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MFN 09-786, Supplement 1

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Subject: **Partial Response (Part 2) to NRC Request for Additional Information Letter No. 394 Related to ESBWR Design Certification Application – Dose Rates – RAI Number 12.2-28**

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) partial response to the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) 12.2-28, sent by NRC Letter No. 394, Reference 1.

GEH partial response to RAI 12.2-28 is provided in Enclosure 1. Note that this letter provides a partial response to Question 2, only, of the RAI. The response to all other questions in the RAI was provided by GEH via Reference 2. A forthcoming partial response (Part 3 to RAI 12.2-28) will provide the remainder of GEH's response to question 2.

Enclosure 2 contains the DCD markups associated with this response.

If you have any questions or require additional information, please contact me.

Sincerely,

Richard E. Kingston

Richard E. Kingston
Vice President, ESBWR Licensing

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NRO

References:

1. MFN 09-744, Letter from U.S. Nuclear Regulatory Commission to Jerald G. Head, *Request for Additional Information Letter No. 394 Related to ESBWR Design Certification Application*, November 24, 2009
2. MFN 09-786, Partial Response to NRC Request for Additional Information Letter No. 394 Related to ESBWR Design Certification Application – Dose Rates – RAI Number 12.2-28, December 14, 2009

Enclosures:

1. Partial Response (Part 2) to NRC Request for Additional Information Letter No. 394 Related to ESBWR Design Certification Application – Dose Rates – RAI Number 12.2-28
2. Partial Response (Part 2) to NRC Request for Additional Information Letter No. 394 Related to ESBWR Design Certification Application – Dose Rates – RAI Number 12.2-28 – DCD Markups

cc: AE Cubbage USNRC (with enclosures)
JG Head GEH/Wilmington (with enclosures)
DH Hinds GEH/Wilmington (with enclosures)
TL Enfinger GEH/Wilmington (with enclosures)
eDRF Section 0000-0110-8336 (Part 1 of response, for reference)
0000-0112-1250 (Part 2 of response)

Enclosure 1

MFN 09-786, Supplement 1

Partial Response (Part 2) to NRC Request for Additional Information Letter No. 394 Related to ESBWR Design Certification Application

Dose Rates

RAI Number 12.2-28

NRC RAI 12.2-28

Section 12.2 of the Tier 2 FSAR, "Plant Sources," states in part:

"Airborne sources are calculated using the source terms given in Section 11.1. . . ."

Table 11.1-3 was revised in Revision 6 of the Tier 2 FSAR to indicate that the ratio of condensate demineralizer flow to steam flow is 66.3%, versus the previous 100%. The staff was unable to determine the specific rationale for the change.

The staff noted that this change appears to result in greater buildup of radionuclides in liquid inventory, instantaneous liquid effluent release rates, and other aspects of plant operation potentially affecting worker and public dose. However, there did not appear to be a corresponding analysis of the change in dose estimations, in particular regarding whether and to what extent the radionuclide concentrations as listed in Tables 11.1-4a through 11.1-7b would be affected by the change in the ratio of condensate demineralizer versus steam flow rate. The staff needs to evaluate the effect on release rates and dose.

Please explain:

1. *The rationale that addresses the change in the ratio of condensate demineralizer flow to steam flow.*

2. *The effects on liquid and gaseous concentrations in systems and effluents, including any changes in public and population dose, and dose to the maximally exposed individual.*

3. *The interaction between the design basis and normal source term values in Section 11.1, and the doses listed in Section 12.2.*

4. *The effect of the changes to system radionuclide inventory on sources of in-plant exposure as described in Section 12.2.*

5. *Any implications for radiation protection design considerations (section 12.1.2 of the Tier 2 FSAR). The changes made to Table 11.1-3 appear to have resulted in increases in most or all of component activities listed in Tables 12.2-6 through 12.2-14. For <u>each</u> of these radioactive components,*

    a. *Verify that you have performed a detailed analysis on the affected components to determine the effects of the increased component activity on the expected component dose rates.*

    b. *Describe what effect the increase in component activity has on the dose rate levels and radioactive zone designations in the vicinity of <u>each of these components</u> (provide verification for your response) and reference*

appropriate Section 12.3 plant layout figures where radiation zone increases have been made.

