Fraction of year that beef-cattle are on pasture
- Fraction of beef-cattle intake that is from pasture while on pasture
- Milk production (liters/year) by distance and sector
- Meat production (kilograms/year) by distance and sector

Response

The values used as inputs for the GASPAR II computer program are as follows:

- Distance (miles) from site to northeast corner of US – this parameter is only used by GASPAR II if NEPA doses are calculated; NEPA doses, which extend to the population beyond 50 miles of the plant, are not calculated because they are not specified by NUREG-1555
- Fraction of year leafy vegetables are grown – 0.5
- Fraction of year that milk-cows are on pasture – 0.67
- Fraction of the maximum individual's vegetable intake that is from his own garden – 0.76
- Fraction of milk-cow feed intake that is from pasture while on pasture – 1
- Average absolute humidity over the growing season – 8 g/m^3
- Average temperature over the growing season – not used when absolute humidity is specified
- Fraction of year that goats are on pasture – 0.75
- Fraction of year that beef-cattle are on pasture – 0.67
- Fraction of beef-cattle intake that is from pasture while on pasture – 1
- Milk production (liters/year) by distance and sector – uniform production option used with total of 6.94E8 liters/year
- Meat production (kilograms/year) by distance and sector – uniform production option used with total of 1.66E9 kilograms/year

Application Revision

None.

RAI E5.4.4-1

Section 5.4.4 of ER (Impacts to Biota Other Than Members of the Public) – Section 5.4.4.2 of the ER indicated that external ground deposition doses calculated by GASPAR II were increased to account for closer proximity of terrestrial organisms to the ground. Provide the factor used to account for this, and the technical basis for its use.

Response

Although GASPAR II does not explicitly calculate biota doses from gaseous releases as LADTAP II does from liquid releases, most of the doses calculated for humans in GASPAR II may be conservatively applied to biota.

In applying the ground deposition doses to biota, the doses calculated by GASPAR II were multiplied by a factor of two to account for the closer proximity of biota to the ground compared to humans. The factor of two is based on an adjustment made internally by LADTAP II in estimating biota exposure to shoreline deposits.

Page 3.36 of the LADTAP II technical reference (NUREG/CR-4013) states that a shore-width factor of 2.0 is used when calculating biota exposure to sediment and shoreline to adjust for biota being closer to the contamination than the 1 meter assumed for humans. As explained on Page 3.21 of NUREG/CR-4013, the shore-width factor represents the fraction of the dose from an infinite plane source that would be received from a given shoreline situation that may not be well described as an infinite plane. Therefore, LADTAP II is doubling the infinite plane dose when considering biota.

GASPAR II calculates ground deposition doses assuming an infinite plane source with the detector 1 meter above the plane (NUREG/CR-4653, Page 3.13). Hence, based on the LADTAP II guidance in NUREG/CR-4013, the infinite plane ground deposition doses calculated by GASPAR II for humans are doubled when applying to biota.

Application Revision

Section 5.4.4.2 will be revised to read as follows:

5.4.4.2 **Gaseous Pathway**

Gaseous effluents contribute to the terrestrial doses. Immersion and ground deposition doses are largely independent of organism size, and the doses for the MEI, as described in Section 5.4.2, can be applied to biota. However, the external ground deposition doses, as calculated by GASPAR II, were increased by a factor of two to account for the closer proximity of terrestrial organisms to the ground, similar to the adjustments made for biota exposures to shoreline sediments in LADTAP II.

RAI E5.7-1

Section 5.7.2.3.1 of ER (Uranium Fuel Cycle Impacts) - Provide the bases and reference for the discussion on the environmental impacts of the operation of the fuel fabrication facility for a modular high temperature gas reactor.

Response

As described in Section 5.7.2.3.1, information on the fuel fabrication was taken from two sources: conceptual design information received from one of the gas-cooled reactor vendors and conceptual design information for a TRISO fabrication plant planned for the New Production Reactor. The information on the GT-MHR is from Reference 1. The information on the conceptual design for the New Production Reactor is from Reference 2.

References:

1. May 3, 2003 Letter from Adrian George and E. Wallace, Pebble Bed Modular Reactor (Pty) Ltd., to Michael J. Cambria, Parsons Energy and Chemicals, "Follow-up Questions to ESP-8: Reactor Vendor Questionnaire." Contained in Idaho National Engineering & Environmental Laboratory Engineering Design File 3747, May 2003 (NRC Accession Number ML040580285).
2. "Report of The Fuel and Target Fabrication Technical Working Group," July 1984.

Application Revision

None.

RAI E5.7-2

Section 5.7.2.3.2 of ER (Uranium Fuel Cycle Impacts) - Provide the bases and reference for the statement that centrifuge technology requires less than 10 percent of the energy needed for the gaseous diffusion process and as such, the environmental impacts associated with the electrical generation would be correspondingly less.

