U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

BRANCH TECHNICAL POSITION 11-6

POSTULATED RADIOACTIVE RELEASES DUE TO LIQUID-CONTAINING TANK FAILURES

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of the effectiveness of radwaste systems and health physics in modeling radiation exposure scenarios and in confirming compliance with dose acceptance criteria.

Secondary - Organizations responsible for the review of site geology and hydrology characteristics and the use of conceptual models in surface and groundwater transport; civil engineering in evaluating building plant structures and foundations; and mechanical engineering for the review of the plant's structures, systems and components and design of mitigating features.

A. Background

During normal operation, nuclear power plants generate radioactive materials, as fission and activation products, which are present in primary coolant and secondary coolant and steam. Primary and secondary coolants are processed by the liquid waste management system (LWMS). The LWMS is designed to ensure that liquids and liquid wastes produced during normal operation, including anticipated operational occurrences, are handled, processed, recycled as coolant, or released in accordance with relevant U.S. Nuclear Regulatory Commission (NRC) regulations. The LWMS is comprised of permanently installed plant systems and mobile processing equipment. Typically, such systems include tanks, piping, pumps, valves, filters, demineralizers, and additional equipment that are necessary to process

Revision 4 – January 2016

and treat liquid wastes. The design of the LWMS is governed by General Design Criteria (GDC) 2, "Design Bases for Protection against Natural Phenomena"; GDC 60, "Control of Releases of Radioactive Materials to the Environment"; GDC 61, "Fuel Storage and Handling and Radioactivity Control"; and GDC 64, "Monitoring Radioactivity Releases," of Appendix A, "General Design Criteria for Nuclear Power Plants," to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," and 10 CFR 50.34a, "Design Objectives for Equipment to Control Releases of Radioactive Material in Effluents—Nuclear Power Reactors." The requirements for operational procedures and technical specifications (TS) are mandated under 10 CFR 50.36a, "Technical Specifications on Effluents from Nuclear Power Reactors." The Standard Review Plan (SRP) Section 11.2, "Liquid Waste Management System," describes the design acceptance criteria for the LWMS. The classification of LWMS equipment and piping and bases governing design criteria should be developed in accordance with the guidance of Regulatory Guide (RG) 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Reactor Power Plants," Revision 2, issued November 2001.

In addition, the design should incorporate features to reduce leakage and spills, and to facilitate operation and maintenance in accordance with the requirements of 10 CFR 20.1406, "Minimization of Contamination." Compliance with the requirements of 10 CFR 20.1406, addressing the minimization of contamination of plant facilities and avoidance of unmonitored and uncontrolled releases of radioactive materials, is addressed separately in SRP Sections 11.2 and 12.3 -12.4, "Radiation Protection Design Features." Additional NRC guidance is presented in RG 1.143, RG 4.21, "Minimization of Contamination and Radioactive Waste Generation: Life Cycle Planning," and Interim Staff Guidance (ISG) DC/COL-ISG-06, "Evaluation and Acceptance Criteria for 10 CFR 20.1406 to Support Design Certification and Combined License Applications." Industry guidance is contained in American National Standards Institute/American Nuclear Society (ANSI/ANS) 2007 and Nuclear Energy Institute (NEI) 08-08A, "Generic FSAR Template Guidance for Life Cycle Minimization of Contamination," issued September 2009, in considering the incorporation of specific design features.

The LWMS design features and characteristics differ among plants, but the most important common characteristic among plants is that designs incorporate the guidance in RG 1.143. As a result, a gross failure of the LWMS is considered highly unlikely (e.g., such as a failure involving the near total loss of the system's inventory of radioactive materials). However, the malfunction of a tank and its components, a valve misalignment, tank overflow, or an operator error appear more likely and are assumed to be the types of failures warranting an evaluation of their consequences. Although this Branch Technical Position **(**BTP) does not designate any specific type of system failure as being representative, the guidance considers that for the evaluation of such systems, the type of malfunctions analyzed should be limited to the postulated failure or rupture of a tank and components located outside of containment or outdoors. The evaluation considers the impact of the failure on the nearest potable water supply in the unrestricted area and the long-term use of water for direct human consumption or indirectly through animals (livestock watering), crops (agricultural irrigation), and food processing (with water being an ingredient), with all potential exposure pathways, as described herein.

The purpose of this BTP is to provide guidance in defining the mechanism of the failure, assumptions used for the analysis, and the approach applied in assessing the radiological impact. The objective is to develop an estimate of the amounts of radioactive materials released in an unrestricted area, and to assure that the radiological consequences will not exceed SRP acceptance criteria. Licensees use the results of this analysis to develop TS limits

for liquid holding tanks to comply with 10 CFR 50.36a and design objectives for liquid effluents under 10 CFR 50.34a.

Section B, below, provides an acceptable approach in addressing the concerns outlined above. This position paper sets forth minimum requirements. It does not prohibit the implementation of more rigorous design codes, standards, or quality assurance measures, nor does it prohibit applications of more conservative site geology and hydrology characteristics and site-specific conceptual models for surface water and ground water transport than those indicated in this BTP. Also, it does not require a reevaluation of LWMS with limiting conditions or controls for operation based on more conservative analysis and calculational assumptions. If the results of site-specific analyses still do not conform with the acceptance criteria of this BTP, the applicant is expected to propose TS limiting the total amount of radioactivity in such tanks and components. In all instances, the applicant is requested to provide sufficient information for the staff to conduct independent analyses to confirm compliance with NRC regulations using NRC guidance and acceptance criteria of this BTP.

Under SRP Section 11.2, this BTP is applicable to all license applications submitted under the requirements of 10 CFR Part 50 or 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," 6 months after its issuance. However, the guidance of the March 2007 version of BTP 11-6 remains in effect for holders of nuclear power reactor operating licenses (OLs) under 10 CFR Part 50 or for combined licenses (COLs), under 10 CFR Part 52 prior to the effective date of this BTP, and for applicants for nuclear power reactor OLs under 10 CFR Part 50 or for COLs under 10 CFR Part 52 that have committed, in applications docketed with the NRC as of the effective date of this BTP, to specific guidance in assessing the radiological consequences of a postulated failure of a tank containing radioactive materials.

B. BRANCH TECHNICAL POSITION

The NRC staff will review the information describing the design features of the LWMS provided in the safety analysis report (SAR), the design certification (DC) application, or the COL application, to the extent not addressed in a referenced certified design, including the relevant parts of SRP Section 2.4.1, "Hydrologic Description"; SRP Section 2.4.12, "Groundwater"; and SRP Section 2.4.13, "Accidental Releases of Radioactive Liquid Effluents in Ground and Surface Waters"; in accordance with RG 1.70 or RG 1.206. The requirements and acceptance criteria of SRP Section 2.4.13 include 10 CFR 100.10(c) and 10 CFR 100.20(c); GDC 2 of 10 CFR Part 50, Appendix A; 10 CFR 52.17(a)(1)(vi) for early site permit (ESP) applications and 10 CFR 52.79(a)(1)(iii) for COL applications; and RG 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I," issued April 1977.

The reviewer will select and emphasize material from the procedures described below, as may be appropriate for a particular case. If an applicant were to make use of assumptions and calculation methods that differ from NRC guidance and this BTP, the applicant should describe in details the bases for the alternative methods and parameters applied in the analysis.

The staff's review consists of eight major steps and is shared by two technical disciplines. The review steps include the evaluation of the following factors:

- failure mechanism and radioactivity releases
- mitigating design features
- radioactive source term

- calculations of transport capabilities in groundwater and surface water
- exposure scenarios and acceptance criteria
- SRP dose acceptance criteria
- specifications on tank waste radioactivity concentration levels
- evaluation findings for reviews of 10 CFR Part 52, COL and other applications

Two different technical disciplines, health physics and hydrologic engineering, take part in the review process. The revised guidance presented in the following sections identifies the responsible technical discipline for each step of the process. The health physics staff is responsible for leading the evaluation of all steps except the fourth step. The fourth step, addressing the transport of radioactivity in surface water and groundwater and deriving radionuclide concentrations in unrestricted areas, is the responsibility of the hydrologic engineering staff. The corresponding guidance for the Health Physics staff is described in this BTP and the guidance for the hydrologic engineering staff is provided in SRP Section 2.4.13.

The review responsibilities are shared as follows:

1. The health physics staff will confirm the applicant's approach used in developing the postulated tank failure scenario, will confirm the radiological source term for the assumed failed tank and components, will confirm the assumptions applied in modeling exposures and doses to members of the public, conduct an independent assessment of dose results, will confirm that dose results are consistent with the SRP acceptance criteria, and will determine whether the results of the analysis warrant, (as TS) the imposition of maximum radioactivity limits in the tank(s) identified by the applicant. The heath physics staff will coordinate its review with other technical disciplines, including civil engineering in evaluating building plant structures and foundations and mechanical engineering for the review of plant systems and components and design of mitigating features. The corresponding guidance for the health physics staff is described in SRP Section 11.2 and in this BTP.

