U.S. NUCLEAR REGULATORY COMMISSION

DESIGN-SPECIFIC REVIEW STANDARD FOR mPOWER^{TM} iPWR DESIGN

2.4.13 ACCIDENTAL RELEASES OF RADIOACTIVE LIQUID EFFLUENTS IN GROUND AND SURFACE WATERS

REVIEW RESPONSIBILITIES

Primary - Organization responsible for review of issues related to hydrology

Secondary - Organization responsible for review of solid waste and liquid and gaseous effluents

Organization responsible for review of radiation protection

I. AREAS OF REVIEW

This section of the Design-Specific Review Standard (DSRS) provides guidance for the U.S. Nuclear Regulatory Commission (NRC) staff's review of the section of the applicant's final safety analysis report (FSAR) that evaluates the hydrogeological characteristics of the site to describe the effects of accidental releases of radioactive liquid effluents to ground and surface waters on existing uses and known and likely future uses of ground and surface water resources.

Chapter 2 of the DSRS, of which this section is a part, discusses the site characteristics that could affect the safe design and siting of a plant. The staff reviews information presented by the applicant for a design certification (DC), early site permit (ESP), or combined license (COL) concerning the hydrological setting of the site as it is related to safety-related or risk-significant structures, systems, and components (SSCs). The staff's review and findings are described in the appropriate section of the final safety evaluation report (FSER).

The accidental release is assumed to come from the Liquid Waste Management System (LWMS). The source term from a postulated accidental release is reviewed under DSRS 11.2 following the guidance provided in Branch Technical Position (BTP) 11-6 (NRC, 2007). The source term is determined from a postulated release from a single tank outside of containment; this tank is identified based on the guidance given in BTP 11-6. Normal operational releases and accidental releases of other kinds are not considered here, but are considered in the applicant's environmental report. Other kinds of accident are also considered elsewhere in this DSRS, in particular in Chapter 15, Accident Analysis.

The mPower^{TM} LWMS has been categorized as nonsafety-related and nonrisk-significant. Failure of the subsystem should not compromise any safety-related system or component, nor should it prevent the safe shutdown of the plant. However, the failure of specific subsystems or components may have some impacts on offsite dose receptors and on compliance with NRC regulations. The applicant's FSAR must provide sufficient information to confirm that any failure of essential subsystems meets these criteria. The LWMS is relied on to control releases of radioactive materials in liquid effluents to the environment, therefore having a direct impact on public health and safety. Therefore, the review of the LWMS and assumed failure of a tank

ADAMS Accession No. ML12221A021

containing radioactive materials require a more detailed review than other nonsafety-related and nonrisk significant systems.

The specific areas of review are as follows:

1. Contaminant Pathways: The staff reviews the applicant's preferred conceptual site model, which is a conceptualization that identifies the hydrological features of the site that control possible movement of water and contaminants that move with water, and which is believed to be the most probable of all plausible site models. Because of uncertainties about site conditions, the preferred model may imply more than one possible pathway. On this basis, the staff reviews all possible pathways by which radionuclides released in liquid effluents could migrate in water from the release location to the location of an offsite receptor. Pathways may be through groundwater, surface water, or a sequence or combination of both. Pathways are defined based on hydrological site conditions as described by the conceptual site model, such as topography, geometry and hydraulic conductivity of aquifers and confining beds, and geometry and elevation of surface water features. Pathways that are physically impossible do not need to be considered. The staff identifies pathways that could result in unacceptable impacts on existing and future uses of groundwater and surface water near the site. This review will be done in conjunction with the review of characteristics that affect transport, as described below. For sites located in the permafrost region the review includes information on freezing, thawing, subsurface thermal gradients and impacts of gas hydrates on groundwater flow, pathways, and safety of SSCs.

2. Alternative Conceptual Site Models: In addition to reviewing the applicant's preferred conceptual site model, the staff also reviews alternative conceptual site models. These are other models that appear to be plausible, even if less probable, and which cannot be excluded given the limitations and uncertainties of information available about the site. The set of alternative models should reasonably bound the known hydrological conditions at the site that affect radionuclide transport in groundwater and surface water. The staff reviews the alternative conceptual site models to identify radionuclide pathways that could result in unacceptable impacts on existing and future uses of groundwater and surface water near the site.

3. Characteristics that Affect Transport: Based on the identification of pathways, the staff reviews the ground and surface water environments with respect to their ability to delay, disperse, dilute, or concentrate accidentally released radioactive liquid effluent during its transport. The staff review includes assessment of scenarios for the transport of radioactive effluents to identify the scenario most likely to produce the maximum dose at an offsite receptor point. The staff's review will consider whether such transport is associated with extreme hydrologic events such as floods or low flows. For sites located in the permafrost region the review includes information on freezing, thawing, subsurface thermal gradients and impacts of gas hydrates on groundwater flow, pathways, and safety of SSCs.

4. Other Site-Related Evaluation Criteria: The staff review includes an assessment of scenarios wherein accidental release of radioactive effluents is combined with potential effects of seismic and non-seismic events (e.g., assessing the potential effects of seismically-induced land subsidence, and effects of hydraulic structures located upstream and downstream of the plant in the event of structural or operational failures and the ensuing sudden changes in the regime of flow).

5. Additional Information for Title 10 of the *Code of Federal Regulations* (10 CFR) Part 52 Applications: Additional information will be presented dependent on the type of application. For a COL application, the additional information is dependent on whether the application references an ESP, a DC, both, or neither. Information requirements are prescribed within the "Contents of Application" sections of the applicable Subparts to 10 CFR Part 52.

Review Interfaces

Other DSRS and Standard Review Plan (SRP) sections and other guidance interface with this section as follows:

1. Groundwater characteristics, reviewed following the guidance in DSRS Section 2.4.12 "Groundwater," provide the basis for assessing subsurface radionuclide transport.

2. Surface water characteristics, reviewed following the guidance in DSRS Sections 2.4.2 "Floods," 2.4.3 "Probable Maximum Flood (PMF) on Streams and Rivers," 2.4.4 "Potential Dam Failures," 2.4.5 "Probable Maximum Surge and Seiche Flooding," 2.4.6 "Probable Maximum Tsunami Hazards," and 2.4.11 "Low Water Considerations," provide the basis for assessing radionuclide transport in surface waters.

