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Sandia National Laboratories

Waste Isolation Pilot Plant

Analysis Package for CCDFGF:

CRA-2004 Performance Assessment Baseline

Calculation

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1.0 Introduction

The Waste Isolation Pilot Plant (WIPP) is a deep geologic repository developed by the U.S. Department of Energy (DOE) for the disposal of transuranic (TRU) radioactive waste. Containment of TRU waste at the WIPP is regulated by the U.S. Environmental Protection Agency (EPA) according to the regulations set forth in Title 40 of the Code of Federal Regulations (CFR), Parts 191 (EPA 1985) and 194 (EPA 1996). In March of 2004, Sandia National Laboratories (SNL) completed a Performance Assessment (PA) of the WIPP. This PA was part of the Compliance Recertification Application (CRA-2004) (DOE 2004) submitted by the DOE to the EPA to demonstrate compliance with the radiation protection regulations of 40 CFR 191 (EPA 1985) and 40 CFR 194 (EPA 1996). The EPA has begun both a completeness review and a technical adequacy review of the CRA-2004. EPA has since required that DOE and SNL complete another PA to incorporate technical changes to the CRA-2004 (Cotsworth 2005). This PA will replace the CRA-2004 and "will establish the baseline against which future changes at WIPP are evaluated" (Cotsworth 2005). This new analysis has been termed the 2004 CRA Performance Assessment Baseline Calculation (CRA-2004 PABC).

Analysis plan AP-122 (Kanney and Leigh 2005) presents the full set of PA calculations required for the CRA-2004 PABC and details the changes that were made for the CRA-2004 PABC. This analysis package documents the calculations performed by the code CCDFGF, included as part of the CRA-2004 PABC.

2.0 Background

Analysis plan AP-122 (Kanney and Leigh 2005) explains the methodology used to calculate direct releases for the CRA-2004 PABC, and AP-121 (Kanney 2005) details the methodology for calculating transport releases via the Culebra. Direct releases to the surface include cuttings and cavings releases, spallings releases, and direct brine releases (DBRs). The code CCDFGF assembles the release estimates from all other components of the WIPP PA system to generate cumulative complementary distribution functions (CCDFs) of releases (WIPP PA 2003). Releases are discussed and displayed in the form of CCDFs. The total release CCDFs and the major release mechanisms that comprise the total releases are investigated. The mathematical models, theory, design, and input and output file of the CCDFGF code will not be discussed here. They are discussed in the Design Document and User's Manual for CCDFGF (WIPP PA 2003).

3.0 Methodology

The performance assessment methodology accommodates both stochastic and subjective uncertainty in its constituent models. Stochastic uncertainty pertains to unknowable future events such as intrusion times and locations that may affect repository performance and is treated by generating random sequences of future events. Subjective uncertainty concerns parameter values that are assumed to be constants and the constants' true values are uncertain because of a lack of knowledge about the system. An example of a subjectively uncertain parameter could be the permeability of a material, and subjective uncertainty is treated by sampling the parameter values from assigned distributions. One set of sampled values is termed a vector. The performance assessment models are executed for three replicates of 100 vectors of possible parameter values; for each vector, the releases for each of 10,000 possible sequences of future events are tabulated.

By regulation, performance assessment results are presented as a distribution of CCDFs of releases (EPA 1996). Each individual CCDF summarizes the likelihood of releases across all futures for one vector of parameter values. The uncertainty in parameter values result in a distribution of CCDFs.

Releases from the WIPP fall into two principal categories: (1) Direct releases, which may occur at the time of a drilling intrusion, and (2) Long-term releases, which may take place throughout the regulatory period.

Direct releases are subdivided into three components: cuttings and cavings; spallings; and direct brine releases. Cuttings refer to the waste material actually encountered by a drill bit as it passes through the waste. Cavings include material eroded from the walls of the waste and brought to the surface by the drilling fluid. Spallings accounts for additional material that may be brought to the surface through venting of repository gas pressure to the lower-pressure borehole. Direct brine releases are flows of brine from the repository to the surface during the few days before a borehole is assumed to be plugged.

Long-term releases include radionuclide transport in groundwater through the various geologic units to the land withdrawal boundary. The most transmissive unit is the Culebra. Radionuclides may be transported to the Culebra primarily by brine flow up boreholes. Other transport paths, such as through the shaft seals, or through the marker beds, have been demonstrated to be insignificant (Helton et al., 1998).