2. In a parallel effort, the hydrologic engineering staff will review and evaluate the applicant's approach in modeling the transport of radioactivity in surface water and groundwater, will confirm the validity of the defined point of entry in unrestricted areas in light of available site-specific information and stated assumptions, and will verify the resulting radionuclide concentrations at the point of entry in unrestricted areas. The hydrologic engineering staff will confirm whether the information and results comply with the acceptance criteria of SRP Section 2.4.13 and the requirements in 10 CFR 100.20(c). The health physics staff will use the resulting radionuclide concentrations in its evaluation once the approach used in modeling the transport of radioactivity in surface water or groundwater and resulting radionuclide concentrations in unrestricted areas are deemed acceptable by the hydrologic engineering staff. The corresponding guidance for the hydrologic engineering staff is described in SRP Section 2.4.13.

Review Procedure

As part of the review process, the staff will evaluate whether the applicant has applied a screening approach to the consequence analysis, starting with a simple worst-case scenario and then progressing to more realistic site-specific analyses. If the results of the worst-case

analysis are not consistent to the SRP acceptance criteria, the applicant could conduct a more refined analysis using a site-specific conceptual model and parameters to demonstrate conformance with SRP acceptance criteria is demonstrated. If the results of site-specific analyses still do not conform to the SRP acceptance criteria, the applicant should propose TS limiting the total amount of radioactivity in such tanks and components, or explain its alternative method for meeting the regulations in sufficient detail for the staff to do an independent evaluation. In all instances, the applicant is requested to provide sufficient information for the staff to conduct independent analyses to confirm compliance with the regulations and conformance with SRP acceptance criteria.

1. Failure Mechanism and Radioactivity Releases

   The health physics staff will verify the identification of the liquid waste tank and components outside of containment or outdoors that could release the most radioactivity to the environment in the event of a failure. The components selected for the analysis should reflect the specific design features of the plant, as described in COL applications (e.g., Final Safety Analysis Report (FSAR) Sections 5, 9, 10, 11, and 12).

   For ESP and construction permit applications, applicants may not have sufficiently detailed descriptions of structures, systems, and components and design features that would contain or mitigate releases of radioactivity following the postulated failure of a tank or components containing radioactive materials. In such instances, the applicants should describe the approach and assumptions used in the analysis, identify which elements of the analysis are based on preliminary design information, and describe the reasonableness of the assumptions applied in the analysis and degree of conservatism used in modeling the failure scenario and selection of model parameters. If necessary, applicants may consider assigning an appropriate COL action item for the purpose of revising the analysis once more definitive information on design features becomes available at the OL and COL stage. Applicants should provide sufficient details for the staff to conduct an independent evaluation.

   The health physics staff will evaluate the assumed failure and release mechanisms to ensure that the proposed failure scenario is consistent with plant design features and that the applicant has applied reasonably conservative assumptions. For example, the staff will assess whether the applicant has considered the following:

   - technical justification for defining the limiting event for the consequence analysis, given known plant process systems that are expected to contain radioactive materials

   - all systems with potential sources of radioactivity contained in tanks and components located outside of containment and outdoors where there is a potential for radioactive materials to reach the environment. Such systems include permanently installed processing equipment and skid-mounted processing systems connected to the permanently installed LWMS or solid waste management system, with and without due consideration for durable and passive mitigation features

   - types of failure mechanisms and descriptions of the types of durable and passive design features applied in mitigating the impacts of such releases

   - whether the event results in a prompt release to surface water or a delayed release to groundwater

- conditions where surface water and groundwater could be impacted by a single event

- radiological impacts on members of the public for a given point of entry located in unrestricted areas in surface water and groundwater resources

The health physics staff will assess whether the applicant has:

A. evaluated and ranked tanks and components in terms of radioactivity levels and radionuclide concentrations,

B. considered whether the use of mobile skid-mounted processing systems located in readily accessible truck loading bays present a greater likelihood of failure and spills/leaks beyond the physical boundary of the building housing such equipment, and

C. applied a graded approach to considering all types of events, radioactive source terms, design features (durable and passive) assumed in mitigating releases, and potential offsite impacts.

For example, the volumes of liquid radioactive waste in tanks and components vary among plant systems. The LWMS tanks usually contain less liquid than condensate storage tanks and refueling water storage tanks. For LWMS, the amounts are typically on the order of a few to several thousand gallons, while the volumes of condensate storage tanks and refueling water storage tanks are typically on the order of several hundred thousand gallons. The volumes of tanks used in other plant systems are typically on the order of a few thousand gallons or less. Similarly, the inventories of radioactivity vary, with higher radionuclide concentrations found in LWMS tanks and components, and lower concentrations observed in condensate storage tanks and refueling water storage tanks. Finally, the use of skid-mounted processing equipment connected to permanently installed LWMS and possible failures associated with system interfaces should be evaluated to confirm whether the system tank and/or components selected for the analysis are conservatively bounding in terms of the total inventory of radioactive materials assumed in the failure scenario.

The health physics staff should account for these aspects and their interrelationships when confirming whether the applicant has selected (a) a case that assumes the highest release of radioactivity to the environment, or (b) an event involving plant systems and inventories of radioactive materials associated with system designs that exclude the use of mitigating features.

2. Mitigating Design Features

The health physics staff will consider the use of design features (e.g., steel liners or walls in areas housing components, dikes for outdoor tanks, and overflow and sump/drain provisions incorporated to mitigate the effects of a postulated tank and components failure). The types of failed system components typically are waste collection tanks or sample tanks, among others. However, the components selected for the analysis should reflect the specific design features of the plant, as described in COL applications (e.g., FSAR Sections 5, 9, 10, 11, and 12). The purpose of this review is to ensure that the analysis considers the proper selection of assumed failed equipment, appropriate release mechanisms from the selected equipment and buildings and structures housing such systems, and determine whether the proposed design is

capable of retaining the liquid inventory of the failed tank and components and includes provisions to pump the spilled inventory back to proper processing systems with sufficient holding capacity. If an analysis takes credit for liquid retention design features, the applicant must provide information that demonstrates that such features are durable and passive and that the receiving system has the storage capacity to hold the expected volume of liquid wastes. Mitigating design features that rely primarily on operator actions for their effectiveness are not acceptable. Similarly, credit may not be taken for nuclear grade coatings and joint sealants applied to concrete floor and wall surfaces in rooms where tanks and components are located, or for leakage barriers outside of building foundations since such materials are not durable as they require repeated applications.

Applicants may use empirical evidence, operating experience, and modeling results to assess and confirm the efficacy of specific design features in retaining releases or retarding the movement of radioactivity once in the environment. In addition, applicants can review and apply the guidance of RG 1.143 and RG 4.21 and in industry standards ANSI/ANS 2007 and NEI 08-08A in considering the incorporation of specific design features. Based on this information, the staff will determine if the analysis can take credit for the proposed design features. In cases where mitigating design features of tanks meet the conditions of the guidance, the staff may waive the need for a consequence analysis in the context of SRP Section 11.2 and BTP 11-6 since the use of durable and passive design features would provide reasonable assurance that the SRP acceptance criteria would be met and, thus, NRC requirements.

The presence of mitigating design features does not change the guidance in SRP Section 2.4.12 that relates to demonstrating the adequacy of the site's hydrogeologic properties via a consequence analysis that uses combined literature data and site-specific parameters characterizing transport mechanisms, such as aquifer materials, hydraulic conductivity, and porosity, etc. (See SRP Section 2.4.13 for details on the type of information and site data that would be acceptable for characterizing the hydrogeologic properties of a site and staff's approach in evaluating the information provided by the applicant.)

3. Radioactive Source Term

The health physics staff will review the proposed radionuclide distributions and concentrations assumed for the postulated failure of a tank and components using the information presented by the applicant in instances where credit for durable and passive design features is not applied in mitigating the impacts of such releases. Conceptually, the analysis assumes that a system or component fails to meet the design bases as required by 10 CFR 50.34a or 10 CFR 52.79, and GDC 60, GDC 61 and GDC 64. The staff will evaluate the basis and assumptions used in developing the source term, radionuclide distributions and concentrations to ensure that the highest potential radioactive material inventory is selected among the expected types of liquid and wet waste streams processed by plant systems. Conceptually, the health physics staff will confirm whether the applicant's approach in developing the radioactive source term has considered the following:

A. reactor system and thermal power consistent with the design certification,

B. description of system and components assumed to fail as permanently installed process equipment, including the interface of skid-mounted mobile processing systems, as justified,

C. process or waste streams selected,

D. location of failed tank and components in plant buildings and at outdoor locations, if applicable,

E. nominal volume of failed tank and components,

F. failed fuel fraction applied in deriving radioactivity inventory, if different than default value of SRP guidance,

G. radionuclide re-concentration factors applied in deriving radioactivity inventory, as mandated by the selected process or specific waste streams,

H. assumed radionuclide distributions and concentrations and total radioactivity inventory in tanks and components of systems located indoors and outdoors,

I. for systems located indoors, description of the release mechanism starting from the room or cubicle housing such systems to the underlying ground immediately below the building's foundation boundary,

J. for systems located outdoors, description of the release mechanism starting from the retention basin or diked area to the nearest point of entry into the site's surface water runoff discharge system and location of its outfall in unrestricted areas, and groundwater if a pathway exists,

K. assumed dilution, retardation factors, and travel times in instances where groundwater or surface water models were not used to describe the transport of radioactivity from the site to the point of entry in unrestricted areas, and

L. assumed dilution factors applied beyond the point of entry in unrestricted areas in instances where groundwater or surface water models were not used to describe the movement of radioactivity between the point of entry into unrestricted areas and location of dose receptors.

