

11.0 RADIOACTIVE WASTE MANAGEMENT

11.1 Introduction

This section describes the U.S. Nuclear Regulatory Commission (NRC) staff's evaluation of the information provided in Chapter 11, "Radioactive Waste Management," of the Site Safety Analysis Report (SSAR) contained in Part 2 of the Tennessee Valley Authority (TVA) Clinch River Nuclear (CRN) Site Early Site Permit (ESP) Application, Revision 0 (TVA, 2016 - Agencywide Document Access and Management System [ADAMS] Accession No. ML16144A074). Revision 1 of SSAR Part 2 was submitted in the TVA letter to the NRC, CNL-17-151, dated December 15, 2017 (TVA, 2017 - ADAMS Accession No. ML18005A067).

The information in SSAR Chapter 11 describes the liquid and gaseous effluent releases (i.e., normal plant parameter envelope [PPE] liquid and gaseous effluent release source terms), exposure pathways, and projected offsite doses to demonstrate that reactor units could be sited at the proposed CRN Site without undue risk to the health and safety of the public, in compliance with the relevant requirements in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 20, "Standards for Protection Against Radiation;" 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low As is Reasonably Achievable' [ALARA] for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents;" 10 CFR 52.17, "Contents of Applications;" 10 CFR Part 100, "Reactor Site Criteria;" and the Environmental Protection Agency's (EPA's) 40 CFR Part 190, "Environmental Radiation Protection Standards for Nuclear Power Operations."

Liquid and gaseous effluent release source terms and exposure pathway doses provided in SSAR Chapter 11 are developed using a PPE approach. A representative activity for each of the radionuclides derived from information for the four light-water-cooled small modular reactor (SMR) technologies: BWXT mPower (Generation mPower LLC design), NuScale (NuScale Power, LLC, design), SMR-160 (Holtec SMR, LLC, design), and Westinghouse SMR (Westinghouse Electric Company, LLC, design), were considered in the development of the PPE for the CRN Site. These radionuclides and their associated activity are described in SSAR Chapter 2, "Site Characteristics," and in the TVA letter to the NRC, CNL-17-075, "Resubmittal of Supplemental Information Regarding Radiation Protection Accident Consequences in Support of Early Site Permit Application for Clinch River Nuclear Site," dated June 16, 2017 (TVA, 2017 - ADAMS Accession No. ML17167A150).

In support of the ESP application safety review, input, output, and modified computer code files in native format were submitted with the TVA letter to the NRC, CNL-16-157, "Submittal of Groundwater Calculation Input and Output Files in Support of Early Site Permit Application for Clinch River Nuclear Site," dated September 30, 2016 (TVA, 2016 - ADAMS Accession No. ML16280A066).

Also, the NRC issued an audit plan (NRC, 2017 - ADAMS Accession No. ML17069A045) consisting of two phases: 1) a face-to-face meeting between the NRC staff, the applicant, and the applicant's contractor staff at Bechtel Power Corporation in Reston, Virginia, on April 14-17, 2017, and 2) an additional face-to-face meeting between the same parties at the TVA Knoxville Complex in Knoxville, Tennessee, on April 24-27, 2017, which included a visit to the proposed site location and surrounding area to become familiar with the site setting and layout on April 25,

2017. The NRC audit report documenting the interactions between the parties and NRC staff audit observations is located under ADAMS Accession No. ML17341A276.

11.1.1 Summary of Application

The applicant provided information on liquid and gaseous effluent releases (i.e., normal PPE liquid and gaseous effluent release source terms) and exposure pathway doses that would be generated as a normal byproduct of nuclear power operations. The applicant stated that these effluents will be collected, processed, stored, and released in a controlled manner. The applicant further stated that the proposed facility will have the ability to handle these effluents in a manner that minimizes effluent releases to the environment and maintains exposure to the public during normal plant operations including anticipated operational occurrences (AOOs), and maintenance at levels that are ALARA.

In the SSAR, the applicant considered the guidance in Nuclear Energy Institute (NEI) 10-01, Revision 1, "Industry Guidance for Developing a Plant Parameter Envelope in Support of an Early Site Permit" (2012), for developing the normal PPE liquid and gaseous effluent release source terms in SSAR Section 11.2.3 (and SSAR Table 2.0-6) and SSAR Section 11.3.3 (and SSAR Table 2.0-4). These source terms are used to describe the types and quantities of liquid and gaseous effluents released annually from normal plant operations. The four SMR design technologies used to develop the normal PPE liquid and gaseous effluent release source terms in the surrogate plant for the PPE based on NEI 10-01 are summarized in Table 11.1-1.

Table 11.1-1 SMR Design Technologies Considered in the PPE

SMR Design	No. Units	Per Unit MWt (MWe)	RCP Per Unit MWt	Total MWt (MWe)
BWXT mPower	4	530 (171)	2.1	2,120 (684)
NuScale	12	160 (50)	No RCP	1,920 (600)
Holtec SMR-160	4	525 (154)	No RCP	2,100 (616)
Westinghouse SMR	3	800 (240) *	4.0	2,420 (720) **

* Maximum megawatt thermal (MWt) and megawatt electric (MWe) core output considered for all SMR designs at CRN Site.

