

Using Weibull Distribution Analysis to Evaluate ALARA Performance

D.A. Hagemeyer

ISOE North American ALARA Symposium
January 11 – 13, 2010
Ft. Lauderdale, Florida

Introduction – Who We Are

- **Janice Watkins and Derek Hagemeyer of Oak Ridge Associated Universities (ORAU)**
- **Ed Frome, Consulting Scientist for Oak Ridge Institute for Science and Education (ORISE)**
- **Project work through ORISE**
- **Under contract to the U.S. Department of Energy and the U.S. Nuclear Regulatory Commission**
- **ORAU maintains the occupational radiation exposure databases for DOE and NRC.**

Measuring ALARA

- ALARA is a fundamental philosophy of radiation protection codified in NRC and DOE regulations
- ALARA requires a *balance* between collective and individual dose optimization
- Current performance indicators give valuable but incomplete information
 - Collective dose,
 - Number of workers with measurable dose,
 - Average measurable dose,
 - Three-year average dose per reactor
- These are based on collective data and do not consider the distribution of dose to individuals

Our Goal

- **To develop objective, data-driven statistically justifiable ALARA performance indicators**
- **Applicable to a variety of facility types**
- **In combination with existing parameters, provides a more balanced measure of radiation protection performance based on the way the dose is distributed among the exposed workforce**

Research Objectives

- **Objective 1**
Evaluate utility of Weibull distribution for assessing ALARA application to radiation exposed workers
- **Objective 2**
Derive ALARA performance indicators based on Weibull distribution parameters
- **Objective 3**
Design graphics that illustrate ALARA performance indicators and properties of site dose distributions

ALARA Performance Indicators

- **Multiple ALARA indicators possible**
 - Shape parameter α
 - Slope of Weibull probability plot regression line (negative)
 - Fitted 99th percentile with confidence interval -- or
 - Percent exceedance with confidence interval
- **Weibull probability plots**
 - Provide visual evidence of ALARA effectiveness

Details of Weibull Probability Plot

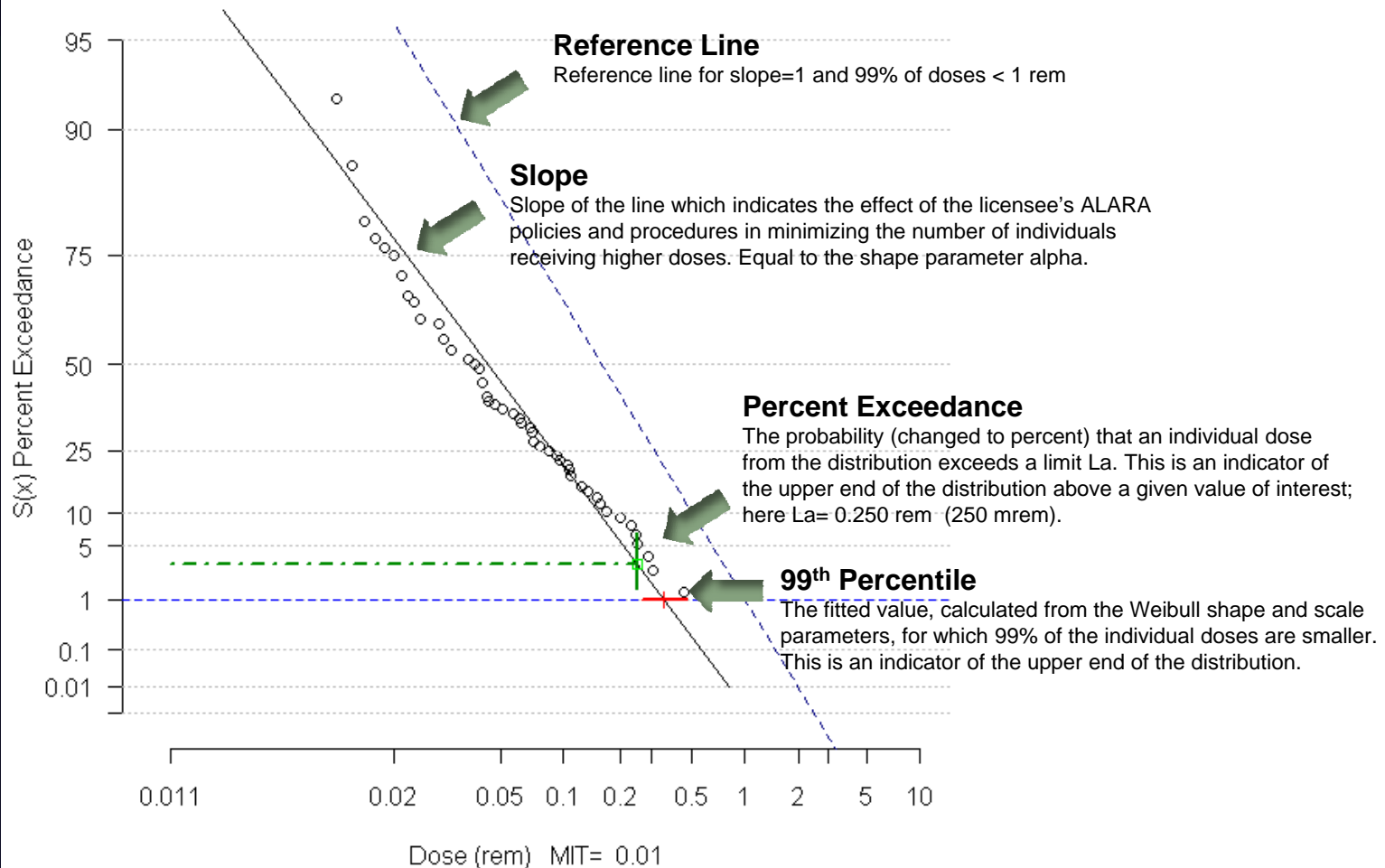
- Points ($\ln x$, $-\ln(-\ln x)$)
- Regression line: solid black line
- Labels on axes adjusted
 - Horizontal: TEDE before MIT subtracted
 - Vertical: % exceedance for values of interest
- Fitted 99th %tile:
 - Intersection of blue horizontal dashed line at 1% with regression line
 - 95% CL indicated by horizontal red segment

Details of Weibull Probability Plot (cont.)