3. Review of information on seismically-induced land subsidence information is performed under SRP Section 2.5.1, "Basic Geologic and Seismic Information."

4. The location of the tank within the liquid waste management system that is assumed as the source of the release, the tank's volume, the species and concentrations of radionuclides in the tank, release scenarios, and the presence of mitigating design features are reviewed following the guidance in DSRS Section 11.2, BTP 11-6, and ISG-013 (NRC, 2013a).

5. Receptor locations, exposure scenarios, and evaluation of radionuclide concentrations and doses are reviewed following the guidance in DSRS 11.2 and ISG-013 (NRC, 2013a), as incorporated in BTP 11-6 in DSRS Section 11.2.

6. Radionuclide transport mechanisms and pathways in surface water and groundwater are reviewed following the guidance in DSRS Section 2.4.12 and ISG-014 (NRC, 2013b), as incorporated here.

7. Geologic information on subsurface conditions that influence groundwater and contaminant movement is reviewed under SRP Section 2.5.1, "Basic Geologic and Seismic Information.

8. Information on rock and soil properties that influence groundwater and contaminant movement is reviewed under SRP Section 2.5.4, "Stability of Subsurface Materials and Foundations."

9. For DC applications and COL applications referencing a DC rule or DC application, review of the site parameters in the Design Control Document (DCD) Tier 1 and Chapter 2 of the DCD Tier 2 submitted by the applicant is performed under SRP Section 2.0, Site Characteristics and Site Parameters. Review of site characteristics and site-related design parameters in ESP applications or in COL applications referencing an ESP is also performed under SRP Section 2.0.

II. ACCEPTANCE CRITERIA

Requirements

Acceptance criteria are based on meeting the relevant requirements of the following Commission regulations:

1. 10 CFR Part 100, as it relates to identifying and evaluating hydrological features of the site. The requirements to consider physical site characteristics in site evaluations are specified in 10 CFR 100.20(c).

2. 10 CFR 100.23(d) sets forth the criteria to determine the siting factors for plant design bases with respect to seismically induced floods and water waves at the site.

3. 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 2 as it relates to consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

4. 10 CFR Part 50, Appendix A, GDC 60, as it relates to releases occurring as anticipated operational occurrences, as described in DSRS Section 11.2 and BTP 11-6.

5. 10 CFR 52.17(a)(1)(vi), for ESP applications, and 10 CFR 52.79(a)(1)(iii), for COL applications, as they relate to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

6. 10 CFR 20.1406, as it relates to the development of site conceptual surface and groundwater models for the purpose of minimizing contamination of the subsurface environment.

DSRS Acceptance Criteria

Specific DSRS acceptance criteria acceptable to meet the relevant requirements of the NRC's regulations identified above are set forth below. The DSRS is not a substitute for the NRC's regulations, and compliance with it is not required. Identifying the differences between this DSRS section and the design features, analytical techniques, and procedural measures proposed for the facility, and discussing how the proposed alternative provides an acceptable method of complying with the regulations that underlie the DSRS acceptance criteria, is sufficient to meet the intent of 10 CFR 52.47(a)(9), "Contents of applications; technical information." The same approach may be used to meet the requirements of 10 CFR 52.17(a)(1)(xii) and 10 CFR 52.79(a)(41), for ESP and COL applications, respectively.

1. Contaminant Pathways: To meet the requirements of 10 CFR 100.20(c), 10 CFR 100.23(d), GDC 2, 10 CFR 52.17, 10 CFR 52.79, and 10 CFR 20.1406, the applicant's preferred conceptual site model should be clearly described. The field data, both current and historical, on which it is based should be clearly stated and described. Appropriate references should be made to relevant geotechnical data, such as from test borings and soil property tests, that are presented outside Chapter 2. Sufficient information should be provided to assure that all plausible groundwater and surface water pathways have been identified. Pathways identified should be consistent with the

data that support them. Analysis of transport of a release through the pathways, in terms of concentrations at an offsite receptor point, should be performed and compared to effluent concentration limits (ECLs). For sites located in the permafrost region the review includes information on freezing, thawing, subsurface thermal gradients and impacts of gas hydrates on groundwater flow, pathways, and safety of SSCs.

2. Alternative Conceptual Site Models: To meet the requirements of GDC 2, 10 CFR 52.17, and 10 CFR 52.79, alternative conceptual site models should be evaluated similarly to the preferred model. Features that distinguish them from the preferred model, and the reasons that alternative models are considered less probable, should be discussed. Why and how the alternative models bound known hydrological conditions at the site that affect radionuclide transport in groundwater and surface water should be discussed. Data gaps that affect the interpretation of alternative models should be discussed, in particular whether specific additional data might change the evaluation of the plausibility of alternative models.

3. Characteristics that Affect Transport: To meet the requirements of 10 CFR 100.20(c), 10 CFR 100.23(d), GDC 2 and 60, 10 CFR 52.17, 10 CFR 52.79, and 10 CFR 20.1406, radionuclide transport characteristics of the surface and subsurface environments with respect to existing and known and likely future users should be described. For the surface environment, advection and dispersion characteristics that arise from overland flow, channels, lakes/reservoirs, and open coastal systems should be described and should be consistent with site characteristics. The description should conform to the stipulation of 10 CFR 100.20(c)(3) including the effect of extreme hydrologic events such as floods or low flow. In addition, the effects of sediment uptake on retention and transport should also be considered as indicated in Regulatory Guide (RG) 1.113 (NRC, 1977). For the subsurface environment, estimates and bases for characteristics such as coefficients of dispersion, adsorption, groundwater velocities, travel times, gradients, permeabilities, porosities, and subsurface hydraulic heads between the site and potential offsite receptor locations should be described, and should be consistent with site characteristics and conform to the stipulation of 10 CFR 100.20(c)(3).

4. Consideration of Other Site-Related Evaluation Criteria: To meet the requirements of 10 CFR 100.23(d), GDC 2, 10 CFR 52.17, and 10 CFR 52.79,the applicant should assess the potential effects of site-proximity hazards (such as dams and chemical facilities), seismic, and non-seismic events on the radioactive concentration at an offsite receptor resulting from the postulated tank failure that causes an accidental release of radioactive liquid effluents to ground and surface waters at the proposed plant site. This assessment should be sufficient to demonstrate that the applicant's design bases appropriately account for these effects (including the potential effects of seismically-induced land subsidence, and of hydraulic structures located upstream and downstream of the plant in the event of structural or operational failures and the ensuing sudden changes in the regime of flow).