Response

The information was taken from the following statement on the USEC web site (Reference 1) talking about the centrifuge technology:

> "**Low operating costs:** Its energy requirements are less than 10% of the requirements of a comparably sized gaseous diffusion plant."

This is conservative based on the following statement in NUREG-1484 (Reference 2):

> "The amount of energy to produce one separative work unit (SWU) is about 50 times greater for the gaseous diffusion technology than the energy required for centrifuge technology."

References:

1. USEC website, http://www.usec.com/v2001_02/HTML/Aboutusec_centrifugeTechnology.asp
2. NUREG-1484, "Final Environmental Impact Statement for the Construction and Operation of Claiborne Enrichment Center, Homer, Louisiana," U. S. Nuclear Regulatory Commission, Volume 1, August 1994.

Application Revision

None.

RAI E7.1-2

Section 7.1.2 The ER stated that the χ/Q values are calculated using the methodology of Regulatory Guide 1.145, *Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants,* and site-specific meteorological data. The request for additional information for Section 2.3, "Meteorology" of the North Anna Site Safety Analysis Report, which is being sent by separate correspondence, also applies to this section of the North Anna ESP Environmental Report.

Response

The request for additional information for Section 2.3 has no impact on Section 7.1.2, which simply utilizes the χ/Q values from ER Section 2.7.5.2.

Application Revision

None.

RAI 7.1-3

<u>Section 7.1.4</u> Table 7.1-3 to Table 7.1-28 present the time-dependent activity releases for each design basis accident. Provide the references and the methodology used to determine the time-dependent activity releases.

<u>Response</u>

The methodologies used for calculating time-dependent activity releases for the ABWR and AP1000 designs are presented in the respective design certification documents, References 1 and 2, respectively.

The activity releases for the ABWR accidents were obtained from the following tables within the ABWR SSAR (Reference 1):

Application Table	Accident Description	Reference ABWR SSAR Table
7.1-12	Failure of Small Lines Carrying Primary Coolant Outside Containment	15.6-2
7.1-18	MSLB	15.6-6
7.1-23	LOCA	15.6-10, 15.6-12
7.1-27	FHA	15.7-10

The ABWR activity releases shown in the application tables cited above were converted from the unit of Mega Bequerel (MBq) to Curie (Ci) and scaled up by the power ratio of 4386 MWt to 4005 MWt, consistent with the approach in Section 7.1.4 to adjust doses.

The AP1000 activity releases in the application tables listed below were obtained from correspondence from Westinghouse:

Application Table	Accident Description
7.1-3	MSLB, Pre-Existing Iodine Spike
7.1-5	MSLB, Accident-Initiated Iodine Spike
7.1-7	Locked Rotor Accident
7.1-9	Rod Ejection Accident
7.1-14	SGTR, Pre-Existing Iodine Spike
7.1-16	SGTR, Accident-Initiated Iodine Spike

Application Table	Accident Description
7.1-21	LOCA
7.1-25	FHA

References:

1. Document 23A6100, ABWR Standard Safety Analysis Report, General Electric, Revision 8.
2. AP1000 Document No. APP-GW-GL-700, AP1000 Design Control Document, Tier 2 Material, Westinghouse, Revision 2, 2002.

Application Revision

None.

RAI E7.2-2

Section 7.2.2 Please provide an up-to-date, site-specific assessment of the adverse health effects from fallout onto open bodies of water, considering the ESP site parameters (e.g., water flow rates and contaminant residence times). Justify that the generic conclusion with respect to such matters that was reached in NUREG-1437 is valid for a future reactor at the ESP site.

Response

In NUREG-1437 (GEIS), North Anna is described as a "small river site" for surface water pathway purposes. In Table 5.15 of NUREG-1437, the site is listed as one that may not be bounded by the Fermi 2 surface water analysis. The GEIS estimated for these sites that the population dose would be expected to remain a small fraction of the value estimated for the atmospheric pathway. This estimate was based on combined residence time, surface area-to-volume ratio, and population levels. It was further stated that the sites are considered to be at least as amenable to interdictive measures as Fermi, which would further reduce the population dose. Site information provided in the response to RAI E7.2-3 and the population projections in the ER Section 2.1.3 show that these site assumptions are expected to remain valid for a future reactor at the ESP site. Therefore, the GEIS generic conclusions are expected to remain valid for a future reactor at the ESP site.

Application Revision

None.

RAI E7.2-3

Section 7.2.2 Please provide an up-to-date, site-specific assessment of the adverse health effects from potential releases to groundwater, considering the ESP site parameters. Justify that the generic conclusion with respect to such matters that was reached in NUREG-1437 is valid for a future reactor at the ESP site.

Response

In NUREG-1437 (GEIS), North Anna is described as a "small river site" for groundwater pathway purposes. In Table 5.19, the site is compared with two basis studies on four factors: reactor size, distance to nearest downgradient surface water, on-site river flow rate, and downstream population at risk. From the study of the four factors, the GEIS observes that for some sites including the North Anna site, the risk from groundwater releases may be similar to that from atmospheric releases because of uncertainties and the unavailability of a site-specific liquid pathway study.