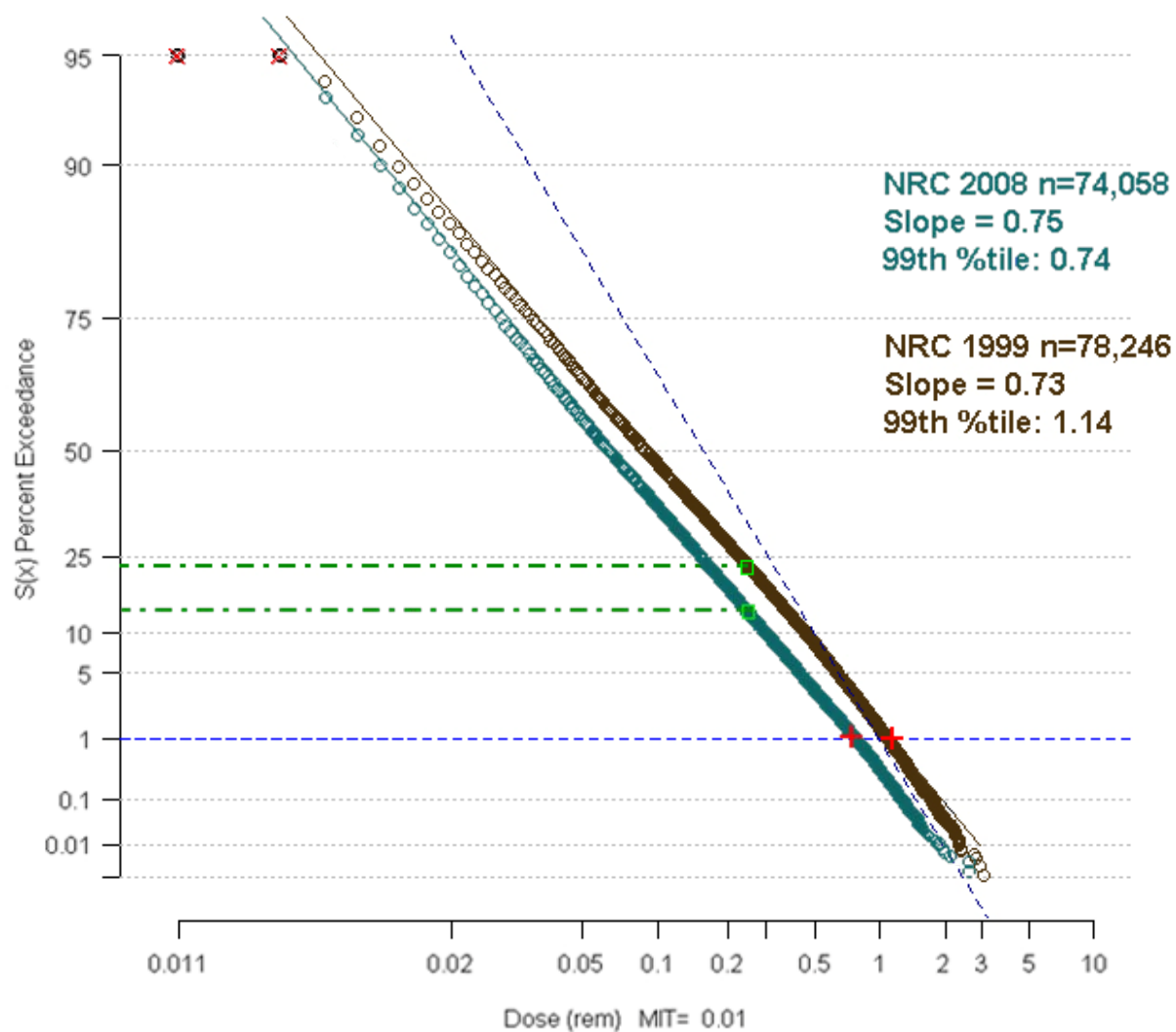
- Percent exceedance: Shown for 0.25 rem
 - Intersection of green horizontal dot-dashed line with regression line
 - 95% confidence interval indicated by vertical green segment
- Reference line for comparisons
 - Slanted green dashed line with slope = 1
 - Indicates boundary for 99% of doses being < 1 rem