3.1 Code Version

Several modifications have been made to the code PRECCDFGF and CCDFGF since completion of the CRA-2004. The following sections summarize the most significant modifications made to these codes.

3.1.1 PRECCDFGF Modifications

PRECCDFGF Version 1.00B was run for the CRA-2004 PA. After the CRA-2004 PA, several modifications were made to the code (Kirchner and Vugrin 2005, WIPP PA 2005). The major modifications contained in PRECCDFGF Version 1.01 are listed below:

1) In Version 1.00B, spallings volumes were multiplied by the parameter REFCON: FVRW, which has a value of 1. In version 1.01, spallings volumes are not multiplied by this parameter. (It should be noted that this multiplication had no impact on the performance of the code.)

2) Version 1.01 reads release data for direct solids releases from a single output file created by CUTTINGS_S instead of a set of 78 files from SUMMARIZE.

3) Version 1.01 retrieves GLOBAL:PBRINE parameter values from a set of CAMDAT files instead of a text output file created by LHS.

4) Version 1.01 has automated error checking capabilities for reading the input files created by SUMMARIZE. PRECCDFGF reads the headers of the SUMMARIZE files, and if they do not match the format that PRECCDFGF expects, the code aborts after writing an error message to a log file.

PRECCDFGF version 1.01 was used for the CRA-2004 PABC.

3.1.2 CCDFGF Modifications

CCDFGF version 5.00A was originally run for the CRA-2004. After the CRA-2004 results were submitted in March of 2004 (DOE 2004), an error was detected that affected how spallings releases were calculated. In Version 5.00A the spallings release from a single intrusion is erroneously calculated by multiplying the volume by the average repository activity. This error was corrected in subsequent versions of the code and its impact on CRA calculations were documented in (Kirchner and Vugrin 2005, Vugrin 2004a).

CCDFGF Version 5.02 was used for CRA-2004 PABC calculations. The major difference between Version 5.00A and 5.02 affects calculations of spallings releases. Version 5.02 correctly calculates the spallings release from a single intrusion by multiplying the volume by the average repository activity and the parameter REFCON:FVW, the fraction of the repository occupied by waste. Additional modifications were made to CCDFGF that yielded CCDFGF version 5.02. For further discussion of these minor modifications affecting the development of CCDFGF see (Kirchner and Vugrin 2005).

3.2 Random Seed in the CCDFGF Control Files

One of the features that the CCDFGF control file controls is the random number generator in the code. Setting the random number seed in the control file determines the sequence of random numbers that CCDFGF uses. This sequence of numbers affects several stochastic parameters, such as the drilling location, depth, and type of plugging pattern, when CCDFGF simulates the drilling of boreholes at the surface of the WIPP repository.

For the CRA-2004, the same random seed for CCDFGF was used for all three replicates. In order to fully express the variability due to the stochastic parameters, a different random seed for CCDFGF was used for each replicate.

3.3 Run Control

Run control for this analysis is documented in Long and Kanney (2005).

4.0 Analysis and Results

This section presents total normalized releases for the CRA-2004 PABC, followed by discussion of each of the four categories of releases that constitute the total release: cuttings and cavings; spallings; DBRs; and transport releases. Within each following section, CRA-2004 PABC results are compared with CRA-2004 results.

4.1 Total Releases

Figure 4. 1, Figure 4. 2, and Figure 4. 3 show the complementary cumulative distribution functions (CCDFs) for total releases for replicates 1, 2. and 3 of the CRA-2004 PABC, respectively. Total releases are calculated by totaling the releases from each release pathway: cuttings and cavings releases, spallings releases, DBRs, and transport releases. Each CCDF lies below and to the left of the limits specified in 40 CFR § 191.13(a). Thus, the WIPP continues to comply with the containment requirements of 40 CFR Part 191.

To compare the distributions of CCDFs among replicates and to demonstrate sufficiency of the sample size, mean and quantile CCDFs are calculated. At each value for normalized release R on the abscissa, the CCDFs for a single replicate define 100 values for probability. The arithmetic mean of these 100 probabilities is the mean probability that release exceeds R; the curve defined by the mean probabilities for each value of R is the mean CCDF. The quantile CCDFs are defined analogously.

Figure 4. 4 compares the mean, median, 90^{th}, 50^{th}, and 10^{th} quantiles for each replicate's distribution of CCDFs for total releases. Figure 4. 4 shows that each replicate's distribution is quite similar, and shows qualitatively that the sample size of 100 in each replicate is sufficient to generate a stable distribution of outcomes.