** Includes additional reactor coolant pump (RCP) thermal output (if applicable to SMR design) for margin.

The applicant used the guidance in Regulatory Guide (RG) 1.109, Revision 1, "Calculation of Annual Doses to Man From Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I" (NRC, 1977), and RG 1.111, Revision 1 (with Errata), "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors" (NRC, 1977), to evaluate the exposure pathway doses for the normal PPE liquid and gaseous effluents released annually on a per unit and site basis in SSAR Sections 11.2.3.1 and 11.3.3.1, respectively.

Further, the applicant used analytical methods and the applicable guidance including the NRC endorsed LADTAP II (NUREG/CR-4013, "LADTAP II – Technical Reference and User Guide" (NRC, 1986)), XOQDOQ (NUREG/CR-2919, "XOQDOQ: Computer Program for the

Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations” (NRC, 1982)), and the GASPAR II (NUREG/CR-4653, “GASPAR II – Technical Reference and User Guide” (NRC, 1987)), computer codes to evaluate the calculated doses from normal PPE liquid and gaseous effluent releases to members of the public as documented in SSAR Sections 11.2.3.2 and 11.3.3.2, respectively.

11.1.2 Regulatory Basis

The acceptance criteria for addressing doses to a member of the public from liquid and gaseous effluents due to normal plant operations are based on meeting the relevant requirements of:

1. 10 CFR 20.1301, 10 CFR 20.1302, and Table 2, Columns 1 and 2 and Note 4 of Appendix B to 10 CFR Part 20, as they relate to radioactivity in liquid and gaseous effluents released to unrestricted areas and doses to offsite receptors located in unrestricted areas;
2. 10 CFR Part 50, Appendix I, Sections II.A, II.B, and II.C, as they relate to the numerical guides on ALARA design objectives and limiting conditions for operation;
3. 10 CFR 52.17(a)(1)(ii), as it relates to anticipated maximum levels of radiological and thermal effluents each facility will produce;
4. 10 CFR 100.21(c)(1), as it relates to the requirement that site atmospheric dispersion characteristics be evaluated and dispersion parameters established such that radiological effluent release limits associated with normal operation from the type of facility to be located at the site can be met for any individual located offsite; and
5. 40 CFR Part 190 (the EPA’s generally applicable environmental radiation standards), as implemented under 10 CFR 20.1301(e)), as it relates to limits on annual doses from all sources of radioactivity contained in liquid and gaseous effluents and external radiation from site buildings and facilities (with single or multiple reactor units).

11.2.3 Liquid Effluent Releases

The following sections describe the normal PPE liquid effluent source term, evaluation of exposure pathways, and calculated public doses surrounding the CRN Site. The staff’s technical evaluation involving these aspects of liquid effluent releases is discussed in Section 11.4 of this safety evaluation report (SER).

11.2.3.1 Normal PPE Liquid Effluent Release Source Term

In the TVA letter to the NRC, CNL-17-075, dated June 16, 2017 (TVA, 2017 - ADAMS Accession No. ML17167A150), the applicant provided SSAR markups and the bases for the normal PPE liquid effluent release source terms to address the staff’s audit observations described in the NRC audit report (NRC, 2018 - ADAMS Accession No. ML17341A276).

An overview of the input from the four SMR designs used to create a surrogate plant, as defined in NEI 10-01, and for developing the normal PPE liquid and gaseous effluent release source terms, is provided in the enclosure to TVA letter CNL-17-075 (TVA, 2017 - ADAMS Accession No. ML17167A150). The four SMR designs are randomly represented as Vendors 1 through 4.

This enclosure contains SSAR markups and updates in Attachment 1 (SSAR Sections 1.11, 2.4.13.1, 2.4.13.8, 11.2.3.1, 11.2.4, 11.3.3.1, and 11.3.4), Attachment 2 (Tellurium (Te)-129 and Te-131 unit and site liquid effluent release rates), and Attachment 3 (asterisks on noted site gaseous effluent release rates for Vendors 2 and 4 in Table 7-B). No other changes were identified for the additional attachments in the enclosure.

In the markup, the applicant revised SSAR Section 1.11 to indicate a basis summary for each plant parameter is provided in the SSAR section indicated in SSAR Table 2.0-2 for that plant parameter. The staff found the markup acceptable because the basis summary and SSAR section of each plant parameter was provided, and the staff confirmed that Revision 1 of SSAR, Section 1.11 and Table 2.0-2 included this information.

Additionally, the applicant revised SSAR 11.2.3.1 to specify that the guidance in NEI 10-01 was used for developing the surrogate plant source term for liquid effluent releases. The staff found the markup acceptable because NEI 10-01 was described and referenced, and the staff confirmed that Revision 1 of SSAR, Section 11.2.3.1 included this information.