c. *Describe what effect the increase in component activity will have on the doses to personnel performing maintenance on these components (in particular, describe how the doses associated with liquid and solid waste handling operations (such as condensate demineralizer maintenance) will be affected).*

d. *Describe what effect the potential increase in component doses will have on the total plant collective dose described in DCD Tables 12.4-1 through 12.4-7.*

e. *In describing the basis of the dose assessment for the ESBWR design, Section 12.4 of the DCD states the dose rates listed in Tier 2 Tables 12.4-2 through 12.4-7 are based on a combination of ESBWR radiation zoning levels and "experiential" data based on previous and current BWR plant designs. RG 8.19, "Occupational Radiation Dose Assessment in Light Water Reactor Power Plants- Design Stage Man-Rem Estimates" states that "to the extent possible, estimates should include consideration of the design of the proposed plant, including radiation field intensities calculated on the basis of the plant-specific shielding design, taking into account the effect of any dose-reducing design changes." Describe to what extent the estimated average dose rates listed in Tier 2 Tables 12.4-2 through 12.4-7 are based on the actual estimated ESBWR radiation zoning levels as depicted in Tier 2 Figures 12.3-1 through 12.3-22 and provide representative examples from Tables 12.4-2 through 12.4-7 where actual estimated ESBWR dose rates are used.*

In reviewing Tier 2 Section 12.4 of Revision 6 of the DCD, the staff noted that there are several references to the fact that 100% of the condensate water will be processed through the demineralizer instead of the 66.3% as listed in revised (Revision 6) Tier 2 Table 11.1-3.

6. *Modify the following sections of Tier 2 Section 12.4 to reflect the revised condensate cleanup percentage as reflected in Tier 2 Table 11.1-3:*

   (Section 12.4.6, paragraph 4 of "Drywell" section) "In addition, deposited activity in the feedwater lines is expected to be lower than typical BWRs owing to an enhanced condensate system with full cleanup of all condensate water ..."

   (Section 12.4.6, paragraph 4 of "Turbine Building" section) "Low-pressure feedwater drains from the feedwater heaters are cascaded back to the condenser, thus, all corrosion products from these drains are filtered via condensate filter/demineralizers before returning to the RPV."

GEH Partial Response

Note: The response to all questions other than question 2 of this RAI was provided in Letter MFN 09-786, dated December 14, 2009.

Question/Comment:
2. The effects on liquid and gaseous concentrations in systems and effluents, including any changes in public and population dose, and dose to the maximally exposed individual.

Response:

The effects on the liquid concentrations were incorporated in DCD Revision 6 Tables 11.1-4a through 11.1-5b, 11.1-7a, and 11.1-7b. The effects on liquid releases and dose results were incorporated in DCD Revision 6 Tables 12.2-19b and 12.2-20b respectively.

As a result of changes in the reactor coolant design basis concentrations, the ESBWR long-term dispersion estimates (X/Q and D/Q) were revised to ensure 10 CFR 50 Appendix I dose limits were not exceeded. The effect of the changes to the X/Q and D/Q values is shown in the updated DCD Tables 2.0-1 and 12.2-15.

Additionally the text in DCD Subsection 12.2.2.1 is revised to clarify that the X/Q and D/Q values simply bound a significant majority of the compiled data points for the evaluated locations. A sentence is also added to emphasize the need for a specific site to use its site-specific values in the determination of airborne dose evaluations.

The revised offsite gaseous effluent releases are shown in Table 12.2-16.

The revised airborne releases and concentration values are shown in Table 12.2-17.

The revised annual average doses from airborne releases are shown in Table 12.2-18b.

The verified changes to building airborne radioactivity concentrations in DCD Tables 12.2-23a through 12.2-23e will be provided to the NRC in an additional partial response (Part 3), which will complete the response to this RAI.

DCD Impact

DCD Tier 2, Table 2.0-1 will be revised (Revision 7) as noted in the attached markup.

DCD Tier 2, Subsection 12.2.2.1 will be revised (Revision 7) as noted in the attached markup.

DCD Tier 2, Tables 12.2-15 through 12.2-17 and 12.2-18b will be revised (Revision 7) as noted in the attached markups.

Enclosure 2

MFN 09-786, Supplement 1

Partial Response (Part 2) to NRC Request for Additional Information Letter No. 394 Related to ESBWR Design Certification Application

Dose Rates

RAI Number 12.2-28

DCD Markups

Table 2.0-1

Envelope of ESBWR Standard Plant Site Parameters[1] (continued)