The overall mean CCDF in Figure 4. 4 is computed as the arithmetic mean of the three mean CCDFs from each replicate. To quantitatively determine the sufficiency of the sample size, a confidence interval is computed about the overall mean CCDF using the Student's t-distribution and the mean CCDFs from each replicate. Figure 4. 5 shows 95 percent confidence intervals about the overall mean.

Figure 4. 6, Figure 4. 7, and Figure 4. 8 show the mean CCDFs for each component of total releases, for replicates 1, 2, and 3 of the CRA-2004 PABC. respectively. For comparison, the mean CCDFs for each component of total releases for replicates 1, 2, and 3 from the CRA-2004 are shown in Figure 4. 9, Figure 4. 10, and Figure 4. 11, respectively.

Two significant differences between the analyses are observed. The first is that DBRs make a larger contribution to total releases in the CRA-2004 PABC than in the CRA-2004. For probabilities exceeding 0.01, cuttings and cavings are still the release mechanism that has the greatest impact on total releases. In fact, for probabilities larger than 0.02, the CRA-2004 PABC cuttings and cavings mean CCDF exceeds the other mean CCDFs by at least an order of magnitude. However, at low probabilities (<0.002), mean CRA-2004 PABC DBR releases exceed all other mean releases. In general, the mean DBR CCDF was at least an order of magnitude less than the mean cuttings and cavings CCDF for all probabilities of the CRA-2004. Further discussion of normalized DBRs follows in Section 4.4.

The second major difference between the two analyses concerns the mean spallings CCDFs. The mean spallings releases for the CRA-2004 were larger than the mean spallings releases from the CRA-2004 PABC at all probabilities. In fact, at a probability of 0.1, the mean spallings CCDFs from the CRA-2004 exceed those from the CRA-2004 PABC by approximately two orders of magnitude (10^{-2} EPA units versus 10^{-4} EPA Units). Additionally, mean DBR releases are larger than mean spallings releases at all probabilities for the CRA-2004 PABC, whereas the opposite was true for almost all probabilities in the CRA-2004. Further discussion of spallings releases follows in Section 4.3.

Figure 4. 12 provides an additional comparison between the CRA-2004 and CRA-2004 PABC. At probabilities exceeding 0.001, the overall mean CCDFs for total normalized releases from the two analyses are very similar. Table 4. 1 lists the overall mean total release at probabilities of 0.1 and 0.001 for the Compliance Certification Application (CCA) Performance Assessment Verification Test (PAVT). Mean total releases differ by less than 10^{-2} EPA units at a probability of 0.1 and by less than 10^{-1} EPA units at a probability of 0.001 (Table 4. 1). The same trend holds true for the 90th quantile CCDFs for total releases. For lower probabilities, the CRA-2004 PABC mean CCDF slightly exceeds the CRA-2004 mean CCDF. This is attributed to the increased DBRs at these probabilities. Additionally, the CRA-2004 PABC confidence intervals on the overall means are narrower than the CRA-2004 confidence intervals at probabilities of 0.1 and 0.001. Explanation of this narrowing follows in Section 4.3.

In comparison to the CCA PAVT results, mean total releases decreased slightly at a probability of 0.1 but slightly increased at a probability of 0.001. Results for the 90th quantiles followed this trend.

Despite the differences between the CCDFs for the two analyses, there are some definite similarities. First, for most probabilities, cuttings and cavings are the most significant pathways for release radioactive material to the land surface. Secondly, release by subsurface transport in the Salado or Culebra make essentially no contribution to total releases. Finally, the resulting CCDFs of both analyses are within regulatory limits.