Annotated Probability Plot

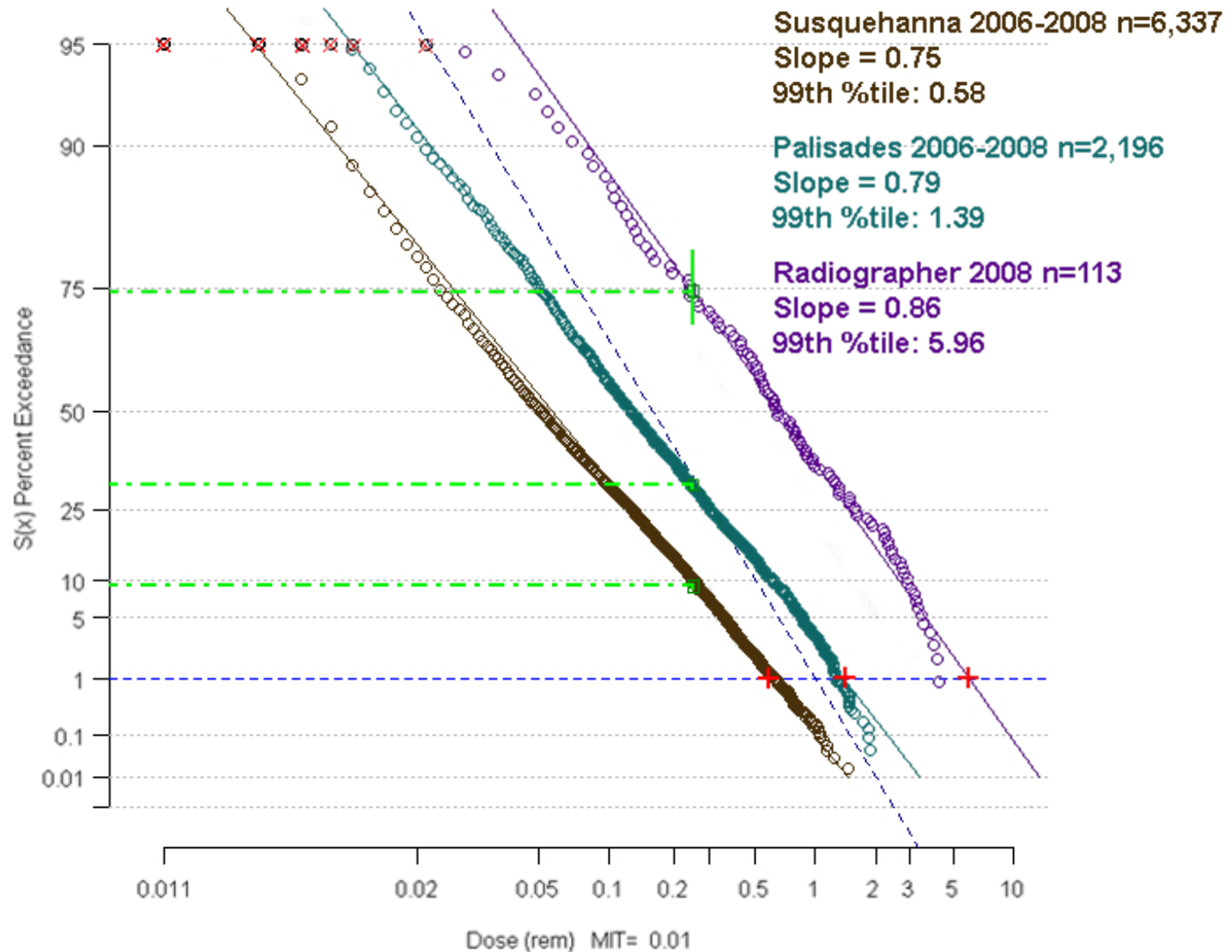
DOE 2008 NTS nx= 75 Median=0.038 Mean=0.07
Percent Exceedance for $L_a=0.25$ is 3.115: 95% CLs (1.446 , 6.71)
99th Percentile is 0.35 :95% CLs (0.262 , 0.469)



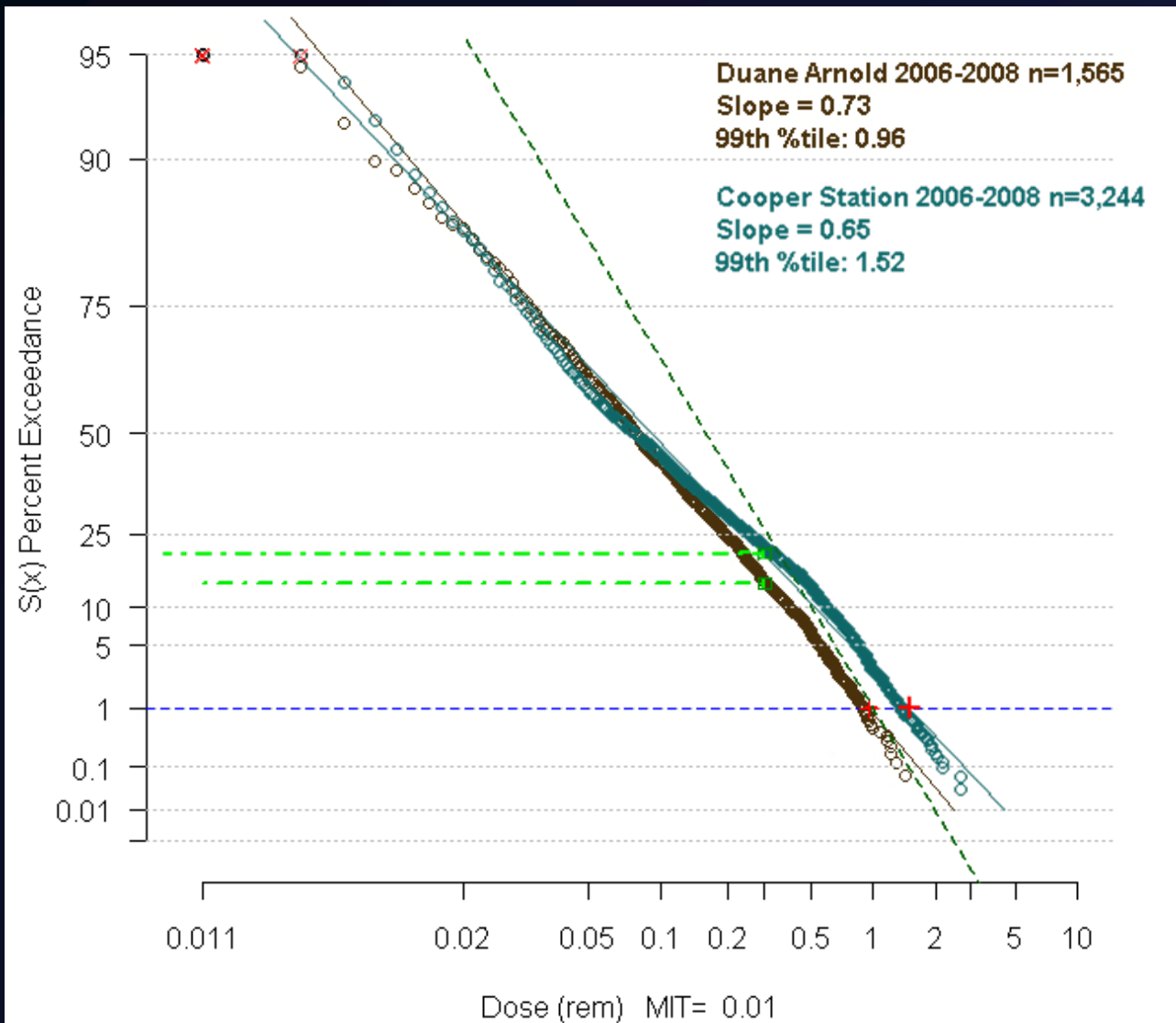
All NRC Reactors Combined - 1999 and 2008



