Interim Staff Guidance
On Standard Review Plan Sections 2.4.12 and 2.4.13
Assessing Groundwater Flow and
Transport of Accidental Radionuclide Releases

Purpose

The purpose of this interim staff guidance (ISG) is to clarify previous U.S. Nuclear Regulatory Commission (NRC) guidance for reviewing the required analysis for the radiological consequences of accidental releases of radioactive liquid wastes to groundwater performed during the licensing review for a new nuclear power plant.

During its review of recent early site permit (ESP) and combined license (COL) applications, the NRC staff identified recurring issues involving inconsistencies and gaps between guidance provided in the Standard Review Plan (SRP) Section 2.4.13 and SRP Section 11.2 with Branch Technical Position (BTP) 11-6 relating to on-site hydrogeologic testing and measurements, conceptual model development of radionuclide transport in groundwater, and analysis of the radiological consequences of releases. To address these issues, this ISG focuses on resolving the inconsistencies and gaps in the existing guidance.

Because of the complexity of the issues related to groundwater contamination, the Interim Staff Guidance has been divided between ISG-014 (herein) and ISG-013.

ISG-013 emphasizes the definition of the location and conditions of the assumed release, the role of mitigating design features, the definition of exposure scenarios, and potential technical specifications limiting radioactive tank contents. ISG-013 focuses on resolving discrepancies among three existing guidance documents:

- SRP Section 11.2 (“Liquid Waste Management System”);
- BTP 11-6 (“Postulated Radioactive Releases Due to Liquid-Containing Tank Failures”); and
- SRP 2.4.13 (“Accidental Releases of Radioactive Liquid Effluents in Ground and Surface Waters”).

This ISG (ISG-014) provides additional guidance on analyzing the aqueous transport of radionuclides through the subsurface with groundwater through the use of a structured hierarchical approach. ISG-014 emphasizes the consideration of the hydrogeologic conditions and flow system that control the transport of radionuclides in the analysis. ISG-014 supplements the following SRP guidance:

- SRP Section 2.4.12 (“Groundwater”); and
- SRP Section 2.4.13 (“Accidental Releases of Radioactive Liquid Effluents in Ground and Surface Waters”)

Background

ISG-014 is primarily concerned with clarifying the guidance of SRP Sections 2.4.12 and 2.4.13 of NUREG-0800. The regulatory basis of these SRP sections appears in 10 CFR 20.1301 and 10 CFR 20.1302, Appendix B to 10 CFR Part 20, 10 CFR 52.79, and 10 CFR 100.20.

SRP Section 2.4.12 provides guidance for the evaluation of site hydrogeologic characteristics to describe the effects of groundwater on plant foundations, reliability of a safety-related water supply, and dewatering systems.

SRP Section 2.4.13 provides guidance for the evaluation of hydrogeologic characteristics to describe the effects of accidental releases of radioactive liquid effluents in ground and surface waters on existing users and known and likely future users of ground water or surface water. Included is guidance on the review of alternative conceptual models of groundwater conditions that dictate radionuclide movement, plausible pathways, and characteristics (such as dispersion and retardation coefficients) that may delay, disperse, dilute, or concentrate contaminants in groundwater.

Because a release scenario and the associated transport of radionuclides are closely coupled, the guidance in ISG-014 (i.e., transport) must be considered in relation to the guidance in ISG-013 (i.e., release scenario). Providing guidance to SRP Section 11.2 (supplemented by BTP 11-6), ISG-013 provides clarification in defining the accidental release scenario and assumptions for the consequence analysis. SRP Section 11.2 describes the review of the Liquid Waste Management System (LWMS) for handling liquid wastes during normal plant operations whereas BTP 11-6 defines the assumptions for a release from the LWMS as a source term in the release analysis. Although SRP Sections 2.4.13 and 11.2 both deal with accidental release of radiological liquid effluents, SRP Section 2.4.13 adopts a *concentration*-based consequence analysis, while SRP Section 11.2 uses a *dose*-based analysis for regulated effluent releases.

SRP Sections 2.4.12 and 2.4.13 suggest a detailed analysis of on-site groundwater flow and transport processes important in performing the analysis of radiological consequences and determining the extent of on-site hydrogeologic testing and measurements. In complex hydrological flow systems, SRP Sections 2.4.12 and 2.4.13 consequence analysis may require implementation and development of a calibrated numerical groundwater flow and transport model to assess plausible pathways and develop predictive simulations of contaminant fate and transport. Alternatively, SRP Section 11.2 implements a simplistic conceptual pathway model to focus on the effects of radiological contamination exposure to the public through direct (i.e., water use) uptake and indirect (i.e., biota consumption) uptake. For the radiological source term, SRP Sections 2.4.13 and 11.2 assume a sudden accidental release from one tank or vessel in the LWMS. However, SRP Section 2.4.13 does not clearly define the hydrologic base condition or the acceptance criteria for the consequence analysis.

Through supplementing the guidance in SRP Sections 2.4.12 and 2.4.13, ISG-014 is intended to clarify issues related to:

- The definition of on-site hydrogeologic base conditions required for SRP 2.4.13 analyses;
- The development of conceptual site models; and

- The consequence analyses of accidental radiological releases.

In addition, this guidance includes updates to the Review Areas, Review Interfaces, and Regulatory Requirements as described in SRP Sections 2.4.12 and 2.4.13.

Through supplementing the guidance in SRP Sections 11.2 and BTP 11-6, ISG-013 is intended to clarify:

- Postulated accidental release scenarios;
- Identification of release source terms;
- Identification of assumptions and methods for the consequence analysis;
- Definition of the approach for assessing impact at potential receptors; and
- Assessment of mitigating design features.