In assigning radionuclide distributions and concentrations for the relevant exposure scenario, the staff should consider whether the site conceptual model defines the release as through a surface water or groundwater pathway, and also consider conditions where surface water and groundwater resources could be impacted by a single event. For scenarios that include surface water pathways, the source term should consider both short and long-lived radionuclides. The rationale for including both types of radionuclides in surface water release scenarios is that releases to useable surface water resources and impacts would occur promptly with minimal time for retardation after a release. In assessing the movement of radioactivity in surface water bodies and streams, the dispersion of radioactivity is expected to be affected by various mechanisms, including near- and far-field mixing patterns, recirculation driven by current directions and flow rates, differences in temperatures in relation to the receiving water body, and impacts of tidal action, among others.

For groundwater pathways, the source term should consider radionuclides that are expected to persist in groundwater, taking into account radioactive half-lives, distribution coefficients, retardation factors, and environmental mobility in groundwater. For scenarios involving groundwater, the rationale is that releases to useable water resources and impacts to users are assumed to occur over protracted time periods, years to decades, which afford time for the radioactive decay of short-lived radionuclides

with half-lives expressed in months or less than a few years. As a result, this consideration would include long-lived and mobile radionuclides, such as tritium, C-14, Ni-63, Sr-90, Tc-99, I-129, and Cs-137, among others, and both parent and progeny radionuclides for radionuclides with decay chains.

The radionuclide inventory for the tank and its components that are assumed to fail should be based on a conservative estimate of 80 percent capacity of that tank and its components. The selection of 80 percent assumes that some of the content of the failed tank would remain in the tank and room or cubicle where the tank is located, with the associated amounts of radioactive materials being retained in the building itself and, therefore, not available for environmental transport. Appendix A to this BTP presents a list of radionuclides which should be considered when defining source terms for surface water and groundwater release pathways. Depending on the type of scenario being considered in the radiological assessment, an applicant may exclude specific radionuclides, but must provide adequate justification to the staff for specific omissions. In those instances, the staff will review the basis of the justification for omitting specific radionuclides and evaluate the associated impacts on the results of the radiological assessment and confirm whether the applicant continues to meet the SRP acceptance criteria.

The health physics staff will confirm that the selection of the type of radioactive materials and radionuclide distributions correspond to the highest expected concentrations and inventory of radioactivity in selected systems and components, and that the listed radionuclides are consistent with the plant design (see Appendix A), proposed release mechanism and exposure pathways at the point of entry into the nearest source of usable surface water or groundwater located in an unrestricted area.

The health physics staff will use the resulting radionuclide concentrations in its analysis once the approach used in modeling the transport of radioactivity in surface water or groundwater and resulting radionuclide concentrations in unrestricted areas are deemed acceptable by the Hydrologic Engineering staff.

The above-described process for developing the assumed radioactive source term updates the methods and use of the computer code described in Chapter 4.4 and Appendices A and B of NUREG-0133, “Preparation of Radiological Effluent Technical Specifications for Nuclear Power Plants.” Applicants may propose and use alternate methods for developing radioactive source terms. In such instances, applicants are responsible for providing sufficient information and justification to enable the staff to perform an independent evaluation of any proposed alternative methods. With respect to the guidance of NUREG-0133, this BTP updates that guidance for applications submitted six months after the issuance of the final version of this BTP. However, the guidance of NUREG-0133 remains in effect for holders of nuclear power reactor OLs under 10 CFR Part 50 or COLs under 10 CFR Part 52 prior to the effective date of this BTP, and for applicants for nuclear power reactor OLs under 10 CFR Part 50 or COLs under 10 CFR Part 52 that have committed, in applications docketed with the NRC as of the effective date of this BTP, to specific guidance in assessing the radiological consequences of a postulated failure of a tank containing radioactive materials.

4. Calculations of Transport Capabilities in Groundwater or Surface Water

The Hydrologic Engineering staff will make independent calculations of transport mechanisms and potential contamination pathways to surface water and groundwater

environments that may, under accident conditions, transport radioactive contaminants to existing and future water users located in unrestricted areas.

See SRP Sections 2.4.12 and 2.4.13 for details on the type of information and site data that would be considered in the development of a site conceptual model and staff's approach in evaluating the information provided by the applicant.

5. Exposure Scenarios and Acceptance Criteria

The health physics staff will review exposure scenarios and assumptions describing exposure pathways associated with the release of radioactivity from a postulated failed tank and components. The scenarios include:

A. Direct Water Use - This Scenario Assumes That Members Of The Public Would Consume Drinking Water Withdrawn Near Or At The Point Of Entry In An Unrestricted Area. The Sources Of Water Include A Groundwater Well, Or From A Surface Water Body Or River.

B. Indirect Water Use - This Scenario Assumes The Use Of Water In Indirect Human Consumption. Such Scenarios May Include Livestock Watering Or Irrigation Of Grazing Pastures, Consumption Of Animal Products (Meat And Milk Products), Fish And Invertebrate Consumption, Crop Irrigation And Consumption Of Such Crops, Or Water Used As An Ingredient In Food Products Or In Food Processing.

C. Combined Use of Water - This scenario assumes both direct and indirect water use. In such an instance, the scenarios would be modeled separately and the resulting doses would be summed up and compared to the SRP acceptance criteria.

For the purpose of the consequence analysis, the point of entry in unrestricted areas is defined as a location beyond the site boundary where the applicant has no administrative controls that could be used to restrict the use of surface water or groundwater resources, or require the treatment of surface water or groundwater for use as finished drinking water. When considering surface water resources, the selected point of entry in unrestricted areas should be identified as that location in a surface water body or stream affected only by near-field dilution near the point of entry. Modeling approaches that assume the effects of far-field dilution or turbulent mixing will not be acceptable to the staff as such assumptions are expected to result in excessively high and non-conservative dilution factors. In instances where far-field dilution and turbulent mixing are the only processes by which accidental releases are dispersed in the environment, the applicant should provide a justification for this approach and sufficient information to enable the staff to conduct an independent evaluation of the proposed dispersion processes. For groundwater resources, the applicant should assume the presence of a hypothetical well located at a nearby distance from the site boundary and depth within an aquifer, where the effects of groundwater hydraulic gradient, recharge properties, and velocity are suitable for groundwater contamination, would be acceptable in characterizing radionuclide concentrations in groundwater. As before, groundwater modeling approaches that result in excessively high and non-conservative dilution factors will not be acceptable to the staff. Finally, the consequence analysis may not take credit for the use of typical water supply system treatment methods as a mean of removing the presence of radioactivity or reducing radionuclide concentrations in finished drinking water or water used in food processing and as an ingredient.

The health physics staff will review the supporting basis for the selected scenario, the reasonableness of assumptions, and the degree of conservatism applied in modeling the scenario and selection of model parameters. With respect to consumption rates of water and food products impacted by indirect uses of water, the analysis should initially apply the recommended values for the maximum exposed individual in Table E-5 of RG 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I." issued October 1977. The values of Table E-5 provide initially a reasonable level of conservatism in defining consumption rates and in estimating associated doses. For scenarios that consider the consumption of fish and invertebrates, the analysis should apply appropriate bio-accumulation factors for the assumed aquatic environment. The staff will confirm the appropriateness of the selected scenario and acceptability of underlying assumptions using the information provided by the applicant and information obtained from the results of a land-use census, if available, or information gleaned from Federal, State, and local or regional sources.

In its review, the health physics staff will use the radionuclide concentrations in water at the point of entry located in unrestricted areas that were calculated and determined to be acceptable by the Hydrologic Engineering staff, as described in Item 4, above.

6. SRP Dose Acceptance Criteria

The health physics staff will compare the results of the analyses of radiological impacts with the appropriate acceptance criteria when assessing the acceptability of these results. The acceptance criteria presented here are based on doses to members of the public, rather than on effluent concentration limits, as was the case in previous guidance. The reason for this change is the need to better account for the effects of multiple exposure pathways. Releases may affect surface water and groundwater differently; consequently, the impact in some instances may be by way of direct consumption of water, while in others the impact may be only by indirect use of water (e.g., for livestock watering or crop irrigation). These different exposure scenarios and pathways can be quantified, because the applicant is expected to describe uses of water resources based on local or regional land-use census information.

As described in the 2007 version of BTP 11-6, the acceptance criteria stated that the postulated release should not result in radionuclide concentrations in useable surface water or groundwater exceeding the effluent concentration limits (ECLs) of 10 CFR Part 20, "Standards for Protection against Radiation," Appendix B, "Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage," Table 2, Column 2, and Note 4 for radionuclide mixtures. While the ECLs are a reasonable standard for direct consumption of water, their use is not as obvious or practical for indirect uses of water or for the consumption of impacted food products. As a result, the revision of this BTP applies a dose-based limit instead, because it provides the most flexibility in assessing and meeting the acceptance criteria, regardless of the postulated exposure scenarios.

The dose acceptance criteria are as follows:

A. Radioactive releases associated with the postulated failure of a tank and components should not do the following:

i. result in radioactive material concentrations leading to a dose in excess of 100 mrem (1 mSv) at the point of entry into the nearest existing or a known future water supply when (1) used as a source of water for direct human consumption or (2) used indirectly through livestock watering or irrigation of grazing pastures, consumption of animal products (meat and milk products), fish and invertebrate consumption, crop irrigation and consumption of such crops, or used as an ingredient in food products or food processing, or

ii. result in a total dose in excess of 100 mrem (1 mSv) in instances where a scenario assumes the dual use of water, direct and indirect usage. In such an instance, the dose from each scenario must be derived separately and the resulting doses must be added, with the summation of doses compared to the SRP dose acceptance criteria.

