SAND2011-3602C

Acceptable Seismic Risks at Nuclear Facilities

Institute Of Nuclear Management, Palm Desert, CA
52nd Annual Meeting
July 17-21, 2011

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Introduction

Objectives

- Discuss the seismic design process of DOE nuclear facility SSCs for new facilities or major modifications to existing facilities.
- Review general impacts to the seismic design of Structures, Systems, and Components (SSCs) associated with the transition from Department of Energy (DOE) Order 420.1B, *Facility Safety* to DOE-Standard 1189-2008, *Integration of Safety into the Design Process*.
- Review the modification of the prescribed methodology provided in American National Standards Institute (ANSI)/American Nuclear Society (ANS) 2.26-2004, *Categorization of Nuclear Facility Structures, Systems, and Components for Seismic Design* in conjunction with the three accompanying standards, ANS-2.27, ANS-2.29, as interpreted by the new DOE-STD-1189-2008.

Major Seismic Design Standards for DOE Facilities

- **Categorization of Nuclear Facility Structures, Systems, and Components for Seismic Design, ANSI/ANS Standard 2.26**
  - Pertains to both new nuclear facilities and existing nuclear facilities.
  - ANSI/ANS 2.26-2004, and ASCE/SEI 43-05. National Standards were developed jointly by ANS and ASCE at the initiative of DOE to provide methods, guidelines, requirements, and criteria for the seismic design of SSCs. The standards development working groups of these standards included DOE, NRC, the Defense Nuclear Facility Safety Board (DNFSB), and industrial representation.
- **Integration of Safety into the Design Process, DOE-STD-1189**
  - Applicable to New Facilities
  - Major Modifications of Existing facilities: Criteria are used with the following caveats:
    - Backfit analyses are required to examine the need to upgrade interfacing structures, systems, and components in accordance with these criteria
    - Determine whether there should be relief from the criteria

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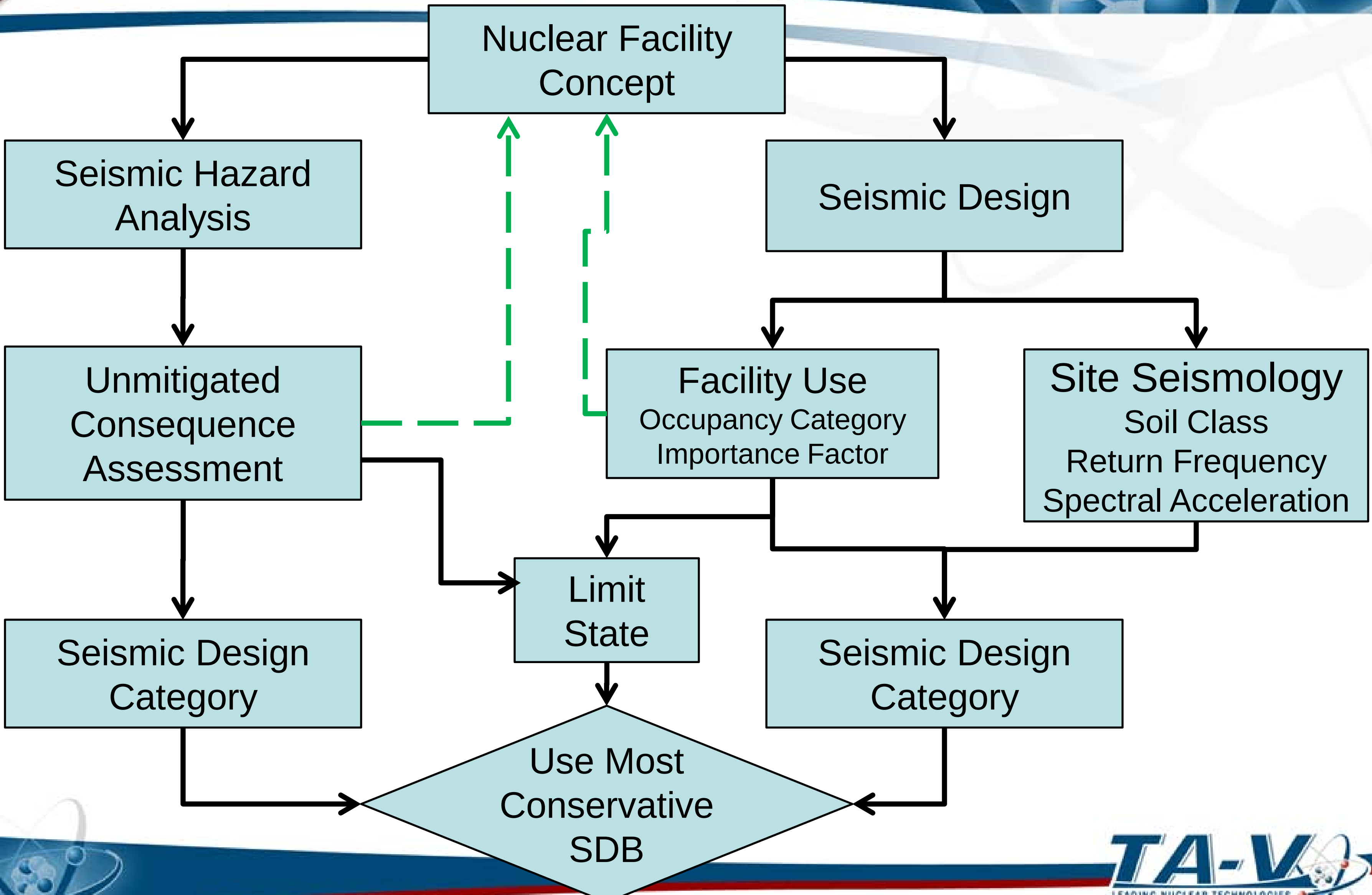
Major Seismic Design Standards for DOE Facilities