Meteorological Dispersion (X/Q): [11] ***(continued)***	*Fuel Building*		
	0-2 hours:	*2.80E-03 s/m³*	*2.80E-03 s/m³*
	2-8 hours:	*2.50E-03 s/m³*	*2.50E-03 s/m³*
	8-24 hours:	*1.25E-03 s/m³*	*1.25E-03 s/m³*
	1-4 days:	*1.10E-03 s/m³*	*1.10E-03 s/m³*
	4-30 days:	*1.00E-03 s/m³*	*1.00E-03 s/m³*
* *First value is for unfiltered inleakage. Second value is for air intakes (emergency and normal)*	*Technical Support Center X/Q:**		
	Reactor Building		
	0-2 hours:	*1.00E-03 s/m³*	*1.00E-03 s/m³*
	2-8 hours:	*6.00E-04 s/m³*	*6.00E-04 s/m³*
	8-24 hours:	*3.00E-04 s/m³*	*3.00E-04 s/m³*
	1-4 days:	*2.00E-04 s/m³*	*2.00E-04 s/m³*
	4-30 days:	*1.00E-04 s/m³*	*1.00E-04 s/m³*
	Turbine Building		
	0-2 hours:	*2.00E-03 s/m³*	*2.00E-03 s/m³*
	2-8 hours:	*1.50E-03 s/m³*	*1.50E-03 s/m³*
	8-24 hours:	*8.00E-04 s/m³*	*8.00E-04 s/m³*
	1-4 days:	*6.00E-04 s/m³*	*6.00E-04 s/m³*
	4-30 days:	*5.00E-04 s/m³*	*5.00E-04 s/m³*
	Passive Containment Cooling System / Reactor Building Roof		
	0-2 hours:	*2.00E-03 s/m³*	*2.00E-03 s/m³*
	2-8 hours:	*1.10E-03 s/m³*	*1.10E-03 s/m³*
	8-24 hours:	*5.00E-04 s/m³*	*5.00E-04 s/m³*
	1-4 days:	*4.00E-04 s/m³*	*4.00E-04 s/m³*
	4-30 days:	*3.00E-04 s/m³*	*3.00E-04 s/m³*
Long Term Dispersion Estimates: [12]	***X/Q:***		
	Reactor/Fuel Building Ventilation Stack	~~*3.0E-07*~~***1.5E-07*** *s/m³*	
	Turbine Building Ventilation Stack	~~*2.0E-07*~~***1.2E-07*** *s/m³*	
	Radwaste Building Ventilation Stack	~~*2.0E-05*~~***5.0E-06*** *s/m³*	
	D/Q:		
	Reactor/Fuel Building Ventilation Stack	~~*1.0E-08*~~***4.8E-09*** *m⁻²*	
	Turbine Building Ventilation Stack	~~*6.0E-09*~~***3.5E-09*** *m⁻²*	
	Radwaste Building Ventilation Stack	~~*3.0E-08*~~***1.9E-08*** *m⁻²*	

Post-Accident Radioactive Sources

Potential releases in the RW are contained by isolating the RW atmosphere and sealing any water releases in the building. The RW is seismically designed in accordance with Regulatory Guide 1.143 and the tank area concrete is provided with a sealant and a steel liner, as described in Subsection 11.2.2.3.2, to prevent any potential water releases from high activity areas.

12.2.1.5 Other Contained Sources

The COL Applicant will address any additional contained radiation sources (including sources for instrumentation and radiography) not identified in Subsection 12.2.1. (COL 12.2-4-A)

12.2.2 Airborne and Liquid Sources for Environmental Consideration

This subsection deals with the models, parameters, and sources required to evaluate the airborne concentration of radionuclides during plant operations in various plant radiation areas where personnel occupancy is expected. This subsection also deals with the sources and parameters required to evaluate airborne and liquid releases during normal plant operation for compliance with 10 CFR 20 and 10 CFR 50, Appendix I criteria.

12.2.2.1 Airborne Releases Offsite

Airborne sources are calculated using the source terms given in Section 11.1.

The bases for these calculations are shown in Table 12.2-15.

The ESBWR standard design employs three ventilation stacks (airborne release points). Individual stacks service the ventilation flows from the RB/FB, the TB and the RW. The offsite airborne release analysis of the ESBWR ventilation stack design employs separate long term atmospheric dispersion (X/Q) and deposition (D/Q) parameter values for each release location. The specific values for these parameters are shown in Table 12.2-15 and were determined by performing an analysis of available meteorological data for 25 ~~sites~~ locations evaluated for the ABWR program and two existing nuclear power plant sites. The meteorological data were used to generate X/Q and D/Q parameters for the each of the described release points using the XOQDOQ computer code (NUREG/CR-2919 – Reference 12.2-5). The atmospheric dispersion X/Q and D/Q parameters were generated for each of the 27 ~~sites~~ locations assuming an 800 meter exclusion area boundary (site boundary). The values shown in Table 12.2-15 ~~were then selected to~~ bound (i.e., ~~were~~ are greater than) ~~at least 97%~~ a significant majority of the maximum generated X/Q and D/Q parameters for all the evaluated ~~sites~~locations. Because the 27 locations represent a sampling of geographic areas, site-specific X/Q and D/Q are to be used for airborne dose evaluations at a specific site.

The subject X/Q and D/Q values in Table 12.2-15 are used in the calculation of the gaseous effluent normal operation doses in Table 12.2-18b. Calculation of site-specific doses is discussed in Subsection 12.2.2.2.

Table 12.2-15 contains values used in calculating the annual airborne release source term provided in Table 12.2-16. Design basis noble gas, iodine, and other fission product concentrations are taken from the tables in Chapter 11. The methodology of NUREG-0016 was used in determining the annual airborne release values in Table 12.2-16. Specific details and information on the derivation of the airborne source terms are provided in Appendix 12B.