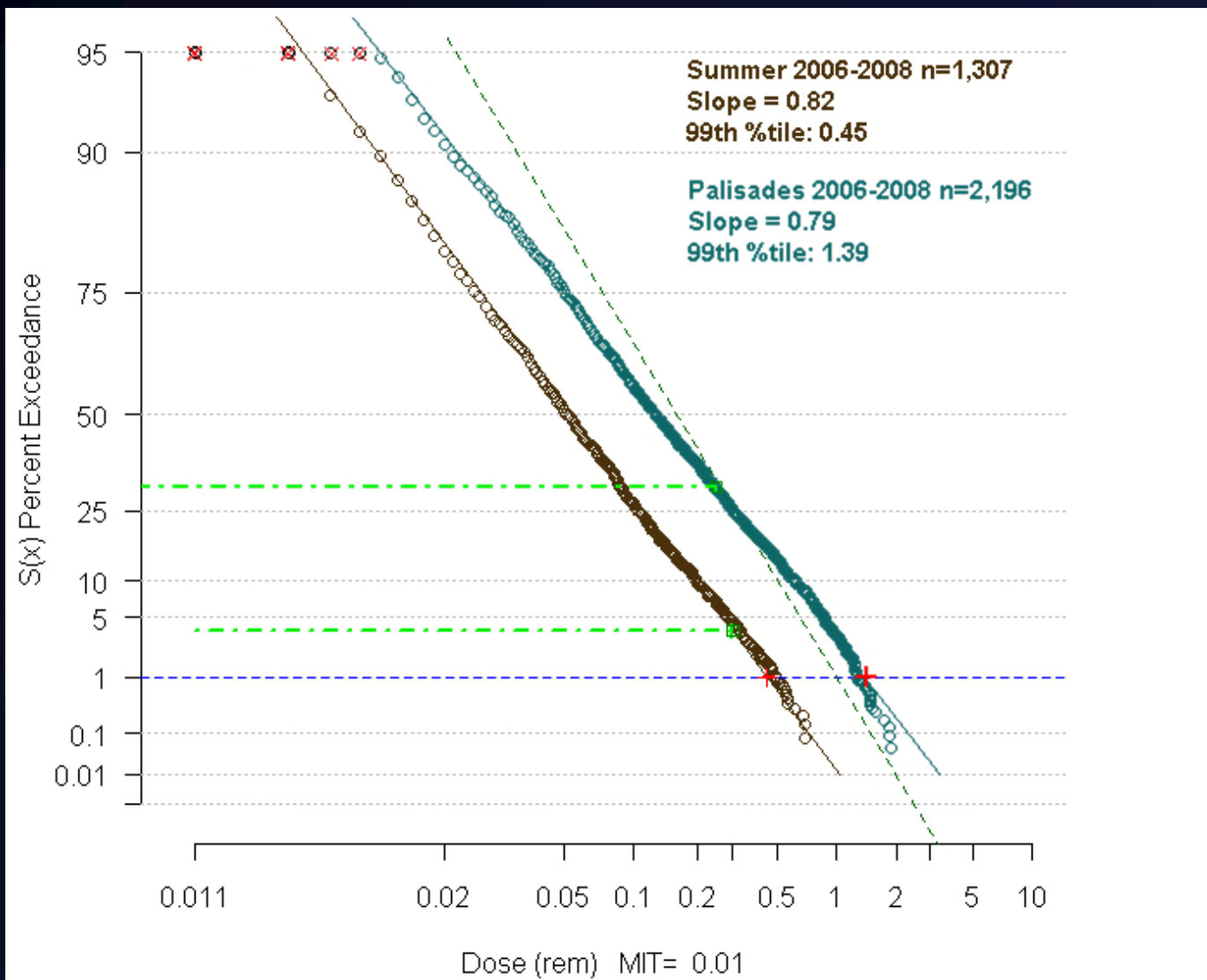
Comparison of NRC Licensees



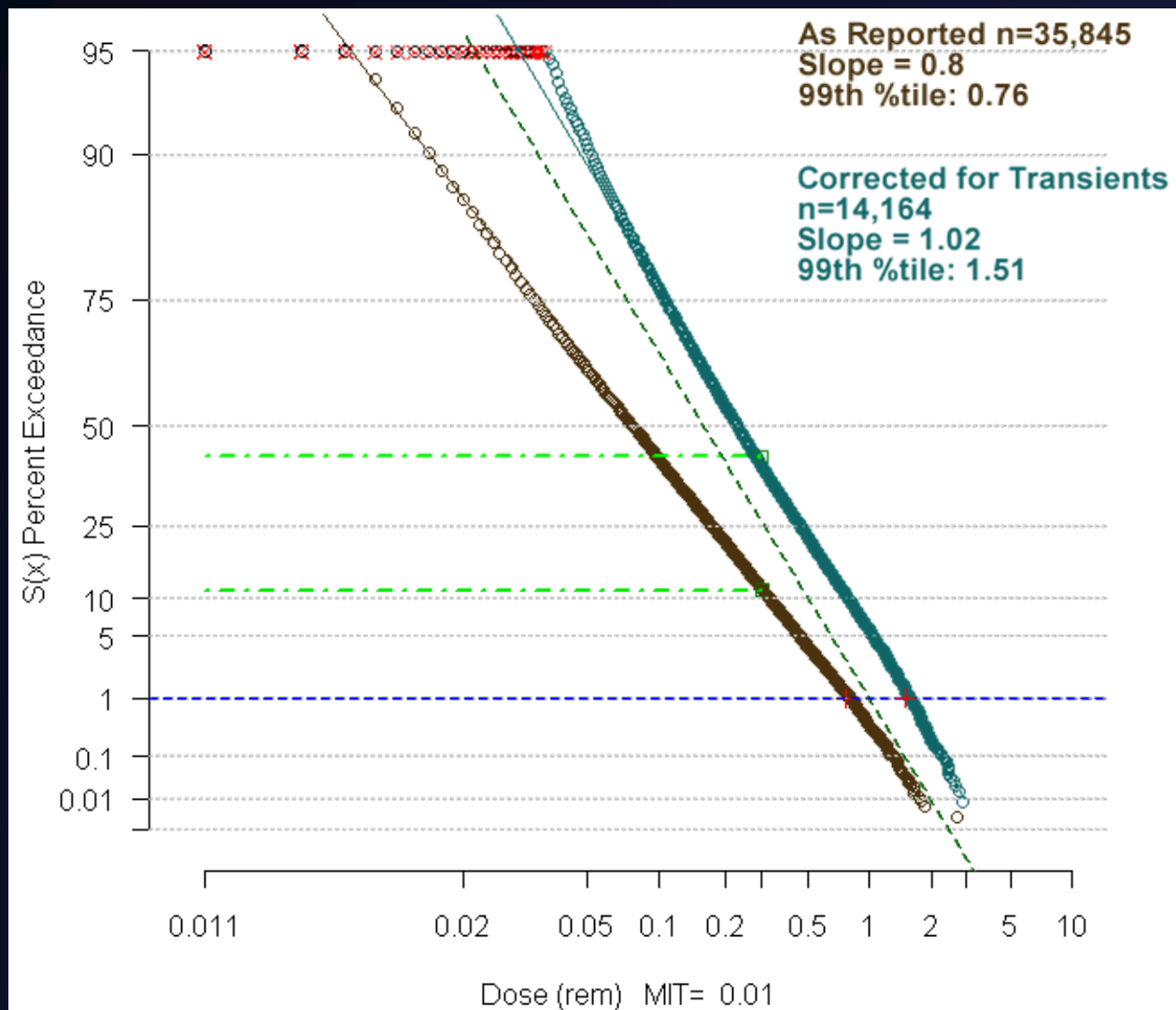