The projected individual reactor size for the ESP site would not exceed double the size for the two basis sites. The on-site river flow is much lower than for the basis sites. From Table 5.30 in the GEIS, the population at risk was estimated as less than 10,000. Population at risk for the two basis sites were on the order of four million, so that even if a very conservative doubling or tripling of the population at risk were to be projected, if would still be much less that the two acceptable basis sites. Only the relatively low distance to the nearest downgradient water is such as to introduce an uncertainty that adsorption cannot be relied upon to delay entry of radioisotopes into nearby surface water as a population groundwater pathway.

As described in the GEIS Supplement 7, regarding the existing units, the station is situated on a peninsula on the southern shore of Lake Anna, approximately 8 km (5 mi) upstream from the North Anna Dam. Lake Anna, a man-made reservoir, was created in 1971 by erecting a dam on the main stem of the North Anna River. The entire lake is approximately 13,000 acres of water surface. Lake Anna was created primarily as a source of cooling water for North Anna Power Station, although it has become a popular recreation area, while the dam provides downstream flood control. It is not used as a source of potable or industrial water. VEPCO owns the land, above and below the surface, around the lake, up to the expected 255-ft high-water mark above mean sea level. These factors will remain substantially the same over the period of interest here.

In the NRC report on the existing units' license renewal, it was noted that, with respect to groundwater use and quality, the staff has not identified any significant new information on this issue, and did not call into question the conclusions in NUREG-1437. Therefore the GEIS conclusion of small significance impact would remain.

The impact conclusion for the ESP site would be essentially the same, i.e., small significance. The factors contributing to this include: the very low population at risk, the very large dilution expected in the waters of Lake Anna, the fact that the lake itself is not used as a source of potable or industrial water; and even if necessary, the possibility of straightforward interdiction on use of the lake outflow stream (the North Anna River).

Application Revision

None.

RAI E7.2-4

<u>Section 7.2</u> Provide a site-specific analysis of the environmental consequences of a potential severe accident at a new reactor located on the ESP site using a Level 3 probabilistic risk assessment (PRA) consequence code such as the MACCS2 code. This could involve characterizing the spectrum of credible releases from candidate future plant designs, in terms of representative source terms and their respective frequencies, and using these release characteristics in conjunction with site-specific population and meteorology to determine site-specific risk impacts for the potential design. Release characteristics could be developed through a survey of severe accident analyses for previously certified advanced LWRs and/or operating reactors. The following information should be provided as part of this analysis:

a. a description of the computer code used as the basis for the calculations, including any modifications to the officially released version of the code, and important deviations from recommended or default code input values,

b. a description of the site-specific meteorology data used in the calculation, including the treatment of rain/precipitation events, and the degree to which the data represents or bounds year-to-year variations in weather at the ESP site,

c. a description of the site-specific population data used in the calculation, and justification that this data is representative of the time period through which new unit operations could extend,

d. a description of the major input assumptions for modeling economic impacts, including farm and non-farm values, evacuation costs, value of crops and milk contaminated or condemned, costs of decontamination of property, and costs associated with loss of use of property as a result of the accident (including contamination and condemnation of property),

e. a description of the protective actions considered in the evaluation, including criteria for sheltering and evacuation, criteria for interdiction and condemnation of property and/or crops, and the assumed level of medical support to aid the exposed population,

f. a description of the source terms used to represent the reference or surrogate plant design(s), including the radionuclide inventory and the release frequency and characteristics for each release category. These characteristics include release fractions for the major radionuclide groups, release times and durations, and elevation and energy of release,

g. the results of the calculations in terms of probabilistically-weighted population dose, early and latent fatalities, economic costs, and contaminated and condemned land areas, for the reference or surrogate plant design(s). Sufficient information should be provided to enable results to be displayed in a manner similar to later final environmental statements (FESs, e.g., Tables 5.10 through 5.13 in NUREG-0921), and

h. a listing of the input file for the ESP site (including weather data).

Response

a. The severe accident consequence analysis was calculated using the Level 3 probabilistic risk assessment (PRA) MACCS2 (Melcor Accident Consequence Code System) code. The analysis was performed with the MACCS2 version designated as Oak Ridge National Laboratory RSICC Computer Code Collection MACCS2 V.1.12, CCC-652 Code Package. MACCS2, Version 1.12 simulates the impact of severe accidents at nuclear power plants on the surrounding environment. The principal phenomena considered in MACCS2 are atmospheric transport, mitigating actions based on dose projections, dose accumulation by a number of pathways including food and water ingestion, early and latent health effects, and economic costs.