Table 12.2-15

Airborne Sources Calculation

Calculation Bases	
Methodology	Appendix 12B
Noble Gas Source at t=30 min	740 MBq/sec (20,000 μCi/sec)
I-131 Release Rate	3.7 MBq/sec (100 μCi/sec)
Meteorology Boundary	800 Meters
Meteorology χ/Q	
RB/FB Ventilation Stack	~~3.0E-07~~1.5E-07 s/m^3
TB Ventilation Stack	~~2.0E-07~~1.2E-07 s/m^3
RW Ventilation Stack	~~2.0E-05~~5.0E-06 s/m^3
Meteorology D/Q	
RB/FB Ventilation Stack	~~1.0E-08~~4.8E-09 m^{-2}
TB Ventilation Stack	~~6.0E-09~~3.5E-09 m^{-2}
RW Ventilation Stack	~~3.0E-08~~1.9E-08 m^{-2}
Plant Availability Factor	0.92
Offgas System:	
Offgas stream temperature	100°F
Flow rate at 100°F	54 m^3/hr
K_d (Kr)	18.5 cm^3/g
K_d (Xe)	330 cm^3/g
K_d (Ar)	6.4 cm^3/g
Guard tank charcoal mass	7,500 kg (single tank)
Adsorber tank charcoal mass	27,750 kg (each)
Adsorber tank arrangement	2 parallel trains of 4 tanks each
Turbine Gland Sealing System Exhaust:	
I-131 release	0.81 Ci/yr per μCi/g of I-131 in coolant
I-133 release	0.22 Ci/yr per μCi/g of I-133 in coolant

Table 12.2-16

Annual Airborne Releases for Offsite Dose Evaluations (MBq)**

Nuclide*	Reactor Building	Turbine Building	Radwaste Building	Mechanical Vacuum Pump	Turbine Seal	Offgas System	Drywell
Kr-83m						1.4E-04	8.5E+01
Kr-85m	9.0E+04	5.6E+05				6.6E+03	3.4E+02
Kr-85						5.2E+06	7.5E+01
Kr-87	4.5E+04	1.4E+06				8.5E-10	3.1E+02
Kr-88	9.0E+04	2.0E+06				1.4E+01	6.9E+02
Kr-89	4.5E+04	1.3E+07	6.5E+05				8.3E+01
Xe-131m						1.5E+05	4.1E+01
Xe-133m						8.1E-01	1.9E+02
Xe-133	2.5E+06	3.4E+06	5.0E+06	2.9E+07		8.5E+05	1.1E+04
Xe-135m	1.4E+06	9.0E+06	1.2E+07				8.5E+01
Xe-135	2.9E+06	7.4E+06	6.3E+06	1.1E+07		4.4E-37	2.6E+03
Xe-137	4.1E+06	2.3E+07	1.9E+06				1.2E+02
Xe-138	1.8E+05	2.3E+07	4.5E+04				2.7E+02
I-131	2.0E+039.4E+02	1.1E+045.2E+03	7.0E+023.4E+02	3.9E+031.8E+03	9.8E+014.7E+01		7.1E+023.4E+02
I-132	1.4E+048.5E+03	7.5E+044.6E+04	4.9E+033.0E+03				8.0E+014.9E+01
I-133	1.3E+046.2E+03	7.0E+043.4E+04	4.6E+032.2E+03		1.7E+028.4E+01		6.8E+023.3E+02
I-134	2.1E+041.5E+04	1.2E+058.4E+04	7.6E+035.5E+03				4.8E+013.4E+01
I-135	1.7E+048.6E+03	9.4E+044.7E+04	6.1E+033.1E+03				2.9E+021.4E+02
H-3	1.2E+06	1.2E+06					2.6E+05
C-14						5.3E+05	
Na-24							5.9E+005.4E+00
P-32							1.5E+003.3E+00
Ar-41						1.4E+03	