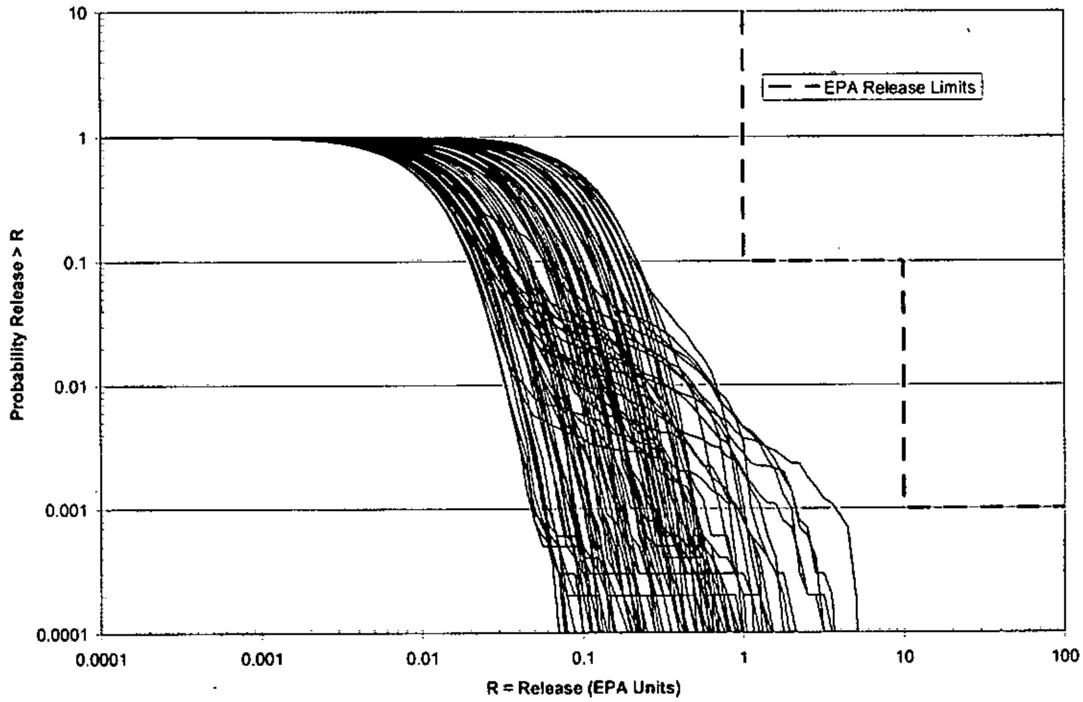

Figure 4. 1. Total Normalized Releases: Replicate 1 of the CRA-2004 PABC

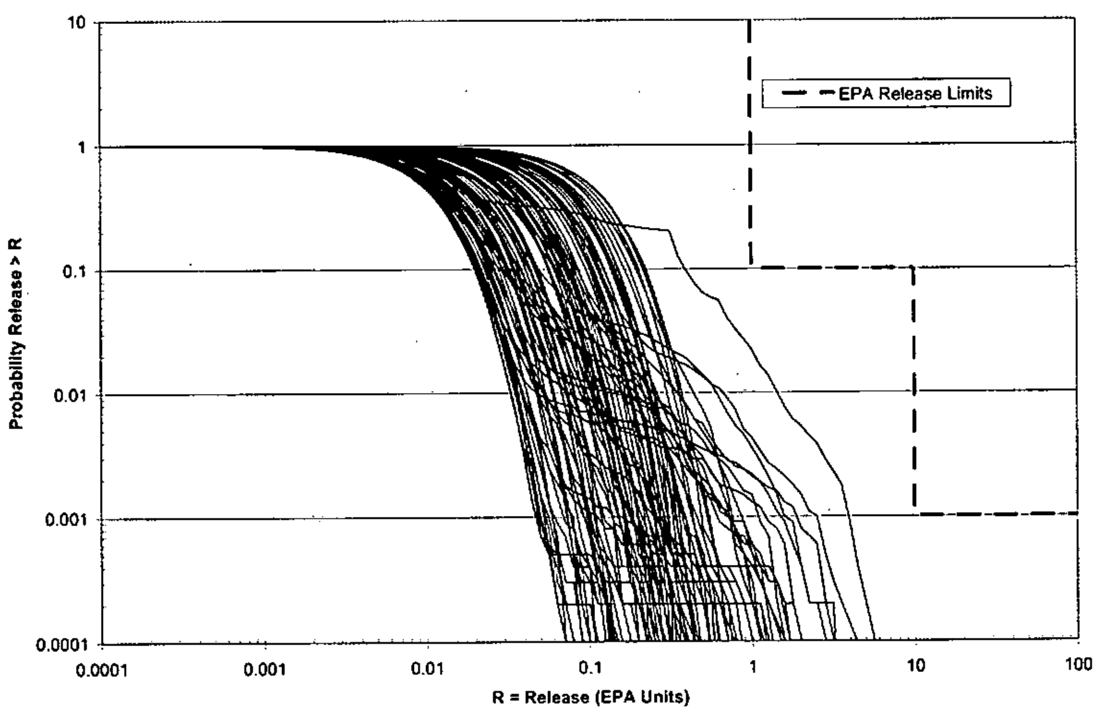

Figure 4. 2. Total Normalized Releases: Replicate 2 of the CRA-2004 PABC