The basis model had no important deviations from the default code input values, except where site-specific values were required. The code values modified from the NAPS model for the future designs were those specific to that design and in the main are the source term data from their Level 2 probabilistic safety analyses. The respective reactor vendors provided the Level 2 data for the AP1000 and ABWR designs. This data includes the radionuclide inventory, power level, release fractions and corresponding frequencies, plume release start time, plume release height, delay and duration. Values for the ATMOS input data file (one of the five input files used by MACCS2) was modified as necessary to use data appropriate for the ABWR or AP1000 source terms and probability frequencies (Refer to the response to part f.). The remaining four input files were taken from the MACCS2 analysis used to support the North Anna License Renewal Application. The NRC staff approved the North Anna analysis in NUREG-1437, Supplement 7.

Three years (1996 -1998) of site-specific hourly meteorological data were used in the analyses. Three consecutive years are considered to be a representative set of data for the site and represents a reasonable bound of year-to-year variations at the ESP site. The 1998 dataset was used as the base case. The 1996 and 1997 datasets were used for sensitivity analysis.

The hourly data (wind direction, wind speed, stability category, and precipitation) were collected on-site at the North Anna Power Station met tower. The wind direction and wind speed were recorded at vent height (tower upper elevation), the stability data were determined by a Delta T system measuring the temperature at 10 meters and at vent height, and precipitation was measured at ground level. The instruments were calibrated quarterly. The data were temporarily stored at the site in dataloggers which were polled nightly to transfer the data to a personal computer at a corporate technical support center. The data were quality controlled each business day by the Dominion personnel. Professional meteorologists resolved any unusual data situations. Each month, the data were transferred to the corporate mainframe computer and were converted to and stored in SAS datasets. SAS programs were written to produce the hourly data files in MACCS2 format for the NMET input data file.

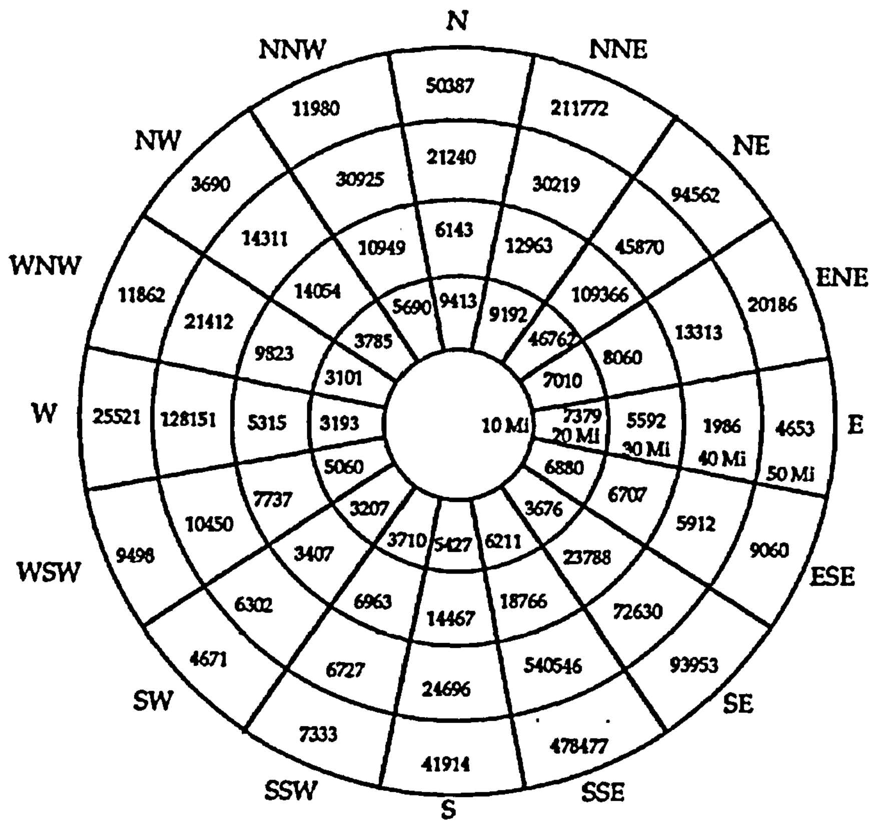
Morning and afternoon mixing height values for 1996 through 1998 were obtained from the National Climatic Data Center. The mixing height data were derived from radiosonde measurements taken by the National Weather Service at their station near Dulles Airport (Sterling, Virginia). Dulles Airport is the nearest inland upper air station to North Anna. Missing values were replaced where possible as prescribed by Reference 1. All non-missing values greater than zero were considered valid.

MACCS2 calculations examine a representative subset of the 8,760 hourly observations contained in one year's data set (typically about 150 sequences). The representative subset is selected by sampling the weather sequences after sorting them into weather bins defined by wind speed, atmospheric stability, and rain conditions at various distances from the site. The treatment of rain/precipitation events follows the default recommend parameter values given in the ATMOS file supplied with the MACCS2 code.

c. The population distribution and land use information for the region surrounding the ESP site are specified in the SITE input data file. Contained in the SITE input data file are the geometry data used for the site (spatial intervals and wind directions), population distribution, fraction of the area that is land, watershed data for the liquid pathways model, information on agricultural land use and growing seasons, and regional economic information. Some of the detailed data in this input file supercedes certain data in the EARLY input data file.

