NextEra Energy Seabrook, LLC
(Seabrook Station, Unit 1)
License Renewal Application

NRC Staff Answer to Motion for Summary Disposition of Contention 4B

ATTACHMENT 4B-J

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

NUREG/CR-7110, Vol. 2

State-of-the-Art Reactor Consequence Analyses Project

Volume 2: Surry Integrated Analysis

Office of Nuclear Regulatory Research

4. MELCOR MODEL OF THE SURRY PLANT

The Surry MELCOR model applied in this report was originally generated at Idaho National Engineering Laboratories (INEL) in 1988 [10]. The model was updated by Sandia National Laboratories (1990 to present) for the purposes of testing new models, advancing the state-of-the-art in modeling of PWR accident progression, and providing support to decision-makers at the NRC for analyses of various issues that may affect operational safety. Significant changes were made during the last twenty years in the approach to modeling core behavior and core melt progression, as well as the nodalization and treatment of coolant flow within the RCS and reactor vessel. Detailed reports have been prepared to discuss this model evolution as part of the MELCOR code development program [13], and these discussions will not be repeated here. It is simply noted that the model described herein is a culmination of these efforts and represents the state-of-the-art in modeling of potential PWR severe accidents.

In preparation for the SOARCA analyses described in this report, the model was further refined and expanded in two areas. The first area is an upgrade to MELCOR Version 1.8.6 core modeling. These enhancements include:

- A hemispherical lower head model that replaces the flat bottom-cylindrical lower head model,
- New models for the core former and shroud structures that are fully integrated into the material degradation modeling, including separate modeling of debris in the bypass region between the core barrel and the core shroud,
- Models for simulating the formation of molten pools both in the lower plenum and the core region, crust formation, convection in molten pools, stratification of molten pools into metallic and oxide layers, and partitioning of radionuclides between stratified molten pools,
- A reflood quench model that separately tracks the component quench front, quench temperature, and unquenched temperatures,
- A control rod silver aerosol release model, and
- An application of the CORSOR-Booth release model for modern high-burn-up fuel.

The second area focused on the addition of user-specified models to represent a wide spectrum of plant design features and safety systems to broaden the capabilities of MELCOR to a wider range of severe accident sequences. These enhancements included:

- Update of the containment leakage/failure model (see Section 4.7),
- Update of core degradation modeling practices,

- Modeling of individual primary and secondary system relief valves with failure logic for rated and degraded conditions,

- Update of the containment flooding characteristics,

- Heat loss from the reactor to the containment,

- Separate motor and turbine-driven auxiliary feedwater models with control logic for plant automatic and operator cooldown responses,

- New turbine-driven auxiliary feedwater models for steam flow, flooding failure, and performance degradation at low pressure,

- Nitrogen discharge model for accumulators,

- Update of the fission product inventory, the axial and radial peaking factors, and an extensive fission product tracking control system, and

- Improvements to the natural circulation in the hot leg and steam generator and the potential for creep rupture (see Section 4.4).

Table 4-1 provides a brief summary of plant design parameters that are helpful in comparing the configuration of Surry to other reactors of interest.

The model description is subdivided into description of the vessel and reactor coolant system (Section 4.1), primary and secondary system relief valve modeling (Section 4.2), the decay heat power modeling (Section 4.3), the natural circulation modeling (Section 4.4), the core degradation modeling (Section 4.5), the containment model (Section 4.6), the containment leakage model (Section 4.7), and the auxiliary building model (Section 4.8). Section 4.9 summarizes the best modeling practices applied to accident progression analyses conducted under the SOARCA project. The best practices include discussions of the base case approach to modeling key phenomena that have significant importance to the progression of the accident and uncertainty in their response. The Safeguards Area, Contaiment Spray Pump Area, and Main Steam Valve House are described in Section 4.10. The Safeguards ventilation system is described in Section 4.11, and the low head safety injection piping is described in Section 4.12. Section 4.13 describes the radionuclide deposition model for the low head safety injection piping, and Section 4.14 describes the methodology used for the two MELCOR models involving the low head safey injection piping.

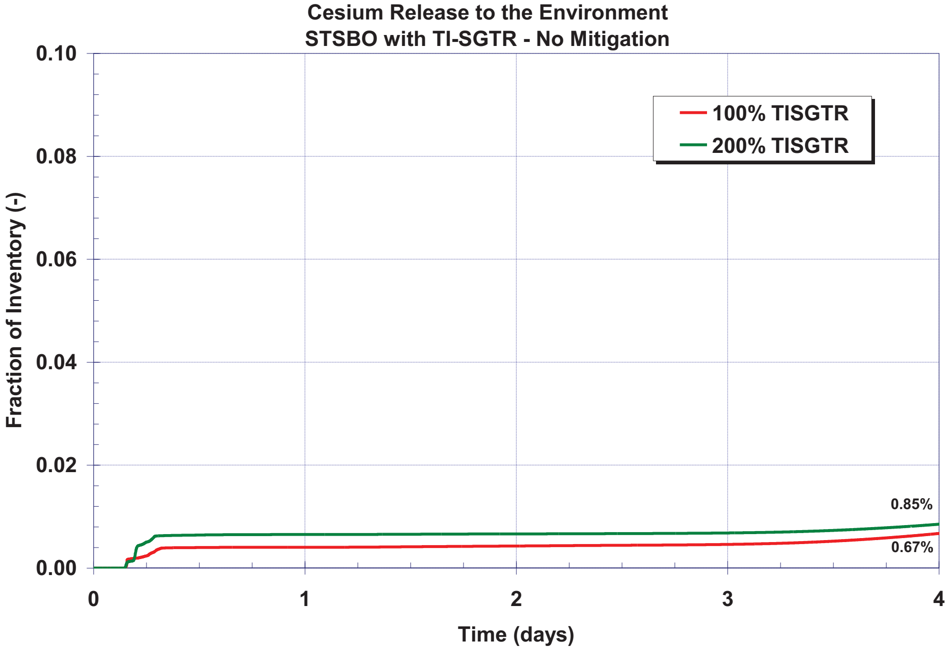

Figure 5-70 The unmitigated 100% and 200% TI-SGTR short-term station blackout cesium fission product distribution history