Table 12.2-16

Annual Airborne Releases for Offsite Dose Evaluations (MBq)**

Nuclide*	Reactor Building	Turbine Building	Radwaste Building	Mechanical Vacuum Pump	Turbine Seal	Offgas System	Drywell
Cr-51	5.5E+012.6E+01	4.5E+012.2E+01	3.5E+011.7E+01				1.3E+021.1E+02
Mn-54	7.0E+013.3E+01	3.0E+011.4E+01	2.0E+029.6E+01				1.8E+001.7E+00
Mn-56							1.2E+011.1E+01
Fe-55							5.1E+014.7E+01
Fe-59	2.0E+019.3E+00	5.0E+002.4E+00	1.5E+017.2E+00				1.4E+001.2E+00
Co-58	1.5E+017.2E+00	5.0E+012.4E+01	1.0E+014.8E+00				4.8E+004.4E+00
Co-60	2.5E+021.2E+02	5.0E+012.4E+01	3.5E+021.7E+02				1.0E+019.4E+00
Ni-63							5.2E-024.7E-02
Cu-64							7.5E+006.9E+00
Zn-65	2.5E+021.2E+02	3.0E+021.4E+02	1.5E+017.2E+00				5.1E+014.6E+01
Rb-89							2.0E-01
Sr-89	2.5E+001.2E+00	3.0E+021.4E+02					4.7E+004.3E+00
Sr-90	5.0E-012.4E-01	1.0E+004.8E-01					3.6E-013.3E-01
Y-90							8.9E-028.1E-02
Sr-91							7.5E+006.7E+00
Sr-92							4.9E+004.6E+00
Y-91							1.9E+001.7E+00
Y-92							3.8E+003.7E+00
Y-93							8.1E+007.2E+00
Zr-95	5.0E+012.4E+01	2.0E+009.6E-01	4.0E+011.9E+01				3.8E-013.5E-01
Nb-95	5.0E+022.	3.0E-	2.0E-019.6E-				3.6E-

Table 12.2-16

Annual Airborne Releases for Offsite Dose Evaluations (MBq)**

Nuclide*	Reactor Building	Turbine Building	Radwaste Building	Mechanical Vacuum Pump	Turbine Seal	Offgas System	Drywell
	4E+02	011.4E-01	02				013.3E-01
Mo-99	3.3E+031.6E+03	1.0E+024.8E+01	1.5E-017.2E-02				2.6E+012.4E+01
Tc-99m							2.4E+002.2E+00
Ru-103	2.1E+021.0E+02	2.5E+001.2E+00	5.0E-022.4E-02				9.1E-018.2E-01
Rh-103m							3.8E-033.5E-03
Ru-106							1.6E-011.4E-01
Rh-106							5.2E-064.5E-06
Ag-110m	1.2E-015.7E-02						5.1E-024.6E-02
Sb-124	2.5E+002.2E+00	5.0E+004.4E+00	3.5E+001.7E+00				
Te-129m							1.8E+006.6E+00
Te-131m							6.0E-015.5E-01
Te-132							1.5E-011.4E-01
Cs-134	2.4E+021.1E+02	1.0E+018.8E+00	1.2E+025.7E+01				1.4E+003.3E+00
Cs-136	2.5E+012.2E+01	5.0E+004.4E+00					6.4E-015.8E-01
Cs-137	3.0E+024.4E+02	5.0E+014.4E+01	2.0E+029.6E+01				3.7E+004.4E+00
Cs-138							8.5E-01
Ba-140	1.1E+035.3E+02	5.0E+024.4E+02	2.0E-019.6E-02				1.4E+013.3E+01
La-140							1.4E+013.3E+01
Ce-141	4.5E+012.2E+01	5.0E+024.4E+02	3.5E-011.7E-01				1.4E+002.2E+00
Ce-144							1.6E-011.3E-01
Pr-144							1.8E-041.6E-04

Table 12.2-16

Annual Airborne Releases for Offsite Dose Evaluations (MBq)**

Nuclide*	Reactor Building	Turbine Building	Radwaste Building	Mechanical Vacuum Pump	Turbine Seal	Offgas System	Drywell
W-187							1.4E+00~~1.3E+00~~
Np-239							9.0E+01~~8.3E+01~~

* Table 11.1-5a provides the basis for the airborne releases of the following radionuclide pairs:
Sr-90/Y-90
Zr-95/Nb-95
Mo-99/Tc-99m
Ru-103/Rh-103m
Ru-106/Rh-106
Ba-140/La-140
Ce-144/Pr-144
The coolant concentration of the daughter in Table 11.1-5a is assumed to be that of the parent. The annual airborne release of each radionuclide is determined utilizing the methodology provided in Appendix 12B.

** The releases (as designed in the table column headings) from the building stacks are as follows:
Reactor Building/Fuel Building stack: "Reactor Building" and "Drywell"
Turbine Building stack: "Turbine Building", "Mechanical Vacuum Pump", "Turbine Seal", and "Offgas System"
Radwaste Building stack: "Radwaste Building"