5. DSRS Section 11.2 and BTP 11-6 provide guidance and acceptance criteria for assessing a potential release of radioactive liquids following the postulated failure of a tank and its components, located outside of containment, and impacts of the release of radioactive materials for an offsite dose receptor, located 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..

6. Interim Staff Guidance (ISG) -013 (NRC, 2013a) provides additional guidance on defining the mechanism of the assumed tank failure, development of the radioactive source term, assumptions and level of conservatism used in the analysis, and the approach used in assessing the radiological impact at the assumed location of an offsite receptor, as incorporated in DSRS Section 11.2 and BTP 11-6.

7. ISG-014 (NRC, 20YY) provides additional guidance on methods and data for analyzing the transport of radionuclides through the subsurface by groundwater. The staff uses best current practices, including modeling, to analyze subsurface transport of radioactive liquid effluents, as incorporated here.

8. Appropriate sections of RG 4.21 (NRC, 2008), as it relates to minimizing contamination of the subsurface environment, are used by staff for the review of the acceptance criteria.

9. Appropriate sections of RG 1.113 (NRC, 1977), as it relates to selection of surface water models, are used by the staff for the review of the acceptance criteria.

Technical Rationale

The technical rationale for application of these acceptance criteria to the areas of review addressed by this DSRS section is discussed in the following paragraphs:

1. Compliance with 10 CFR 100.20 (c) requires that the site's physical characteristics (including seismology, meteorology, geology, and hydrology) be taken into account when determining its acceptability for a nuclear power reactor.

   To satisfy the hydrological requirements of 10 CFR Part 100, the applicant's FSAR should consider local geological and hydrological characteristics when determining the acceptability of a nuclear power plant site. The geological and hydrological characteristics of the site may have a bearing on the potential consequences of radioactive effluents accidentally released from the facility. Special precautions should be planned if a reactor will be located at a site where a significant quantity of radioactive effluent could accidentally flow into nearby streams or rivers or find ready access to aquifers. Such cases may be evaluated using appropriate sections of RG 1.113 (NRC, 1977). In the case of deeply-embedded safety-related or risk-significant SSCs, which may penetrate confining layers, the review should include careful consideration of the effects of both groundwater level and subsurface hydraulic head[1] on the conceptual site models and the potential for subsurface radionuclide transport.

   These criteria apply to DSRS Section 2.4.13 because the reviewer evaluates site hydrologic characteristics with respect to the potential consequences of radioactive materials escaping from the facility. Radionuclide transport characteristics of ground and surface water environments are reviewed with respect to accidental releases in

[1] "Groundwater level," as used in this section, refers to the elevation of the water table. "Subsurface hydraulic head" refers to the hydraulic head at locations below the water table. This may be greater or less than the water table elevation, depending on the vertical component of groundwater flow, the presence of confining beds, and other factors. This distinction may be significant for deep structures, which can experience greater or smaller hydraulic head near their bases than would be indicated by the groundwater level.

order to ensure that current and known and likely future users of ground and surface water are not adversely affected.

Meeting this requirement provides assurance that when accidental releases of radioactive liquid effluents to ground and surface waters occur, their adverse impact on public health and safety will be minimized.

2. 10 CFR 100.23(d) requires that geologic and seismic factors be considered when determining the suitability of the site and the acceptability of the design for each nuclear power plant.

   10 CFR 100.23 is applicable to DSRS Section 2.4.13 because it addresses requirements for investigating vibratory ground motion, including the hydrologic conditions at and near the site and the effect of possible seismically-induced increases in groundwater level or subsurface hydraulic head on safety-related or risk-significant SSCs. Changes in groundwater conditions due to seismic effects may impact groundwater pathways and radionuclide transport.

3. Compliance with GDC 2 requires that nuclear power plant structures, systems, and components important to safety be designed to withstand the effects of natural phenomena such as earthquake, tornado, hurricane, flood, tsunami, and seiche without loss of capability to perform their safety functions. The criterion further specifies that the design bases for these structures, systems, and components shall reflect the following:

   A. Appropriate consideration of the most severe natural phenomena historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and time period in which the historical data have been accumulated;

   B. Appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena; and

   C. The importance of the safety functions to be performed.

   This criterion is applicable to DSRS Section 2.4.13 because the hydrologic and transport characteristics determine the pathways and impacts of an accidental release of radioactive liquid effluents.

   For applications under 10 CFR Part 52, meeting the applicable requirements of 10 CFR 52.17 and 10 CFR 52.79 that correspond to GDC 2 and 60 provides a level of assurance that the most severe hydrologic site characteristics, including those affecting transport pathways and impacts of an accidental release of radionuclide liquid effluents, have been identified. Whether GDC 2 is met with respect to the adequacy of the associated design bases will be evaluated under other DSRS sections.

4. Compliance with 10 CFR Part 50, Appendix A, GDC 60 requires applicants to design LWMS with sufficient hold up capacity and features to control releases of radioactive materials to the environment.

   This criterion is applicable to DSRS Section 2.4.13 because it is used to define the SSCs assumed to fail, location of the failed component within structures housing tanks that

contain radioactive materials, and develop the radioactive source terms postulated for the accidental release of radioactive liquids in surface or groundwater.

5. 10 CFR 20.1406 requires that applications describe how facility design and procedures for operation will, to the extent practicable, minimize contamination of the environment. 10 CFR 20.1406 is applicable to DSRS Section 2.4.13 because this section, together with DSRS Section 2.4.12, addresses the need for a conceptual site model reflecting the site configuration following construction, as described in RG 4.21 (NRC, 2008). A conceptual site model provides the basis for minimizing contamination by identifying potential pathways of radioactive contaminants through the surface and subsurface, facilitating the development of an onsite monitoring program to provide early detection and quantification of leaks and spills, and providing a framework for planning and implementing mitigative actions.