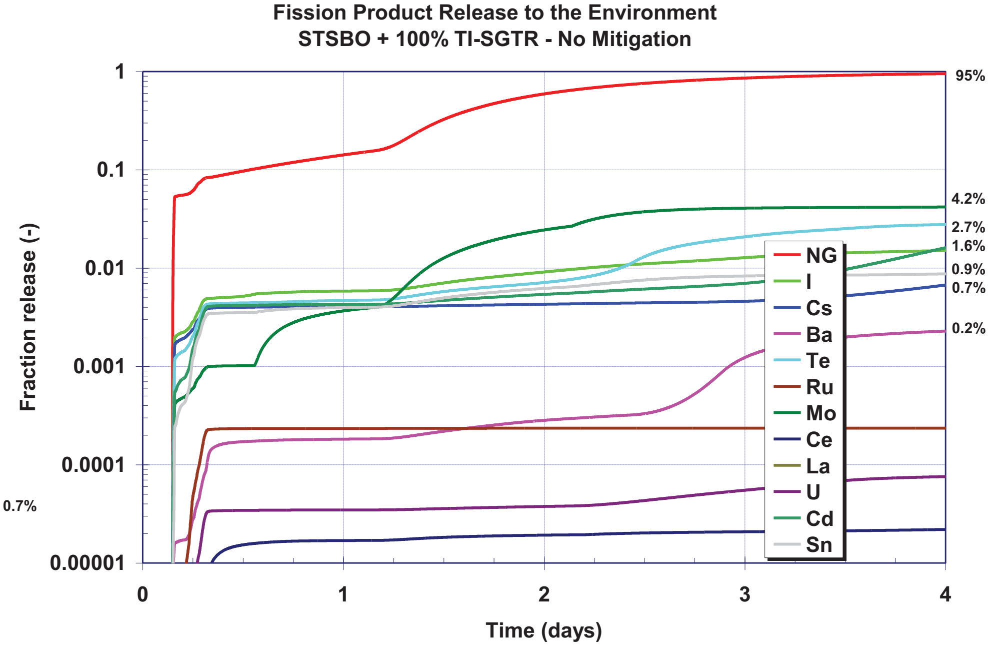

Figure 5-71 The unmitigated 100% TI-SGTR short-term station blackout environmental release history of all fission products

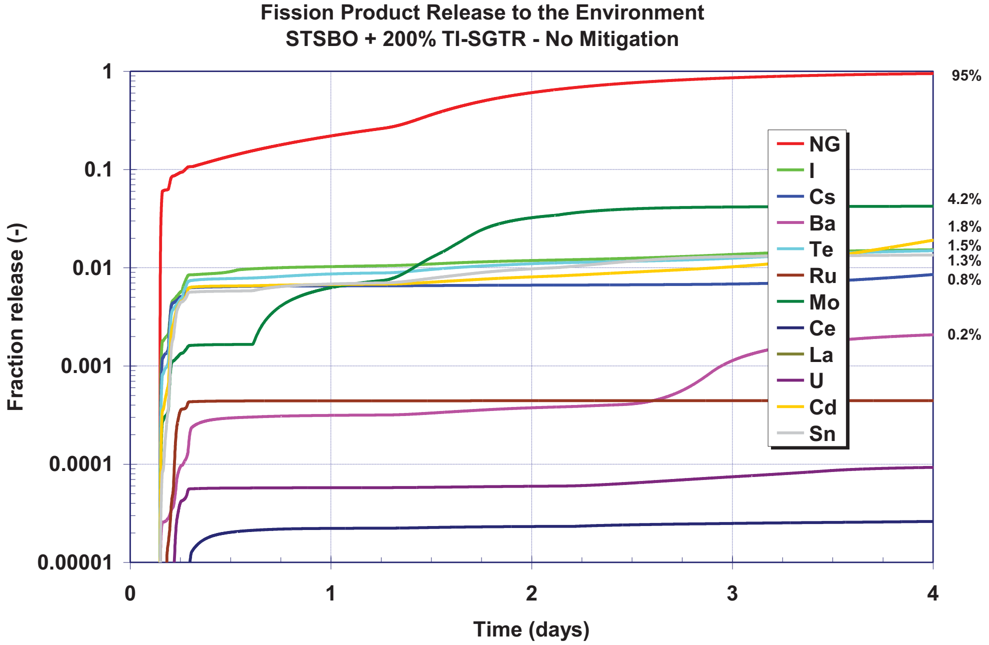

Figure 5-72 The unmitigated 200% TI-SGTR short-term station blackout environmental release history of all fission products