In the TVA letter to the NRC, CNL-17-086, "Submittal of Supplemental Information Related to Plant Parameter Envelope Source Terms in Support of Early Site Permit Application for Clinch River Nuclear Site," dated June 26, 2017 (TVA, 2017 - ADAMS Accession No. ML17178A330), the applicant provided a markup correcting the Te-129 and Te-131 unit and site liquid effluent release rates in Composite Tables 10-A (unit) and 10-B (site) in Attachments 2 and 3 of TVA letter CNL-17-075 (TVA, 2017 - ADAMS Accession No. ML17167A150). The Te-129 and Te-131 unit and site liquid effluent release rates are also provided in the TVA ESP Application Part 3, Environmental Report, Tables 3.5-1 and 3.5-2. The staff found the markup acceptable because the Te-129 and Te-131 unit and site liquid effluent release rates were corrected, and the staff confirmed that Revision 1 of SSAR, Tables 2.0-6 and 11.2-4 included this information.

11.2.3.2 Normal PPE Liquid Effluent Release Concentrations

The normal PPE liquid effluent release source term for the surrogate plant is evaluated for compliance with the water (liquid) effluent concentration limits (ECLs) in 10 CFR Part 20, Appendix B, Table 2, Column 2, for release to the environment using the unity rule or sum of fractions calculation. SSAR Table 11.2-4 (Sheets 1 through 3) provides the projected annual liquid effluent concentrations in the Clinch River arm of the Watts Bar Reservoir. Liquid effluent release concentrations in SSAR Table 11.2-4 (Sheets 1 through 3) are taken from Composite Table 10-B (Site) in Attachment 2 of TVA letter CNL-17-075 (TVA, 2017 - ADAMS Accession No. ML17167A150) containing the normal PPE liquid effluent release source term. SSAR Table 11.2-4 (Sheets 1 through 3) shows the normal PPE liquid effluent release source term projected into the Clinch River arm of the Watts Bar Reservoir results in a calculated sum of fractions value less than one.

11.2.3.3 Doses from Normal PPE Liquid Effluent Release Source Terms

The applicant's receptor locations are based on the CRN Site Land Use Survey conducted on January 7-10, 2014, and the guidance in Section 3/4.12.2, "Land Use Census," of NUREG-1302, "Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Boiling Water Reactors" (NRC, 2011 - ADAMS Accession No. ML11182C055). Section 3/4.12.2 of NUREG-1302 states, "a Land Use Census shall be conducted and shall

identify within a distance of 8 kilometers (5 miles) the location in each of the 16 meteorological sectors of the nearest milk animal, the nearest residence, and the nearest garden of greater than 50 m² (500 ft²) producing broad leaf vegetation.” This guidance for conducting a Land Use Census that complies with the regulations is the same as that found in Section 3/4.12.2 of NUREG-1301, “Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Pressurized Water Reactors” (NRC, 2009 - ADAMS Accession No. ML091050061).

The guidance in NUREG-1301 and NUREG-1302 for developing an Offsite Dose Calculation Manual (ODCM), including controls and surveillance requirements for instrumentation, effluents, radiological environmental monitoring, and technical and regulatory bases, are described in NEI 07-09A, Revision 0, “Generic FSAR Template Guidance for Offsite Dose Calculation Manual (ODCM)” (ADAMS Accession No. ML091050233). At the time of the combined license (COL) application, a COL applicant may use a COL application information item (or COL Action Item) to commit to follow the NRC endorsed guidance in NEI 07-09A, Revision 0, as an alternative to providing the full programs for the ODCM, and Radiological Environmental Monitoring Program (REMP). As such, the ODCM and REMP are outside the review scope for an ESP application.

The applicant used the methodology described in RG 1.109 to determine the sensitive receptors for the maximally exposed individual (MEI) in the exposure pathway dose analyses. The guidance in RG 1.109 is an acceptable method to demonstrate compliance with the ALARA design objectives in 10 CFR Part 50, Appendix I, and to perform the exposure pathway dose analyses from licensed operations. When the ALARA design objectives in 10 CFR Part 50, Appendix I on a per unit basis are met along with the EPA’s radiation standards in 40 CFR Part 190 for the site, as implemented under 10 CFR 20.1301(e), then the dose limit of 100 millirem (mrem) total effective dose equivalent (TEDE) to a member of the public in 10 CFR 20.1302 is satisfied.

The results of the CRN Site Land Use Survey identified the nearest beef cattle, nearest garden, and nearest residence, and did not show any dairy cows and goats within a 5 mile radius around the CRN Site. For the purpose of calculating the population dose at the 50 mile boundary, the applicant considered dairy cows and dairy goats within a 50 mile radius in the exposure pathway dose analyses. The applicant’s exposure pathway dose analyses using the NRC endorsed LADTAP II and GASPARI codes, the guidance in RG 1.109, its demonstration of compliance with the ALARA design objectives in Appendix I to 10 CFR Part 50, the public dose limit in 10 CFR 20.1301, and environmental dose limits in 40 CFR Part 190, are discussed in Sections 11.2.3, 11.3.3, and 11.4 of this SER.