ISG-013, developed for use with SRP Section 11.2, is cross-referenced herein for consistency of hydrogeologic characterization and subsurface radionuclide transport analyses.

Issues

The following summarizes the major issues targeted for clarification in SRP Sections 2.4.12 and 2.4.13:

- The regulation in Title 10 of the *Code of Federal Regulations* (CFR) 100.20(c)(3) specifically requires the establishment of the on-site hydrogeology characteristics needed to analyze radiological transport in the groundwater. However, no regulatory guide (RG) provides specific guidance on the acceptable extent of the on-site hydrogeologic measurements.

- To define the base hydrologic conditions used in a consequence analysis, SRP Section 2.4.13 specifies the use of "demonstrably conservative assumptions and coefficients", whereas SRP Section 11.2 and BTP 11-6 specify the use of an annual average hydrologic (e.g., rainfall, surface water/groundwater flow, water level) occurrence. This inconsistency between SRP Sections 2.4.13 and Section 11.2/ BTP 11-6 is addressed in this ISG.

- SRP Sections 2.4.12 and 2.4.13 do not provide clear guidance in reviewing applicant-submitted groundwater pathways and receptors, conceptual site models, and radiological consequence analyses. In particular, SRP Section 2.4.13 does not specify whether an applicant is required to perform a radiological consequence analysis when the proposed plant contains optional mitigating design features as described in SRP Section 11.2 and Section B.3 ("Mitigating Design Features") of BTP 11-6,

- SRP Sections 2.4.12 and 2.4.13 do not provide guidance for developing alternate conceptual models or numerical groundwater flow models.

Rationale

The staff finds current guidance incomplete and inconsistent based on experience with reviews of recent ESP and COL applications. To address these issues the staff should:

- Redefine the Review Areas, Review Interfaces, and Regulatory Requirements addressed in SRP Sections 2.4.12 and 2.4.13.
- Reconcile the differences between SRP Sections 2.4.13 and 11.2, and clarify how BTP 11-6 and the newly developed ISG-013 may be used to guide the concentration-based consequence analysis needed in Safety Analysis Report (SAR) Section 2.4.13.
- Clarify the degree of conservatism necessary and the base hydrologic conditions applicable to the consequence analysis in SRP Section 2.4.13.
- Provide the guideline for choosing the potential receptor locations of accidental releases for the radiological consequence analysis.
- Clarify how mitigation design measures should be considered when performing a radiological consequence analysis for SRP Section 2.4.13.
- Propose practical guidance to meet the requirement of on-site hydrogeology measurements specified in 10 CFR 100.20(c)(3).
- Provide guidance for development of sound conceptual site models and the determination of plausible groundwater pathways.
- Specify acceptance criteria for the development of groundwater flow models that may help evaluate future groundwater flow directions and pathways in the aquifer system.

Proposed Interim Staff Guidance

This ISG is intended to supplement SRP Sections 2.4.12 and 2.4.13 until these SRP sections are revised. The consequence analysis under SRP Section 2.4.13 requires several sequential steps for the determination of hydrogeologic parameters and for the fate and transport analysis of groundwater radionuclide contamination.

To clarify the steps in this process, a hierarchical approach (Figure 1) is recommended for addressing the issues covered by SRP Sections 2.4.12 and 2.4.13. The analysis begins by determining the basic conditions for the analysis: site conceptualization and hydrogeologic characteristics; release location; receptors; groundwater pathways; travel time; and the release volume and concentration. If satisfactory mitigating design features are present and acceptable, the analysis can then be concluded. Otherwise, contaminant transport analysis is initially performed using a simplistic model considering only advection, decay and dilution. If the calculated concentrations and doses at the receptor point are within regulatory limits, the analysis can be concluded. Progressively more complex transport mechanisms and modeling techniques are applied to the extent that they are supported by site data to verify that the site meets the effluent concentration limits (ECLs) as defined in 10 CFR Part 20, Appendix B, Table 2. If these ECLs are not attainable, health physics staff reviewing the SAR Section 11.2 may request the applicant to consider either a modification to technical specification to limit the volume and concentration of tank contents, or mitigating design features (e.g., steel liners, earthen berms) to minimize radiological releases.

The following seven subsections describe guidance for Area of Review, Review Interfaces, Regulatory Requirements, On-site Hydrogeologic Characterization, Contaminant Source and Receptor Locations, Groundwater Modeling and Pathway Predictions, and Radioactive Consequence Analysis.