5.3.2 Mitigated Short-Term Station Blackout with Thermally Induced Steam Generator Tube Rupture

Table 5-9 summarizes the timings of the key events in the mitigated STSBO with a TI-SGTR. One (i.e., equivalent of 100% flow area) steam generator tube failed prior to any other RCS creep rupture failures along with a stuck open secondary safety relief valve. Consequently, there is a containment bypass pathway for fission products once the steam generator tube fails. As described in Section 3.2, the accident scenario initiates with a complete loss of all onsite and offsite power. The reactor successfully trips and the containment isolates but all powered safety systems are unavailable. The mitigated STSBO credits the successful connection of the portable, low-pressure, diesel-driven (Godwin) pump to the containment spray system at 8 hr. The Godwin pump is a high-flow, low-head pump with a design capacity of 2000 gpm at 120 psi. A reliable source of water is maintained while 1,000,000 gallons is injected into the containment through the containment sprays. At the time of the analysis, there was no guidance in the emergency procedures for the duration of the spray operation or termination, so the 1,000,000 gallons amount was somewhat arbitrarily selected. The sequence of events is identical to the unmitigated STSBO with a TI-SGTR until 8 hr. In particular, the core has degraded and failed the vessel lower head prior to the spray actuation (see Table 5-9). The emergency containment sprays are effective at reducing the containment pressure and knocking down airborne fission products while they are operating. However, the containment subsequently pressurizes after the sprays are terminated to the failure pressure. While not investigated, intermittent operation of the sprays and deeper flooding could have further delayed failure of the containment. Section 5.3.2.1 summarizes the thermal-hydraulic response of the reactor and containment while Section 5.3.2.2 summarizes the associated radionuclide release from the fuel to the environment.

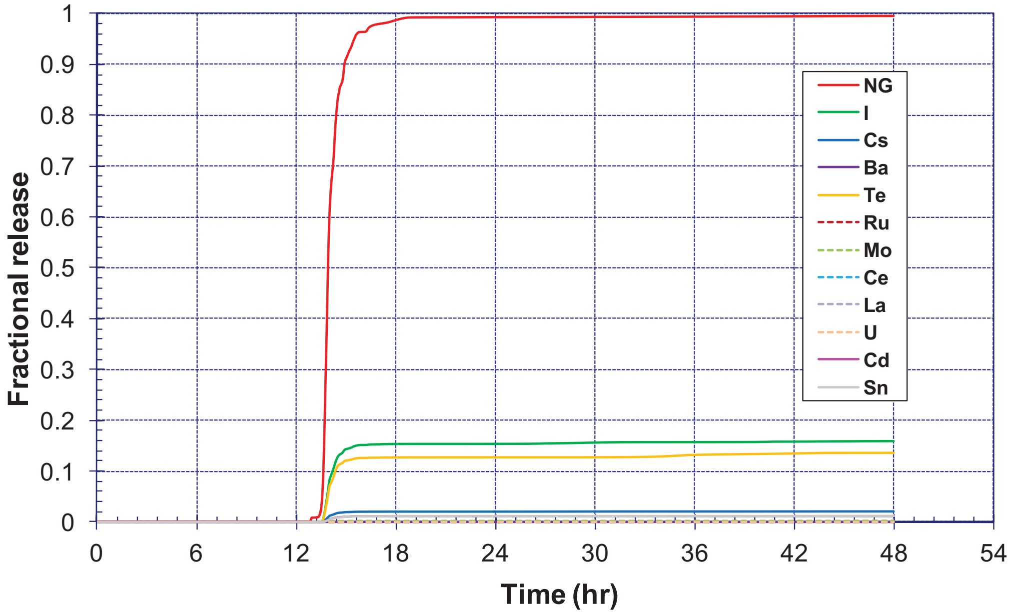

Figure 5-126 ISLOCA Fission Product Release to the Environment

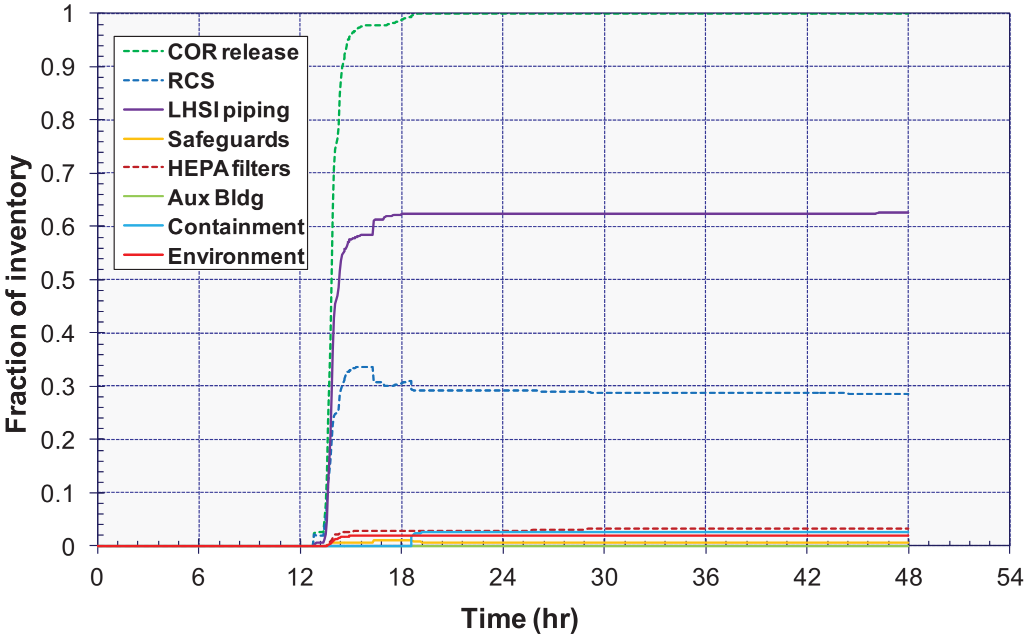

Figure 5-127 ISLOCA Cesium Distribution

large. Because less remedial action is taken, the contribution of an individual chemical group to risk is greater when it is released on its own than when it is part of a larger release. To make the fractional contributions from individual chemical classes add to unity, the contribution from a single chemical class must be normalized by the sum of the individual contributions of the chemical classes rather than the risk calculated for the combined effect of all chemical classes. This inherent nonlinearity tends to diminish the effect of the major contributors and exaggerate the effect of the minor contributors.