- **DOE-STD-1189**
  - Provisions of ASCE/SEI 43-05 and ASCE/SEI 7-05 replace seismic design requirements and performance criteria of DOE-STD-1020-2002. Seismic-related performance categorization guidelines of DOE-STD-1021-93 are replaced by the provisions of ANSI/ANS 2.26-2004, as modified by DOE-STD-1189-2008, Appendix A. The standards ASCE/SEI 43-05, and ASCE/SEI 7-05, and ANSI/ANS 2.26-2004 are to be used in conjunction with ANSI 2.27 and ANSI 2.29.
- **DOE Order 420.1B and DOE G 420.1-2, *Guide for the Mitigation of Natural Phenomena Hazards for DOE Nuclear Facilities and Non-Nuclear Facilities***
  - DOE standards are in a state of flux. ANS 2.27 and ANS 2.29 referenced in ANS 2.26, have been formally issued. DOE plans to adopt these ANSI/ANS standards and to update DOE G 420.1-2.

Selecting Seismic Design Criteria

- Two primary areas of potential impact based on transition to the new criteria and procedures are: **Seismic Design & Seismic Hazard Analysis**.
- Determination of Seismic Design Category (SDC) for a SSC is an iterative process between the methodologies based on:
  - The Occupancy Category (OC), which is determined by the critical nature of the facility (hospital, school, large occupancy), or the hazard inventory of the facility
  - The severity of the design earthquake motion per site seismology per seismic codes and standards
  - The unmitigated radiological consequence analysis determined by Seismic Hazard Analysis

Selecting Seismic Design Criteria



Seismic Design

- Seismic Design Criteria and Limit State matrix defines the Seismic Design Basis (SDB) for each SSC.
- SDC is a function of location, building occupancy, and soil type and sets the design earthquake levels. Building performance during a seismic event depends on both the severity of subsurface rock motion and the type of soil upon which a structure is founded. SDCs specify the probability levels for design earthquakes and structural performance (acceptance criteria). SDCs range from 1 for conventional buildings to 5 for more hazardous facilities such as nuclear power plants.
- The Limit State is used to set the analysis methodology, design procedures and acceptance criteria. Four Limit States are defined - A, B, C, and D - where A is just short of collapse and D is essentially elastic behavior.

  Example: An SSC with SDB-3C would use criteria for SDC-3 and Limit State C. A total of 20 SDBs are defined in ANS 2.26 that can match seismic design criteria to SSC safety function and importance, implementing a graded approach.

Seismic Design

- SDBs defined by SDC 1 and 2 are covered by the approach presented in ASCE 7-05 (IBC). ANSI/ASCE/SEI 43-05 presents design and analysis requirements for SDBs defined by SDC 3, 4, and 5 and all Limit States. The approach presented for SDC 3, 4, and 5 has been adapted from that used in the U.S. Department of Energy Standard 1020, ASCE 4, and the U.S. Nuclear Regulatory Commission Standard Review Plan (NUREG-0800).
- The goal of the Standards is to ensure that nuclear facilities can withstand the effects of earthquake ground shaking with desired performance, expressed as probabilistic Target Performance Goals.