Much of the data was initially prepared by the computer program SECPOP90 (Reference 2). This code contains a database extracted from Bureau of the Census PL 94-171 (block level census) CD-ROMS, the 1992 Census of Agriculture CD ROM Series 1B, the 1994 US Census County and City Data Book CD-ROM, the 1993 and 1994 Statistical Abstract of the United States, and other appropriate sources. The reference contains details on how its database was created and checked. The output from SECPOP90 is a data file in the MACCS2 SITE input data file format based on the data in its reference database for the specified site.

The ESP site is located within the boundary of the existing NAPS site (ER Section 2.1.1.1). A 50-mile radius area around the site was divided into sixteen directions that are equivalent to a standard navigational compass rosette. This rosette was further divided into inner radial rings, each with sixteen azimuthal sections. A picture of the rosette for 50-mile radii is shown below.



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The SECPOP90-prepared data was modified for license renewal and updated using the NAPS UFSAR Section 2.1.3 50-mile population distribution for the year 2030, in place of the 1990 Census SECPOP90 data. This data is appropriate for this evaluation. It was approved for the 50-mile population for the middle year of the license renewal period in accordance with Year 2030 projections in the GEIS (NUREG-1437) Table 5.3 and the GEIS Supplement 7 Table 2-10.

In addition, given that Year 2040 50-mile projections for new unit operation are within reasonable population growth curves, and overlap middle year extended operation of the existing units, it was decided to utilize existing analysis SITE data with new unit source term inputs to compare consequences. This methodology reduced variability from additional projections and justified a closer unit-to-unit comparison.

d. Land use statistics including farmland values, farm product values, dairy production, and growing season information were provided on a countywide basis within 50 miles.

Much of the data was prepared by utilizing SECPOP90 previously described. The SECPOP90 regional economic values were updated to 1999 using cost of living and other data from the Bureau of the Census and the Department of Agriculture. Agricultural data was taken from the 1997 Census of Agriculture (Reference 3). This was accomplished by replacing the SECPOP90 data for the counties within the 50-mile radius by the 1997 value. That is, the SECPOP90 county database was modified so that the results produced by the code were correctly assigned to the various economic regions.

Economic costs data used in the CHRONC input data file were the recommended MACCS2 values as given for the NUREG-1150 study, updated using recent Consumer Price Indexes (CPI) from the Bureau of Labor. NUREG-1150 used economic values that were based on 1986 consumer price index. The CPI values of 108.9 for 1986 and 127.9 for 1990 were obtained. Therefore, the unit costs from NUREG-1150 have been multiplied by a factor of (127.9/108.9 =) 1.17 to represent revised North Anna region values.

Additionally, a value for the CPI of 158.9 for 1998 was obtained from Reference 4. Sensitivity unit costs from Reference 5 have been multiplied by a factor of (158.9/108.9 =) 1.46 to represent current North Anna region values.

Data utilized for this file were not modified for ESP analysis.

e. The EARLY module of the MACCS2 code models the time period immediately following a radioactive release. This period is commonly referred to as the emergency phase. It may extend up to one week after the arrival of the first plume at any downwind spatial interval. The subsequent intermediate and long-term periods are treated by CHRONC module of the code. In the EARLY module the user may specify emergency response scenarios that include evacuation, sheltering, and dose-dependent relocation. The EARLY module has the capability for combining results from up to three different emergency response scenarios. This is accomplished by appending change records to the EARLY input data file. The first emergency-response scenario is defined in the main body of the EARLY input data file. Up to two additional emergency-response scenarios can be defined through change record sets positioned at the end of the file.

The emergency evacuation model has been modeled as a single evacuation zone extending out 10 miles from the site. The average evacuation speed is estimated to be on the order of 4 mph (1.8 m/s). For the purposes of this analysis an average evacuation speed of 1.8 m/s is used with a 7200 second delay between the alarm and start of evacuation, with no sheltering for the base case.

Overall results were not sensitive to variations in the emergency evacuation model. Data utilized for this file were not modified for ESP analysis.

f. The ATMOS input data file calculates the dispersion and deposition of material released "source terms" to the atmosphere as a function of downwind distance. Source term release fractions (RELFRC) for the ABWR and AP1000 are shown below, as are plume characterizations, respectively.

The ABWR shows 10 different source term categories (STCs). See Table 1. The release times and durations, and elevation and energy of release for the ABWR were extracted from the GE ABWR licensing submittal document. Parameters are assigned to each source term according to STC number. Each release plume is assumed to have only one segment. See Table 2.