B. If the results of site-specific analyses do not conform with the SRP dose acceptance criteria, the applicant should propose TS limiting the total amount of radioactivity in such tanks and components such that the total inventory of radioactivity will not result in doses in excess of 100 mrem (1 mSv) at the point of entry into the nearest existing or a known future water supply located in unrestricted areas when used as a source of water for direct and indirect human consumption.

C. In complying with the above SRP dose acceptance criteria, this guidance does not relieve any applicant or license holder from complying with the dose limits of 10 CFR 20.1301, "Standards for Protection against Radiation," 10 CFR 20.1301(e); and 10 CFR 20.1302, "Compliance with Dose Limits for Individual Members of the Public"; Column 2 effluent concentration limits and Note 4 of Appendix B to 10 CFR Part 20; and design objectives and as low as is reasonably achievable (ALARA) provisions of Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low As Is Reasonably Achievable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents," to 10 CFR Part 50.

For the purpose of this BTP (and SRP Section 2.4.13), a receptor is defined as a member of the public assumed to consume and use water at a point of entry located in an unrestricted area. "Member of the public" means any individual who is not receiving an occupational dose. "Unrestricted area" means an area, access to which is neither limited nor controlled by the licensee (10 CFR 20.1003). The point of entry in an unrestricted area is assumed be a domestic well, or part or all of a fresh surface water body (e.g., stream, river, lake). In the context of this BTP, the point of entry is not the same as the point of discharge, in light of the definition given in RG 1.21 ("Measuring, Evaluating, and Reporting Radioactive Material in Liquid and Gaseous Effluents and Solid Waste," Revision 2). Under this BTP (and SRP Section 2.4.13), radiological impacts associated with postulated accidental releases of radioactive materials are not used in demonstrating literal compliance with the requirements of 10 CFR 20.1301, 10 CFR 20.1302, and 10 CFR 20.1301(e) and design objectives and ALARA provisions of Appendix I to 10 CFR Part 50. Rather, the SRP dose acceptance criteria are defined as a measure of acceptability in assessing the radiological impacts of a postulated tank failure on usable sources of surface water or groundwater. Compliance with the above noted regulatory requirements is addressed in SRP Sections 11.2 to 11.5, "Process and Effluent Radiological Monitoring Instrumentation and Sampling Systems," using the guidance of RG 1.21 and 4.15 ("Quality Assurance for Radiological Monitoring Programs

(Inception Through Operations to License Termination) – Effluent Streams and the Environment," Revision 2) implemented under a plant and site-specific Offsite Dose Calculation Manual (ODCM).

The health physics staff will independently confirm whether the dose results presented by the applicant comply with the acceptance criteria using the information provided in the supporting documentation and results of the parallel evaluation of surface water and groundwater transport models conducted by the Hydrologic Engineering staff.

7. Specifications on Tank Waste Radioactivity Concentration Levels

If the results of site-specific analyses do not conform with the SRP acceptance criteria, as described above and in Appendix B to this BTP, the applicant should propose TS limiting the total amount of radioactivity in such tanks and components. Chapter 16, TS Section 5.5, "Programs and Manuals," of the FSAR addresses this commitment in COL applications. Information on the associated implementation is presented in standard technical specifications, including NUREG-1430, "Standard Technical Specifications—Babcock and Wilcox Plants," issued April 2012; NUREG-1431, "Standard Technical Specifications—Westinghouse Plants," issued April 2012; NUREG-1432, "Standard Technical Specifications—Combustion Engineering Plants," issued April 2012; NUREG-1433, "Standard Technical Specifications—General Electric Plants (BWR/4)," issued April 2012; and NUREG-1434, "Standard Technical Specifications—General Electric Plants (BWR/6)," issued April 2012. The health physics staff will evaluate the proposed technical specification limiting the radioactivity content of liquid-containing tanks and components to ensure that the TS are consistent with the safety evaluation. The maximum inventory of radioactive materials, in the event of an uncontrolled release of radioactivity, is based on that quantity of radioactivity that will not exceed the SRP dose acceptance criteria of 100 mrem (1 mSv) from all relevant pathways at the defined point of entry in unrestricted areas. The milestones for the development and implementation of such plant and site-specific requirements are addressed in FSAR Sections 11.5 and 13.4 of COL applications. In addressing the implementation of Chapter 16, Section 5.5, this BTP does not relieve any applicant or license holder from complying with the dose limits 10 CFR 20.1301 and 10 CFR 20.1302, Column 2 effluent concentration limits and Note 4 in Appendix B to 10 CFR Part 20, and the design objectives and ALARA provisions of Appendix I to 10 CFR Part 50.

As part of the ODCM, the applicant is required, under 10 CFR Part 50, Appendix I Sections III and IV, to confirm, via the conduct of yearly land-use census, whether the identified uses of water resources are still valid and limiting in establishing the maximum total inventory of radioactivity in the tank(s) and components assumed to have failed in the consequence analysis. If not, the applicant is should revise the consequence analysis using updated land-use information and define a new maximum total inventory of radioactivity for such a tank(s) and components.

Appendix B to this BTP supersedes the corresponding guidance described in Section 4.4 of NUREG-0133 as indicated in the statement of applicability. The guidance of Section 4.4 of NUREG-0133 remains in effect for 10 CFR Part 50 licensees and 10 CFR Part 52 applicants and license holders that have incorporated the guidance of Section 4.4 of NUREG-0133 in their current licensing basis prior to the conditions noted in the statement of applicability.

C. TECHNICAL RATIONALE

The technical rationale for these acceptance criteria applied in reviewing the postulated radioactive releases due to liquid-containing tank and component failures is as follows:

1. Compliance with GDC 2, GDC 60, GDC 61 and GDC 64 require, in part, that the nuclear power plant design shall include means to control and monitor releases of radioactive materials in gaseous and liquid effluents, and provide adequate safety during normal reactor operation, including anticipated operational occurrences.

   GDC 2 and GDC 61 are applicable because these SRP sections are concerned with tanks and associated components outside of containment or outdoors that could contain radioactive liquids. A single failure of one of these tanks and components could release radioactive liquids to surface water or groundwater and potentially impact the public and result in unnecessary radiation exposures.

   GDC 60 and GDC 64 are applicable to this BTP because this section is concerned with tanks and associated components outside of containment that could contain radioactive liquids. A single failure of these tanks could release radioactive liquids to surface water or ground water and potentially impact public health and safety.

   Compliance with GDC 60 and GDC 64 requires, as addressed in SRP Section 11.5 in demonstrating compliance with liquid effluent releases, that the nuclear power plant design shall include the means to control and monitor releases of radioactive materials in gaseous and liquid effluents and provide adequate safety during normal reactor operation, including anticipated operational occurrences.

   Meeting these criteria provides reasonable assurance that releases of radioactive materials due to a single failure of liquid-containing tanks and components outside of containment during normal operations or anticipated operational occurrences will not result in usable water concentrations and doses to members of the public exceeding the acceptance criteria identified above.

2. Conformance with the acceptance criteria of 100 mrem (1 mSv) at the point of entry into the nearest existing or a known future water supply requires that radioactive materials contained in a failed tank and component do not result in radionuclide concentrations in excess of those values that would yield doses in excess of 100 mrem (1 mSv) for all potential exposure pathways, as described by the applicant.

   A single failure of tanks and components could release radioactive liquids to surface and ground water and potentially impact the public. GDC 60 and GDC 64 require that the nuclear power unit design include the means to control and monitor the release of radioactive materials in gaseous and liquid effluents, and 10 CFR Part 20 (Appendix B, Table 2, Column 2) provides ECLs in the unlikely event of a single failure of liquid-containing tanks outside of containment.

   Meeting these criteria provides assurance that releases of radioactive materials due to a postulated single failure of liquid-containing tanks and components located outside of containment during normal operations or anticipated operational occurrences will not result in radionuclide concentrations in excess of those values that would yield doses in excess of 100 mrem (1 mSv) for all potential exposure pathways involving usable surface water and groundwater.

The dose-based acceptance criteria should not be construed as a literal demonstration of compliance with 10 CFR 20.1301 and 10 CFR 20.1302. Rather, the acceptance criteria are defined here as a measure of acceptability in assessing the radiological impacts of a postulated tank failure on usable sources of surface water or groundwater. While the ECLs of 10 CFR Part 20, Appendix B, Table 2, Column 2 are a reasonable standard for direct consumption of water, their use is not as obvious or practical for indirect uses of water and for the consumption of impacted food products. As a result, a dose-based limit is applied instead, because it provides the most flexibility in assessing compliance, regardless of the postulated exposure scenarios.

3. If the results of site-specific analyses do not conform with SRP acceptance criteria, as described here and in Appendix B to this BTP, the applicant is should propose TS limiting the total amount of radioactivity in such tanks and components. The health physics staff will evaluate the proposed technical specification limiting the radioactivity content of liquid-containing tanks and components to ensure that the TS are consistent with the safety evaluation. Chapter 16, Section 5.5, "Programs and Manuals," of the SRP identifies the requirements for this technical specification and commitments in COL applications. In addition, this requirement is supported in the ODCM, NUREG-1301 "Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Pressurized-Water Reactors," issued April 1991, for pressurized water reactors (PWRs) and NUREG-1302, "Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Boiling-Water Reactors," issued April 1991, for boiling water reactors (BWRs), which includes the procedures to comply with this requirement.