Seismic Design

SDC	Annual Probability (P_f)	Approximate Return Period (yrs)	Seismic Design Category & Limit States Matrix For SDBs			
			LIMIT STATE			
			A	B	C	D
			PERMANENT DISTORTIONS			ESSENTIALLY ELASTIC
			LARGE	MODERATE	LIMITED	
1	$< 1x10^{-3}$	1000	SDB-1A ASCE 7-05	SDB-1B ASCE 7-05	SDB-1C ASCE 7-05	SDB-1D NA
			DOE PC-1			
2	$< 4x10^{-4}$	2500	SDB-2A ASCE 7-05	SDB-2B ASCE 7-05	SDB-2C ASCE 7-05	SDB-2D NA
				DOE PC-2		
3	$\sim 1x10^{-4}$	10000	SDB-3A ASCE 43-05	SDB-3B ASCE 43-05	SDB-3C ASCE 43-05	SDB-3D ASCE 43-05
					DOE PC-3	
4	$\sim 4x10^{-4}$	25000	SDB-5A ASCE 43-05	SDB-4B ASCE 43-05	SDB-4C ASCE 43-05	SDB-4D ASCE 43-05
5	$\sim 1x10^{-5}$	100000	SDB-4A ASCE 43-05	SDB-5B ASCE 43-05	SDB-5C ASCE 43-05	SDB-5D ASCE 43-05
					DOE PC-4	NRC NPP

Seismic Hazard Analysis

- **Unmitigated Consequence Analysis**
  - The other key factor in the assignment of an SDC is based on the consequences of the unmitigated failure of the SSC
  - Takes into account the Quantity (inventory) of hazardous materials, form of that material and energy sources available to (impact) disperse the hazardous material
  - Assumptions are made to estimate atmospheric dispersal of released hazardous materials
  - Does consider SSC interactions and common mode failures

Seismic Hazard Analysis

- **ANSI/ANS 2.26-2004, Categorization of Nuclear Facility Structures, Systems, and Components for Seismic Design**
  - Methodology uses **mean** values for release fractions and prospective site meteorology
  - Workers are those impacted by released hazardous materials, other than those workers impacted by mechanical failure induced by the seismic event (co-located)
  - Establishes public and worker consequence thresholds for selecting SDC based on failure of SSC
- **DOE-Standard 1189-2008, Integration of Safety into the Design Process**
  - Methodology uses **bounding** values for release fractions
  - For public consequences uses **95th percentile** (two σ) site meteorology
  - For worker consequences a non-site specific dispersal factor (χ/Q) is provided to evaluate dose at 100 m from facility
  - Also establishes public and worker consequence thresholds for selecting SDC based on failure of SSC

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Seismic Hazard Analysis

DOE & ANS Guidance for SSC Design Category

UNMITIGATED CONSEQUENCE of SSC Failure Per DOE & ANSI/ANS-2.26					
SDC	IBC*- ASCE/ SEI 43-05	DOE STD-1189-2008		ANSI/ANS 2.26-2004	
	Target Performance Goals for SDC	Requirements For Categorization of SSCs		Guidance on Unmitigated Consequence of SSC	
		Collocated Worker	Public	Worker	Public
	P_F	100m	MEOI	100m	MEOI
1	$*<1x10^{-3}$	Dose<5 rem	N/A	Injury to Facility Worker due to Failure of SSC	N/A
2	$*<4x10^{-4}$	5 rem< Dose<100 rem	5 rem< Dose<25 rem	Consequence <SDC3, No Permanent health effects <25 rem	5 rem< Dose<25 rem
3	$\sim 1x10^{-4}$	100 rem<Dose	25 rem < Dose	25 rem<Dose<100 rem	5 rem<Dose<100 rem
4	$\sim 4x10^{-5}$			100 rem<Dose<500 rem	25 rem<Dose<100 rem
5	$\sim 1x10^{-5}$			Worker Fatality due to Radiological effects	100 rem <Dose

Seismic Hazard Analysis

ASSUMPTIONS

Public Protection Criteria: Guidance of DOE G 421.1-2 and DOE-STD-3009-94, CN 3, Appendix A. "Challenging" or "in the rem range" interpreted as radiological doses equal to or greater than 5 rem TEDE, but less than 25 rem TEDE. SSCs designated as Safety Class are designated as SDC-3 for seismic design, at a minimum.