6. ISG-013 (NRC, 2013a) and ISG-014 (NRC, 2013b) are applicable to DSRS Section 2.4.13 because they address the details of evaluating the postulated tank release and subsequent transport of radionuclides more fully than is provided in the regulations or in other guidance documents.

III. REVIEW PROCEDURES

The procedures outlined below are used to review ESP applications and COL applications that do not reference an ESP to determine whether data and analyses for the proposed site meet the acceptance criteria given in Subsection II of this DSRS section. As applicable, reviews of COLs include a determination on whether the content of technical specifications related to hydrologic site characteristics are acceptable and whether the technical specifications reflect consideration of any unique conditions.

The review of accidental releases of radioactive liquid effluents requires close coordination between two different technical disciplines: Hydrology and Health Physics. The overall coordination between disciplines is discussed first. This is followed by a discussion of the review activities performed by the hydrology staff which are the primary focus of DSRS Section 2.4.13.

Coordination of Review Activities Between Hydrology and Health Physics: The review process consists of eight major steps, including evaluation or preparation of:

1. Failure Mechanism and Radioactivity Releases,

2. Mitigating Design Features,

3. Radioactive Source Term,

4. Transport Capabilities in Groundwater and Surface Water

5. Exposure Scenarios,

6. DSRS Acceptance Criteria,

7. Specifications on Tank Waste Radioactivity Concentration Levels, and

8. Evaluation Findings for Reviews of COL and Other Part 52 Applications.

The hydrology staff is primarily responsible for the fourth step, which addresses the transport of radioactivity in surface water and groundwater and derives radionuclide concentrations in unrestricted areas. Guidance for the Hydrology staff is described in the current DSRS Section, 2.4.13. The guidance for the Health Physics staff is described in DSRS Section 11.2 and BTP 11-6.

The review process is shared between staff as follows:

1. In accordance with 10 CFR 52.47(a)(8),(21), and (22), for new reactor license applications submitted under Part 52, the applicant is required to (1) address the proposed technical resolution of unresolved safety issues (USIs) and medium- and high-priority generic safety issues (GSIs) that are identified in the version of NUREG-0933 current on the date 6 months before application and that are technically relevant to the design; (2) demonstrate how the operating experience insights have been incorporated into the plant design; and, (3) provide information necessary to demonstrate compliance with any technically relevant portions of the Three Mile Island requirements set forth in 10 CFR 50.34(f), except paragraphs (f)(1)(xii), (f)(2)(ix), and (f)(3)(v). These cross-cutting review areas should be addressed by the reviewer for each technical subsection and relevant conclusions documented in the corresponding FSER section.

2. The hydrology staff reviews and evaluates the applicant's approach in modeling the transport of radioactivity in surface water and groundwater, confirms the validity of the defined point of entry in unrestricted areas in light of available site-specific information and stated assumptions, and verifies the resulting radionuclide concentrations at the point of entry in unrestricted areas. The hydrology staff confirms that the information and results comply with the acceptance criteria of DSRS Section 2.4.13 and requirements of 10 CFR 100.20(c)(3). The health physics staff will use the resulting radionuclide concentrations in its evaluation once the approaches used in modeling the transport of radioactivity in surface water or groundwater and in calculating radionuclide concentrations in unrestricted areas are deemed acceptable by the hydrology staff.

3. In a parallel effort, the health physics staff confirms the applicant's approach used in developing the postulated tank failure scenario, confirms the radiological source term for the assumed failed tank or component, confirms the assumptions applied in modeling exposures and doses to members of the public, conducts an independent assessment of dose results, confirms compliance with the DSRS acceptance criteria, and determines whether the results of the analysis warrant, as specifications, the imposition of maximum radioactivity limits in the tank(s) identified by the applicant. The health 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 DSRS Section 11.2 and BTP 11-6.

As part of the review process, the staff evaluates 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 do not demonstrate compliance with the DSRS acceptance criteria, the applicant should conduct increasingly more refined, comprehensive, and detailed analyses using a site-specific

conceptual model and parameters until the analyses demonstrate either that (a) based on an acceptable combination of conceptual model and parameters, and to a reasonably degree of certainty, the consequences can be shown to be in compliance with the DSRS acceptance criteria, or (b) no acceptable combination of conceptual model and parameters predicts consequences that are in compliance with the DSRS acceptance criteria. This process is described more fully in ISG-014 (USNRC, 2013b).

If the results of site-specific analyses still do not demonstrate compliance with the DSRS acceptance criteria, the applicant should propose technical specifications to limit the total amount of radioactivity in the assumed tanks or components. In all instances, the applicant should provide sufficient information for the staff to conduct independent analyses to confirm compliance with the regulations and DSRS acceptance criteria.

The transport analysis requires several sequential steps for the determination of hydrogeologic parameters and for the fate and transport analysis of released radionuclides in ground and surface waters.

The analysis begins by determining the basic conditions for the transport analysis:

1. Site conceptualization and hydrogeologic characteristics;
2. Location of release from identified tank or component;
3. Receptor points (e.g., points of entry of contaminated water from the release point to public water bodies);
4. Groundwater and surface pathways and their characteristics; and
5. Travel times to the point of entry in unrestricted areas.

The information regarding the postulated accidental release scenario, which includes the release location, and volume and concentrations of radionuclide effluents, is obtained from FSAR Section 11.2 and the health physics staff. Groundwater pathways and their characteristics are usually inferred from boring logs, groundwater levels, and similar field information. Travel times may be predicted using an analytical model for a simple groundwater system, or if warranted, a more detailed numerical model for a more complex groundwater system.

The groundwater contaminant transport analysis may initially be performed using a simple model that considers only advection, decay and dilution. The estimated radionuclide concentrations to surface and/or groundwater environments for existing and future water resource users located in unrestricted areas will be provided to the Health Physics staff which will analyze various exposure scenarios.

As discussed in DSRS Section11.2 and BTP 11-6, 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 ECLs of 10 CFR Part 20, Appendix B, Table 2, Column 2. 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 and for the consumption of impacted food products. As a result, a dose-based limit is applied instead by the health physics staff, because it provides the most flexibility in assessing compliance, regardless of the postulated exposure scenarios, or for exposure scenarios that include the consumption of impacted food products and drinking of surface or groundwater.