   As part of the ODCM, the applicant is required, under 10 CFR Part 50, Appendix I Sections III and IV, to confirm, via the conduct of yearly land-use census, whether the identified uses of water resources are still valid and limiting in establishing the maximum total inventory of radioactivity in tanks and components assumed to have failed in the consequence analysis. If not, the applicant is should revise the consequence analysis using updated land-use information and define a new maximum total inventory of radioactivity for such tanks and components. The milestones for the development and implementation of a plant-and site-specific ODCM are addressed in FSAR Sections 11.5 and 13.4 of COL applications. The health physics staff will evaluate separately the scope of these commitments as part of the review of FSAR Sections 11.5 and 13.4 of COL applications.

4. With respect to the guidance in Section 4.4 of NUREG-0133 describing specifications for the content of radioactivity in liquid-containing tanks, Appendix B to this BTP updates that guidance for applications submitted 6 months after the issuance of this BTP. However, the guidance in Section 4.4 of NUREG-0133 remains in effect for holders of nuclear power reactor OLs under 10 CFR Part 50 or COLs under 10 CFR Part 52 as of the effective date of this BTP, and for applicants for nuclear power reactor OLs under 10 CFR Part 50 or COLs under 10 CFR Part 52 that have committed, in applications docketed with the NRC as of the effective date of this BTP and SRP Section 2.4.13, to specific guidance in assessing the radiological consequences of a postulated failure of a tank containing radioactive materials.

   Similarly, this BTP updates the guidance of Section 4.4 and Appendices A and B of NUREG-0133 addressing the development of assumed radioactive source terms in failed tank and components. The reasons for updating the guidance of NUREG-0133 is that the computer code is no longer supported by the NRC, the computer code considers a very limited suite of radionuclides in the consequence analysis, and the acceptance criteria built into the code are not consistent with the current effluent concentration limits

of Appendix B (Table 2, Column 2) to 10 CFR Part 20. While this BTP provides equivalent guidance, applicants may propose and use alternative methods in developing radioactive source terms. In such instances, applicants are responsible for providing sufficient information and justification to enable the staff to perform an independent evaluation of any proposed alternative method.

The guidance in Appendices A and B of NUREG-0133 remains in effect for holders of nuclear power reactor OLs under 10 CFR Part 50 or COLs under 10 CFR Part 52 as of the effective date of this BTP, and for applicants for nuclear power reactor OLs under 10 CFR Part 50 or COLs under 10 CFR Part 52 that have committed, in applications docketed with the NRC as of the effective date of this BTP, to specific guidance in assessing the radiological consequences of a postulated failure of a tank containing radioactive materials.

D. EVALUATION FINDINGS

The health physics and hydrologic engineering staff will document the results of the evaluation of site characteristics and conformance with the SRP radiological acceptance criteria. In its evaluation and conclusions, the health physics staff will refer to the evaluation performed by the hydrologic engineering staff and not reiterate in its analysis and conclusions the results presented by the hydrologic engineering staff in response to SRP Section 2.4.13. Together, the evaluations of the hydrologic engineering and health physics staff support the staff's conclusions as to whether the SRP acceptance criteria have been met and whether the applicant has appropriately applied applicable NRC guidance.

The reviewers will describe what was done to evaluate the applicant's SAR. The staff's evaluation will verify the applicant's results, determine whether the applicant followed applicable regulatory guidance or used an alternative approach, perform independent calculations, and confirm the adequacy of all stated assumptions and model parameters used in the consequence analysis, as well as conclusions presented in the analysis.

The reviewers will summarize the information used in assessing the consequence of tank and component failures, including the assumed failure scenarios, the basis of the radioactive source term, site characteristics and parameters used in modeling the transport of radioactivity to the point of entry in unrestricted areas, and exposure scenarios and resulting doses to members of the public who use impacted surface water or groundwater.

The reviewers will then articulate the bases for the staff's conclusions and for acceptance of the results and supporting information. The reviewers will verify that the applicant has provided sufficient information and that the review and calculations (if applicable) support the conclusions of the reviewers.

The reviewers may state that certain information provided by the applicant was not considered to be essential to the staff's review and was not reviewed by the staff, or that the staff used alternative information or parameters in performing its independent evaluation.

The following are examples of conclusions that will be included in the staff's Safety Evaluation Report (SER), based on the approach and methods used by the applicant in demonstrating consistency with NRC guidance and acceptance criteria of SRP Section 11.2 and BTP 11-6.

1. The review confirmed the postulated radionuclide concentrations in the applicable failed components based on the default PWR fuel failure rate or BWR fuel release rate, and the effect of site hydrologic characteristics for those systems that have not been

equipped with design features to mitigate the effect of tank and component failures. The selection of the failed tank and tank volume, radionuclide distributions and concentrations, total radioactive inventory, and assumed failure scenarios were found to be acceptable. The acceptance is based on the staff's review and independent evaluations confirming that the applicant has considered the appropriate plant systems, tanks and components assumed to fail, locations of tanks and components in the plant, appropriate credit for design features applied in mitigating the consequences of a tank and component failures, and the assumed mechanism for the radioactivity to enter a surface water body or groundwater beyond the physical boundary of the building housing such systems.

2. For cases where design features were incorporated in mitigating the consequences of a failure of a tank and components, the staff found such features acceptable. The design features that were evaluated include steel liners or walls or dikes surrounding the failed tanks and their components and tank overflow and sump/drain provisions. The basis for the staff's acceptance is the capability of design features (Note: Staff should list and describe specific features in SER) to prevent the release of radioactivity from entering a surface water body or groundwater in unrestricted areas using durable and passive features requiring no operator interventions. Therefore, the staff concludes that the design provisions incorporated by the applicant are acceptable and that they provide reasonable assurance in mitigating the effects of the failure of a tank and components, as described in the application.

3. The review confirmed the applicant's approach to modeling the transport of radioactivity in surface water or groundwater starting from the building housing the assumed failed tank and components to the nearest point of entry in unrestricted areas. For the reasons presented in SER Section 2.4.13, the review concludes that the identification and consideration of the potential effects of postulated releases of radioactive liquid effluents in groundwater and surface water in the vicinity of the site are acceptable and meet the requirements of 10 CFR Part 50, Appendix A, GDC 2 and GDC 61 and 10 CFR 100.10(c) or 10 CFR Part 52 and 10 CFR 100.20(c), and are consistent with the guidance in SRP Section 2.4.13.

4. The staff concludes that (1) the postulated failure of a tank and components has been evaluated, (2) the design features are acceptable and meet the requirements of 10 CFR Part 50, Appendix A, GDC 60 and GDC 64 for controlling and limiting releases of radioactive materials to the environment, and (3) the design features provide an adequate level of safety during normal reactor operation, including anticipated operational occurrences. Plant facility structures and system design features described in the application provide reasonable assurance that the assumed release will not result in radionuclide concentrations in surface water or groundwater exceeding the SRP acceptance criterion of a total dose of 100 mrem (1 mSv) when used in unrestricted areas. For applicants that have used alternate methods and assumptions, other than that described in this BTP, the staff concludes, after conducting an independent evaluation, that the supporting information and results of the consequence analysis are acceptable and the staff finds that the dose results are consistent with the acceptance criteria.

5. For an ESP or a CP application in which the results of the consequence analyses and comparisons to BTP 11-6 acceptance criteria rely on preliminary design information, the staff confirm that the applicant has proposed appropriate COL action items for the purpose of revising the analysis once more definitive information on design features becomes available at the OL and COL stage. In the review of the information provided

in the ESP or CP, the staff confirms that the applicant has met BTP 11-6 acceptance criteria based on the approach and model assumptions described in the analysis, including the reasonableness of the assumptions applied in the analysis and degree of conservatism in modeling the failure scenario and doses to a receptor located in unrestricted areas.

6. The staff concludes that the applicant's proposed TS limiting the total amounts of radioactivity in tanks and components, as described in the application, are adequate based on the results of the staff's review and evaluation. The basis of the staff's acceptance of the TS is based on the evaluation of the selected system and failed tank and components, assumed inventory of radioactive materials in the failed tank and components, assumed failure scenario, methods and assumptions used in modeling the transport of radioactivity into unrestricted areas, and definition of limiting exposure scenarios for direct and indirect uses of surface water or groundwater in unrestricted areas. The evaluation demonstrates that the results of the analysis are consistent with the SRP acceptance criterion in meeting the total dose criterion of 100 mrem (1 mSv) for surface water or groundwater used in unrestricted areas. The health physics staff confirmed that the proposed TS limiting the radioactivity content for the stated liquid-containing tank and components have been incorporated into Chapter 16, Section 5.5, "Programs and Manuals," of the FSAR, and identified as a program element, as addressed in FSAR Sections 11.5 and 13.4 of COL applications.

E. REFERENCES

1. American National Standards Institute/American Nuclear Society, ANSI/ANS-40.37-2009, "American National Standard, Mobile Low-Level Radioactive Waste Processing Systems," 2009. Superseded ANSI/ANS-40.37-1993 in 2009. Standards are available at http://www.ANSI.org.