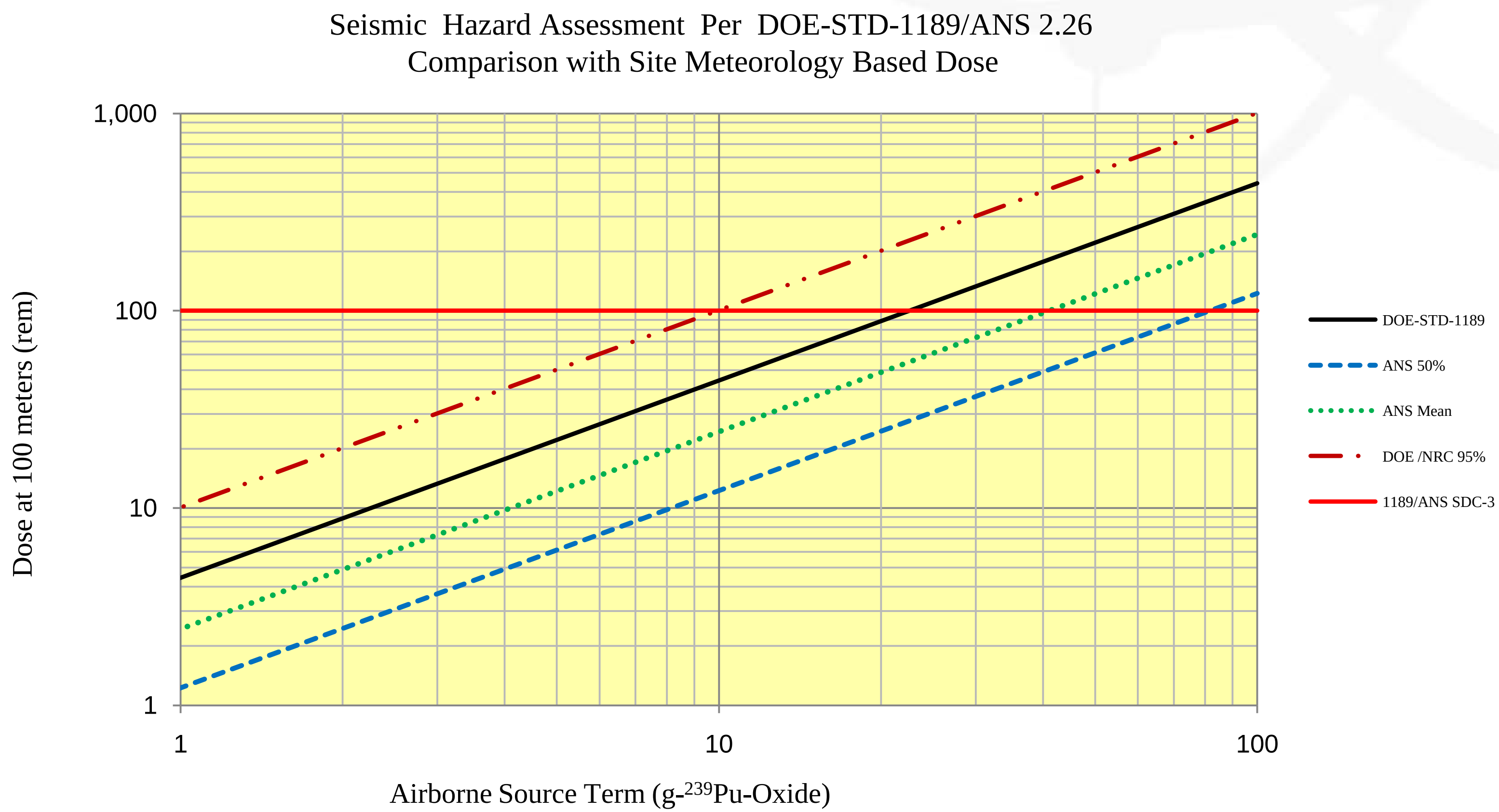
Collocated Worker Protection Criteria: Radiological Source Term Quantities: DR=1 & LPF=1. ARF based on DOE-HDBK-3010 and ANSI/ANS 5.10. ***χ/Q value*** *at 100 m of 3.5E-3 sec/m3 is used for* the dispersion calculation. Basis - NUREG 1140 (no buoyancy, F-stability, 1.0 m/sec wind speed at 100 m, small building size [10 m x 25 m], and 1 cm/sec deposition velocity). 100 rem TEDE designation of Facility-level Safety SSCs as SS.