Table 12.2-17

Comparison of Airborne Concentrations with 10 CFR 20 Concentrations

	Airborne Release	Concentration	10 CFR 20
Nuclide	MBq/yr	Bq/m^3	Bq/m^3
Kr-83m	8.5E+01	4.0E-07~~8.0E-07~~	2.E+06
Kr-85m	6.6E+05	2.6E-03~~4.5E-03~~	4.E+03
Kr-85	5.2E+06	2.0E-02~~3.3E-02~~	3.E+04
Kr-87	1.4E+06	5.4E-03~~9.1E-03~~	7.E+02
Kr-88	2.1E+06	8.2E-03~~1.4E-02~~	3.E+02
Kr-89	1.4E+07	1.5E-01~~5.0E-01~~	4.E+01
Xe-131m	1.5E+05	5.6E-04~~9.3E-04~~	7.E+04
Xe-133m	1.9E+02	9.2E-07~~1.8E-06~~	2.E+04
Xe-133	4.1E+07	9.3E-01~~3.4E+00~~	2.E+04
Xe-135m	2.2E+07	1.9E+00~~7.6E+00~~	1.E+03
Xe-135	2.8E+07	1.1E+00~~4.1E+00~~	3.E+03
Xe-137	2.8E+07	4.0E-01~~1.4E+00~~	4.E+01
Xe-138	2.3E+07	9.4E-02~~1.7E-01~~	7.E+02
I-131	1.8E+04~~8.7E+03~~	1.8E-04~~2.7E-04~~	7.E+00
I-132	9.4E+04~~5.8E+04~~	1.1E-03~~2.3E-03~~	7.E+02
I-133	8.9E+04~~4.3E+04~~	1.1E-03~~1.7E-03~~	4.E+01
I-134	1.5E+05~~1.1E+05~~	1.8E-03~~4.2E-03~~	2.E+03
I-135	1.2E+05~~5.9E+04~~	1.4E-03~~2.3E-03~~	2.E+02
H-3	2.8E+06	1.2E-02~~2.2E-02~~	4.E+03
C-14	5.3E+05	2.0E-03~~3.4E-03~~	1.E+02
Na-24	5.9E+00~~5.4E+00~~	2.8E-08~~5.2E-08~~	3.E+02
P-32	1.5E+00~~1.3E+00~~	7.1E-09~~1.3E-08~~	2.E+01
Ar-41	1.4E+03	5.4E-06~~9.0E-06~~	4.E+02
Cr-51	2.7E+02~~1.8E+02~~	6.6E-06~~1.2E-05~~	1.E+03
Mn-54	3.0E+02~~1.5E+02~~	3.2E-05~~6.1E-05~~	4.E+01
Mn-56	1.2E+01~~1.1E+01~~	5.6E-08~~1.0E-07~~	7.E+02

Table 12.2-17

Comparison of Airborne Concentrations with 10 CFR 20 Concentrations

	Airborne Release	Concentration	10 CFR 20
Nuclide	MBq/yr	Bq/m^3	Bq/m^3
Fe-55	5.1E+01~~4.7E+01~~	2.4E-07~~4.5E-07~~	1.E+02
Fe-59	4.1E+01~~2.0E+01~~	2.5E-06~~4.7E-06~~	2.E+01
Co-58	8.0E+01~~4.0E+01~~	1.9E-06~~3.3E-06~~	4.E+01
Co-60	6.6E+02~~3.2E+02~~	5.7E-05~~1.1E-04~~	2.E+00
Ni-63	5.2E-02~~4.7E-02~~	2.5E-10~~4.5E-10~~	4.E+01
Cu-64	7.5E+00~~6.9E+00~~	3.6E-08~~6.6E-08~~	1.E+03
Zn-65	6.2E+02~~3.2E+02~~	5.0E-06~~7.0E-06~~	1.E+01
Rb-89	2.0E-01	9.5E-10~~1.9E-09~~	7.E+03
Sr-89	3.1E+02~~1.5E+02~~	1.2E-06~~9.6E-07~~	7.E+00
Sr-90	1.9E+00~~1.0E+00~~	7.9E-09~~8.4E-09~~	2.E-01
Y-90	8.9E-02~~8.1E-02~~	4.2E-10~~7.7E-10~~	3.E+01
Sr-91	7.5E+00~~6.7E+00~~	3.6E-08~~6.4E-08~~	2.E+02
Sr-92	4.9E+00~~4.6E+00~~	2.3E-08~~4.4E-08~~	3.E+02
Y-91	1.9E+00~~1.7E+00~~	9.2E-09~~1.7E-08~~	7.E+00
Y-92	3.8E+00~~3.7E+00~~	1.8E-08~~3.5E-08~~	4.E+02
Y-93	8.1E+00~~7.2E+00~~	3.8E-08~~6.9E-08~~	1.E+02
Zr-95	9.2E+01~~4.4E+01~~	6.6E-06~~1.2E-05~~	1.E+01
Nb-95	5.0E+02~~2.4E+02~~	2.4E-06~~2.3E-06~~	7.E+01
Mo-99	3.4E+03~~1.7E+03~~	1.6E-05~~1.6E-05~~	7.E+01
Tc-99m	2.4E+00~~2.2E+00~~	1.2E-08~~2.1E-08~~	7.E+03
Ru-103	2.1E+02~~1.0E+02~~	1.0E-06~~9.9E-07~~	3.E+01
Rh-103m	3.8E-03~~3.5E-03~~	1.8E-11~~3.3E-11~~	7.E+04
Ru-106	1.6E-01~~1.4E-01~~	7.4E-10~~1.3E-09~~	7.E-01
Rh-106	5.2E-06~~4.5E-06~~	2.5E-14~~4.3E-14~~	4.E+01
Ag-110m	1.7E-01~~1.0E-01~~	8.1E-10~~9.9E-10~~	4.E+00
Sb-124	1.1E+01~~5.3E+00~~	5.9E-07~~1.1E-06~~	1.E+01
Te-129m	1.8E+00~~1.6E+00~~	8.6E-09~~1.5E-08~~	1.E+01
Te-131m	6.0E-01~~5.5E-01~~	2.9E-09~~5.2E-09~~	4.E+01
Te-132	1.5E-01~~1.4E-01~~	7.3E-10~~1.3E-09~~	3.E+01
Cs-134	3.7E+02~~1.8E+02~~	2.0E-05~~3.8E-05~~	7.E+00
Cs-136	3.1E+01~~1.5E+01~~	1.4E-07~~1.3E-07~~	3.E+01
Cs-137	5.5E+02~~2.7E+02~~	3.3E-05~~6.2E-05~~	7.E+00