Calculated doses for total body and various body organs are evaluated by the applicant with the normal PPE liquid effluent release source term and parameters specific to the CRN Site using the guidance in RG 1.109 and the NRC endorsed LADTAP II code. SSAR Section 11.2.3.1 describes the exposure pathways considered in RG 1.109 and in the LADTAP II code. The parameters, values, and bases for calculating doses to the MEI and to the general population are presented in SSAR Tables 11.2-1 (Sheets 1 and 2) and 11.2-3. SSAR Section 11.2.3.2 describes the exposure pathway activities considered for calculating doses to the MEI surrounding the CRN Site and to the projected general population within 50 miles of the CRN Site in SSAR Table 11.2-2.

Results of total body and organ doses to the MEI from the exposure pathways and normal PPE liquid effluent release source terms are presented in SSAR Tables 11.2-5 (unit) and 11.2-6

(site). In SSAR Tables 11.2-7 and 11.2-8, the total body, organ, and gamma and beta air doses to the MEI are compared to the ALARA design objectives in Sections II.A, II.B, and II.C of Appendix I to 10 CFR Part 50, and the calculated dose from all sources in 40 CFR Part 190, as implemented under 10 CFR 20.1301(e). SSAR Tables 11.2-7 and 11.2-8 show all doses calculated using the LADTAP II code are within the ALARA design objectives in Appendix I to 10 CFR Part 50, and the EPA's radiation standards in 40 CFR Part 190. Calculated doses per unit and for the projected general population within 50 miles of the CRN Site resulting from the normal PPE liquid effluent release source term is compared to the dose from natural background in SSAR Table 11.2-9. The staff's technical evaluation involving these aspects of exposure pathway doses from liquid effluent releases is discussed in Section 11.4 of this SER.

11.3.3 Gaseous Effluent Releases

The following sections describe the normal PPE gaseous effluent release source term, evaluation of exposure pathways, and calculated public doses surrounding the CRN Site. The staff's technical evaluation involving these aspects of gaseous effluent releases is discussed in Section 11.4 of this SER.

11.3.3.1 Normal PPE Gaseous Effluent Release Source Term

In the TVA letter to the NRC, CNL-17-075, dated June 16, 2017 (TVA, 2017 - ADAMS Accession No. ML17167A150), the applicant provided updates and the bases for unit and site normal PPE gaseous effluent release source terms to address the staff's audit observations described in the NRC audit report (NRC, 2018 - ADAMS Accession No. ML17341A276).

As discussed in Section 11.2.3.1 of this SER, the enclosure to TVA letter CNL-17-075 contains SSAR markups and updates. In particular, Attachment 1 (SSAR Sections 11.3.3.1 and 11.3.4) and Attachment 3 (asterisks on noted release rates for Vendors 2 and 4 in Table 7-B) are relevant to gaseous effluent releases.

In the markup, the applicant revised SSAR 11.3.3.1 to specify that the guidance in NEI 10-01 was used for developing the surrogate plant source term for gaseous effluent releases. The staff found the markup acceptable because NEI 10-01 was described and referenced, and the staff confirmed that Revision 1 of SSAR, Section 11.3.3.1 included this information.

As discussed in the basis for normal gaseous effluent releases in Attachment 3, Krypton (Kr)-85 and Kr-85m release rates are inadvertently reversed in Table 7-A (unit) of Attachment 3 for Vendor 2. The correct release rates for Kr-85 and Kr-85m are 633 Ci/yr and 23.2 Ci/yr, respectively. The staff found the updated Attachment 3 acceptable because these Kr release rates were corrected, and confirmed that Table 7-A (unit) of Attachment 3 for Vendor 2 included this information.

11.3.3.2 Normal PPE Gaseous Effluent Release Concentrations

The normal PPE gaseous effluent release source term in the surrogate plant is evaluated for compliance with the air (gaseous) ECLs in 10 CFR Part 20, Appendix B, Table 2, Column 1 for release to the environment using the unity rule or sum of fractions calculation. SSAR Table 11.3-3 (Sheets 1 and 2) provides the projected annual normal gaseous effluent concentrations at the CRN Site Exclusion Area Boundary (EAB). Gaseous effluent release

concentrations in SSAR Table 11.3-3 (Sheets 1 and 2) are taken from Composite Table 10-B (site) in Attachment 3 of TVA CNL-17-075 (ADAMS Accession No. ML17167A150) containing the normal PPE gaseous effluent release source term. SSAR Table 11.3-3 (Sheets 1 and 2) shows the normal PPE gaseous effluent release source term projected at the CRN Site EAB results in a calculated sum of fractions value less than one.

Maximum atmospheric dispersion (X/Q) and relative (ground) deposition (D/Q) factors (also referred to as X/Q and D/Q values) for receptor locations are shown in SSAR Table 11.3-2. Meteorological information used for developing the X/Q and D/Q factors is described in SSAR Section 2.3, "Meteorology," which is evaluated by the staff in Section 2.3.5 of this SER. Both X/Q and D/Q factors are used to calculate the doses from the normal PPE gaseous effluent release source term for compliance with the public dose limit in 10 CFR 20.1301, the ALARA design objectives in Appendix I to 10 CFR Part 50, and the EPA's radiation standards in 40 CFR Part 190, as implemented under 10 CFR 20.1301(e).