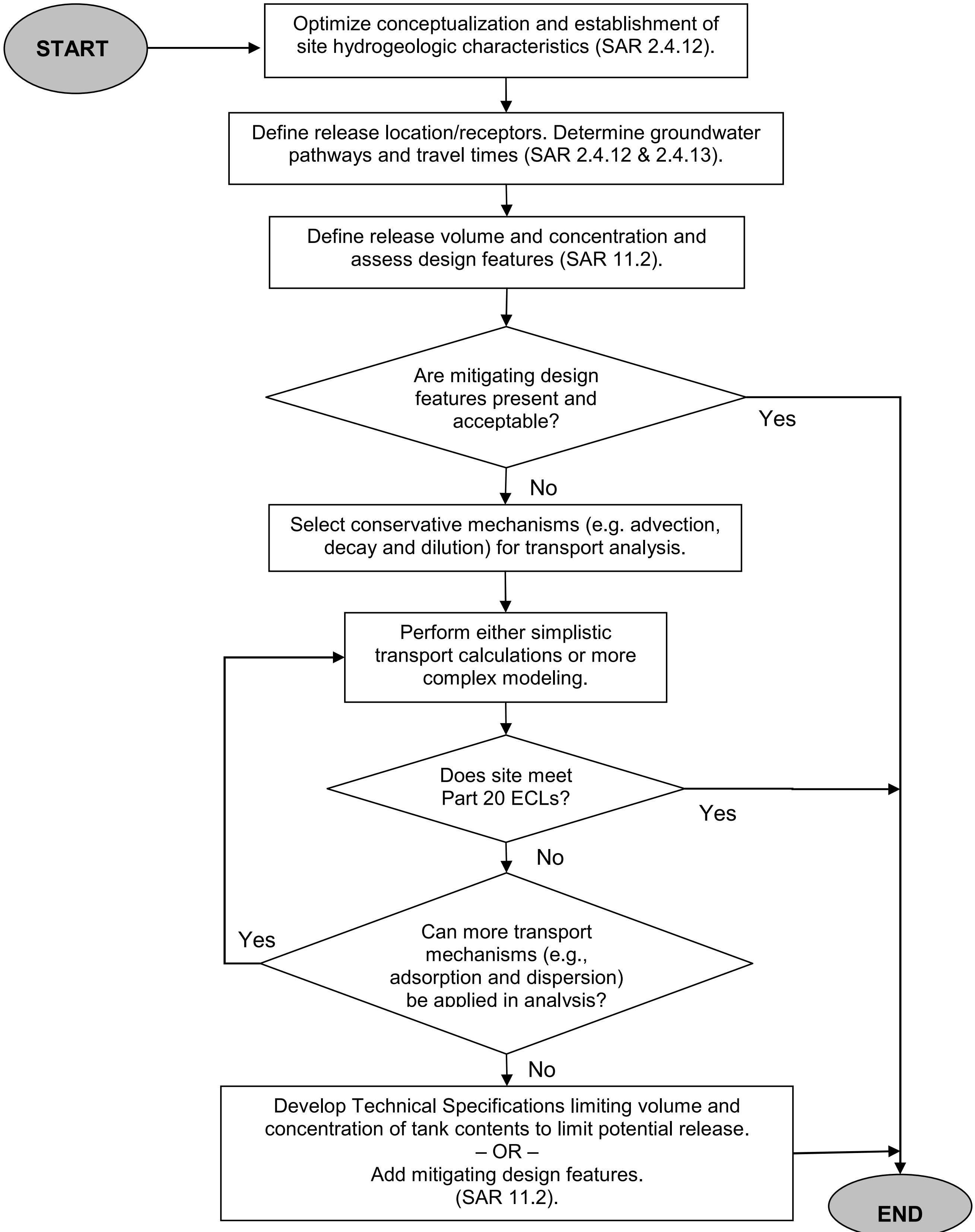

Figure 1. Hierarchical approach to analyzing radiological consequences in groundwater.

1. Area of Review

The review areas defined in SRP Sections 2.4.12 and 2.4.13 differ from those in RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)" which applicants have been using in preparing recent COL applications. Therefore, this guide recommends reconciling format differences with RG 1.206, and addressing additional components required for consideration in the radiological consequence analysis as follows:

(a) The specific areas of review in SRP Section 2.4.12 will be replaced by those areas as defined in RG 1.206: (1) description of hydrogeology and water use; (2) groundwater sources; (3) subsurface pathways; (4) monitoring or safeguard requirements; and (5) site characteristics for subsurface hydrostatic loading.

(b) The specific areas of review in SRP Section 2.4.13 will be replaced by those areas as defined in RG 1.206: (1) description of release mechanisms and transport parameters; (2) direct release to groundwater; and (3) direct release to surface water.

(c) Staff should refer to Sections C.I.2.4.12 and C.I.2.4.13 of RG 1.206 as they describe the content of the above specified review areas. Specifically, RG 1.206 includes a detailed description of the site characteristics for subsurface hydrostatic loading in Section C.I.2.4.12.

2. Review Interfaces

Item (a) is added to supplement Review Interfaces listed in SRP Section 2.4.12, and items (b) through (d) are added to supplement Review Interfaces in SRP Section 2.4.13:

(a) SRP Section 2.5.1 presents specific guidance for reviewing the regional and site geology information collected by the applicant while SRP Section 2.5.4 focuses on the review of the geotechnical aspects of foundation, excavation, and backfill. Therefore, the staff should cross reference SAR Sections 2.5.1 and 2.5.4 with SAR Sections 2.4.12 and 2.4.13 in reviews of issues pertinent to establishing on-site hydrogeologic characteristics.

(b) The focus of SRP Section 11.2 is on the radiological LWMS to ensure that liquid wastes produced during normal operation are handled, processed, recycled as coolant, or released in accordance with NRC regulations. SRP Section 11.2 also guides the reviewer in analyzing the consequences of accidental releases and in confirming the adequacy of mitigating design features proposed by the applicant to prevent or minimize the release of contamination.

(c) BTP 11-6 provides a guide for defining the radioactive source term, mitigation design features, and tank radionuclide concentration levels. For the source term, BTP 11-6 defines a postulated release from a rupture-type failure from a tank and associated components based on 80 percent of the volume capacity of that tank and components. BTP 11-6 also specifies that the applicant should either meet the limits set in 10 CFR Part 20, Appendix B, Table 2 (10 CFR Part 20, Appendix B compliance); or the applicant should implement specified mitigating design features. Compliance with

10 CFR Part 20, Appendix B ensures that the radiological consequences will not exceed a public dose limit of 50 millirem (mrem) to the receptors via all appropriate water exposure pathways.

(d) Staff reviewing SAR Section 2.4.13 should also refer to ISG-013 to supplement the guidance provided in both SRP Section 11.2 and BTP 11-6. ISG-013 provides additional guidance in reviewing the failure mechanism and radiological release scenario, mitigating features, radioactive source term, exposure scenario, acceptance criteria, and specification of tank waste maximum radioactivity concentration levels.