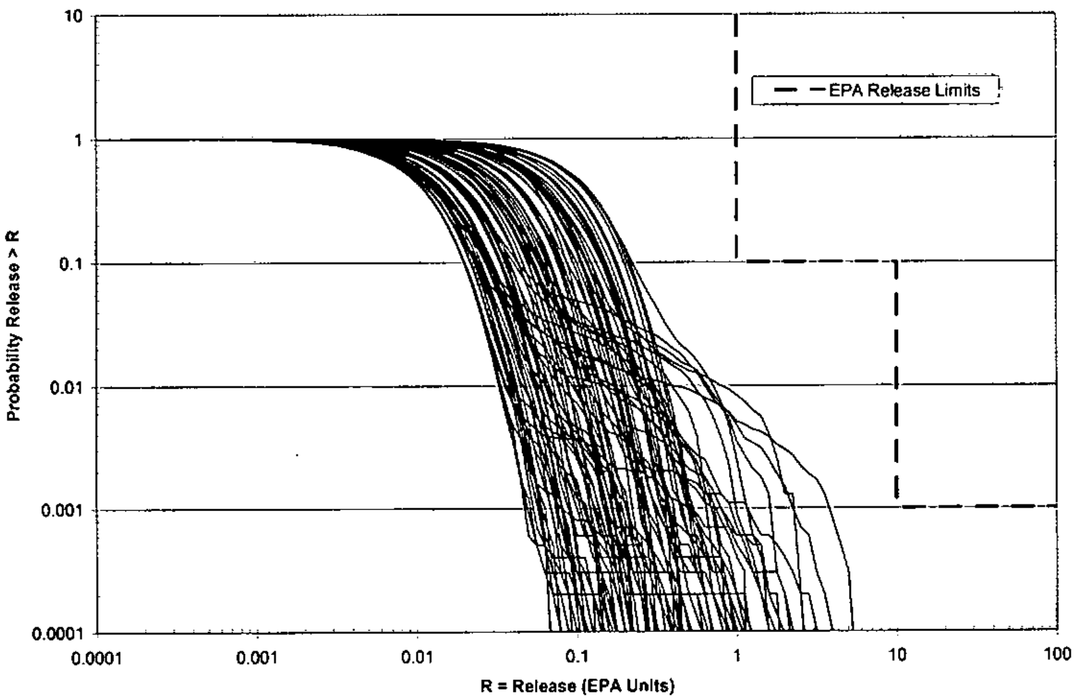

Figure 4. 3. Total Normalized Releases: Replicate 3 of the CRA-2004 PABC

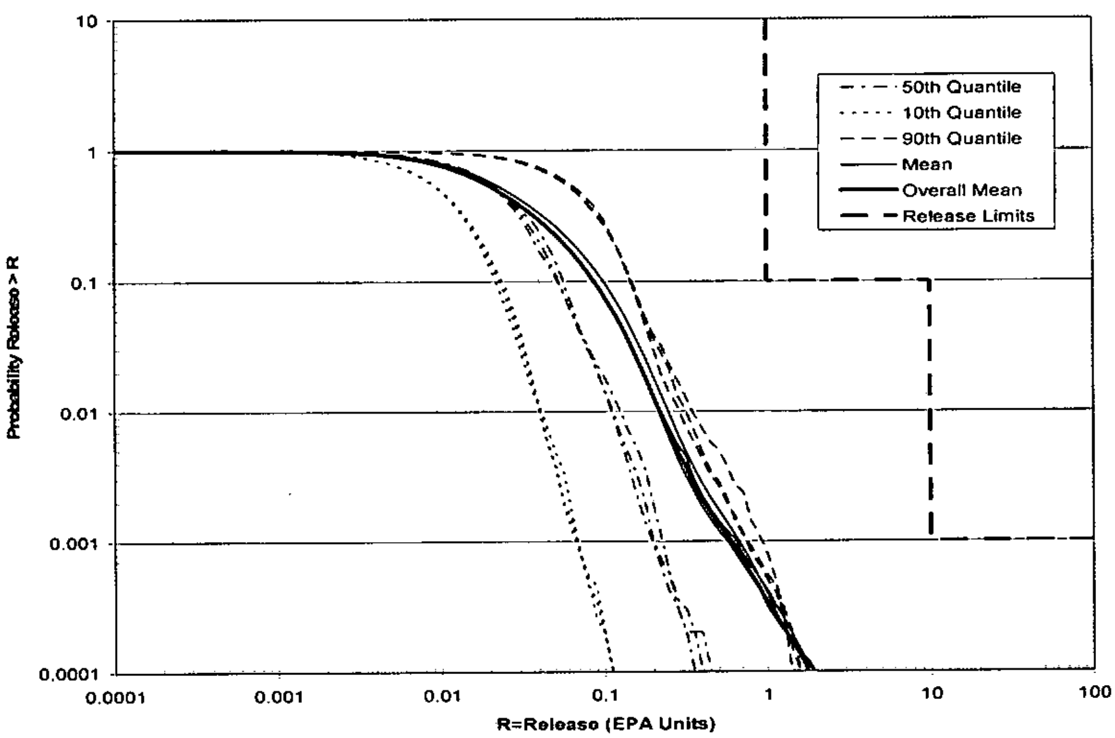

Figure 4. 