2. American National Standards Institute/American Nuclear Society, ANSI/ANS-55.6-1993 (R2007), "Liquid Radioactive Waste Processing System for Light Water Reactor Plants," Reaffirmed in 2007. Standards are available at http://www.ANSI.org.

3. Nuclear Energy Institute, NEI 08-08A, "Generic FSAR Template Guidance for Life Cycle Minimization of Contamination," Revision 0, October 2009. ADAMS Accession No. ML093220530.

4. U.S. Code of Federal Regulations, "Standards for Protection Against Radiation," Part 20, Chapter 1, Title 10, "Energy," Appendix B, "Annual Limits on Intake and Derived Air Concentrations of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage."

5. U.S. Code of Federal Regulations, "Design Objectives for Equipment to Control Releases of Radioactive Material in Effluents in Nuclear Power Reactors,"§ 50.34a, Chapter 1, Title 10, "Energy."

6. U.S. Code of Federal Regulations, "Technical Specifications on Effluents from Nuclear Power Reactors," § 50.36a, Chapter 1, Title 10, "Energy."

7. U.S. Code of Federal Regulations, "Domestic Licensing of Production and Utilization," Part 50, Chapter 1, Title 10, "Energy," Appendix A, "General Design Criteria for Nuclear Power Plants," General Design Criterion 2, "Design Bases For Protection Against Natural Phenomena."

8. U.S. Code of Federal Regulations, “Domestic Licensing of Production and Utilization,” Part 50, Chapter 1, Title 10, “Energy,” Appendix A, “General Design Criteria for Nuclear Power Plants,” General Design Criterion 60, “Control of Releases of Radioactive Materials to the Environment.”

9. U.S. Code of Federal Regulations, “Domestic Licensing of Production and Utilization,” Part 50, Chapter 1, Title 10, “Energy,” Appendix A, “General Design Criteria for Nuclear Power Plants,” General Design Criterion 61, “Fuel Storage and Handling and Radioactivity Control.”

10. U.S. Code of Federal Regulations, “Domestic Licensing of Production and Utilization,” Part 50, Chapter 1, Title 10, “Energy,” Appendix A, “General Design Criteria for Nuclear Power Plants,” General Design Criterion 64, “Monitoring Radioactivity Releases.”

11. U.S. Code of Federal Regulations, "Reactor Site Criteria-Purpose," §100.10, Chapter 1, Title 10, "Energy.” (Factors to be Considered When Evaluating Sites under Subpart A, Evaluation Factors for Stationary Power Reactor Site Applications, before January 10, 1977 And For Testing Reactors)

12. U.S. Code of Federal Regulations, "Reactor Site Criteria-Scope," §100.20, Chapter 1, Title 10, "Energy.” (Factors to be Considered When Evaluating Sites under Subpart B, Evaluation Factors for Stationary Power Reactor Site Applications,” on or after January 10, 1977)

13. U.S. Nuclear Regulatory Commission, DC/COL-ISG-06, “Final Interim Staff Guidance Evaluation and Acceptance Criteria for 10 CFR 20.1406 to Support Design Certification and Combined License Applications,” (as incorporated in SRP Section 12.3-12.4). September 9, 2008.

14. U.S. Nuclear Regulatory Commission, DC/COL-ISG-014, “Interim Staff Guidance - Assessing the Radiological Consequences of Accidental Releases of Radioactive Materials from Liquid Waste Tanks in Ground and Surface Waters for Combined License Applications.” ADAMS Accession No. ML12191A330.

15. U.S. Nuclear Regulatory Commission, “Liquid Radioactive Release Lessons Learned Task Force,” Final NRC Report, September 2006. ADAMS Accession No. ML062650312.

16. U.S. Nuclear Regulatory Commission, NUREG-0133, “Preparation of Radiological Effluent Technical Specifications for Nuclear Power Plants.” October 1987. ADAMS Accession No. ML091050057.

17. U.S. Nuclear Regulatory Commission, NUREG-0800, Branch Technical Position 11-6 “Postulated Radioactive Releases Due to Liquid-Containing Tank Failures,” March 2007. ADAMS Accession No. ML070720635.

18. U.S. Nuclear Regulatory Commission, NUREG-0800, SRP Section 11.2, “Liquid Waste Management System,” March 2007. ADAMS Accession No. ML063600412.

19. U.S. Nuclear Regulatory Commission, NUREG-0800, SRP Section 2.4.1, “Hydrologic Description,” March 2007. ADAMS Accession No. ML070100646.

20. U.S. Nuclear Regulatory Commission, NUREG-0800, SRP Section 2.4.12, “Groundwater,” March 2007. ADAMS Accession No. ML070730443.

21. U.S. Nuclear Regulatory Commission, NUREG-0800, SRP Section 2.4.13, “Accidental Releases of Radioactive Liquid Effluents in Ground and Surface Waters,” March 2007. ADAMS Accession No. ML070730449.

22. U.S. Nuclear Regulatory Commission, NUREG-1301, “Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Pressurized Water Reactors.” April 1991. ADAMS Accession No. ML091050061.

23. U.S. Nuclear Regulatory Commission, NUREG-1302, “Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Boiling Water Reactors.” April 1991. ADAMS Accession No. ML091050059.

24. U.S. Nuclear Regulatory Commission, NUREG-1430, "Standard Technical Specifications - Babcock and Wilcox Plants.” April 2012. ADAMS Accession No. ML12100A177 and ML12100A178.

25. U.S. Nuclear Regulatory Commission, NUREG-1431, "Standard Technical Specifications - Westinghouse Plants." April 2012. ADAMS Accession No. ML12100A222 and ML12100A228.

26. U.S. Nuclear Regulatory Commission, NUREG-1432, "Standard Technical Specifications - Combustion Engineering Plants." April 2012. ADAMS Accession No. ML12102A165 and ML12102A169.

27. U.S. Nuclear Regulatory Commission, NUREG-1433, "Standard Technical Specifications - General Electric Plants (BWR/4)." April 2012. ADAMS Accession No. ML12104A192 and ML12104A193.

28. U.S. Nuclear Regulatory Commission, NUREG-1434, "Standard Technical Specifications - General Electric Plants (BWR/6)." April 2012. ADAMS Accession No. ML12104A195 and ML12104A196.

29. U.S. Nuclear Regulatory Commission, “Measuring, Evaluating, and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Materials in Liquid and Gaseous Effluents from Light-Water-Cooled Nuclear Power Plants,” Regulatory Guide 1.21. Revision 2, June 2009. ADAMS Accession No. ML091170109.

30. U.S. Nuclear Regulatory Commission, “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,” Regulatory Guide 1.109. October 1977. ADAMS Accession No. ML13350A285.

31. U.S. Nuclear Regulatory Commission, “Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I,” Regulatory Guide 1.113. April 1977. ADAMS Accession No. ML003740390.

32. U.S. Nuclear Regulatory Commission, “Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants,” Revision 2. Regulatory Guide 1.143, ADAMS Accession No. ML013100305.

33. U.S. Nuclear Regulatory Commission, “Combined License Applications for Nuclear Power Plants (LWR Edition),” Regulatory Guide 1.206. June 2007. ADAMS Accession No. ML070630003.

34. U.S. Nuclear Regulatory Commission, “Quality Assurance Program Requirements (Operation),” Regulatory Guide 1.33. ADAMS Accession No. ML13109A458.

35. U.S. Nuclear Regulatory Commission, “Minimization of Contamination and Radioactive Waste Generation: Life-Cycle Planning,” Regulatory Guide 4.21. June 2008. ADAMS Accession No. ML082120212.

APPENDIX A TO BTP 11-6

SOURCE TERM RADIONUCLIDES

Table 1 below contains a list of radionuclides that should be included, at a minimum, in any assessment of an accidental release of radioactive material from liquid waste tanks. The list includes all those nongaseous radionuclides listed in ANSI/ANS 18.1-1999, "Radioactive Source Term for Normal Operation of Light Water Reactors." This standard is the basis in developing predicted reactor coolant and steam concentrations and annual effluent releases presented in FSAR Chapter 11 and contained radioactive sources in plant systems presented in FSAR Chapter 12. In addition to those radionuclides, the table also includes I-129 and Tc-99 because they are fission products that can escape into the reactor coolant and, when they are released into the environment, they move readily with groundwater with little retardation and radiological decay.