3. <u>Regulatory Requirements</u>

The regulatory requirements for the SAR Sections 2.4.12 and 2.4.13 are described below with items (a) and (b) applicable to SAR Section 2.4.12 and items (c) and (d) to SAR Section 2.4.13 as follows:

(a) 10 CFR 52.17(a)(1)(vi) for ESP applications, and 10 CFR 52.79(a)(1)(iii) for COL applications, specify the regulatory requirement for establishing hydrologic site characteristics. These sections require the 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. This requirement is applicable to the analysis of a maximum groundwater level for subsurface hydrostatic loading in SAR Section 2.4.12, but not to the analysis of radiological consequences as discussed in subsection 7 herein.

(b) 10 CFR 100.20(c)(3) of Part 100 specifies that factors important to hydrological radionuclide transport (e.g., soil, sediment, and rock characteristics, adsorption and retention coefficients, groundwater velocity, and distances to the nearest surface body of water) must be obtained from on-site measurements.

(c) The regulations primarily responsible for ensuring that licensees maintain adequate control over radioactive effluent discharges appear in 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities,” and 10 CFR Part 20. The specific regulatory requirements underlying the consequence analysis in SRP Section 2.4.13 are 10 CFR 20.1101 and 20.1302, which provides dose limits for individual members of the public.

(d) SRP Section 11.2 specifies compliance with General Design Criterion (GDC) 60, “Control of Releases of Radioactive Materials to the Environment,” and GDC 61, “Fuel Storage and Handling and Radioactivity Control,” of Appendix A, “General Design Criteria for Nuclear Power Plants,” to 10 CFR Part 50. These criteria apply to the design of tanks containing radioactive material and associated components outside the reactor containment building. Meeting these criteria ensures that accidental releases during normal operations or anticipated operational occurrences will not result in radionuclide concentrations in potable water exceeding the concentration limits specified in 10 CFR Part 20, Appendix B. Health physics staff who review the SAR Section 11.2 are responsible for final verification of 10 CFR Part 20, Appendix B compliance.

4. On-site Hydrogeologic Characterization

(a) The regulation in 10 CFR 100.20(c)(3) specifies that factors important to analyzing hydrological radionuclide transport must be obtained from on-site measurements. This interim guide clarifies that the specific objective of the on-site samples and measurements in SAR Sections 2.4.12 and 2.4.13 is to provide sufficient data to predict groundwater pathways, travel times, and the fate and transport of released radionuclide liquid effluents in the subsurface. The regulation provides examples of parameters but these examples are not intended to be comprehensive.

(b) The staff needs to verify the applicant meets the above requirement by providing sufficient on-site hydrogeologic data in the application to adequately conceptualize and characterize related groundwater systems. Collecting sufficient hydrogeologic data during the licensing stage is imperative due to the difficulty in data collection during the construction and post-construction phases. On-site samples, tests and measurements are essential for a fundamental understanding of site specific hydrogeologic processes.

(c) The radiological consequence analysis in SAR Section 2.4.13 should utilize the long-term annual average hydrogeologic condition as the base case to be consistent with the annual dose limits specified in 10 CFR Part 20, Appendix B. Factors such as rainfall, site surface water level and flow, and groundwater levels should be included for the determination of these long-term annual average conditions. For estimating subsurface hydrostatic loading in SAR Section 2.4.12, the base case condition should use the maximum groundwater level.

(d) At many new proposed sites, long-term data may not be available to establish the annual average hydrologic conditions. In these cases, indirect methods of determining annual average conditions include: (1) estimating on-site conditions based on a transposition of regional studies and data from nearby locations; and (2) correlating groundwater levels from on-site wells with limited data to local or regional wells screened within the same hydrogeologic setting. Because of the uncertainty associated with using indirect methods of characterization, the consequence analysis in these cases should be done under conservative hydrologic conditions and parameter assumptions (e.g., using demonstrably conservative groundwater gradients from a source release to a receptor).

(e) Measured hydrogeologic parameters including hydraulic conductivities should be representative of areal hydrogeologic conditions (e.g., an aquifer pumping test) rather than of conditions within a localized interval or location (e.g., an aquifer slug test). Transport parameters, including porosities and distribution coefficients (K_d), if measured, must be representative of field conditions. These parameters are key components for the analyses of potential contaminant migration during the operating and decommissioning lifecycle, therefore representative values should be obtained from in situ testing (where possible) or from aquifer material samples prior plant construction.

(f) Characterization of K_d values is challenging due to a combination of the potential number of radionuclide species and the spatial variability of aquifer material. When measurements of material K_d values are planned, at least two or three aquifer samples from equally divided segments on each identified pathway should be taken for analysis.

The K_d values determined should be compared and cross-checked with published values for similar material obtained from professional journals or studies conducted by the NRC, the U.S. Environmental Protection Agency (EPA), and the U.S. Department of Energy (DOE) Laboratories.

(g) Determining K_d values for short half-life species is generally not practical because they decay quickly. An acceptable approach would be to perform a simple consequence analysis that conservatively considers only decay and dilution processes with a K_d value of zero, and no dispersion. Given this screening approach, species that exceed the applicable concentration or dose limits at the receptor point are then selected for K_d value determination using aquifer material samples collected on-site.

5. <u>Contamination Source and Receptor Location</u>

(a) The health physics staff is responsible for reviewing the applicant's postulated accidental release scenarios. Each scenario should specify the radionuclide release point, and the volume, radionuclide species and concentrations in the selected tank and its components. In general, this information is available from the waste tank inventory tables provided in the Design Certification (DC) document.

(b) ISG-013 provides updated guidance in postulating the accidental release scenario based on a graded approach that evaluates and ranks all radionuclide-containing tanks and vessels located outside of the containment and then selects the system (e.g., tank) which excludes the use of mitigating design features but results in the highest consequence for the environment. The accidental release scenario should be evaluated independently for surface water and groundwater. The criteria used in the evaluations of tanks and vessels are the functions of each system, stored radioactive waste volumes and radionuclide concentrations, mitigating design features (durable and passive), and potential impacts to the unrestricted area.