BWRs - Duane Arnold, Cooper



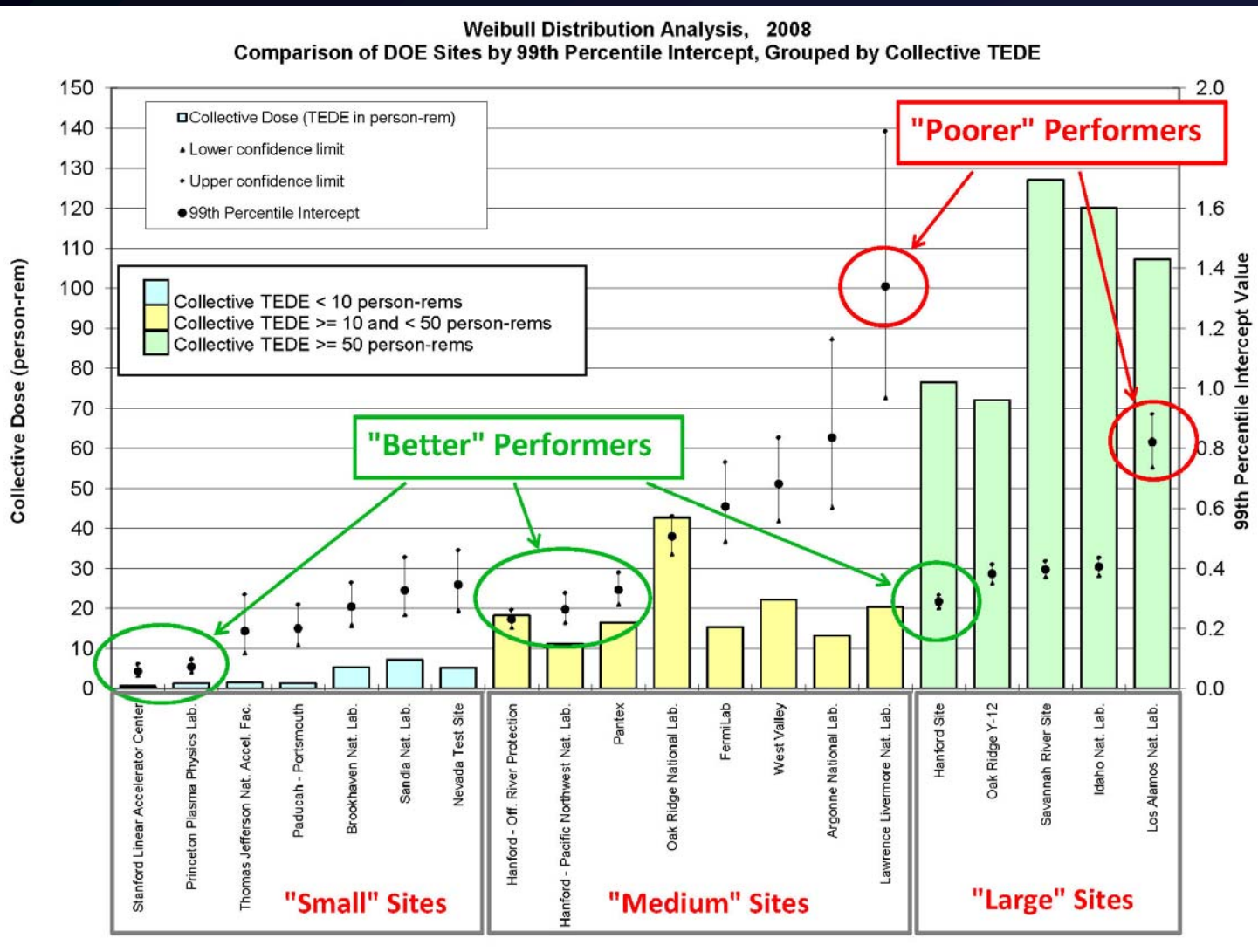
PWRs - Summer, Palisades



Transient Workers at Reactors, 2008