To minimize the effect of the nonlinearities described in the previous paragraph, an alternative approach is adopted here. That is to evaluate the contribution of a chemical class by performing calculations with all but that one chemical class. The effect of that chemical class is then calculated by taking the difference between the risk when all chemical classes are included and the risk for all but that one chemical class (i.e., setting the release fractions for that chemical class to zero).

The relative importance of each chemical class was evaluated for the unmitigated ISLOCA accident sequence, for each dose truncation level: LNT, US BGR, and HPS. The results for the population within 10 miles are shown in Figure 7-12, Figure 7-13, and Figure 7-14. Results at longer distances are shown in subsequent figures.

The first of these, Figure 7-12, is for LNT for the population within 10 miles. It shows the importance of each chemical group on total risk, on just the emergency-phase risk, and on just the long-term-phase risk. The cesium group dominates the total risk and the long-term phase risk, but contributes only a few percent to the emergency-phase risk owing to the relatively long half lives of the cesium isotopes (e.g., ^{137}Cs has a half life of 30 yrs). Tellurium and iodine contribute most of the emergency-phase risk owing to the short half-lives of the isotopes represented by these chemical classes. However, the emergency phase contributes very little to the total risk because 99.5% of the population within 10 miles evacuate and do not receive any dose during the emergency phase.

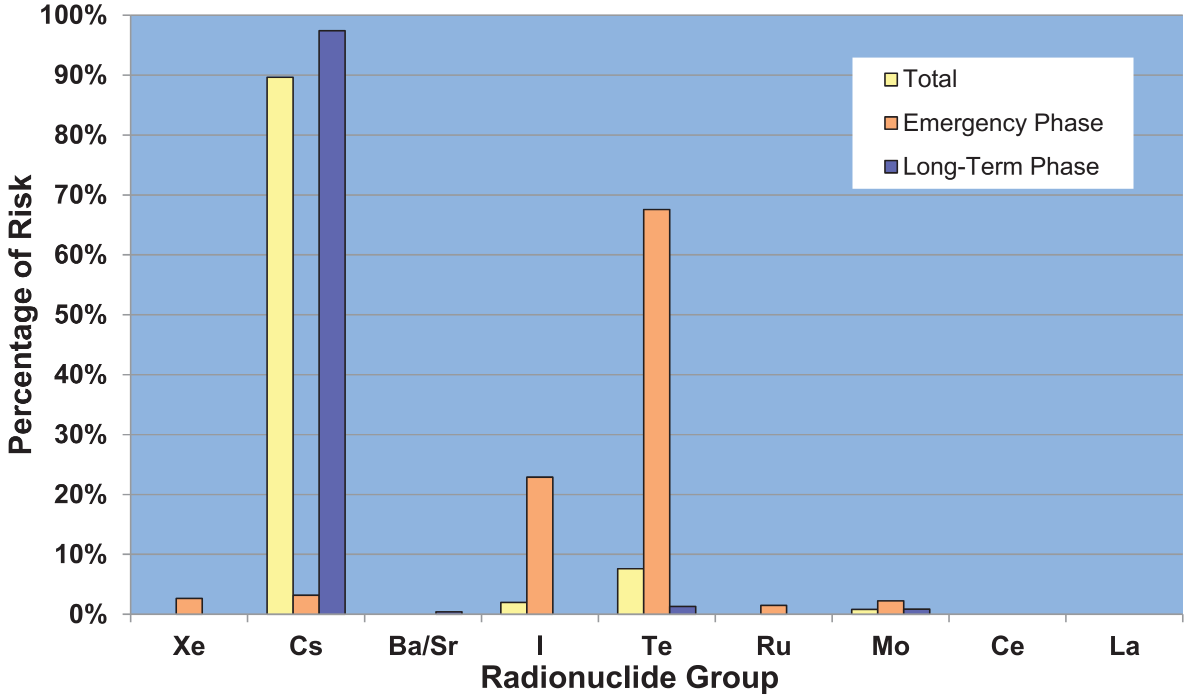

Figure 7-12 Percentage contribution to total, emergency-phase, and long-term-phase, mean, individual risk for the population within 10 miles by chemical class for the Surry unmitigated ISLOCA based on the LNT hypothesis

Figure 7-13 and Figure 7-14 show the total risk contributions of each chemical class for the unmitigated ISLOCA using US BGR dose truncation and truncation based on the HPS Position, respectively. These plots also show risk to the population living within 10 miles of the plant. They only show the total risk contribution because annual doses in the first year are combinations of emergency- and long-term-phase doses. Because of the overlapping contributions to the first year, the individual contributions of the two phases cannot be easily deconvolved from the whole. These figures show that the tellurium, cesium, and iodine chemical classes contribute most of the risk for these dose truncation criteria, with the same order of importance in the two figures. Isotopes with relatively short half-lives tend to be more dominant than those with longer half-lives because most of the risk is from doses received during the first year for the US BGR and truncation based on the HPS Position. Longer-term annual doses are limited by the habitability criterion to values below the dose truncation levels.