Review Activities by Hydrology Staff : Review procedures carried out by the hydrology staff are based on the DSRS acceptance criteria. For deviations from these acceptance criteria, the staff should review the applicant's evaluation of how the proposed alternatives provide an acceptable method of complying with the relevant NRC requirements identified in Subsection II.

1. Alternative Conceptual Site Models: The conceptual site models should be reviewed with consideration given to whether standard and accepted practices have been followed, such as described in American National Standard Institute/American Nuclear Society (ANSI/ANS) -2.17-2010 (ANS, 2010) for evaluation of subsurface radionuclide transport. Whether simple or highly complex multi-dimensional models are employed, conservative or bounding simulations are achieved by representing the existing ground and surface water systems with conservative conceptual site models populated with conservative model parameters. Use of conservative model data in an inappropriate or non-conservative conceptual site model will not provide a conservative analysis. For example, an aquifer in a karst geology with solution channels may not be conservatively represented by a porous medium continuum conceptual site model. A variety of alternative conceptual site models, each based on the geological and hydrological characteristics of the site, needs examination as part of the complete conceptual model for a site, and the combination of ground and surface water conceptual site models yielding the most adverse contaminant concentrations should be used in conservative or bounding analyses.

   Alternative conceptual models should encompass the range of complexities possible at a specific site. Consideration should be given, for example, to preferential flow pathways in the subsurface environment resulting from the geology (e.g., karst geology), or to flow barriers or pathways caused by spatial variability in geologic materials (e.g., impermeable strata forcing groundwater to perch or move laterally and form seeps or springs). Regarding the mobility of contaminants, consideration should be given to the potential for the inclusion of organic or inorganic complexing agents in stored liquids that are also released during an accident. Complexing agents can greatly alter the sorption characteristics normally associated with radionuclides, in some cases making them freely mobile in the groundwater system. In surface water conceptual site models, consideration should be given to the potential for stratified flow to restrict a contaminant release to a fraction of the stream flow or lake volume, and more severely impact the ecology and people at locations influenced by stratification. In addition, the reviewer should consider the effect of suspended sediment on contaminant sorption with the potential creation of contaminated sediment deposits;

2. Pathways: The staff should make independent calculations of the transport capabilities and potential contamination pathways of the subsurface environment under accidental conditions with respect to existing water users and known and likely future users. Special attention should be directed to proposed facilities with permanent dewatering systems to ensure that pathways created by those systems have been identified. The accident release scenario follows the guidance of DSRS Section 11.2, BTP 11-6, and ISG-013 (NRC, 2013a), as incorporated in DSRS Section 11.2 and BTP 11-6. For sites located in the permafrost region the review includes information on freezing, thawing, subsurface thermal gradients and impacts of gas hydrates on groundwater flow, pathways, and safety of SSCs.

   Review of the applicant's analysis of subsurface contaminant transport should begin with simple bounding calculations or models, using demonstrably conservative assumptions and coefficients, to estimate concentration values at receptor points. If estimated

radionuclide concentrations are too high, that is if any such concentrations result in doses to an offsite dose receptor in excess of the acceptance criteria defined in DSRS Section 11.2 and BTP 11-6, then the NRC hydrology staff should consult with the health physics staff and evaluate further steps, such as employing more realistic calculation models to characterize the movement of radioactivity in surface and ground water and exposure pathways, in estimating doses to the offsite receptor. If the preliminary results are not acceptable, further analysis may be conducted using a hierarchical approach of progressively greater realism and less conservatism. Sensitivity analysis based on modeling by the staff or applicant should be conducted as appropriate. Calculations or models should be refined until the staff can conclude that the applicant's analysis is acceptable, that the applicant should provide more specific information to demonstrate compliance with DSRS acceptance criteria, or that additional measures such as license conditions are necessary to avoid possible excessive concentrations or doses at receptor points. DSRS Section 11.2 and BTP 11-6 addresses situations where it may be necessary to impose technical specifications (TS) to limit the radioactivity content that is stated for the liquid-containing tank in FSAR Chapter 16, Section 5.5, "Programs and Manuals," and to identify the TS as a programmatic element in the Offsite Dose Calculation Manual (ODCM), as addressed in FSAR Sections 11.5 and 13.4.

Similar independent calculations should be made of liquid effluent transport for the surface pathways identified. This process is further described in ISG-014 (NRC, 2013b). For preliminary analysis, the staff should employ simplified calculations or models. The analysis should be performed using demonstrably conservative coefficients and assumptions, and the physical conditions (such as lowest recorded river flow) likely to give the most adverse dispersion of the liquid effluent. If the concentrations computed by conservative simplified methods are not acceptable, more realistic and less conservative models (such as those used for hydrothermal prediction) and coefficients should be employed by the staff. The applicant's model assumptions and results should be compared with the staff's results to ensure that the results are comparably conservative. The estimation of liquid effluent dispersion should reflect potential future changes that might result from variations in use by known and likely future surface and ground water users.

The use of numerical models by the applicant should be reviewed with consideration given to whether standard and accepted practices have been followed, such as those described in ANSI/ANS-2.17-2010 (ANS, 2010) for subsurface radionuclide transport. A number of the American Society for Testing and Materials (ASTM) publications may also be used for guidance (see the Reference section). In the performance of detailed model simulations, the review should determine whether the applicant has followed a strategy such as that outlined in NUREG/CR-6805 (NRC, 2003) and NUREG/CR-5621 (NRC, 1998). Additional current guidance on selection and application of contaminant transport models should be obtained from generally accepted sources such as U.S. EPA (1994) and Zheng and Bennett (2002).

3. Characteristics that Affect Transport: Characteristics of both the surface and subsurface environments affect the mobility of contaminants. For instance: retardation of a subsurface contaminant is determined in part by the site-specific properties of the soil interactions with suspended sediment may result in sorption of the contaminant with subsequent creation of contaminated sediment deposits and the mixing of a contaminant in a lake can be limited by stratification. The properties used by the applicant to define the mobility and dilution of a contaminant must be based on site-specific measurements unless it can be shown that these measurements are unnecessary to assure safety. For instance, if the assumption of zero retardation results in acceptable concentrations at

receptor points, then site-specific adsorption studies will not be necessary. For sites located in the permafrost region the review includes information on freezing, thawing, subsurface thermal gradients and impacts of gas hydrates on groundwater flow, pathways, and safety of SSCs.