The X/Q factor is also used to calculate the projected normal gaseous effluent concentrations at the CRN Site EAB for compliance with the gaseous ECLs of 10 CFR Part 20, Appendix B, Table 2, Column 1. The staff's evaluation of these projected normal gaseous effluent concentrations at the CRN Site EAB is discussed in Section 11.4 of this SER.

From the meteorology review of SSAR Section 2.3, the staff requested in Question 02.03.03-2 of RAI No. 9 (eRAI-8972) that the applicant confirm whether the processing of onsite wind direction measurements used as input for developing the X/Q and D/Q factors represented vector- or scalar-averaged values. In the response to eRAI-8972 (TVA, 2017 - ADAMS Accession No. ML17268A391), the applicant provided proposed markups to SSAR Section 2.3. From a review of these markups, the staff shared observations in public meetings with the applicant on the potential effects of using this wind direction averaging methodology along with guidance cited in RG 1.23.

As a result, on April 9, 2018, the applicant voluntarily submitted a response (TVA, 2018 - ADAMS Accession No. ML18100A950) to address the staff's observations. To evaluate the applicant's voluntary submittal, the staff conducted an audit on May 7-21, 2018 (NRC, 2018 - ADAMS Accession No. ML18122A219), to examine the applicant's calculation packages and supporting documents for developing the X/Q and D/Q factors including the calculated normal offsite gaseous effluent doses to members of the public. The NRC audit report documenting the staff's audit observations is located under ADAMS Accession No. ML18248A113.

11.3.3.3 Doses from Normal PPE Gaseous Effluent Release Source Term

According to the applicant, calculated doses for total body and various organ doses, and gamma and beta air doses are evaluated with the normal PPE gaseous effluent release source term and parameters specific to the CRN Site using the guidance in RG 1.109 and the GASPAR II code. SSAR Section 11.3.3.1 describes the exposure pathways considered. The parameters, values, and bases for calculating doses to the MEI and to the general population are presented in SSAR Tables 11.3-1 and 11.3-2. SSAR Section 11.3.3.2 describes the receptor locations considered for calculating doses to the MEI surrounding the CRN Site and to the projected general population within 50 miles of the CRN Site in SSAR Table 11.2-2.

Results of total body and organ doses to the MEI per reactor and for the site from the exposure pathways and gaseous effluent release rates are presented in SSAR Tables 11.3-4 (Sheets 1 and 2) and 11.3-5 (Sheets 1 and 2), respectively. In SSAR Tables 11.2-7 and 11.2-8, the total body, organ, and gamma and beta air doses for the MEI are compared to the ALARA design objectives in Sections II.A, II.B, and II.C of Appendix I to 10 CFR Part 50; and the calculated dose from all sources in 40 CFR Part 190, as implemented under 10 CFR 20.1301(e). SSAR Tables 11.2-7 and 11.2-8 show all doses calculated using the GASPARD II code are within the ALARA design objectives in Appendix I to 10 CFR Part 50; and the EPA's radiation standards in 40 CFR Part 190. Calculated doses per reactor and for the projected general population within 50 miles of the CRN Site from the projected annual release of the normal PPE gaseous effluent source term, compared to the dose from natural background, is shown in SSAR Table 11.2-9. The staff's technical evaluation involving these aspects of exposure pathway doses from gaseous effluent releases is discussed in Section 11.4 of this SER.

11.4 Technical Evaluation

11.4.1 Normal PPE Liquid and Gaseous Effluent Release Source Terms

The guidance in NEI 10-01 recommends the applicant assemble a list of radionuclides released by liquid and gaseous effluent pathways in creating a surrogate plant to bound radionuclide release rates in the PPE. For each reactor technology considered, release rates from each reactor technology are compared and the highest value is selected. The resulting composite table represents the bounding release rates from normal operations for the surrogate plant. Dose calculations are then performed using computer codes to evaluate all exposure pathways to man as described in NUREG-0800, "Standard Review Plan [SRP] for the Review of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)." The SRP describes the guidance in RGs 1.109 and 1.111; and the XOQDOQ, LADTAP II, and GASPARD II codes as acceptable methods for evaluating exposure pathways and calculating doses for demonstrating compliance with NRC regulations.

The bases and listing of normal liquid and gaseous effluents released annually for each SMR design (Vendors 1 through 4) are provided in Attachments 2 and 3, respectively, of TVA letter CNL-17-075 (TVA, 2017 - ADAMS Accession No. ML17167A150). For each vendor, liquid effluent release rates are listed in Tables 10-A (unit) and 10-B (site) of Attachment 2, and gaseous effluent release rates are listed in Tables 7-A (unit) and 7-B (site) of Attachment 3. Unit liquid and gaseous effluent release rates are multiplied by the maximum number of reactor units in the vendor's design to obtain the site liquid and gaseous effluent release rates. As a result, Composite Tables 10-A (unit), 10-B (site), 7-A (unit), and 7-B (site) represent the selected bounding effluent release rates from normal operations in the surrogate plant for the CRN Site. In Attachment 3, the applicant states that any variances (adjustments) to the values (release rates) considered will be evaluated during the development of the COL application.