The scaling factor (CORSCA) was used to adjust the ABWR core inventory for a power level of 4300 MWt. The core inventory was based on the discharge exposure burnup of 35,000 MWD/MT.

The reactor vendor provided the Level 2 data. This data includes the source term inventory, power level, release fractions, plume start time, plume release height, delay and duration. The vendor also provided the AP1000 radionuclide inventory, as well as source term category release fractions and corresponding frequencies for the MACCS2 element groups. Four plume segments of release fraction data were originally reported, but were collapsed to two in order to satisfy the limitations of the MACCS2 Version 1.12 code. Shown in the table below are the collapsed source term release fractions for 7 different source term categories (STCs). See Table 3.

Timing data indicated in the table below was also revised to represent two plume segments. A plume energy level 3.0E+06 W was assigned to the first plume and 2.0E+06 W for the second plume except for the bypass sequence. The plume release height was selected to be 30 meters, which is similar to the North Anna license renewal Level 3 calculation completed in 2000. The ALARM time was selected to be the same as the first plume DELAY time. The balance of the timing data of each plume are taken from the Westinghouse PRA Study document. See Table 4.

The scaling factor (CORSCA) used to adjust the AP1000 core inventory for power level was (3415/3412 =) 1.00. This was determined due to the base 3412 MWt MACCS2 pressurized water reactor default inventory and the actual AP1000 thermal power rating of 3415 MWt.

g. The results of the dose and dollar risk assessments for the Base Case calculations for the AP1000 and ABWR plant designs are provided in Table 5. Risk is defined in these results as the product of source term category frequency and the dose or cost associated with the STC. Although each STC reflects a different release scenario and only one at a time would normally be hypothesized, the total risk is conservatively assumed to be the sum of all scenarios. Also, since the AP1000 and ABWR plant designs reflect different release/source term categories, use of the total/summed risk provides a common reference point.

The maximum dose risk sensitivity to the meteorological data was shown to differ by approximately 11% from the Base Case for both the AP1000 and ABWR plant designs. A similar sensitivity to the meteorological data was seen for the dollar risk.

The Base Case mean values for affected land areas are shown in Table 5. The mean values for affected land areas are given in hectares and are not totaled for all STCs. Instead, the values reflect the maximum area associated with the worst-case single release scenario.

The values for total early and latent fatalities per year were conservatively calculated as the sum of all release scenarios/STCs.

Tables 6, 7, and 8 support the calculated dose/year and dollars/year risks for both advanced reactor designs presented in Table 5.

As can be seen from the above tables and results, consequences from severe accidents from the two advanced reactor designs are products of significantly lower risk factors when compared to existing plant inputs. This is consistent with GEIS findings for existing plants that risk impacts from severe accidents would be small.

h. The input file for the ESP site MACCS2 code run is provided on CD-ROM (enclosed).

References:

1. USEPA document "Procedures for Substituting Values for Missing NWS Meteorological Data for Use in Regulatory Air Quality Models," July 7, 1992.
2. NUREG/CR-6525, "SECPOP90: Sector Population, Land Fraction, and Economic Estimation Program," U. S. Nuclear Regulatory Commission, S. L. Humphreys, et al., September, 1997."
3. 1997 Census of Agriculture," U.S. Department of Agriculture, National Agricultural Statistics Service.
4. "Consumer Price Index-All Urban Consumers ", U. S. Bureau of Labor, Series Catalog: Series ID: CUUR0300SA0, 1999.

5. NUREG/CR-4557, "Evaluation of Severe Accident Risks: Quantification of Major Input Parameters MACCS Input," U. S. Nuclear Regulatory Commission, J. L. Sprung, et al., Vol. 2, Rev. 1., Part 7, December 1990.

Application Revision

None.

Table 1. ABWR Source Term Release Fractions									
Source Term Category	Xe/Kr	I-Br	Cs-Rb	Te-Sb	SR	Co-Mo	LA	CE	BA
0	4.40E-02	2.30E-05	2.30E-05	5.30E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1	1.00E+00	1.50E-07	1.30E-05	3.10E-04	6.30E-06	2.40E-11	7.90E-08	7.90E-08	6.30E-06
2	1.00E+00	5.00E-06	5.00E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3	1.00E+00	2.80E-04	2.20E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	1.00E+00	1.60E-03	1.60E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5	1.00E+00	6.00E-03	5.30E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6	1.00E+00	3.10E-02	7.70E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7	1.00E+00	8.90E-02	9.90E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
8	1.00E+00	1.90E-01	2.50E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
9	1.00E+00	3.70E-01	3.60E-01	1.10E-03	9.30E-03	9.20E-08	2.80E-03	2.80E-03	9.30E-03