(c) The BTP 11-6 accidental release scenario assumes the radionuclide inventory of a tank and its components fail based on 80 percent of the volume capacity of that tank and its components. The scenario assumes only one tank failure regardless of the number of units or the number of tanks in a unit. A critical assumption behind the single-tank failure is that the probability of multiple tank catastrophic failures occurring simultaneously is very low. The cumulative effects of multiple tank failures from multiple units at different times are not considered because each unit is likely to have unique pathway and travel time, thus overlapping of peak concentrations at a downstream receptor point from the tanks at different units is highly unlikely.

(d) Herein, a receptor is defined as the nearest source of potable water located in an unrestricted area. Unrestricted area means an area, access to which is neither limited nor controlled by the licensee (10 CFR 20.1003). For groundwater contamination scenarios, this could include a well or part or all of a fresh surface water body (e.g., stream, river, lake). SRP Section 2.4.13 specifies that the applicant should evaluate the effects of accidental release on existing uses and known and likely future uses of ground and surface water in the vicinity of the site. BTP 11-6 states that the impacts of the release on the nearest potable water that could be used for consumption by the public in an unrestricted area should be considered. The staff should confirm that the applicant has selected an appropriate location from all potential receptor locations in the portion of the unrestricted area that is closest to the site by considering a release point with respect to groundwater and surface water flows. The checkpoint for 10 CFR Part 20, Appendix B compliance is the receptor point; however, the use of an upstream pseudo-compliance point which is demonstrably more conservative in the consequence analysis is acceptable. If located along a receptor pathway, the pseudo-compliance point could be a relatively less-diluted upstream/upgradient point, the site boundary, small pond, or an on-site well.

6. Groundwater Modeling and Pathway Prediction

(a) The modeling process consists of conceptualization and mathematical modeling. The scope of SRP Section 2.4.12 includes development of a conceptual site model of groundwater flow and transport and alternative flow paths. The main objective of creating conceptual site models is to assemble critical on-site hydrogeologic data to evaluate and describe a qualitative representation of the important features, events, and processes of the groundwater flow and transport system.

(b) In identifying groundwater pathways, the staff should appropriately account for model uncertainty, including uncertainty of the assumptions used to develop conceptual model, variability and uncertainty in hydrogeologic data and parameters, and the uncertainty of the future contamination scenarios based on information provided by the applicant.

(c) A mathematical model is a realistic representation of the physical hydrogeologic system developed through the integration of a diverse set of hydrogeologic information and parameters. Simplistic (e.g., semi-analytical and analytical) solution methods for system representation are acceptable if the pattern of groundwater flow and transport is temporally and spatially uniform and stationary. For predictive simulations of complex groundwater flow systems, in-depth numerical modeling should be considered. Numerical modeling should be used if groundwater conditions change significantly over time or the potential effects of the proposed site changes on groundwater flow and transport are significant. Attachment A provides interim guidance for conceptual model development and modeling relatively complex groundwater flow systems.

(d) Properly developed, a numerical groundwater model is a useful tool to predict multiple pathways accurately and efficiently, and for simulating the impact of proposed structures and foundations, temporary and permanent dewatering systems, and engineered backfills.

7. Radioactive Consequence Analysis

7.1. Direct Release to Groundwater

(a) As mentioned previously, in keeping with the objectives of SRP Section 2.4.13, the staff should apply a hierarchical approach (Figure 1) in the contaminant transport analysis for simplicity and consistency of the analysis method.

(b) The staff should review both groundwater pathways to wells and discharge points, and combined pathways through groundwater and surface water. On each identified pathway, the staff should perform a consequence analysis and confirm 10 CFR Part 20, Appendix B compliance. SAR section 2.4.13 specifies analysis of direct intake through public water use only whereas SAR Section 11.2 analyzes both direct and indirect intakes. The health physics staff is responsible for ensuring that the applicant has committed to mitigating design features or technical specifications if the site does not meet 10 CFR Part 20, Appendix B.

(c) 10 CFR 20.1301(e) specifies that the applicant shall comply with the provisions of EPA's generally applicable environmental radiation standards in 40 CFR Part 190, "Environmental Radiation Protection Standards for Nuclear Power." The staff should check for compliance with these standards in its site safety evaluation.

(d) The consequence analysis should account for parent and progeny radionuclides in the contamination source that would be generated during transport. If applicable, the staff should consider the effects of chemical (e.g., chelating) agents that could comingle with radioactive materials and increase the mobility of radionuclides in the environment. Geochemistry at the site should be reviewed by staff for significance in the radionuclide transport processes considered for the consequence analysis.

(e) The consequence analysis described above applies to a case where the proposed plant has not implemented, either partially or entirely, mitigating design features against accidental releases of liquid wastes as specified in BTP 11-6. If mitigating design features are found acceptable by staff, evaluating consequence analysis for the accidental release in SAR Section 2.4.13 may not be necessary. In all cases, SAR Section 2.4.12 should include establishment of site hydrogeologic characteristics for (1) predicting a maximum groundwater level for use in designing structures; foundations, and dewatering systems, and (2) predicting the effects of ground water uses by the plant and other users on the safety-related plant operation.