Table 12.2-17

Comparison of Airborne Concentrations with 10 CFR 20 Concentrations

	Airborne Release	Concentration	10 CFR 20
Nuclide	**MBq/yr**	**Bq/m^3**	**Bq/m^3**
Cs-138	8.5E-01	4.0E-09~~8.1E-09~~	3.E+03
Ba-140	1.6E+03~~7.8E+02~~	7.2E-06~~6.7E-06~~	7.E+01
La-140	1.4E+01~~1.3E+01~~	6.8E-08~~1.2E-07~~	7.E+01
Ce-141	5.5E+02~~2.6E+02~~	2.2E-06~~1.8E-06~~	3.E+01
Ce-144	1.6E-01~~1.3E-01~~	7.4E-10~~1.3E-09~~	7.E-01
Pr-144	1.8E-04~~1.6E-04~~	8.6E-13~~1.5E-12~~	7.E+00
W-187	1.4E+00~~1.3E+00~~	6.6E-09~~1.2E-08~~	4.E+02
Np-239	9.0E+01~~8.3E+01~~	4.3E-07~~7.9E-07~~	1.E+02

Table 12.2-18b

ESBWR Annual Average Doses from Airborne Releases

	Annual Dose (mSv/year)							
PATHWAY	**T. BODY**	**GI-TRACT**	**BONE**	**LIVER**	**KIDNEY**	**THYROID**	**LUNG**	**SKIN**
PLUME	2.20E-03 8.15E-03	2.20E-03 8.15E-03	2.20E-03 8.15E-03	2.20E-03 8.15E-03	2.20E-03 8.15E-03	2.20E-03 8.15E-03	2.23E-03 8.27E-03	5.38E-03 1.94E-02
GROUND	2.51E-03 2.04E-03	2.51E-03 2.04E-03	2.51E-03 2.04E-03	2.51E-03 2.04E-03	2.51E-03 2.04E-03	2.51E-03 2.04E-03	2.51E-03 2.04E-03	2.95E-03 2.38E-03
VEGETABLE								
ADULT	7.46E-04 7.07E-04	5.61E-04 5.59E-04	1.22E-03 1.44E-03	1.01E-03 9.25E-04	5.57E-04 5.52E-04	3.44E-02 2.89E-02	1.82E-04 2.36E-04	9.97E-05 1.67E-04
TEEN	7.78E-04 7.87E-04	6.58E-04 6.93E-04	1.95E-03 2.32E-03	1.55E-03 1.43E-03	8.48E-04 8.48E-04	4.44E-02 3.73E-02	3.10E-04 3.95E-04	1.62E-04 2.72E-04
CHILD	1.02E-03 1.18E-03	7.30E-04 9.40E-04	4.63E-03 5.51E-03	2.68E-03 2.57E-03	1.47E-03 1.56E-03	8.40E-02 7.09E-02	6.08E-04 8.34E-04	3.88E-04 6.50E-04
MEAT								
ADULT	8.99E-05 1.07E-04	2.09E-04 2.23E-04	2.25E-04 3.42E-04	1.11E-04 1.26E-04	6.97E-05 9.12E-05	6.57E-04 5.81E-04	4.36E-05 6.78E-05	3.75E-05 6.25E-05
TEEN	5.96E-05 7.66E-05	1.27E-04 1.41E-04	1.89E-04 2.88E-04	8.95E-05 1.03E-04	5.65E-05 7.48E-05	4.80E-04 4.28E-04	3.72E-05 5.74E-05	3.14E-05 5.25E-05
CHILD	8.58E-05 1.22E-04	1.09E-04 1.45E-04	3.51E-04 5.38E-04	1.32E-04 1.61E-04	8.93E-05 1.25E-04	7.36E-04 6.66E-04	6.54E-05 1.04E-04	5.89E-05 9.82E-05
MILK								
ADULT	4.27E-04 3.93E-04	1.23E-04 1.44E-04	5.33E-04 6.14E-04	6.07E-04 5.48E-04	3.29E-04 3.15E-04	1.78E-02 1.49E-02	9.12E-05 1.11E-04	4.16E-05 6.96E-05
TEEN	4.88E-04 4.77E-04	1.76E-04 2.17E-04	9.61E-04 1.11E-03	1.06E-03 9.59E-04	5.74E-04 5.52E-04	2.82E-02 2.37E-02	1.76E-04 2.10E-04	7.59E-05 1.27E-04