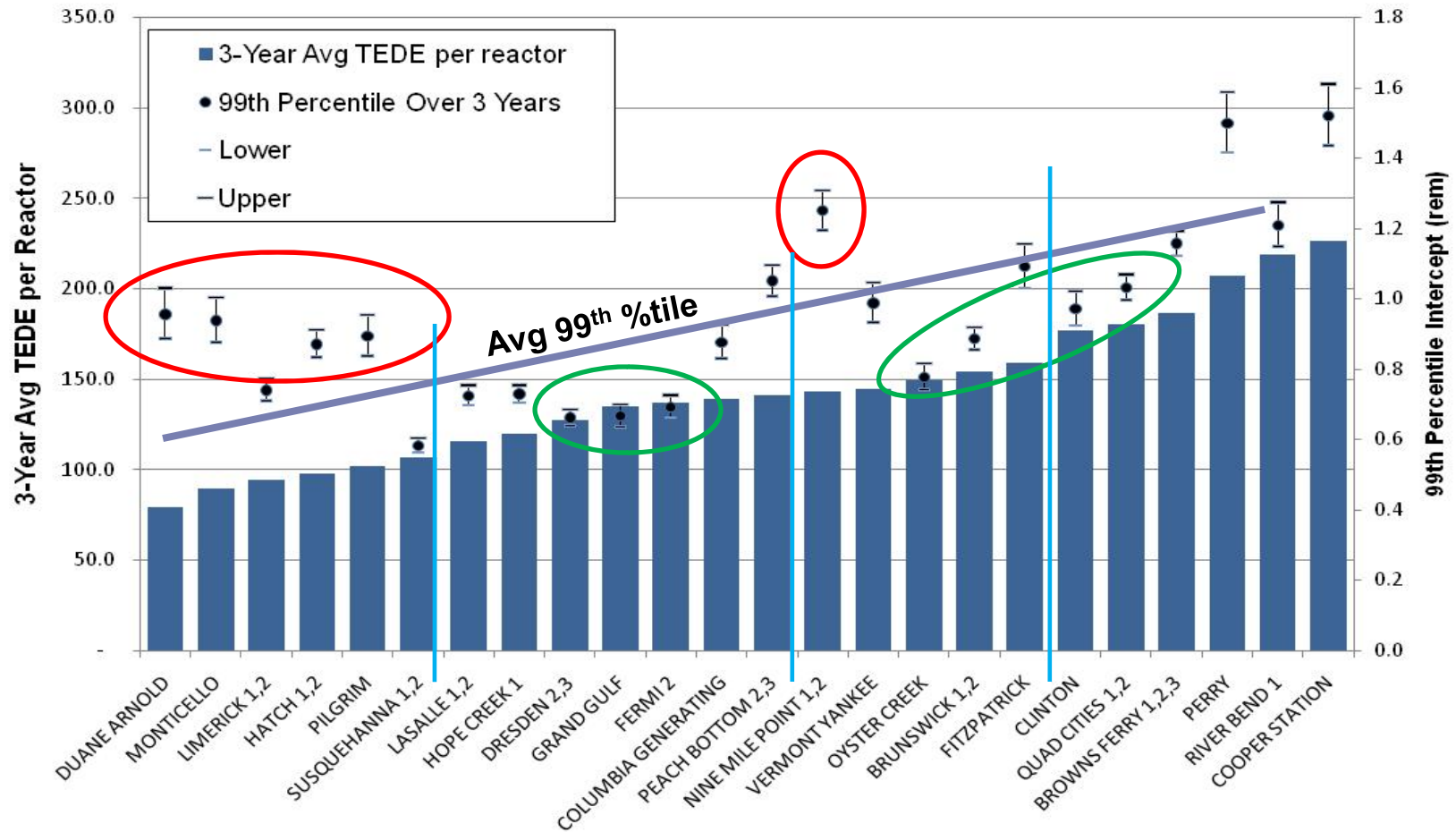


Using Collective Dose and Weibull Performance Indicators to evaluate ALARA among Sites