Table 1. Source Term Radionuclides

H-3	Tc-99
C-14	Ru-103
P-32 BWR only	Ru-106
Cr-51	Rh-103m BWR only
Mn-54	Rh-106 BWR only
Mn-56	Ag-110m
Fe-55	Te-129m
Fe-59	Te-129 PWR only
Co-58	Te-131 PWR only
Co-60	Te-131m
Ni-63 BWR only	Te-132
Cu-64 BWR only	I-129
Zn-65	I-131
Br-84 PWR only	I-132
Rb-88 PWR only	I-133
Rb-89 BWR only	I-134
Sr-89	I-135
Sr-90	Cs-134
Sr-91	Cs-136
Sr-92 BWR only	Cs-137
Y-90 BWR only	Cs-138 BWR only
Y-91	Ba-140
Y-92	La -140
Y-93	Ce-141
Y-91m PWR only	Ce-143 PWR only
Zr-95	Ce-144
Nb-95	Pr-144 BWR only
Mo-99	W-187
Tc-99m	Np-239

APPENDIX B TO BTP 11-6

SPECIFICATIONS ON THE CONTENTS OF RADIOACTIVITY IN LIQUID-CONTAINING TANKS

Under NUREG-1301, "Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Pressurized-Water Reactors," and NUREG-1302, "Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Boiling-Water Reactors," issued April 1991, Standard Technical Specification 3.11.1.4 and Tables 3.3-11 and 4.3-11 list liquid-containing tanks outside containment that are to be analyzed periodically to verify that the radioactivity content (curie or becquerel, excluding dissolved or entrained noble gases) is below specified values. Tanks included in this specification are those that are not surrounded by liners, dikes, or walls capable of holding the tank contents and do not have tank overflow provisions and sumps/drains connected to the LWMS. Indoor tanks are not included unless an analysis based on design basis fission product leakage from fuel assemblies results in doses to members of the public in excess of the SRP acceptance criteria of a total dose of 100 mrem (1 mSv) in the event that leaked or spilled fluids would impact the nearest existing or known future water supply in an unrestricted area. Water "supply" means a well or surface water intake that is used as a source of water for direct human consumption, or that is used indirectly through livestock watering or irrigation of grazing pastures, consumption of animal products (meat and milk products), fish and invertebrate consumption, crop irrigation and consumption of such crops or else is used as an ingredient in food products or food processing. Similarly, "known future" water supply means potential wells or surface water intakes whose current use or future construction may be identified, or may be reasonably deduced from available land-use census information.

For tanks included in Standard Technical Specification 3.11.1.4 and Tables 3.3-11 and 4.3-11, an activity limit (curie/becquerel) should be determined based on the methodology presented in SRP Section 11.2, "Liquid Waste Management System," and BTP 11-6. The methodology is based on the calculated radionuclide inventory in the selected tank and components filled at 80 percent capacity using a design basis fission product source term of:

(a) 0.12% of the operating fission product core inventory being released to the primary coolant for a PWR, or

(b) consistent with a noble gas release rate of 15 uCi/MWt per second (0.56 MBq/MWt per second) with 30-minute decay for a BWR.

The selection of 80- percent assumes that some of the content of the failed tank would remain in the tank and room or cubicle where the tank is located, with the associated amounts of radioactive materials retained in the building itself and, therefore, not available for environmental transport. The method cited above is used to derive the inventory of radioactivity that if contained in the tank and components would result in radioactivity concentrations equal to the SRP acceptance criteria of a total dose of 100 mrem (1 mSv) at the point of entry into the nearest existing or predicted future water supply that is used as a source of water for direct human consumption, or that is used indirectly through livestock watering or irrigation of grazing pastures, consumption of animal products (meat and milk products), fish and invertebrate consumption, crop irrigation and consumption of such crops, or else is used as an ingredient in food products or food processing.

By excluding dissolved and entrained noble gases from surveillance requirements, Standard Technical Specification 3.11.1.4 should apply to the lowest radioactive inventory of activation and mixed fission products determined for any tank and component listed in Standard Technical

Specification 3.11.1.4 as the radioactivity inventory limit for all tanks and components identified in that specification. Dissolved and entrained noble gases are not included since they do not remain in solution and are rapidly aerated out of the liquid phase during processing and spillage, should it occur. Since all process and storage tanks are vented, dissolved and entrained noble gases emanating from process fluids, and rooms where this equipment is located, are collected, monitored, and exhausted via the gaseous waste management system. Tritium is included because it is an environmentally mobile radionuclide and recent operating experience has shown that it is present in most incidents involving spills and leaks, as noted in the NRC's lessons learned task force report on liquid radioactive release.

Operational experience has shown that some operating reactors have used temporary process and storage tanks during maintenance and service periods, or when temporary solidification equipment is used at the plant, and, consequently, Standard Technical Specification 3.11.1.4 should indicate such tanks as being temporary. The limit for the total inventory of radioactive materials in temporary tanks should be $\leq$ 10 curies (0.37 TBq), excluding dissolved and entrained noble gases. If the temporary tank is mobile and not used (i.e., empty of liquid) for more than a calendar quarter, the tank need not be included in Tables 3.3-11 and 4.3-11 of the Standard Technical Specifications.

Regardless of the defined maximum inventory of radioactive materials for such tanks or components, these specifications do not relieve the licensee from regulatory requirements and practical considerations associated with radiation protection of plant personnel, such as conducting periodic surveys in monitoring external radiation levels in nearby and surrounding areas, and posting and restricting access to areas and/or rooms where such tanks are located.

SRP SECTION 11.2, BTP 11-6
Description of Changes

BTP 11-6 "Postulated Radioactive Releases Due To Liquid Containing Tank Failures"

This SRP section affirms the technical accuracy and adequacy of the guidance previously provided in BTP 11-6, as referenced in SRP Section 11.2, Revision 3, dated March 2007 (ADAMS Accession No. ML070720635).

Editorial changes added new abbreviations in several places throughout this section and corrected grammatical errors. Other changes reflect the removal of redundant information.

Technical changes incorporated in this revision include:

I. AREAS OF REVIEW

The areas of review, as described in the background and technical position sections, were revised by expanding technical guidance and identifying additional areas that warrant staff reviews and evaluations in assessing the consequences of a postulated failure of a radwaste tank and component containing radioactive materials. The additional areas of review address:

1. The revision incorporates the revisions presented in DC/COL-ISG-013, "Assessing the Radiological Consequences of Accidental Releases of Radioactive Materials from Liquid Waste Tanks for Combined License Applications," on SRP Section 11.2 and BTP 11-6, in assessing the radiological consequences of accidental releases of radioactive materials from liquid waste tanks for COL applications." (78 FR 6149, January 29, 2013 (ADAMS Accession No. ML12191A325)).

2. Compliance with 10 CFR Part 50, Appendix A, GDC 2 and GDC 61, as they relate to the consequence analyses conducted under SRP Section 11.2 using BTP 11-6.

3. The expanded discussions address design features to prevent, control, and collect radioactive materials in liquids from tank overflows and potential leaks for tanks located indoors and outside of containment that could result in uncontrolled and unmonitored releases, and design features applied to mitigate the effects of a postulated tank failure.

4. The staff's review now consists of eight major steps and is shared by two technical disciplines. The review steps include the following evaluation:

    a. Failure mechanism and radioactivity releases,

    b. Mitigating design features,

    c. Radioactive source term,

    d. Calculations of transport capabilities in groundwater and surface water,

    e. Exposure scenarios and acceptance criteria,

    f. SRP dose acceptance criteria,

    g. Specifications on tank waste radioactivity concentration levels, and

h. Evaluation findings for reviews of 10 CFR Part 52, COL and other applications.

5. The health physics staff is responsible for leading the evaluation of all steps except the fourth step. The fourth step, addressing the transport of radioactivity in surface water and groundwater and deriving radionuclide concentrations in unrestricted areas, is the responsibility of the hydrologic engineering staff. The corresponding guidance for the health physics staff is described BTP 11-6, while the guidance for the hydrologic engineering staff is provided in SRP Section 2.4.13.

6. The acceptance criteria are now based on doses 100 mrem (1 mSv) to members of the public, rather than on liquid effluent concentration limits, as was the case in previous guidance. The reason for this change is the need to better account for the effects of multiple exposure pathways. Releases may affect surface water and groundwater differently; consequently, the impact in some instances may be by way of direct consumption of water, while in others the impact may be only by indirect use of water (e.g., for livestock watering or crop irrigation). These different exposure scenarios and pathways can be quantified, because the applicant is expected to describe uses of water resources, based on local or regional land-use census information.

7. If the results of site-specific analyses do not demonstrate conformance with the BTP acceptance criteria, the applicant is expected to propose TS limiting the total amount of radioactivity in such tanks and components. The health physics staff will evaluate the proposed technical specification limiting the radioactivity content of liquid-containing tanks and components to ensure that the TS are consistent with the evaluation. The maximum inventory of radioactive materials, in the event of an uncontrolled release of radioactivity, is based on that quantity of radioactivity that will not exceed the SRP dose acceptance criteria of 100 mrem (1 mSv) from all relevant pathways at the defined point of entry in unrestricted areas. Chapter 16, TS Section 5.5, “Programs and Manuals,” of the FSAR addresses this commitment in COL applications. Information on the associated implementation is presented in standard technical specifications, including NUREG-1430, NUREG-1431, NUREG-1432, NUREG-1433, and NUREG-1434. The milestones for the development and implementation of such plant and site-specific requirements are addressed in FSAR Sections 11.5 and 13.4 of COL applications.

8. A new table was added (Appendix A, Table 1) presenting a list of radionuclides that should be included, at a minimum, in any assessment of an accidental release of radioactive material from liquid waste tanks. The list includes all those non-gaseous radionuclides listed in ANSI/ANS 18.1-1999, “Radioactive Source Term for Normal Operation of Light Water Reactors.”

9. A new appendix was added (Appendix B) addressing specifications on the inventories of radioactivity in liquid-containing tanks. Appendix B updates the process used in developing the assumed radioactive source term described in Chapter 4.4 and Appendices A and B of NUREG-0133, “Preparation of Radiological Effluent Technical Specifications for Nuclear Power Plants.” Appendix B offers applicants the use of alternate methods in developing radioactive source terms. In such instances, applicants are responsible for providing sufficient information and justification to enable the staff to perform an independent evaluation of any proposed alternative methods.