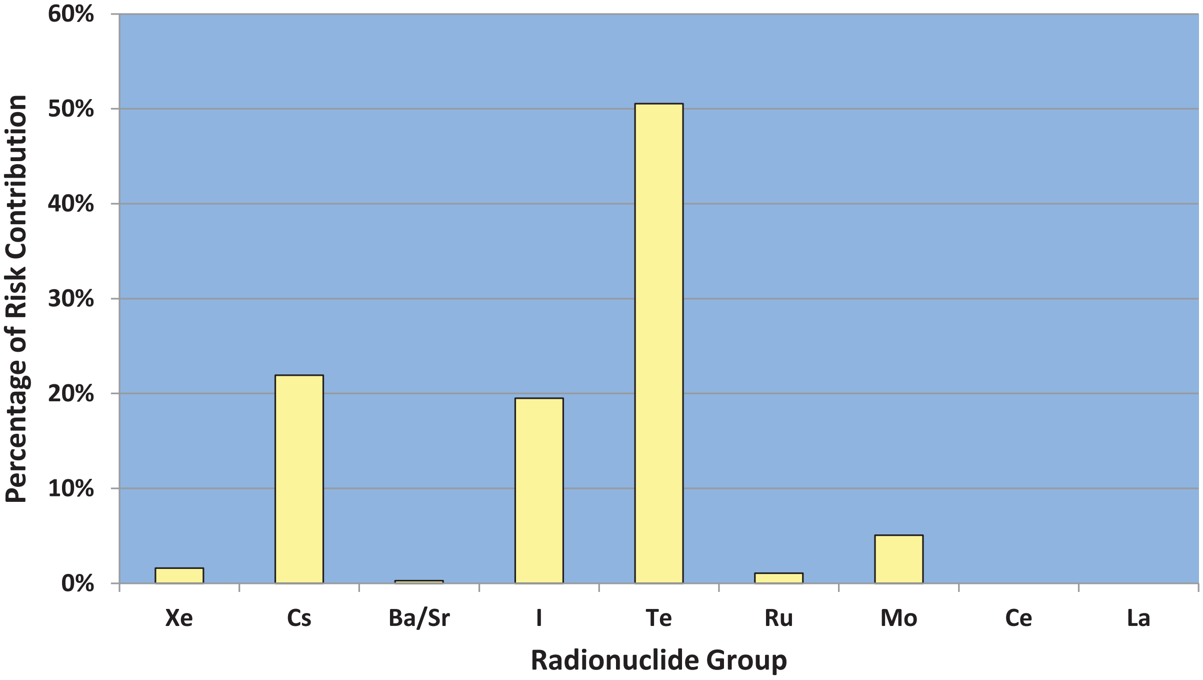

Figure 7-13 Percentage contribution to total, mean, individual risk for the population within 10 miles by chemical class for the Surry unmitigated ISLOCA based on US BGR dose truncation

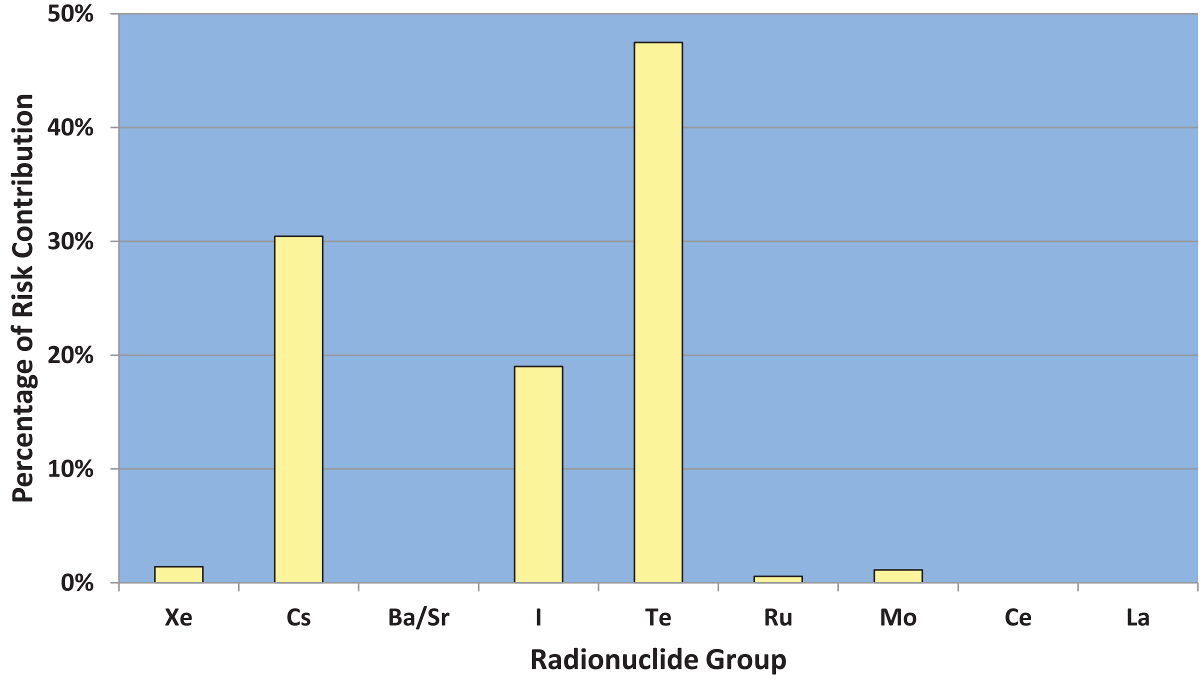

Figure 7-14 Percentage contribution to total, mean, individual risk for the population within 10 miles by chemical class for the Surry unmitigated ISLOCA based on a truncation level reflecting the HPS Position for quantifying health effects

Figure 7-15 through Figure 7-20 are analogous to those above but show the relative importance of the chemical classes for the population within 20 and 50 miles. The trends are similar, but the emergency phase plays a larger role because significant portions of the population do not evacuate before the plume arrives and, thereby, receive a dose during the emergency phase. The most important set of chemical classes using the LNT hypothesis is cesium, tellurium, and iodine in that order. For the two dose truncation criteria, cesium is less important because of the relatively long half-lives of the dominant isotopes.