(f) The mitigation design features specified in ISG-013 include steel liners or walls in areas housing the LWMS tanks or vessels, dikes for outdoor tanks, and overflow provisions to mitigate the effects of releases. Health physics staff reviewers for SAR Section 11.2 are responsible for the acceptability of the proposed mitigating design features. BTP 11-6 specifies that the accidental release scenario and mitigation design features are applied only to LWMS tanks and vessels, condensate storage tanks, refueling water storage tanks, or other major radioactivity-containing facilities. Correspondingly, the accidental release scenario in SAR 2.4.13 is restricted to the radwaste system but not to pipes or small components that are subject to leaks or spills. (Note: For pipes or small components, RG 4.21 provide examples of possible mitigation design features for compliance with 10 CFR 20.1406. Compliance with 10 CFR 20.1406 will be addressed in NEI 08-08, "Generic SAR Template Guidance for Life Cycle Minimization of Contamination," which provides guidance in minimizing groundwater contaminations from leaks and spills.)

7.2. Direct Release to Surface Water

A hierarchical approach similar to that outlined in Figure 1 is recommended for the staff to evaluate direct releases to surface water. Starting with a consequence analysis using one of the simplified computational procedures or models such as those introduced in RG 1.113 and NUREG/CR-3332, "Radiological Risk Assessment, A Textbook on Environmental Dose Analysis", the staff may proceed to a progressively more complex model considering dispersion or boundary layer stratification. If the detailed model does not result in meeting the Part 20 Appendix B limits, the staff should recommend specific mitigating design features. RG 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I," provides guidance for performing radioactive transport analyses in several different types of surface water bodies. RG 1.113 specifies the use of a long-term annual average flow in consequence analysis, however it is acceptable to use an extreme hydrologic condition (e.g., severe drought flow rate) for a conservative estimate.

Final Resolution

The NRC will formally incorporate the ISG-014 in future updates of SRP Sections 2.4.12 and 2.4.13. The updates will include revisions of the Area of Review, Review Interfaces, Acceptance Criteria, Technical Rationale, and Review Procedures. The revisions will also consider the incorporation of the provisions of ISG-013 and BTP 11-6 into the SRP sections. As part of these revisions, the staff will determine the applicability of associated revisions to the review of ESP and DC applications.

Applicability

ISG-014 is applicable to all license applications submitted under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."

References

10 CFR Part 20, "Standards for Protection against Radiation"

- Section 20.1003, "Definitions"
- Section 20.1101, "Radiation Protection Programs"
- Section 20.1301, "Dose Limits for Individual Members of the Public"
- Section 20.1302, "Compliance with Dose Limits for Individual Members of the Public"
- Section 20.1406, "Minimization of Contamination"
- Section 20.1501, "General"
- Appendix B, "Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage"

10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities”

- Section 50.34a, “Design Objectives for Equipment To Control Releases of Radioactive Material in Effluents—Nuclear Power Reactors”

- Section 50.36a, “Technical Specifications on Effluents from Nuclear Power Reactors”

- 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”
  – GDC 61, “Fuel Storage and Handling and Radioactivity Control”
  – GDC 64, “Monitoring Radioactivity Releases”

- 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,” Section IV.B, “Surveillance and Monitoring Program”

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

- Section 52.79, “Contents of Applications: Technical Information in Final Safety Analysis Report”

10 CFR Part 100, “Reactor Site Criteria”

- Section 100.3, “Definitions”

- Section 100.10, “Factors To Be Considered When Evaluating Sites,” Subpart A, “Evaluation Factors for Stationary Power Reactor Site Applications before January 10, 1997 and for Testing Reactors”

- Section 100.20, “Factors To Be Considered When Evaluating Sites,” Subpart B, “Evaluation Factors for Stationary Power Reactor Site Applications on or After January 10, 1997”

40 CFR Part 190, “Environmental Radiation Protection Standards for Nuclear Power”

ASTM D 5979 – 96, 2002 (reapproved). “Standard Guide for Conceptualization and Characterization of Ground-Water Systems”. ASTM International, West Conshohocken, PA.

ASTM E 1689 – 95, 2003 (reapproved). “Standard Guide for Conceptualization and Characterization of Ground-Water Systems”. ASTM International, West Conshohocken, PA.

EPRI 1016099, 2008.“Groundwater Protection Guidelines for Nuclear Power Plants (Public Edition”. Electric Power Research Institute (EPRI), Palo Alto, CA.

NRC, NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," March 2007

- Section 2.4.12, "Groundwater"
- Section 2.4.13, "Accidental Releases of Radionuclide Liquid Effluents in Ground and Surface Waters"
- Section 2.5.1, "Basic Geologic and Seismic Information"
- Section 2.5.4, "Stability of Subsurface Materials and Foundations"
- Section 11.2, "Liquid Waste Management System"
- BTP 11-6, "Postulated Radioactive Releases Due to Liquid-Containing Tank Failures"

NEI 08-08, "Generic FSAR Template Guidance for Life Cycle Minimization of Contamination," Nuclear Energy Institute, Revision 1, May 2009

NRC, RG 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I," April 1977

NRC, RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)," June 2007

NRC, RG 4.21, "Minimization of Contamination and Radioactive Waste Generation: Life-Cycle Planning," June 2008

NRC, NUREG/CR-3332, "Radiological Risk Assessment, A Textbook on Environmental Dose Analysis," September 1983

NRC, "A Comprehensive Strategy of Hydrogeologic Modeling and Uncertainty Analysis for Nuclear Facilities and Sites," NUREG/CR-6805, July 2003

NRC, ISG-013 (Draft), ISG on Assessing the Consequences of an Accidental Release of Radioactive Materials from Liquid Waste Tanks, *Federal Register*, page 20510, Vol. 74, No. 84, May 4, 2009

(Note: This list also includes references for Attachment A)

Attachment A

Guide for Reviewing Groundwater Models to Supplement Standard Review Plan Sections 2.4.12 and 2.4.13

The purpose of this attachment is to provide technical guidance for reviewing development and implementation of a numerical groundwater model in support of the radiological consequence analysis of SAR Sections 2.4.12 and 2.4.13. The consequence analysis requires information on groundwater pathways and travel times which can be accurately predicted using a properly constructed and calibrated numerical groundwater model. This guide is intended to provide the necessary technical rationale and acceptance criteria for the numerical modeling process, including data collection, conceptual site model development, model setup, calibration, validation, simulation, and reporting.