10. With respect to the applicability of the guidance presented in NUREG-0133, BTP 11-6 updates the guidance for applications submitted 6 months after the issuance of the final version of this BTP. However, the guidance of NUREG-0133 remains in effect for holders of nuclear power reactor OLs under 10 CFR Part 50 or COLs under

10 CFR Part 52 prior to the effective date of this BTP, and for applicants for nuclear power reactor OLs under 10 CFR Part 50 or combined licenses under 10 CFR Part 52 that have committed, in applications docketed with the NRC as of the effective date of this revision of BTP 11-6, to specific guidance in assessing the radiological consequences of a postulated failure of a tank containing radioactive materials.

II. ACCEPTANCE CRITERIA

The acceptance criteria section was revised by including citations of existing regulatory requirements not cited in the prior BTP and providing clarification on methods in used determining compliance with acceptance criteria. The major revisions include the addition of:

1. 10 CFR Part 50, Appendix A, GDC 2, as it relates to the design bases of structures housing LWMS and its components using the guidance of RG 1.143 and industry standards.

2. 10 CFR Part 50, Appendix A, GDC 64, as it relates to the monitoring radioactivity releases during routine operations, AOOs, and accident conditions.

3. 10 CFR 100.10, under Subpart A, as it relates to evaluation factors for stationary power reactor sites and test reactors.

III. REVIEW PROCEDURES

The review procedures section was updated in recognition of the revisions identified in the areas of review and acceptance criteria sections, as noted in explanations above.

IV. EVALUATION FINDINGS

The evaluation findings section was revised by expanding the discussions on the results of the staff's evaluation and conclusion of acceptability against cited regulations and guidance. The revisions address:

1. Confirmation that the postulated radionuclide concentrations in the applicable failed components is based upon the default PWR fuel failure rate or BWR fuel release rate, and the effect of site hydrologic characteristics for those systems that have not been equipped with design features to mitigate the effect of tank and component failures.

2. Confirmation that design features were properly considered in mitigating the consequences of a failure of a tank and components.

3. Confirmation of the applicant's approach in modeling the transport of radioactivity in surface water or groundwater starting from the building housing the assumed failed tank and components to the nearest point of entry in unrestricted areas. For the reasons presented in SRP Section 2.4.13, the review would conclude that the identification and consideration of the potential effects of postulated releases of radioactive liquid effluents in groundwater and surface water in the vicinity of the site are acceptable and meet the noted requirements.

4. Confirmation that (1) the postulated failure of a tank and components has been properly evaluated by the applicant and complies with SRP acceptance criteria, (2) the design features are acceptable and meet the requirements of 10 CFR Part 50, Appendix A, GDC 60 and GDC 64 in controlling and limiting releases of radioactive materials to the environment, and (3) the design features provide an adequate level of safety during

normal reactor operation, anticipated operational occurrences, and assumed accident conditions.

5. If the results of site-specific analyses do not demonstrate conformance with the BTP acceptance criteria, confirmation that the applicant's proposed TS limiting the total amounts of radioactivity in tanks and components are adequate. The staff confirms that the proposed TS limiting the radioactivity content for the stated liquid-containing tank and components have been incorporated into Chapter 16, Section 5.5, "Programs and Manuals," of the FSAR, and identified as a program element, as addressed in FSAR Sections 11.5 and 13.4 of COL applications.

V. IMPLEMENTATION

The implementation of BTP 11-6 is addressed in the corresponding part of SRP Section 11.2 on implementation. No new specific provisions were made for the implementation of BTP 11-6.

VI. REFERENCES

The following references were added in support of the expanded discussions presented in areas of review, acceptance criteria, and review procedures. The added references are:

1. American National Standards Institute/American Nuclear Society, ANSI/ANS-40.37-2009, "American National Standard, Mobile Low-Level Radioactive Waste Processing Systems," 2009. Superseded ANSI/ANS-40.37-1993 in 2009. Standards are available at http://www.ANSI.org.

2. American National Standards Institute/American Nuclear Society, ANSI/ANS-55.6-1993 (R2007), "Liquid Radioactive Waste Processing System for Light Water Reactor Plants," Reaffirmed in 2007. Standards are available at http://www.ANSI.org.

3. Nuclear Energy Institute, NEI 08-08A, "Generic FSAR Template Guidance for Life Cycle Minimization of Contamination," Revision 0, October 2009. ADAMS Accession No. ML093220530.

4. U.S. Code of Federal Regulations, "Domestic Licensing of Production and Utilization," Part 50, Chapter 1, Title 10, "Energy," Appendix A, "General Design Criteria for Nuclear Power Plants," General Design Criterion 2, "Design Bases For Protection Against Natural Phenomena."

5. U.S. Code of Federal Regulations, "Domestic Licensing of Production and Utilization," Part 50, Chapter 1, Title 10, "Energy," Appendix A, "General Design Criteria for Nuclear Power Plants," General Design Criterion 64, "Monitoring Radioactivity Releases."

6. U.S. Code of Federal Regulations, "Reactor Site Criteria-Purpose," §100.10, Chapter 1, Title 10, "Energy." (Factors to be Considered When Evaluating Sites under Subpart A, Evaluation Factors for Stationary Power Reactor Site Applications, before January 10, 1977 And For Testing Reactors)

7. U.S. Code of Federal Regulations, "Reactor Site Criteria-Scope," §100.20, Chapter 1, Title 10, "Energy." (Factors to be Considered When Evaluating Sites under Subpart B, Evaluation Factors for Stationary Power Reactor Site Applications," on or after January 10, 1977).

8. U.S. Nuclear Regulatory Commission, DC/COL-ISG-06, “Final Interim Staff Guidance Evaluation and Acceptance Criteria for 10 CFR 20.1406 to Support Design Certification and Combined License Applications,” (as incorporated in SRP Section 12.3-12.4). September 9, 2008.

9. U.S. Nuclear Regulatory Commission, DC/COL-ISG-014, “Interim Staff Guidance - Assessing the Radiological Consequences of Accidental Releases of Radioactive Materials from Liquid Waste Tanks in Ground and Surface Waters for Combined License Applications.” ADAMS Accession No. ML12191A330.

10. U.S. Nuclear Regulatory Commission, “Liquid Radioactive Release Lessons Learned Task Force,” Final NRC Report, September 2006. ADAMS Accession No. ML062650312.

11. U.S. Nuclear Regulatory Commission, NUREG-0800, Branch Technical Position 11-6 “Postulated Radioactive Releases Due to Liquid-Containing Tank Failures,” March 2007. ADAMS Accession No. ML070720635.

12. U.S. Nuclear Regulatory Commission, NUREG-0800, SRP Section 11.2, “Liquid Waste Management System,” March 2007. ADAMS Accession No. ML063600412.

13. U.S. Nuclear Regulatory Commission, NUREG-0800, SRP Section 2.4.1, “Hydrologic Description,” March 2007. ADAMS Accession No. ML070100646.

14. U.S. Nuclear Regulatory Commission, NUREG-0800, SRP Section 2.4.12, “Groundwater,” March 2007. ADAMS Accession No. ML070730443.

15. U.S. Nuclear Regulatory Commission, NUREG-0800, SRP Section 2.4.13, “Accidental Releases of Radioactive Liquid Effluents in Ground and Surface Waters,” March 2007. ADAMS Accession No. ML070730449.

16. U.S. Nuclear Regulatory Commission, NUREG-1301, “Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Pressurized Water Reactors.” April 1991. ADAMS Accession No. ML091050061.

17. U.S. Nuclear Regulatory Commission, NUREG-1302, “Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Boiling Water Reactors.” April 1991. ADAMS Accession No. ML091050059.

18. U.S. Nuclear Regulatory Commission, NUREG-1430, "Standard Technical Specifications - Babcock and Wilcox Plants.” April 2012. ADAMS Accession No. ML12100A177 and ML12100A178.

19. U.S. Nuclear Regulatory Commission, NUREG-1431, "Standard Technical Specifications - Westinghouse Plants." April 2012. ADAMS Accession No. ML12100A222 and ML12100A228.

20. U.S. Nuclear Regulatory Commission, NUREG-1432, "Standard Technical Specifications - Combustion Engineering Plants." April 2012. ADAMS Accession No. ML12102A165 and ML12102A169.

21. U.S. Nuclear Regulatory Commission, NUREG-1433, "Standard Technical Specifications - General Electric Plants (BWR/4)." April 2012. ADAMS Accession No. ML12104A192 and ML12104A193.

22. U.S. Nuclear Regulatory Commission, NUREG-1434, "Standard Technical Specifications - General Electric Plants (BWR/6)." April 2012. ADAMS Accession No. ML12104A195 and ML12104A196.

23. U.S. Nuclear Regulatory Commission, “Measuring, Evaluating, and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Materials in Liquid and Gaseous Effluents from Light-Water-Cooled Nuclear Power Plants,” Regulatory Guide 1.21. Revision 2, June 2009. ADAMS Accession No. ML091170109.

24. U.S. Nuclear Regulatory Commission, “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,” Regulatory Guide 1.109. October 1977. ADAMS Accession No. ML13350A285.

25. U.S. Nuclear Regulatory Commission, “Quality Assurance Program Requirements (Operation),” Regulatory Guide 1.33. ADAMS Accession No. ML13109A458.

26. U.S. Nuclear Regulatory Commission, “Minimization of Contamination and Radioactive Waste Generation: Life-Cycle Planning,” Regulatory Guide 4.21. June 2008. ADAMS Accession No. ML082120212.