4. Consideration of Other Geological and Hydrological Site-Related Evaluation Criteria: Subpart B of 10 CFR Part 100 describes site-proximity hazards, and seismic and non-seismic siting criteria, for power reactor applications. The staff's review should include evaluation of pertinent information to determine if these criteria are appropriately used in postulation of the release of radionuclides from a single tank for accidental releases of radioactive liquid effluent (see DSRS Section 11.2 and BTP 11-6) in ground and surface waters at the proposed plant site, and in the review of the consequences of such a release. This information may include the potential effects of seismically-induced land subsidence, and the effects of hydraulic structures located upstream and downstream of the plant in the event of structural or operational failures and the ensuing sudden changes in the regime of flow.

5. Other Site-Related Evaluation Criteria: Subpart B of 10 CFR Part 100 also describes non-geological and non-hydrological the criteria to be used in evaluating reactor sites. Besides the geological and hydrological characteristics of the site, as described above, Part 100 includes other criteria. These criteria include meteorological conditions, population density and distribution, proximity of man-made hazards such as dams and chemical facilities, and seismic characteristics. The staff's review should evaluate whether any of these characteristics are relevant to the postulated radionuclide release or to the consequences of such a release. This review could include, for example, the potential effects of seismically-induced land subsidence, or the effects of sudden changes in streamflow regime resulting from failure of upstream or downstream hydraulic structures.

6. Review Procedures Specific to 10 CFR Part 52 Application Type

   A. ESP Reviews: Subpart A to 10 CFR Part 52 specifies the requirements and procedures applicable to the Commission's review of an ESP application for approval of a proposed site. Information required in an ESP application includes a description of the site characteristics and design parameters of the proposed site. The scope and level of detail for reviewing data parallel those used for a COL review.

      In the absence of a compliance or adequate protection issue, a modification necessary based on updating ESP-emergency preparedness information or a variance, 10 CFR 52.39 precludes the staff from imposing new site characteristics, design parameters, or terms and conditions on the ESP at the COL stage. Accordingly, the reviewer should ensure that all physical attributes of the site that could affect the design basis of safety-related or risk-significant SSCs are reflected in the site characteristics, design parameters, or terms and conditions on the ESP.

   B. Standard DC Reviews: DC applications do not contain general descriptions of site characteristics because this information is site-specific and will be addressed by the COL applicant. However, pursuant to 10 CFR 52.47(a)(1), a DC applicant must provide site parameters postulated for the design. The reviewer verifies that:

i. The postulated site parameters are representative of a reasonable number of sites that have been or may be considered for a COL application;

ii. Appropriate site parameters are included as Tier 2 information, and the Tier 2 site parameters particularly important for safety are also included as Tier 1 information.[2] Additional guidance on site parameters is provided in SRP Section 2.0;

iii. Pertinent parameters are stated in a site parameters summary table; and

iv. The applicant has provided a basis for each of the site parameters.

C. COL Reviews: For a COL application referencing a certified standard design, NRC staff reviews the application to ensure that sufficient information is presented to demonstrate that the characteristics of the site fall within the site parameters specified in the DC rule. Should the actual site characteristics not fall within the certified standard design site parameters, the COL applicant will need to demonstrate by some other means that the proposed facility is acceptable at the proposed site. This might be done by re-analyzing or redesigning the proposed facility. The applicant may also apply for a departure when submitting the COL application.

For a COL application referencing an ESP, NRC staff reviews the application to ensure that the applicant provides sufficient information to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the ESP as applicable to this DSRS section. In accordance with 10 CFR 52.79(b)(2), should the design of the facility not fall within the site characteristics and design parameters, the application shall include a request for a variance from the ESP that complies with the requirements of 10 CFR 52.39 and 10 CFR 52.93.

In addition, long-term environmental changes and changes to the region resulting from human or natural causes may have introduced changes to the site characteristics that could be relevant to the design basis. In the absence of certain circumstances, such as a compliance or adequate protection issue, 10 CFR 52.39 precludes the staff from imposing new site characteristics, design parameters, or terms and conditions on the ESP at the COL stage. Consequently, a COL application referencing an ESP need not include a re-investigation of the site characteristics that have previously been accepted in the referenced ESP. However, in accordance with 10 CFR 52.6, "Completeness and Accuracy of Information," the applicant or licensee is responsible for identifying changes in site characteristics, of which it is aware, that would make a change in the ESP necessary under the criteria specified in 10 CFR 52.39. Information provided by the applicant in accordance with 10 CFR 52.6(b) will be addressed by the staff during the review of a COL application referencing an ESP or a DC.

[2] Tier 1 means the portion of the design-related information in a DCD that is approved and certified by the Commission by being published as a rule. Tier 2 means the information that is approved by NRC but is not certified. Classification of site parameters as Tier 1 and Tier 2 has become customary, but is not defined by regulation and is not required. Tier 1 and Tier 2 are defined only by way of publication of individual design certification rules. For examples, see 10 CFR Part 52, Appendices A through D.

For a COL application referencing either an ESP or DC or both, the staff should review the corresponding sections of the ESP FSER and DC FSER to ensure that any ESP conditions, restrictions to the DC, or COL action items identified in the FSERs are appropriately handled in the COL application.

IV. EVALUATION FINDINGS

The reviewer verifies that the applicant has provided sufficient information and that the staff's technical review and analysis, as augmented by the application of programmatic requirements in accordance with the staff's technical review approach in the DSRS Introduction, support conclusions of the following type to be included in the staff's safety evaluation report. The reviewer also states the bases for those conclusions.

The staff's evaluation may include performance of independent calculations, and independent validation of appropriate assumptions. While the reviewer may summarize or quote the information offered by the applicant in support of its application, the reviewer should clearly articulate the bases for the staff's conclusions in his or her own language, and should supplement the information submitted by the applicant with information independently derived from other sources.

1. COL Reviews

The following statements should be preceded by a summary of the site characteristics and parameters used for the plant:

As set forth above, the applicant has presented and substantiated information relative to the accidental releases of radioactive liquid effluent in ground and surface waters important to the design and siting of this plant. The staff has reviewed the available information provided and, for the reasons given above, concludes that the identification and consideration of the potential effects of accidental releases of radioactive liquid effluents in ground and surface waters on existing users and known and likely future users of ground and surface water resources in the vicinity of the site are acceptable and meet the requirements of 10 CFR Part 100 10 CFR 100.20(c), with respect to determining the acceptability of the site.