4. Mean and Quantile CCDFs for Total Normalized Releases: All Replicates of the CRA-2004 PABC

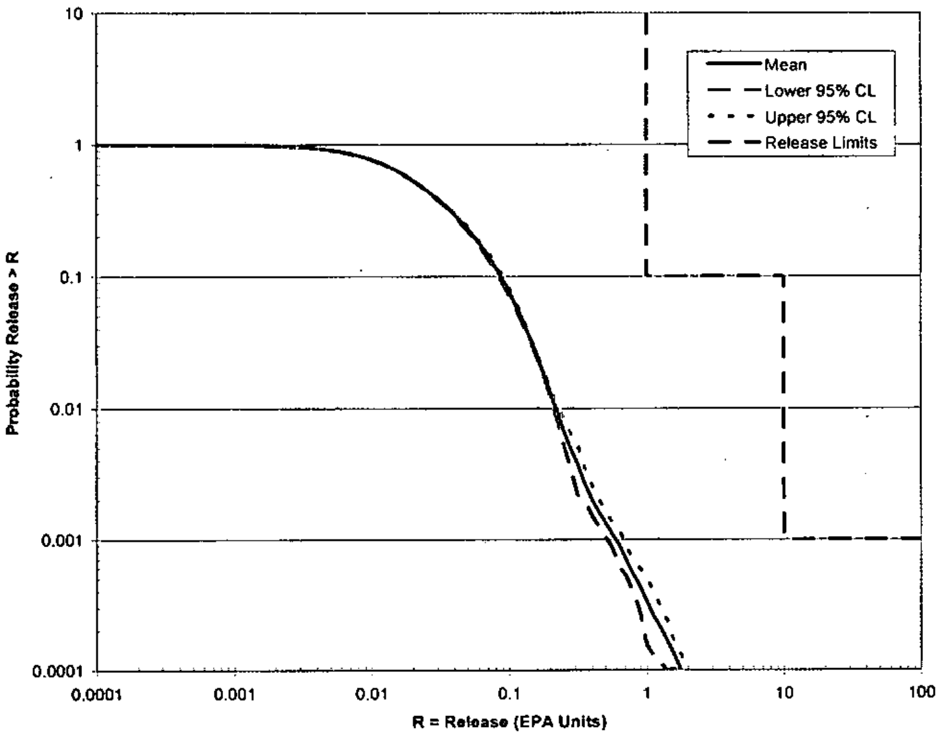

Figure 4. 5. Confidence Interval on Overall Mean CCDF for Total Normalized Releases: CRA-2004 PABC