As described in the bases for these tables in Attachments 2 and 3, adjustments are made on a case-by-case basis to exclude, reduce, or increase release rates for certain radionuclides based on the amount of conservatism and maturity of the source terms available from the vendors at the time. The applicant performed an evaluation on the adjusted release rates to ensure that the dose consequences are conservative compared to source terms for large light-water reactors (LWRs) scaled to a comparable thermal power output for the CRN Site. The staff reviewed the applicant's evaluation and agrees that the adjusted release rates are reasonable

for representing the bounding effluent release rates from normal operations in the surrogate plant as summarized below.

For Vendor 1, the applicant increased liquid and gaseous effluent release rates ten percent (10%) for additional conservatism and margin in Composite Tables 10-A (unit) and 10-B (site) of Attachment 2 and Tables 7-A (site) and 7-B (unit) of Attachment 3, respectively, due to the preliminary nature of the source terms. The staff agrees that increasing the liquid and gaseous effluent release rates adds conservatism and margin for Vendor 1.

For Vendor 2, the applicant made no adjustments to liquid effluent release rates in Composite Tables 10-A (unit) and 10-B (site) of Attachment 2. As stated in Attachment 3, the gaseous effluent release rates for Kr-85m, Kr-89, Xenon (Xe)-131m, Xe-133, Xe-135m, Xe-135, Xe-137, and Xe-138 in Table 7-A (unit); and Carbon (C)-14 in Table 7-B (site) values were excluded due to excessive conservatism from further evaluation in the surrogate plant. With respect to C-14, the applicant reduced its release rate in Composite Table 7-B (site) based on industry guidance from Electric Power Research Institute (EPRI), "Estimation of Carbon-14 in Nuclear Power Plant Gaseous Effluents" Technical Report 1021106, Final Report 2010. Although this release rate is reduced, the selected C-14 value in Composite Table 7-B (site) is higher (more conservative) than the value determined by the EPRI method. The staff performed a confirmatory analysis and verified that the C-14 release rate used in the PPE was conservative for Vendor 2.

For Vendor 3, the applicant adjusted liquid effluent release rates for C-14 and Co-58 in Table 10-A (unit); and H-3, C-14, Co-58, and Co-60 in Table 10-B (site) of Attachment 2 on scaled unit and site power ratios from the Public Service Enterprise Group (PSEG) ESP to CRN Site ESP. The PPE effluent release source terms approved by the NRC in the PSEG ESP considered four large LWR design technologies including both pressurized and boiling-water reactor designs of various power levels: General Electric Nuclear Energy Advanced Boiling-Water Reactor (ABWR); Westinghouse Electric Company Advanced Passive 1000 (AP1000); AREVA NP, Inc., U.S. Evolutionary Pressurized-Water Reactor (U.S. EPR); and Mitsubishi Heavy Industries, Ltd., U.S. Advanced Pressurized-Water Reactor (US-APWR). The staff agrees that scaling power levels from PSEG to the CRN Site is conservative since no single vendor should contain the highest source terms for all radionuclides. Also, the applicant adjusted the gaseous effluent release rate for Ar-41 in Table 7-A (unit) of Attachment 3. The liquid effluent release rates for C-14 and Co-58 in Table 10-A (unit), in addition to H-3 and Co-60 in Table 10-B (site) of Attachment 2, and the gaseous effluent release rate for Ar-41 in Table 7-A (unit) of Attachment 3 were identified by the applicant as values that were adjusted due to excessive conservatism. The applicant performed a sensitivity analysis on the reduced release rates to demonstrate that calculated doses are bounded by the doses in the surrogate plant and are within NRC regulatory limits. The staff performed a confirmatory analysis and verified that the doses in the surrogate plant are bounded for Vendor 3.

For Vendor 4, the applicant did not make adjustments to liquid effluent release rates in Tables 10-A (unit) and 10-B (site) of Attachment 2. As described in Attachment 3, radionuclide quantities (release rates) for Kr-85 in Table 7-A (unit), and Kr-85 and C-14 in Table 7-B (site) were considered overly conservative based on a scaled AP-1000 in Composite Tables 7-A (unit) and/or 7-B (site). Same as with Vendor 2, the applicant reduced the C-14 release rate in Composite Table 7-B (site) of Attachment 3 based on industry guidance from EPRI. Although this release rate is reduced, the selected C-14 value in Composite Table 7-B (site) is higher (more conservative) than the value determined by the EPRI method. The applicant performed a

sensitivity analysis on the reduced Kr-85 and C-14 release rates to demonstrate calculated doses are bounded by the doses in the surrogate plant and are within NRC regulatory limits. The staff performed a confirmatory analysis and verified that the doses in the surrogate plant are bounded for Vendor 4.