The staff finds that the applicant has considered the appropriate site phenomena in establishing the transport of radioactive liquid effluent in ground and surface waters that are important to safety of ground and surface water resources in the vicinity of the site. The staff has generally accepted the methodologies used to determine the potential effects of accidental releases of radioactive liquid effluents in ground and surface waters on existing users and known and likely future users of ground and surface water resources, as documented in safety evaluation reports for previous licensing actions. The staff concludes that the identified design bases meet the requirement(s) of 10 CFR 100.20(c), with respect to establishing the effects of accidental releases of radioactive liquid effluents in ground and surface waters.

The review conducted by the health physics staff confirmed the applicant's approach in modeling the transport of radioactivity in surface water or groundwater starting from the building housing the assumed failed tank to the nearest point of entry and assumed dose receptor located in unrestricted areas. For the reasons presented in Section 11.2 of this FSER, the review concludes that the identification and consideration of a postulated release of radioactive materials in groundwater and/or surface water in the vicinity of the

site and associated radiological impacts meet the acceptance criteria and are consistent with the guidance of DSRS Section 11.2 and BTP 11-6.

2. ESP Reviews

The following statements should be preceded by a summary of the site characteristics and design parameters to be included in any ESP that might be issued for the proposed site:

As set forth above, the applicant has presented and substantiated sufficient information pertaining to the identification and evaluation of effects of accidental releases of radioactive liquid effluents in ground and surface waters on existing users and known and likely future users of ground and surface water resources in the vicinity of the proposed site. Section 2.4.13, Accidental Releases of Radioactive Liquid Effluents in Ground and Surface Waters, of the DSRS for mPower™ Integral Pressurized Water Reactor (iPWR) Design, provides that the site FSAR should address the requirements of 10 CFR Part 100 as they relate to identifying and evaluating effects of accidental releases of radioactive liquid effluents in ground and surface waters on existing users and known and likely future users near the site. Further, the applicant considered the most severe natural phenomena that have been historically reported for the site and surrounding area while describing the hydrologic interface of the plant with the site, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated. The staff has generally accepted the methodologies used to determine the severity of the phenomena reflected in these site characteristics, as documented in FSERs for previous licensing actions. Accordingly, the staff concludes that the use of these methodologies results in site characteristics containing sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. In view of the above, the site characteristics previously identified are acceptable for use in establishing the design bases for safety-related or risk-significant SSCs, as may be proposed in a COL application.

The review conducted by the Health Physics staff confirmed the applicant's approach in modeling the transport of radioactivity in surface water or groundwater starting from the building housing the assumed failed tank to the nearest point of entry and assumed dose receptor located in unrestricted areas. For the reasons presented in Section 11.2 of this FSER, the review concludes that the identification and consideration of a postulated release of radioactive materials in groundwater and/or surface water in the vicinity of the site and associated radiological impacts meet the acceptance criteria and are consistent with the guidance of DSRS Section 11.2 and BTP 11-6.

Therefore, the staff concludes that the identification and consideration of the site characteristics related to accidental release of radioactive liquid effluents set forth above are acceptable and meet the requirements of 10 CFR 52.17(a)(1)(vi), 10 CFR 100.20(c), and 10 CFR 100.21(d).

In view of the above, the staff finds the applicant's proposed site characteristics related to accidental release of radioactive liquid effluents for inclusion in an ESP for the applicant's site, should one be issued, acceptable.

3. DC Reviews

The following statement should be preceded by a list of all site parameters specified for the plant design. Site parameters should be identified as Tier 1 (approved and certified by NRC) and Tier 2 (approved by NRC), and a value provided for each parameter.

The NRC staff acknowledges that the applicant has selected the site parameters referenced above for plant design inputs (a subset of which is included as Tier 1 information) and agrees that they are representative of a reasonable number of sites that have been or may be considered for a COL application. Effects of accidental releases of radioactive liquid effluents in ground and surface waters on existing users and known and likely future users of ground and surface water resources in the vicinity of the site are site-specific and will be addressed by the COL applicant. This should include the provision of information sufficient to demonstrate that the design of the plant falls within the site parameters specified by the siting review.

V. IMPLEMENTATION

The staff will use this DSRS section in performing safety evaluations of mPower^{TM}-specific DC, COL, or ESP applications submitted by applicants pursuant to 10 CFR Part 52. The staff will use the method described herein to evaluate conformance with Commission regulations.

Because of the numerous design differences between the mPower^{TM} and large light-water nuclear reactor power plants, and in accordance with the direction given by the Commission in SRM- COMGBJ-10-0004/COMGEA-10-0001, "Use of Risk Insights to Enhance the Safety Focus of Small Modular Reactor Reviews," dated August 31, 2010 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML102510405), to develop risk-informed licensing review plans for each of the small modular reactor (SMR) reviews including the associated pre-application activities, the staff has developed the content of this DSRS section as an alternative method for mPower^{TM}-specific DC, COL, or ESP applications submitted pursuant to 10 CFR Part 52 to comply with 10 CFR 52.47(a)(9), "Contents of applications; technical information."

This regulation states, in part, that the application must contain "an evaluation of the standard plant design against the SRP revision in effect six months before the docket date of the application." The content of this DSRS section has been accepted as an alternative method for complying with 10 CFR 52.47(a)(9) as long as the mPower^{TM} DCD FSAR does not deviate significantly from the design assumptions made by the NRC staff while preparing this DSRS section. The application must identify and describe all differences between the standard plant design and this DSRS section, and discuss how the proposed alternative provides an acceptable method of complying with the regulations that underlie the DSRS acceptance criteria. If the design assumptions in the DC application deviate significantly from the DSRS, the staff will use the SRP as specified in 10 CFR 52.47 (a)(9). Alternatively, the staff may supplement the DSRS section by adding appropriate criteria in order to address new design assumptions. The same approach may be used to meet the requirements of 10 CFR 52.17 (a)(1)(xii) and 10 CFR 52.79 (a)(41), for ESP and COL applications, respectively.