AIRBORNE SOURCE TERM

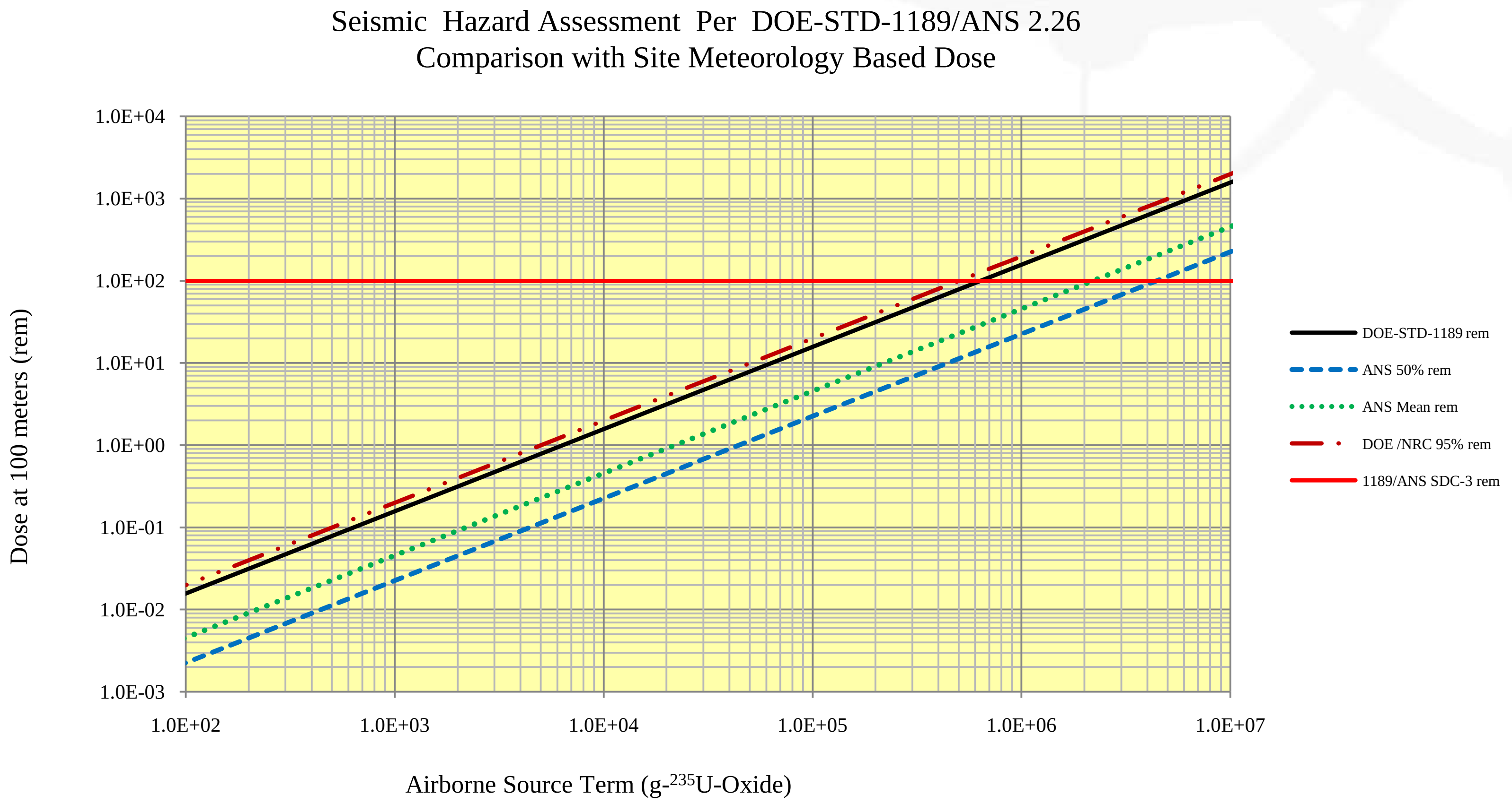
- *AST= Airborne Source Term*
- *SA=Specific Activity*
- *EG_X = Evaluation Guideline*
- *MOI = 25 rem OEP =100 rem*
- *Dose = Site Boundary or 100m*
- *X= MOI or OEP*