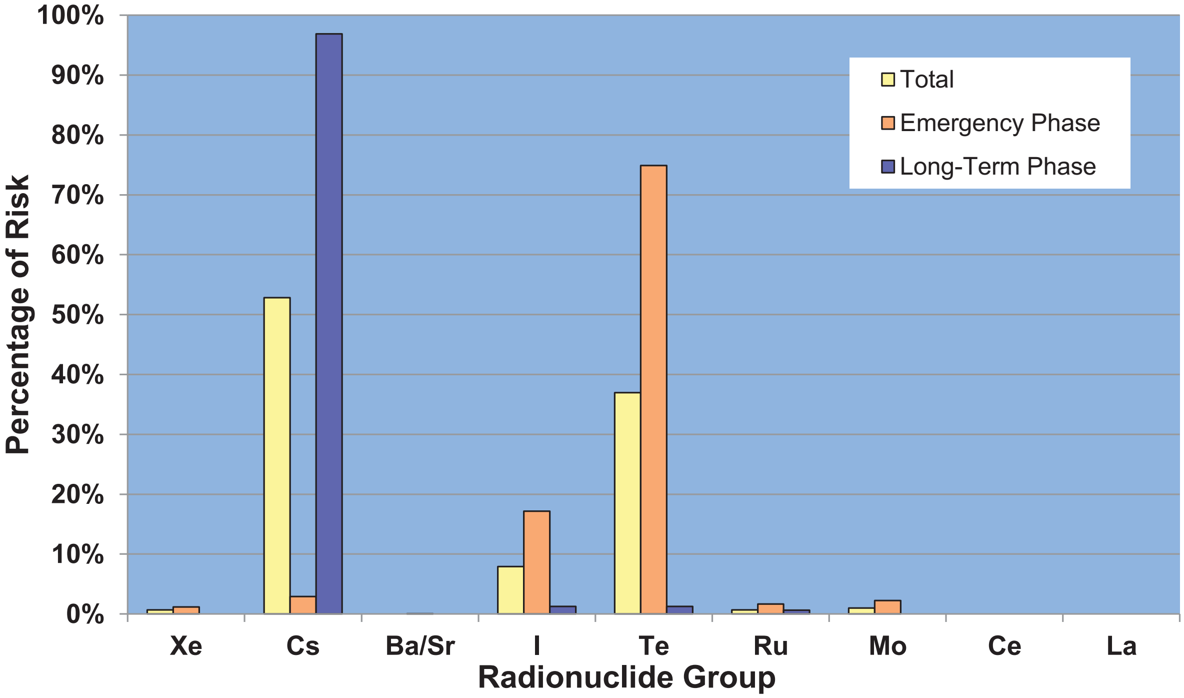

Figure 7-15 Percentage contribution to total, emergency-phase, and long-term-phase, mean, individual risk for the population within 20 miles by chemical class for the Surry unmitigated ISLOCA based on LNT hypothesis

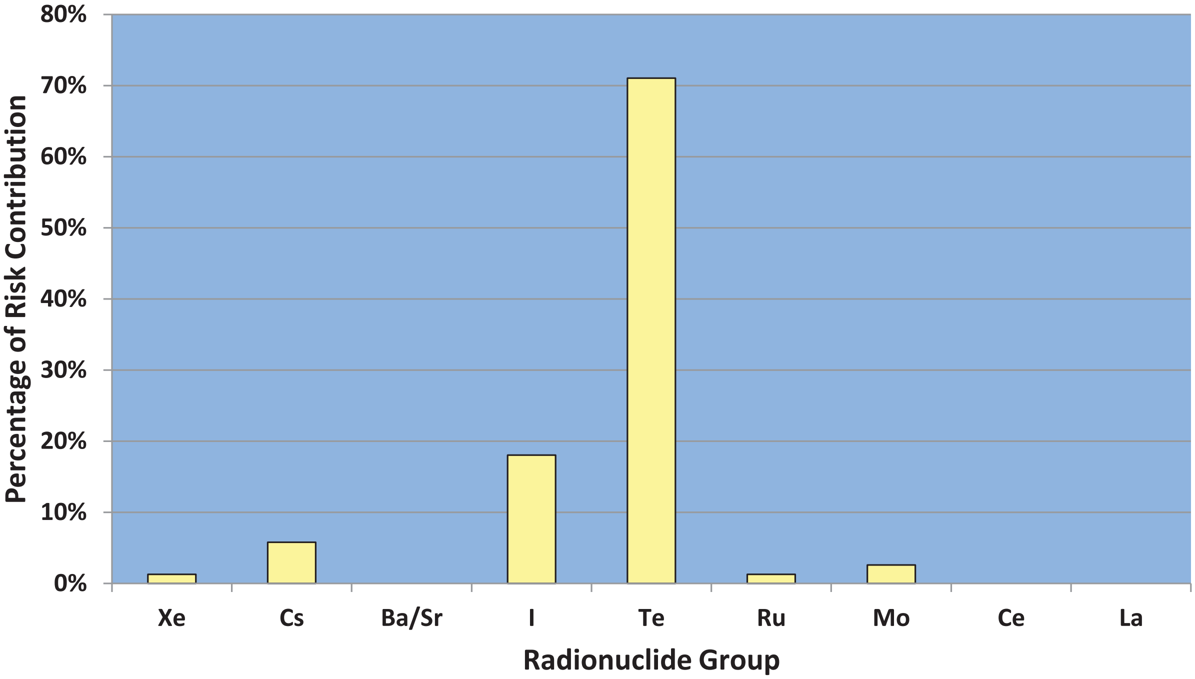

Figure 7-16 Percentage contribution to total, mean, individual risk for the population within 20 miles by chemical class for the Surry unmitigated ISLOCA based on US BGR dose truncation