The staff reviewed the liquid and gaseous effluent concentrations in SSAR Tables 11.2-4 (Sheets 1 through 3) and 11.3-3 (Sheets 1 and 2) for compliance with the liquid and gaseous ECLs in 10 CFR Part 20, Appendix B, Table 2, Columns 1 and 2, respectively, for release to the unrestricted areas using the unity rule or sum of the fractions calculation. Based on the staff's confirmatory analysis the projected normal liquid effluent release concentrations in the Clinch River arm of the Watts Bar Reservoir are within the liquid ECLs of 10 CFR Part 20, Appendix B, Table 2, Column 2. Staff also confirmed that the projected normal gaseous effluent release concentrations at the EAB are within the gaseous ECLs of 10 CFR Part 20, Appendix B, Table 2, Column 1, at the CRN Site.

11.4.2 Doses from Normal PPE Liquid and Gaseous Effluent Release Source Terms

As discussed in Section 11.3.3.2 of this SER, the staff conducted an audit to examine the applicant's calculation packages and supporting documents for developing the X/Q and D/Q values, including the calculated normal offsite gaseous effluent doses to members of the public. The staff's evaluation of these X/Q and D/Q values is discussed in the NRC audit report documented under ADAMS Accession No. ML18248A113, and in Section 2.3.5 of this SER.

The staff reviewed the parameters, values, and bases for calculating doses from the normal PPE liquid and gaseous effluent release source terms in SSAR Tables 11.2-1 (Sheets 1 and 2), 11.2-2, 11.2-3, 11.3-1, and 11.3-2. In addition, the staff reviewed the applicant's calculation package. The staff performed confirmatory analyses using the same parameters and values in Tables 11.4-1 and 11.4-4 of this SER in the NRC Dose 2.3.20 code, which contains the NRC endorsed XOQDOQ, LADTAP II, and GASPAR II codes.

Based on the staff's confirmatory analyses, the calculated total body and organ doses to the MEI in Tables 11.4-2 and 11.4-3 of this SER are within the ALARA design objectives in 10 CFR Part 50, Appendix I, Sections II.A, II.B, and II.C, and within the EPA's radiation standards in 40 CFR Part 190, as implemented under 10 CFR 20.1301(e), at the CRN Site. Therefore, the staff finds these values acceptable.

**Table 11.4-1 Liquid Effluent Dose Calculation Parameters
Used by the Staff for Confirmatory Analysis**

Parameter	Value	Basis
Radionuclide Release Rates	Ci/yr	SSAR Table 2.0-6
Water Type	Freshwater	SSAR Table 11.2-1
Reactor Effluent Discharge Rate	4,000 ft ³ /s	SSAR Table 11.2-1
Population Within 50 Miles	2,658,157	SSAR Table 11.2-1
Impoundment Reconcentration Model	None	Does not apply to river discharge scenario
Shore-Width Factor	0.2	RG 1.109 Table A-2

Parameter	Value	Basis
Dilution Factor for Receptors	1	Does not apply to river discharge scenario
Transit Time to Receptors	0	No dilution assumed (Most conservative value)
Usage and Consumption Rates by Age Group	kg/yr, L/yr, hr/yr, m ³	RG 1.109 Tables E-4 and E-5
Sport Fishing Harvest	1.87E+08 kg/yr	SSAR Table 11.2-1
Commercial Fishing Harvest	5.93E+06 kg/yr	SSAR Table 11.2-1
Sport Invertebrate Harvest	2.71E+05 kg/yr	SSAR Table 11.2-1
Commercial Invertebrate Harvest	8.61E+05 kg/yr	SSAR Table 11.2-1
Population Supplied by Drinking Water	2.49E+05	SSAR Table 11.2-1
Population Shoreline, Swimming, and Boating Usage	3.40E+07 hr/yr	SSAR Table 11.2-1
Irrigation Rate	110 L/m ² /month	SSAR Table 11.2-1
Vegetable Production	7.00E+08 kg/yr	SSAR Table 11.2-3
Milk Production	1.91E+08 kg/yr	SSAR Table 11.2-3
Meat Production	1.63E+08 kg/yr	SSAR Table 11.2-3

Table 11.4-2 Comparison of Doses to the MEI from Liquid and Gaseous Effluents for Compliance with 10 CFR Part 50, Appendix I

Type of Dose	Location	Annual Dose per Unit	
		Site	Limit
Liquid Effluents			
Total Body (mrem)	Watts Bar Reservoir	0.020	3
Maximum Organ = GI-LLI (mrem)	Watts Bar Reservoir	0.097	10
Gaseous Effluents			
Gamma Air (mrad)	Site Boundary	9.5	10
Beta Air (mrad)	Site Boundary	12	20
Total Body (mrem)	Residence	0.9	5
Skin (mrem)	Residence	1.9	15
Iodines and Particulates			
Maximum Organ = Thyroid (mrem)	Residence / Vegetable Garden / Beef Animal	4.5	15

Table 11.4-3 Comparison of Doses to the MEI for Compliance with 40 CFR Part 190

Type of Dose	Site Dose (mrem)				
	Liquid *	Gaseous **	Direct ***	Total #	Limit ##
Total Body	0.17	10	1.0	11	25
Thyroid	0.66	24	0.0	25	75
Other Organ (Bone)	0.54	23	0.0	24	25

* SSAR Tables 11.2-6 and 11.2-8 note (a).