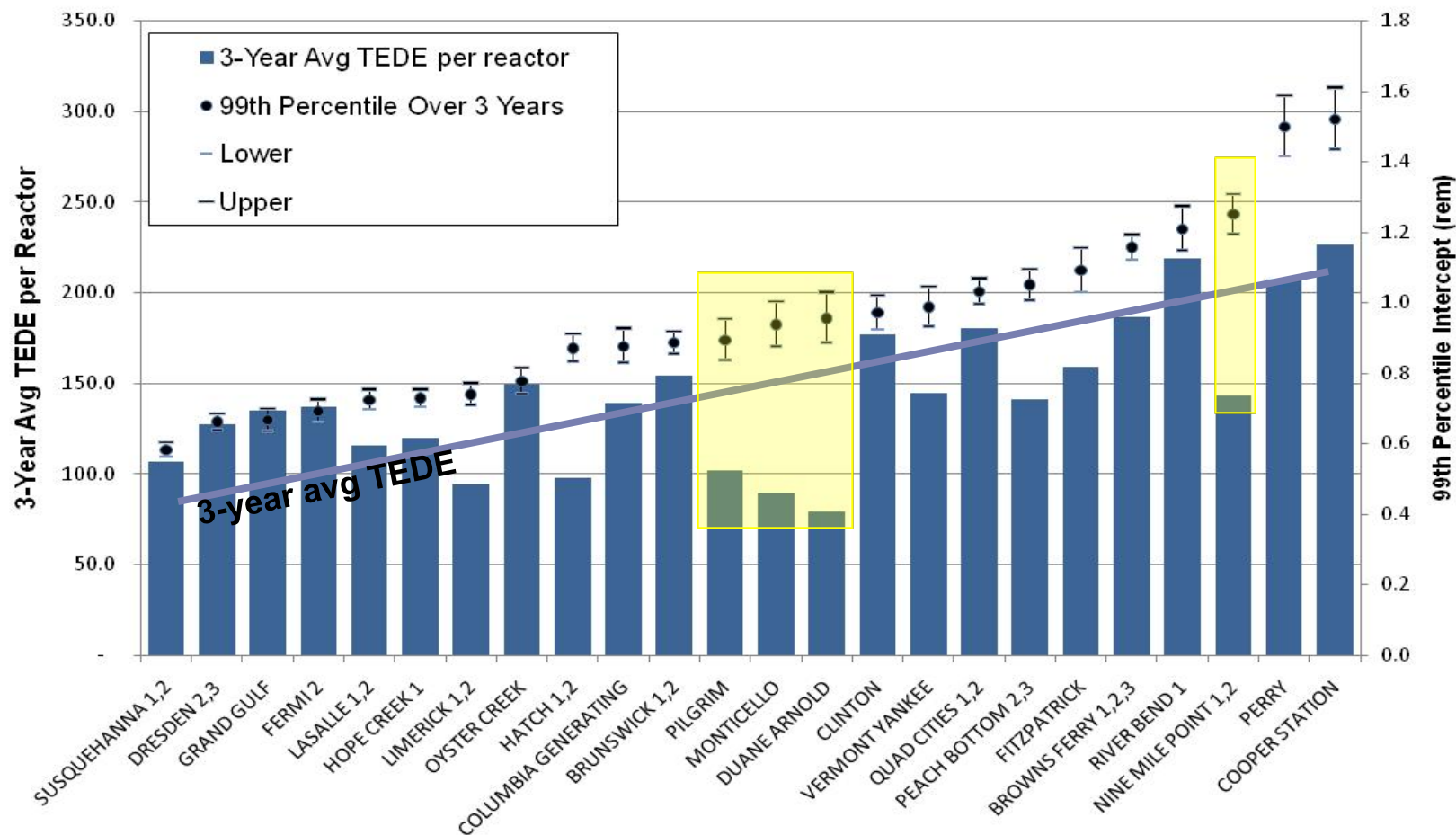
BWRs Listed by 3-Year Avg TEDE

BWR 2006-2008 3-Year Avg TEDE and 99th Percentile

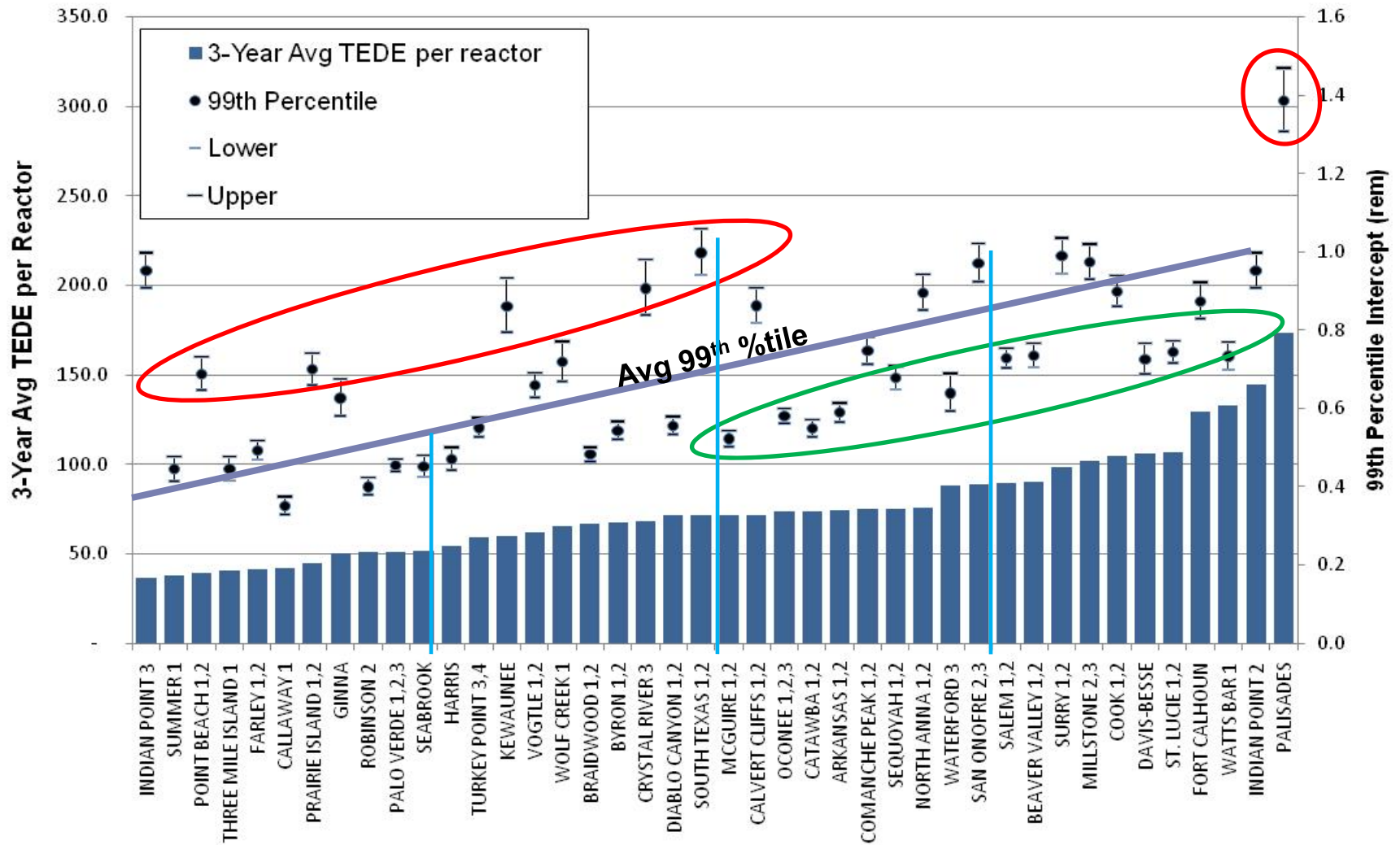


BWRs Listed by 99th Percentile

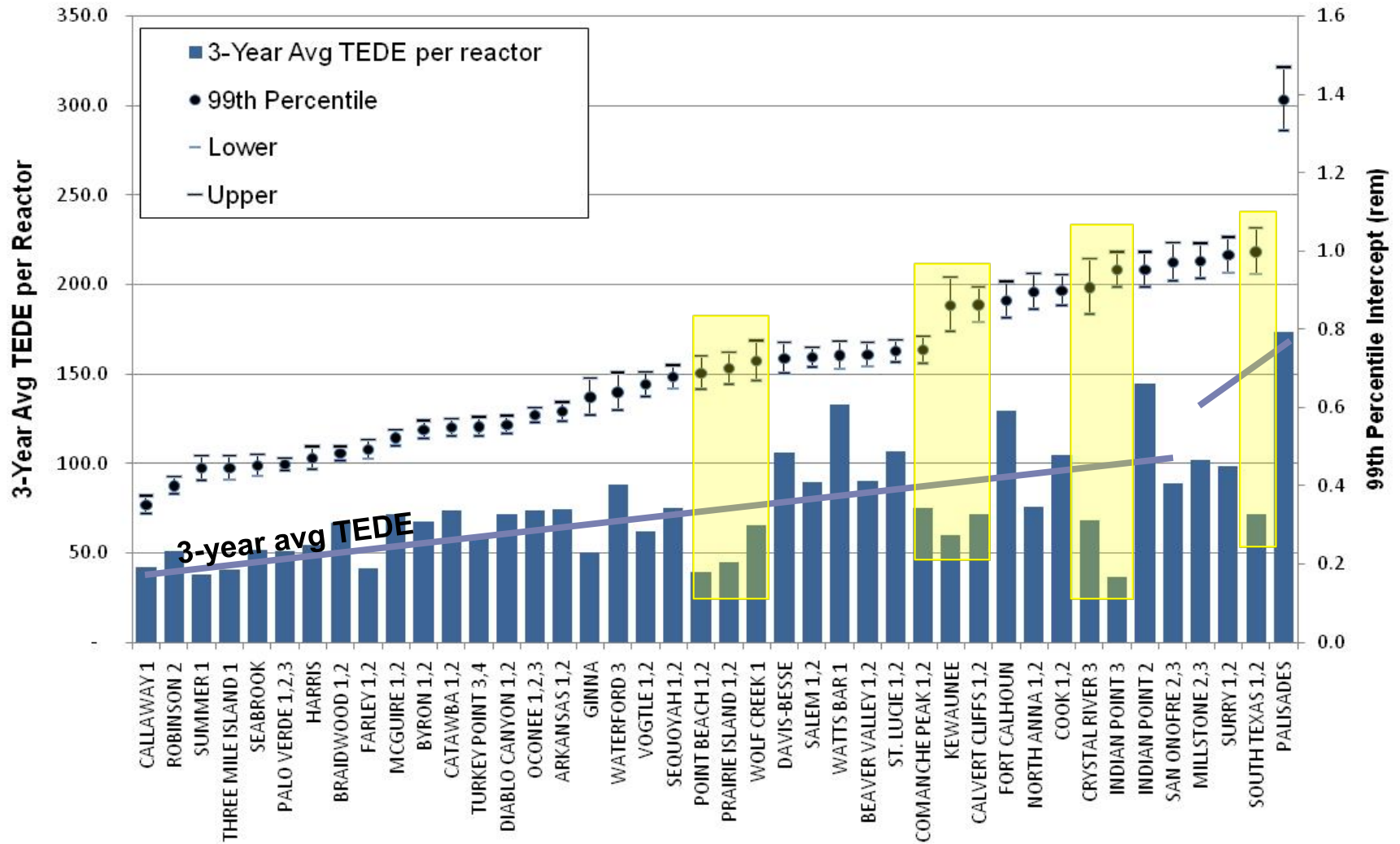
BWR 2006-2008 3-Year Avg TEDE and 99th Percentile



PWR 2006-2008 3-Year Avg TEDE and 99th Percentile



PWR 2006-2008 3-Year Avg TEDE and 99th Percentile



Conclusions

- Objective performance indicators based on Weibull distribution analysis provide enhanced information for evaluating ALARA at a site
- Graphs demonstrate this approach is useful for comparing ALARA over time or among sites
- Analysis of dose distributions from a variety of sites establish the wide applicability of the Weibull approach
- Software is being developed to implement these methods
- Provides *additional* perspective on ALARA performance

Contact

Derek A. Hagemeyer, ORAU

865-241-3615

Derek.Hagemeyer@ orise.orau.gov

End