$$AST_X(g)= [EG_X(rem)/(DOSE_X(rem/Ci)*SA(Ci/g))]$$

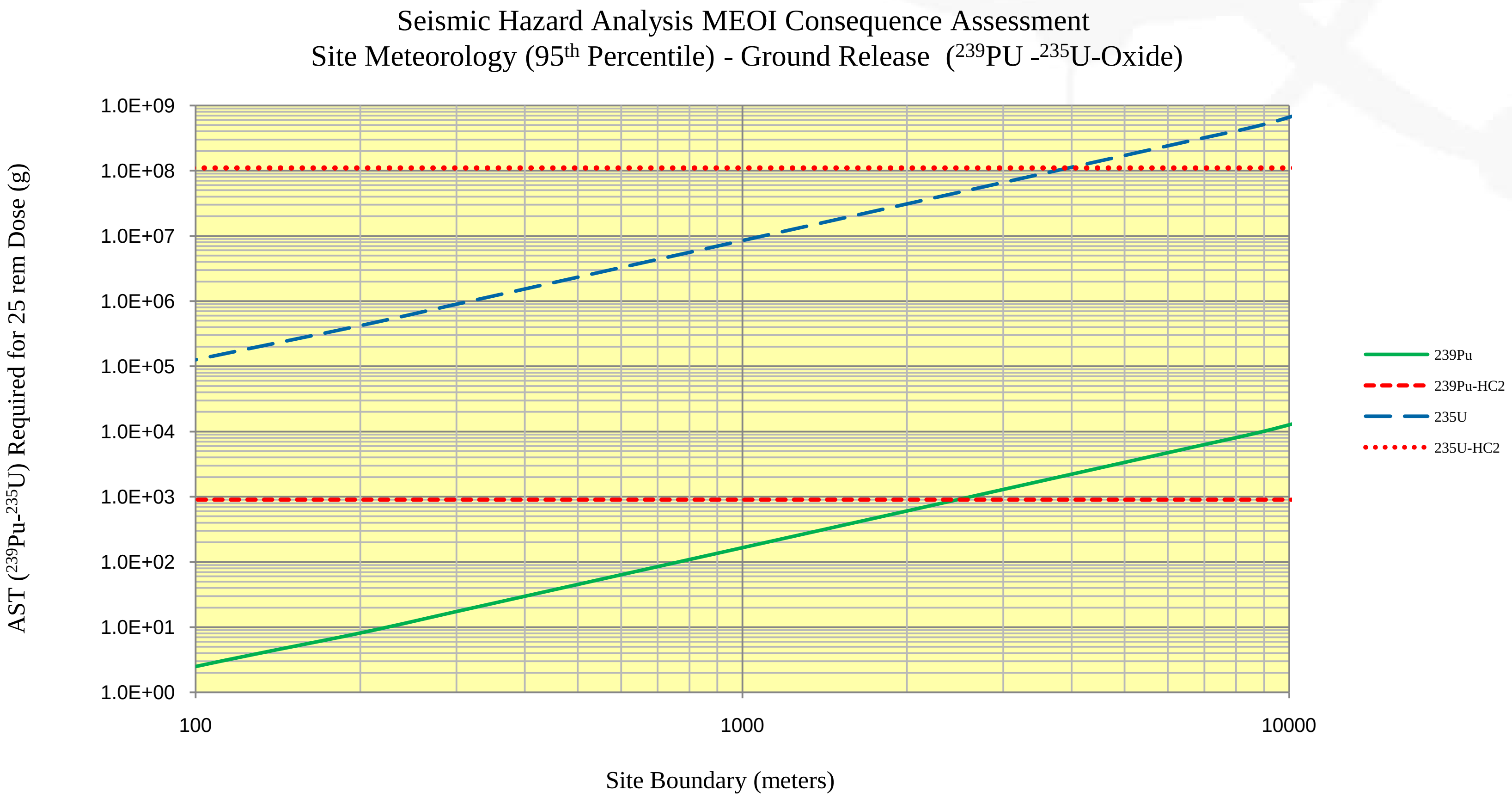
DOE-STD-1189 & ANS 2.26



DOE-STD-1189 & ANS 2.26



DOE-STD-1189 & ANS 2.26



Conclusion

- DOE approach to seismic design involves an iterative and two path approach.
- DOE-STD-1189 is more conservative than ANS 2.26 in methods for seismic hazards analysis.
- DOE-STD-1189 modifies the design standards initiated by DOE (ANS 2.26, ANS 2.27, and ANS 2.29).
- New DOE facilities or major modifications to existing facilities may unnecessarily incur more construction costs due to DOE-STD-1189.
- Design of DOE facilities incorporate sufficient requirements and conservatism that they would comply with the performance requirements of 10 CFR 70.61.
- DOE-STD-1189 may need to be revisited to assure adequate consistency with ANS 2.26.

Questions?