Modeling Objectives

The primary objective of building a groundwater model or models for use in SAR Sections 2.4.12 and 2.4.13 is to predict plausible groundwater pathways and travel times, which in turn serve as a basis for analyzing radionuclide transport in the subsurface. The secondary objectives of the modeling include but are not limited to the following: (1) predicting a maximum groundwater level for use in designing structures; foundations, and dewatering systems; and (2) predicting the effects of water uses on the plant and unrestricted area (public) users. Model assumptions that are conservative for prediction of groundwater levels and gradients are not necessarily conservative for assumptions associated with a contaminant transport model. Therefore, more than one set of model parameters and/or model calibration scenarios may be required to meet differing simulation objectives. This modeling guidance is primarily focused on the estimation of maximum groundwater levels and groundwater use impacts described in SRP Section 2.4.12, and on the radiological consequence analysis described in SRP Section 2.4.13.

Data Needs

Title 10, Section 100.20(c)(3), of the *Code of Federal Regulations* (10 CFR 100.20(c)(3)) specifies that factors important to hydrological radionuclide transport must be obtained from on-site measurements. Typical groundwater flow model data include, but are not limited to the following:

- Current and future topographic and land use data.

- Information (location, elevation, and rate) on surface water bodies and groundwater discharge to streams, rivers, and valleys.

- Geologic data from soil borings and well drillings and information on wells.

- Aquifer characteristics, including elevations, thicknesses, hydraulic conductivities, storage coefficients, and porosity.

- Information on initial and boundary conditions that control the groundwater flow.
- Observed groundwater heads for model calibration.
- Rates of recharge and evaporation.
- Groundwater pumping records.
- Layout (locations, dimensions, and depths) of plant facilities, excavation, backfill, and dewatering scheme.
- Previous studies and work related to modeling, hydrogeologic field tests and data collection.

In addition, radionuclide transport analysis may require the following hydrogeologic information:

- Pathways, hydraulic gradients, flow velocities, and rates of groundwater flow. (could be obtained from the results of flow model simulation).
- Initial and boundary conditions for solute transport.
- Locations of contamination sources and receptors.
- Radionuclide sources, including, volume, species, and concentrations.
- Radionuclide decay rates and progeny information.
- Natural and anthropogenic chemical components important to the transport of radionuclide materials.
- Effective porosity and soil bulk density.
- Distribution (also called partition or sorption) coefficients (K_d).
- Longitudinal and transverse dispersion coefficients.

The groundwater model should be built with conservative parameters if the uncertainty in data and parameters is substantial. The base hydrologic condition of the model should be consistent with the objectives of the modeling. For analyzing subsurface hydrostatic loading, the model should be developed to estimate the maximum groundwater level condition; however, model simulations for radiological contamination consequence analysis should be based on an annual average condition for consistency with the annual average radionuclide concentration limits specified in 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, compliance (10 CFR Part 20, Appendix B compliance). RG 1.113 specifies that ~~t~~the annual average (normal) groundwater level must be based on sufficient historical records. If sufficiently long-term data are not available, extending short records based on longer term data from nearby locations or regional studies should be acceptable. Ideally, a database of hydrogeologic information (i.e., stratigraphy, well boring logs, groundwater and surface water levels) should be developed and maintained for use throughout the lifecycle of the site (e.g., pre-construction, addition of potential future units) and the plant (e.g., decommissioning).

Process Conceptualization

Groundwater modeling consists of conceptualization and mathematical modeling processes, such as described in the following documents:

- ASTM D 5979 – 96 ("Standard Guide for Conceptualization and Characterization of Ground-Water Systems");
- ASTM E 1689 – 95, ("Standard Guide for Conceptualization and Characterization of Ground-Water Systems");
- EPRI 1016099, ("Groundwater Protection Guidelines for Nuclear Power Plants (Public Edition)"); and
- NUREG/CR-6805 ("A Comprehensive Strategy of Hydrogeologic Modeling and Uncertainty Analysis for Nuclear Facilities and Sites").

The conceptualization process, which embodies the description of the qualitative and quantitative physical process, includes analyzing and synthesizing field data in a simple, systematic way to gain a fundamental understanding of the aquifer system. The conceptualization process should be methodical and thorough to avoid fundamental flaws in the understanding of the hydrogeologic flow system. The applicant should include key hydrogeologic elements in the conceptualization including flow direction, aquifer geometry, heterogeneity, and anisotropy of aquifer materials, and transport mechanisms. The conceptualization process must be justified and described in detail. Questions that must be asked during the conceptualization stage include but are not limited to the following:

- Are there sufficient data describing the aquifer characteristics?
- What parameters are sensitive in predicting pathways and travel times?
- Will the pattern of groundwater flow change after the construction of a plant?
- What is the proper model domain in the horizontal and vertical extent, and the associated boundary conditions?
- Is the vertical flow between aquifers significant?
- Do the hydrogeologic data indicate considerable variation or uncertainty?
- Are there any groundwater discharges, drains, or wells?

- Does geochemistry have the potential to impact transport processes?
- Are more field tests and/or data collection activities needed?

Code Selection

If possible, the staff or applicant (i.e., the modeler) should use a well-tested, verified, and documented computer code (e.g., publicly available codes from state or federal agencies). The selected model should account for the specific hydrogeologic processes and conditions occurring at a particular site and the process of model selection should be documented. If the model code is not publicly available, or the modeler developed their own code, or modified the original publicly available source code, the code should be made available with proper model documentation including a user manual, the mathematical and physical basis of the model, and verification of the code with test case results compared with known solutions.