** SSAR Tables 11.3-5 and 11.2-8 note (b).

*** SSAR Table 11.2-8 note (c).

Total site dose (mrem) is the sum of the liquid, gaseous, and direct radiation site doses.

40 CFR Part 190 as implemented under 10 CFR 20.1301(e).

**Table 11.4-4 Gaseous Effluent Dose Calculation Parameters
Used by the Staff for Confirmatory Analysis**

Parameter	Value	Basis
Radionuclide Release Rates	Ci/yr	SSAR Table 2.0-4
Atmospheric Dispersion and Deposition Factors	s/m ³	SSAR Table 11.3-2
Fraction of Year Leafy Vegetables Grown	1	RG 1.109 Table E-15 (Most conservative value)
Fraction of Year Milk Cows on Pasture	1	RG 1.109 default value (Most conservative value)
Fraction of Maximum Individual's Vegetable Intake from own Garden	0.76	RG 1.109 Table E-15 (Most conservative value)
Fraction of Milk-Cow Feed from Pasture	1	Most conservative value
Average Absolute Humidity for Growing Season	8 g/m ³	NUREG/CR-4653 Table 2.2
Average Temperature over Growing Season	0	Not used if absolute humidity is specified
Fraction of Year Goats at Pasture	1	Most conservative value
Fraction of Goat Feed from Pasture	1	Most conservative value
Fraction of Year Beef Cattle at Pasture	1	Most conservative value
Fraction of Beef Cattle Feed from Pasture	1	Most conservative value
Population Within 50 Miles	number	SSAR Table 11.2-2
Milk Production Within 50 Miles	1.91E+08 L/yr	SSAR Table 11.2-3
Meat Production Within 50 Miles	1.63E+08 kg/yr	SSAR Table 11.2-3
Vegetable Production Within 50 Miles	7.00E+08 kg/yr	SSAR Table 11.2-3

As described above, the staff confirmed the adequacy of the applicant's dose calculations from normal operations including AOOs using the normal PPE liquid and gaseous effluent release source terms. The staff determined that since specific details on how the new facility will control, monitor, and maintain liquid and gaseous effluent releases are not known at the ESP stage, a COL applicant or a construction permit (CP) applicant that references this ESP will need to verify that the calculated doses to members of the public from liquid and gaseous

effluent releases for reactor units, which may be constructed at the CRN Site are bounded by the doses evaluated by the staff in this SER. A COL or CP applicant referencing this ESP should address and justify any discrepancies. This includes justifying any changes made to address differences in the reactor design used to calculate doses (e.g., basis of the normal PPE liquid and gaseous effluent release source terms, liquid effluent discharge flow rates, and site-specific dilution flow rates). In addition, a COL or CP application referencing this ESP should include detailed information on the solid waste management system used to process liquid and gaseous effluents to reflect plant- and site-specific COL design considerations. The staff identified these items collectively as **COL Action Item 11-1**.

COL Action Item 11-1

An applicant for a combined license (COL) or a construction permit (CP) referencing this early site permit (ESP) should verify that the calculated doses to members of the public from normal gaseous and liquid effluent releases for a chosen reactor design at the CRN Site are bounded by the doses evaluated in this ESP application, as reviewed by the NRC staff. The applicant should evaluate discrepancies and justify any changes made to address differences in the source term for the reactor design used to calculate the doses for a COL or CP application.

11.5 Conclusion

As set forth above, the staff determined that the applicant provided information adequate to provide reasonable assurance that the normal PPE liquid and gaseous effluent releases from the CRN Site are within the ECLs in 10 CFR Part 20, Appendix B, Table 2, Columns 1 and 2, the public dose limit in 10 CFR 20.1301, and the ALARA design objectives in Sections II.A, II.B, and II.C of Appendix I to 10 CFR Part 50. Under the requirements of 10 CFR 20.1301(e), the applicant also demonstrated compliance with the EPA's radiation standards of 40 CFR Part 190.

Based upon the above findings and considerations, including implementation of COL Action Item 11-1, at the COL or CP application stage, the staff concludes that calculated doses to members of the public from normal operation of the surrogate plant including AOOs represented with the normal PPE liquid and gaseous effluent release source terms for the proposed CRN Site do not present an undue risk to the health and safety of the public. In addition, the staff concludes that the normal PPE liquid and gaseous effluent release source terms are acceptable for constructing reactor units within the applicant's bounding site-specific PPE, and that the proposed CRN Site meets the relevant requirements of 10 CFR Part 52, "Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants," and 10 CFR Part 100, "Reactor Site Criteria."