Table 2. ABWR Plume Characterization Data								
STC	OALARM (S)	NUMREL	MAXRIS	REFTIM (s)	PLHEAT (w)	PLHITE (m)	PLDUR (s)	PDELAY (s)
0	6120.0	1	1	0.0	1.38E+6	37.7	36000.0	9720.0
1	69120.0	1	1	0.0	1.38E+6	37.7	3600.0	72000.0
2	65520.0	1	1	0.0	1.38E+6	37.7	3600.0	68400.0
3	177120.0	1	1	0.0	1.38E+6	37.7	36000.0	180000.0
4	69120.0	1	1	0.0	1.38E+6	37.7	3600.0	72000.0
5	65520.0	1	1	0.0	1.38E+6	37.7	3600.0	68400.0
6	65520.0	1	1	0.0	1.38E+6	37.7	36000.0	68400.0

Table 2. ABWR Plume Characterization Data								
STC	OALARM (S)	NUMREL	MAXRIS	REFTIM (s)	PLHEAT (w)	PLHITE (m)	PLDUR (s)	PDELAY (s)
7	69120.0	1	1	0.0	1.38E+6	37.7	36000.0	72000.0
8	4320.0	1	1	0.0	4.19E+6	37.7	36000.0	7200.0
9	43920.0	1	1	0.0	1.38E+6	37.7	36000.0	84960.0

Table 3. AP1000 Collapsed Source Term Release Fractions									
Source Term Category	Noble Gases	I	CS	TE	SR	RU	LA	CE	BA
CFI	7.98E-01	3.33E-03	3.32E-03	4.35E-04	2.18E-02	9.28E-03	8.06E-03	4.32E-05	1.65E-02
	1.22E-01	0.00E+00	0.00E+00	6.04E-06	0.00E+00	0.00E+00	1.12E-02	4.06E-05	0.00E+00
CFE	8.21E-01	5.66E-02	5.49E-02	1.39E-03	3.48E-03	1.42E-02	6.54E-05	1.00E-06	5.28E-03
	1.42E-01	0.00E+00	0.00E+00	6.04E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DIRECT	4.43E-03	3.61E-05	3.46E-05	2.42E-06	3.22E-05	3.94E-05	4.06E-06	1.76E-08	3.61E-05
	3.50E-03	0.00E+00	0.00E+00	5.44E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
IC	1.48E-03	1.20E-05	1.15E-05	8.09E-07	1.07E-05	1.31E-05	1.36E-06	5.88E-09	1.20E-05
	1.17E-03	0.00E+00	0.00E+00	1.81E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BP	1.00E+00	2.15E-01	1.96E-01	9.84E-03	3.57E-03	4.48E-02	1.30E-04	3.19E-06	8.93E-03
	0.00E+00	2.34E-01	7.60E-02	6.89E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E-06
CI	6.86E-01	4.56E-02	2.10E-02	1.65E-03	2.03E-02	4.04E-02	2.39E-04	2.97E-06	3.16E-02
	8.40E-02	0.00E+00	0.00E+00	9.37E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CFL	1.53E-03	1.21E-05	1.15E-05	1.02E-06	1.67E-05	1.71E-05	1.17E-05	4.79E-08	1.68E-05
	9.79E-01	2.13E-05	1.19E-05	3.67E-05	2.83E-03	1.42E-03	1.41E-01	5.34E-04	2.60E-03

Table 4. AP1000 Collapsed Plume Characterization Data								
STC	OALARM (S)	NUMREL	MAXRIS	REFTIM (s)	PLHEAT (w)	PLHITE (m)	PLDUR (s)	PDELAY (s)
CFI	2924	2	1	0.0	3.0E+6	30	36000	2924
				0.5	2.0E+6	30	36000	32590
CFE	3004	2	1	0.0	3.0E+6	30	36000	3004.
				0.5	2.0E+6	30	36000	19810.
DIRECT	4378.	2	1	0.5	3.0E+6	30	36000	4378.
				0.0	2.0E+6	30	36000	84810.
IC	4378.	2	1	0.5	3.0E+6	30	36000	4378.
				0.0	2.0E+6	30	36000	84810.
BP	31890.	2	1	0.5	3.0E+6	30	36000	31890.
				0.0	3.0E+6	30	36000	46440.
CI	100.8	2	1	0.5	3.0E+6	30	36000	100.8
				0.5	2.0E+6	30	36000	50020.
CFL	2922.	2	1	0.5	3.0E+6	30	36000	2922.
				0.5	2.0E+6	30	36000	26360.