Spatial and Temporal Discretization

Spatial discretization of the physical flow system should be sufficiently fine to allow accurate numerical computations of the processes in the site area. The model boundary should be selected so that all hydrogeologic components that are significant to the determination of pathways and travel times are included. The modeler should justify the adequacy of the following: (1) selection of steady-state or transient simulations; (2) spatial discretization of the model domain; (3) boundary conditions; and (4) the time period chosen for a transient simulation.

Calibration, Validation and Sensitivity Analysis

The model is calibrated by adjusting discretization, input, and parameters to achieve a best match between observed and calculated conditions. The modeler should use error statistics (e.g., R-square, mean square error), the distribution of errors in space and time, convergence, mass balance, and prediction bias in determining the adequacy of the calibration. Where practicable, an automated calibration approach is recommended to determine a solution based on a statistical evaluation of observed to calculated conditions. If the modeler uses a manual calibration approach, the calibration should prioritize analysis of more sensitive parameters. Calibration of a transient model should be based on an initial model consisting of calibrated steady-state parameters and conditions. The transient analyses should use the calibrated hydrogeologic parameter values (e.g., vertical and horizontal hydraulic conductivity) from the steady state simulations as a basis for calibration of transient (temporally variable) parameter values (e.g., recharge and, lake or river level).

Calibrated parameter values should be within the range of measured values or those derived from field test data. Typically, the error in the match of observed to calculated data (e.g., observed to calculated water levels) should be less than 10 percent across the model domain, or the acceptable error should be a similar small fraction of the difference between the highest and lowest heads across the model domain area. The model should be validated by using differing sets of temporal data to verify the adequacy of the calibration.

The modeler should perform a sensitivity analysis by varying key model input and parameters over a reasonable range (typically upper and lower one standard deviations from the respective mean) and document the variability of predicted pathways and travel times. Sensitivity information is also valuable in identifying parameters critical to model calibration. Sensitivity analysis could be done for each parameter individually, or with combinations of mutually dependent parameters as needed.

Model Simulation

A calibrated and verified model should be used to simulate groundwater pathways and travel times. A transient model should build off of a steady state simulation that is calibrated to annual average conditions. Total groundwater pathway travel time to be considered in simulations should be the lifetime of the plant, usually 40 to 60 years. Alternative conceptual models should be accounted for, and all plausible pathways should be identified in considering the uncertainty in the modeling.

Modeling Documentation

The process and results of modeling should be documented thoroughly using tables, figures and graphs as appropriate. Specifically, the modeling report should include the following information:

- The purpose and scope of the model application.

- Key hydrologic and hydrogeologic data and data sources used in the model.

- A description of the modeling process including conceptualization, model grids, and boundary settings.

- A description of the process and result of calibration, validation, and sensitivity analysis.

- Figures displaying plausible pathways, radionuclide travel times, release points and receptor locations.

- A summary of major findings and conclusions.

Recommended figures include: estimated or interpolated surfaces, such as top and bottom elevations of the model layers and hydraulic heads with associated data points used for the interpolation; simulated hydraulic heads with calibration target locations and the residuals between the observed and estimated values; and a statistical best fit regression line for evaluation of model biases towards over or under prediction of groundwater levels. The implications of the model calibration on the predicted release pathways and receptor analysis should be evaluated and discussed. The complete model application process (Figure A-1) should be included in the documentation of the modeling effort.

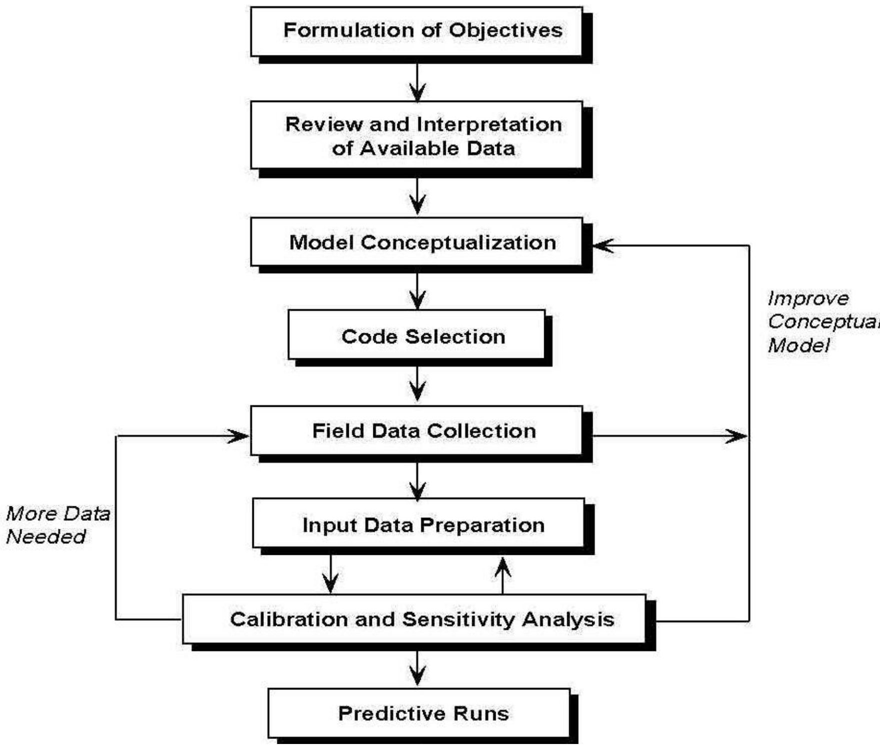

Figure A-1. Schematic of Modeling Process.