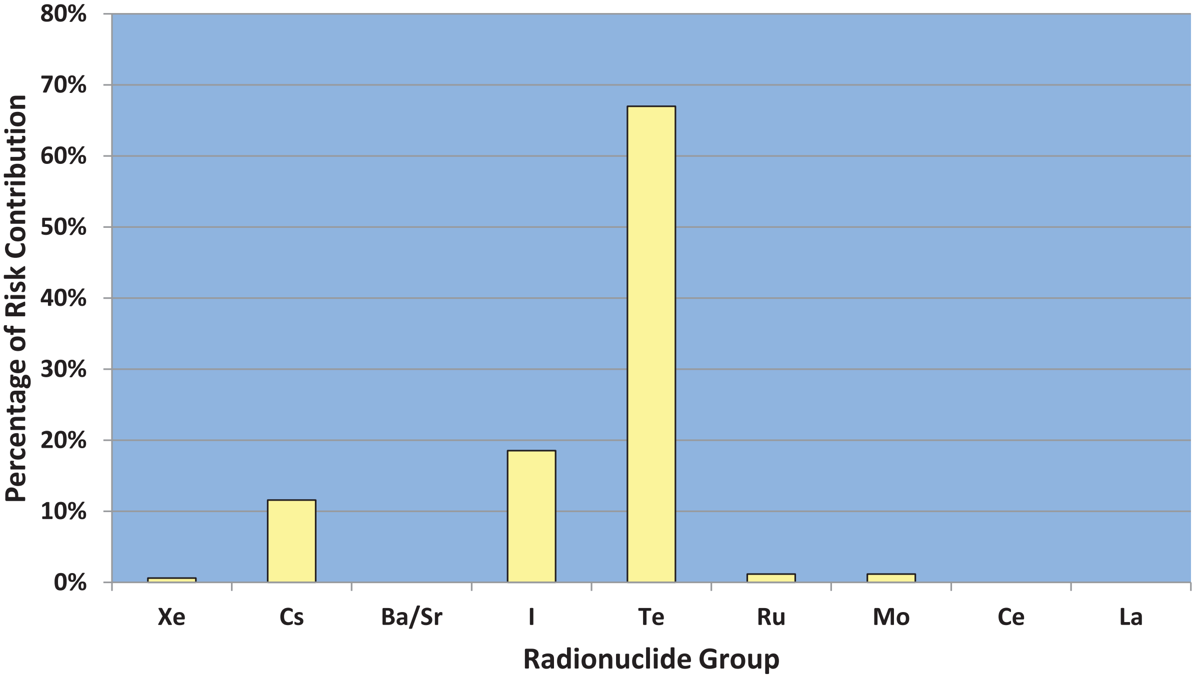

Figure 7-17 Percentage of contribution to total, mean, individual risk for the population within 20 miles by chemical class for the Surry unmitigated ISLOCA based on a truncation level reflecting the HPS Position for quantifying health effects

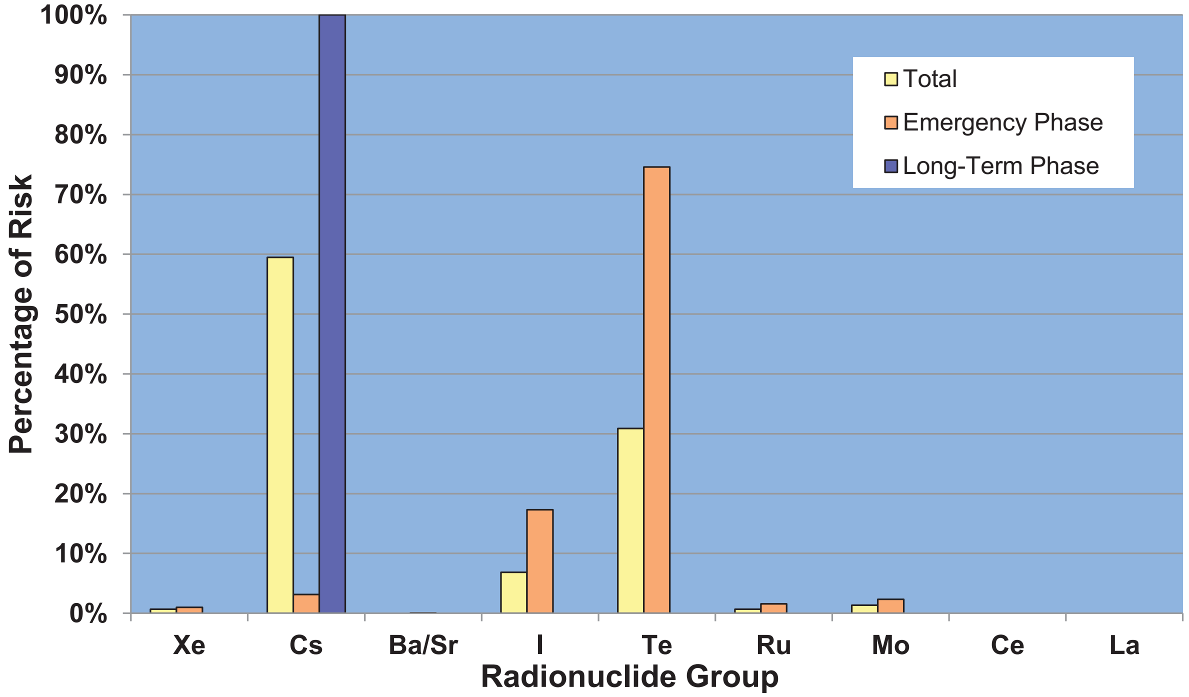

Figure 7-18 Percentage contribution to total, emergency-phase, and long-term-phase, mean, individual risk for the population within 50 miles by chemical class for the Surry unmitigated ISLOCA based on the LNT hypothesis