Table 5. Results Summary Comparison of Plant Designs (0-50 Mile Radius from the ESP Site)

Plant Design	Dose Risk (Person-Rem/Year)	Dollar Risk (Per Year)	Affected Land (in Hectares)	Fatalities Per Year	
				Early	Latent
AP1000	.08	147.0	199,700	1.24E-10	4.02E-05
ABWR	.006	11.1	174,480	2.40E-11	2.65E-06

Table 6. AP1000 Mean Value for Total Dose Risk Assessment (Person-Rem/year)

Release Category	Release Category Annual Frequency	CASE1A 98 Met Data	CASE2A 97 Met Data	CASE3A 96 Met Data
CFI	1.89E-10	3.38E-04	2.95E-04	3.21E-04
CFE	7.47E-09	1.88E-02	1.78E-02	1.79E-02
IC	2.21E-07	1.05E-03	8.64E-04	9.83E-04
BP	1.05E-08	5.96E-02	5.17E-02	5.79E-02
CI	1.33E-09	2.97E-03	2.67E-03	2.94E-03
CFL	3.45E-13	9.66E-07	8.87E-07	9.32E-07
Total	**All**	**8.28E-02**	**7.33E-02**	**8.00E-02**

Table 7. ABWR Mean Value for Total Dose Risk Assessment (Person-Rem/year)				
STC	**STC ANNUAL FREQUENCY**	**CASE1A 98MET**	**CASE2A 97MET**	**CASE3A 96MET**
0	1.34E-07	1.05E-03	8.78E-04	9.97E-04
1	2.08E-08	2.16E-04	1.84E-04	1.99E-04
2	1.00E-10	5.62E-07	4.75E-07	5.18E-07
3	1.00E-10	4.47E-05	3.79E-05	4.22E-05
4	1.00E-10	3.39E-05	2.90E-05	3.11E-05
5	1.00E-10	1.43E-05	1.21E-05	1.32E-05
6	1.00E-10	2.81E-04	2.64E-04	2.71E-04
7	3.91E-10	1.26E-03	1.17E-03	1.18E-03
8	4.05E-10	1.96E-03	1.82E-03	1.87E-03
9	1.70E-10	1.06E-03	9.64E-04	1.02E-03
Total	**All**	**5.93E-03**	**5.36E-03**	**5.63E-03**

Table 8. Dollar Risk Assessment (Dollars/year)				
Design	**Release Category**	**CASE1A 98 Met Data**	**CASE2A 97 Met Data**	**CASE3A 96 Met Data**
AP1000	All	1.47E+02	1.27E+02	1.43E+02
ABWR	All	1.11E+01	9.83E+00	1.05E+01

RAI E7.2-5

Section 7.2 Provide a comparison of the (probabilistically weighted) environmental risk of severe accidents for a future reactor at the ESP site with:

a. the risks (doses) associated with normal and anticipated operational releases from a future reactor at the ESP site, and

b. the risk of severe accidents for the current generation of operating plants (at their respective sites), as characterized in such studies as NUREG-1150, *Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants,* and the plant-specific risk study for North Anna Power Station, Units 1 and 2.

Response

a. As stated in ER Sections 5.4.1.3 through 5.4.3, advanced reactor designs are expected to provide shielding at least as effective as existing light water reactors, and the "direct dose contribution from the new units would be negligible". In addition, the total site "effluent doses from the two existing units and two new units would be well within the regulatory limits". The maximum activity for each isotope in the PPE was used to calculate bounding activities and doses. The calculated maximum annual dose of 8.4 mrem that would be received from normal operation by a maximally exposed individual are conservative and would not represent actual doses near the ESP site.

A 50-mile total population dose consequence for a single unit's annual operation was calculated to be 31 rem (Table 5.4-12). This was a deterministic calculation for normal operation, which would include an expected continuous release. A 50-mile total population dose consequence for a single unit's "intact containment" severe accident analysis was calculated to be 473 rem (based on an AP1000 MACCS2 code run). This was a probabilistic calculation that would include an anticipated short-term release.

b. The mean annual environmental dose risk from severe accidents for several reactor sites is compared in Table 1. The table includes results from NUREG-1150 (Zion, Grand Gulf, and Surry), the existing North Anna Units 1 and 2, and two new reactor designs (AP1000 and ABWR) at the ESP site. These results are probabilistically weighted. The data in Table 1 show that the environmental dose risk of severe accidents for the two new reactor designs at the ESP site is significantly lower than for current design reactors.

Table 1. Mean Annual (Dose) Risk for Several Sites and Reactors	
Plant	Population Dose (50-mile) (person-rem/year)
Zion (Reference 1)	5.47E+01
Grand Gulf (Reference 2)	5.2E-01
Surry (Reference 3)	6.E+00
North Anna	2.51E+01
AP1000	8.28E-02
ABWR	5.93E-03

References:

1. NUREG/CR-4551, "Evaluation of Severe Accident Risks: Zion, Unit 1," U. S. Nuclear Regulatory Commission, Table 5.1-1, Vol. 7, Rev.1, Part 1, March 1993.
2. NUREG/CR-4551, "Evaluation of Severe Accident Risks: Grand Gulf, Unit 1," U. S. Nuclear Regulatory Commission, Table 5.1-1, Vol. 6, Rev.1, Part 1, December 1990.
3. NUREG-1150, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants Final Summary Report," U. S. Nuclear Regulatory Commission, Table 12, Vol. 1, December 1990.

Application Revision

None.

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