VI. REFERENCES

In addition to the following references describing methods and techniques of evaluation, methods, techniques, and data published by Federal, State, and other agencies and organizations may be used as available.

1. 10 CFR 20.1406, "Minimization of Contamination."

2. 10 CFR Part 20, Appendix B, “Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage.”

3. 10 CFR Part 50, Appendix A, “General Design Criteria for Nuclear Power Plants.” GDC 2, “Design Bases for Protection Against Natural Phenomena.”
GDC 60, “Control of Releases of Radioactive Materials to the Environment.”

4. 10 CFR Part 52, “Licenses, Certifications, and Approvals for Nuclear Power Plants.”

5. 10 CFR Part 52, Subpart A, “Early Site Permits.”

6. 10 CFR 52.6, “Completeness and Accuracy of Information.”

7. 10 CFR 52.6(b)

8. 10 CFR 52.17, “Contents of Applications; Technical Information.”

9. 10 CFR 52.17(a)(1)(vi)

10. 10 CFR 52.17(a)(1)(xii)

11. 10 CFR 52.39, “Finality of Early Site Permit Determinations.”

12. 10 CFR 52.47(a)(1)

13. 10 CFR 52.47(a)(9)

14. 10 CFR 52.79, “Contents of Applications; Technical Information in Final Safety Analysis Report.”

15. 10 CFR 52.79(a)(1)(iii)

16. 10 CFR 52.79(a)(41)

17. 10 CFR 52.79(b)(2)

18. 10 CFR 52.93, “Exemptions and Variances.”

19. 10 CFR 52, Appendices
Appendix A – Design Certification Rule for the U.S. Advanced Boiling Water Reactor
Appendix B - Design Certification Rule for the System 80+ Design
Appendix C - Design Certification Rule for the AP600 Design
Appendix D - Design Certification Rule for the AP1000 Design

20. 10 CFR Part 100, “Reactor Site Criteria.”

21. 10 CFR Part 100, Subpart B, “Evaluation Factors for Stationary Power Reactor Site Applications on or After January 10, 1997.”

22. 10 CFR 100.20(c)

23. 10 CFR 100.20(c)(3)

24. 10 CFR 100.21(d)

25. 10 CFR 100.23, “Geologic and Seismic Siting Criteria.”

26. 10 CFR 100.23(d), “Geologic and Seismic Siting Factors.”

27. ANS, 2010, “Evaluation of Subsurface Radionuclide Transport at Commercial Nuclear Power Plants,” ANSI/ANS-2.17-2010, American Nuclear Society, La Grange Park, IL.

28. ASTM 2010, "Standard Guide for Application of a Ground-Water Flow Model to a Site-Specific Problem," ASTM Designation: D 5447-04.

29. ASTM 2008, "Standard Guide for Conducting a Sensitivity Analysis of a Ground-Water Flow Model Application," ASTM Designation: D 5611-94.

30. ASTM 2008, "Standard Guide for Developing Conceptual Site Models for Contaminated Sites," ASTM Designation: E1689-95.

31. ASTM 2006, "Standard Guide for Subsurface Flow and Transport Modeling," ASTM Designation: D 5880-95.

32. ASTM 2008, "Standard Guide for Comparing Ground-Water Flow Model Simulations to Site-Specific Information," ASTM Designation: D 5490-93.

33. ASTM 2008, "Standard Guide for Defining Boundary Conditions in Ground-Water Flow Modeling," ASTM Designation: D 5609-94.

34. ASTM 2008, "Standard Guide for Defining Initial Conditions in Ground-Water Flow Modeling," ASTM Designation: D 5610-94.

35. U.S. EPA 1994, PB 94-205804 EPA 402-R-94-012, "A Technical Guide to Ground-Water Model Selection at Sites Contaminated with Radioactive Substances."

36. NRC, 1977, “Estimating Aquatic Dispersion of Effluents From Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I,” RG 1.113, Revision 1, April 1977, U.S. Nuclear Regulatory Commission, Washington DC.

37. NRC, 1998, “Groundwater Models in Support of NUREG/CR-5512,” NUREG/CR-5621, December 1998, U.S. Nuclear Regulatory Commission, Washington DC.

38. NRC, 2003, “A Comprehensive Strategy of Hydrogeologic Modeling and Uncertainty Analysis for Nuclear Facilities and Sites,” NUREG/CR-6805, July 2003, U.S. Nuclear Regulatory Commission, Washington DC.

39. NRC, 2007, “Postulated Radioactive Releases Due To Liquid-Containing Tank Failures,” Branch Technical Position 11-6, March 2007, *in* “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition,” NUREG-0800, U.S. Nuclear Regulatory Commission, Washington DC.

40. NRC, 2008, “Minimization of Contamination and Radioactive Waste Generation: Life-Cycle Planning,” RG 4.21, June 2008, U.S. Nuclear Regulatory Commission, Washington DC.

41. NRC, 2010, “Use of Risk Insights to Enhance the Safety Focus of Small Modular Reactor Reviews,” Staff Requirements Memorandum (SRM) COMGBJ-10-0004/COMGEA-10-0001, August 31, 2010, U.S. Nuclear Regulatory Commission, Washington DC (ML102510405).

42. NRC, 2013a, “Interim Staff Guidance (ISG-013) on NUREG-0800, Standard Review Plan, Section 11.2 and Branch Technical Position (BTP) 11-6 Assessing the Radiological Consequences of Accidental Releases of Radioactive Materials from Liquid Waste Tanks for Combined License Applications Submitted under 10 CFR Part 50 and 52,” ISG-013, (ML12191A325) 2013, U.S. Nuclear Regulatory Commission, Washington DC.

43. NRC, 2013b, “Interim Staff Guidance (ISG-014) on NUREG-0800 Standard Review Plan, Section 2.4.13 Assessing the Consequences of Accidental Releases of Radioactive Materials from Liquid Waste Tanks in Ground and Surface Waters for Combined License Applications Submitted under 10 CFR Part 50 and 52," ISG-014, (ML12191A330) 2013, U.S. Nuclear Regulatory Commission, Washington DC.

44. Zheng, C. and G.D. Bennett, 2002, “Applied Contaminant Transport Modeling,” John Wiley & Sons, New York.