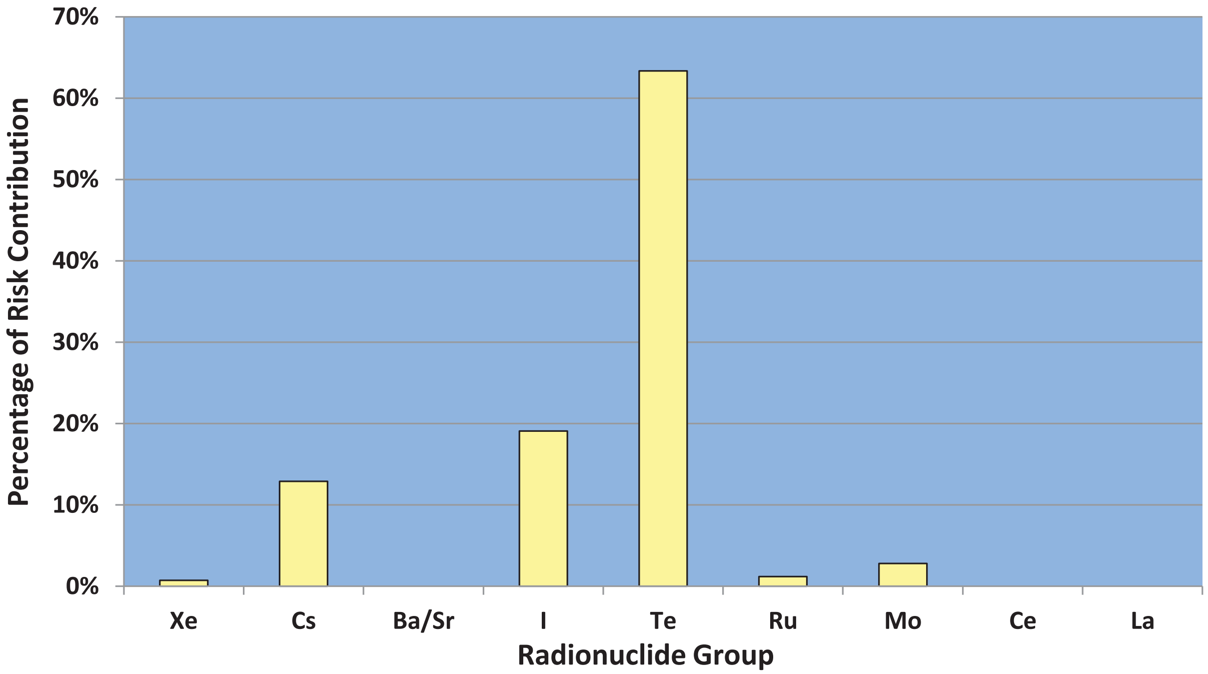

Figure 7-19 Percentage contribution to total, mean, individual risk for the population within 50 miles by chemical class for the Surry unmitigated ISLOCA based on US BGR dose truncation

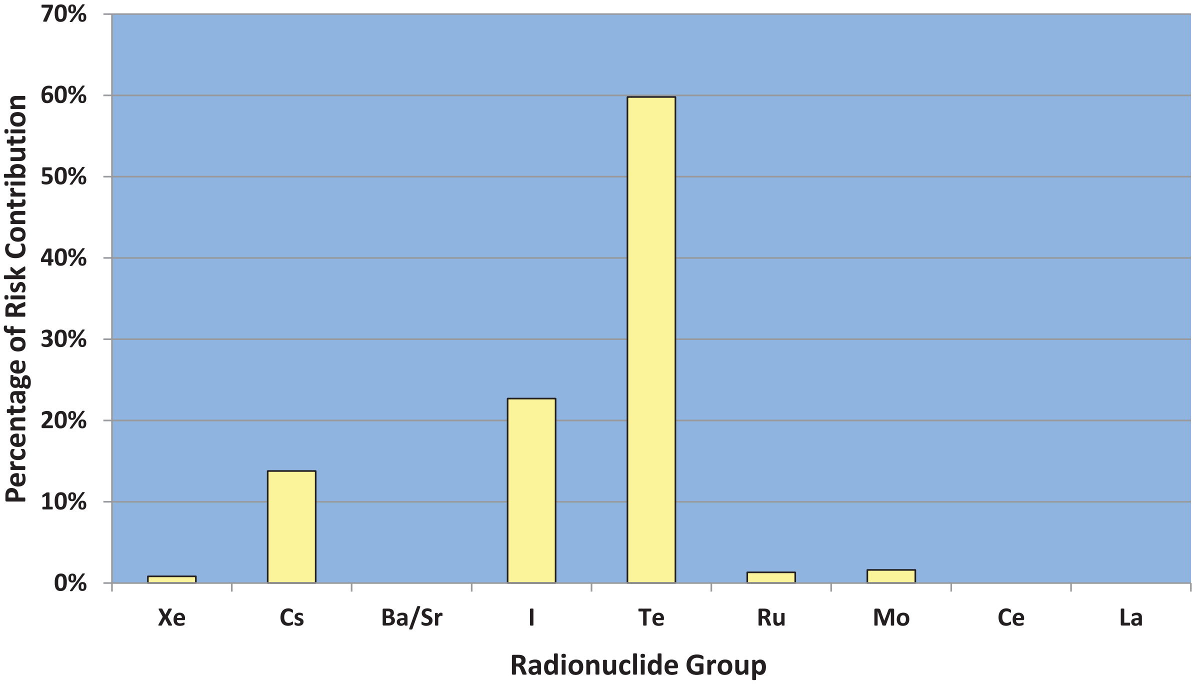

Figure 7-20 Percentage contribution to total, mean, individual risk for the population within 50 miles by chemical class for the Surry unmitigated ISLOCA based on a truncation level reflecting the HPS Position for quantifying health effects

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