Table 12.2-18b

ESBWR Annual Average Doses from Airborne Releases

	Annual Dose (mSv/year)							
PATHWAY	**T. BODY**	**GI-TRACT**	**BONE**	**LIVER**	**KIDNEY**	**THYROID**	**LUNG**	**SKIN**
CHILD	6.07E-04~~6.75E-04~~	2.55E-04~~3.72E-04~~	2.31E-03~~2.69E-03~~	1.83E-03~~1.70E-03~~	9.93E-04~~9.98E-04~~	5.60E-02~~4.71E-02~~	3.36E-04~~4.35E-04~~	1.85E-04~~3.10E-04~~
INFANT	9.04E-04~~1.09E-03~~	6.40E-04~~8.88E-04~~	4.09E-03~~4.92E-03~~	3.58E-03~~3.34E-03~~	1.68E-03~~1.75E-03~~	1.36E-01~~1.14E-01~~	6.55E-04~~8.67E-04~~	3.86E-04~~6.43E-04~~
INHALE								
ADULT	1.45E-05~~2.62E-05~~	1.49E-05~~2.50E-05~~	1.22E-05~~2.14E-05~~	2.38E-05~~4.24E-05~~	2.37E-05~~4.09E-05~~	1.42E-03~~2.23E-03~~	1.18E-04~~2.17E-04~~	2.31E-06~~4.32E-06~~
TEEN	1.40E-05~~2.50E-05~~	1.59E-05~~2.64E-05~~	1.70E-05~~2.97E-05~~	3.14E-05~~5.59E-05~~	3.13E-05~~5.40E-05~~	1.85E-03~~2.92E-03~~	1.71E-04~~3.16E-04~~	2.33E-06~~4.36E-06~~
CHILD	1.12E-05~~1.98E-05~~	9.74E-06~~1.69E-05~~	2.28E-05~~3.98E-05~~	2.96E-05~~5.26E-05~~	2.89E-05~~4.95E-05~~	2.28E-03~~3.60E-03~~	1.39E-04~~2.57E-04~~	2.06E-06~~3.85E-06~~
INFANT	6.64E-06~~1.15E-05~~	4.80E-06~~8.70E-06~~	1.58E-05~~2.73E-05~~	2.35E-05~~4.16E-05~~	1.83E-05~~3.13E-05~~	2.08E-03~~3.28E-03~~	9.09E-05~~1.66E-04~~	1.19E-06~~2.22E-06~~
TOTAL**	**Annual Dose (mSv/year)**							
ADULT	3.79E-03~~3.27E-03~~	3.42E-03~~2.99E-03~~	4.50E-03~~4.45E-03~~	4.26E-03~~3.68E-03~~	3.49E-03~~3.04E-03~~	5.67E-02~~4.87E-02~~	2.94E-03~~2.67E-03~~	3.13E-03~~2.69E-03~~
TEEN	3.85E-03~~3.40E-03~~	3.48E-03~~3.11E-03~~	5.63E-03~~5.78E-03~~	5.24E-03~~4.59E-03~~	4.02E-03~~3.56E-03~~	7.75E-02~~6.64E-02~~	3.20E-03~~3.01E-03~~	3.22E-03~~2.84E-03~~
CHILD	4.23E-03~~4.04E-03~~	3.61E-03~~3.51E-03~~	9.82E-03~~1.08E-02~~	7.18E-03~~6.51E-03~~	5.09E-03~~4.77E-03~~	1.46E-01~~1.24E-01~~	3.66E-03~~3.67E-03~~	3.58E-03~~3.45E-03~~
INFANT	3.42E-03~~3.14E-03~~	3.15E-03~~2.93E-03~~	6.61E-03~~6.98E-03~~	6.11E-03~~5.42E-03~~	4.21E-03~~3.81E-03~~	1.41E-01~~1.20E-01~~	3.25E-03~~3.07E-03~~	3.33E-03~~3.03E-03~~

Annual beta air dose = ~~1.14E-02~~3.23E-03 mGy
Annual gamma air dose = ~~1.24E-02~~ 3.36E-03 mGy

** Total doses correspond to the organ doses from all pathways of exposure (excluding the plume pathway) due to radioactive iodine and radioactive material in particulate form in accordance with 10 CFR 50, Appendix I, Section II.C