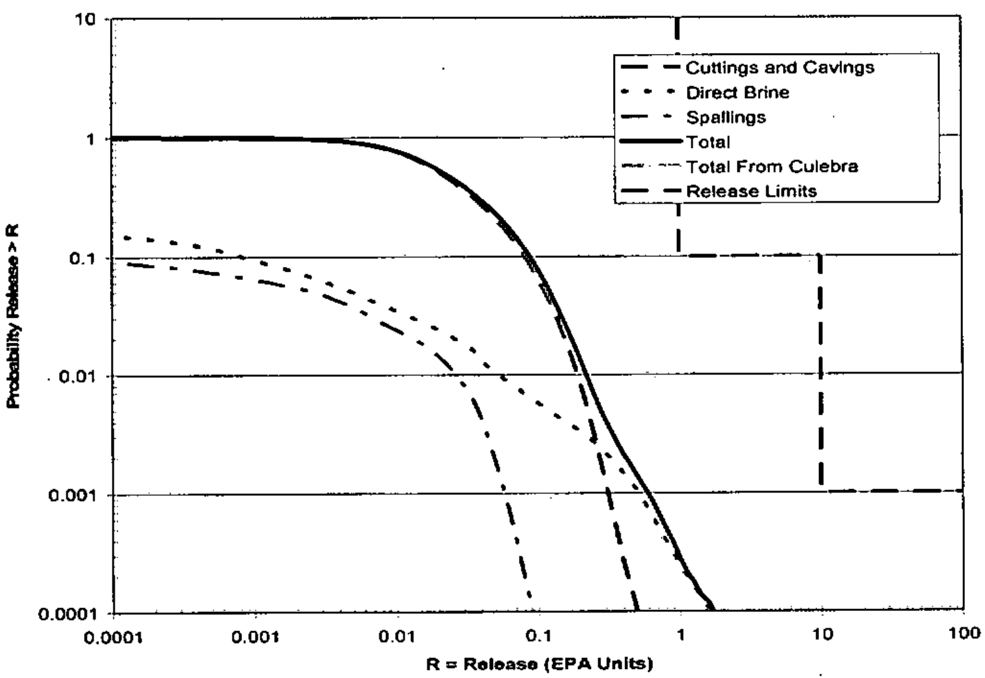

Figure 4. 6. Mean CCDFs for Components of Total Normalized Releases: Replicate R1 of CRA-2004 PABC

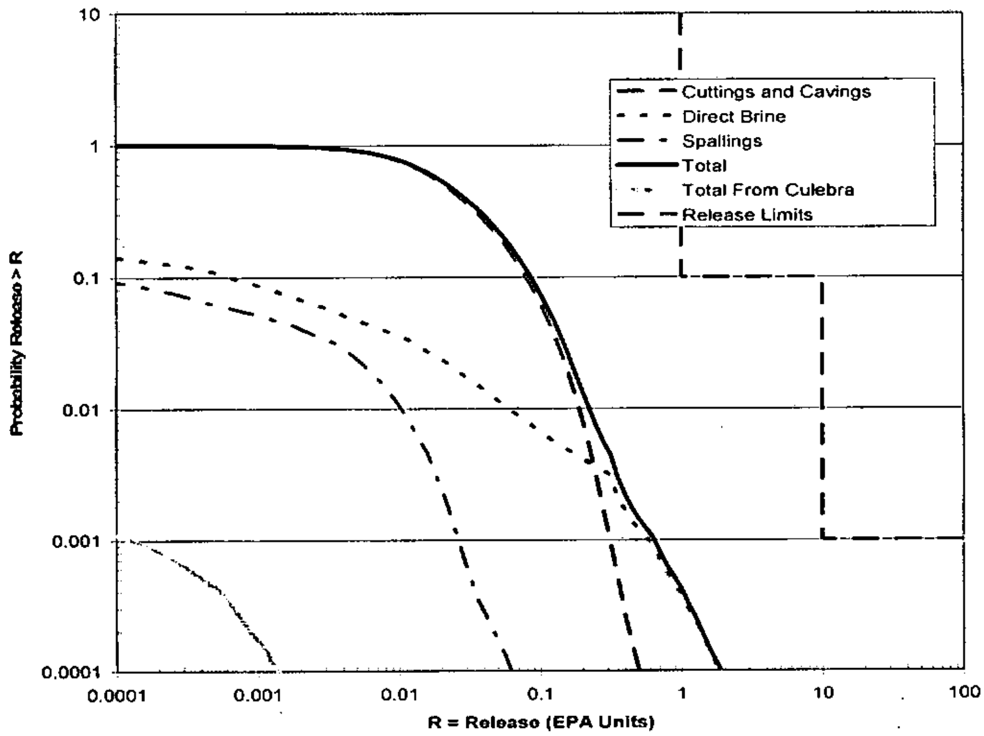

Figure 4. 7. Mean CCDFs for Components of Total Normalized Releases: Replicate R2 of CRA-2004 PABC

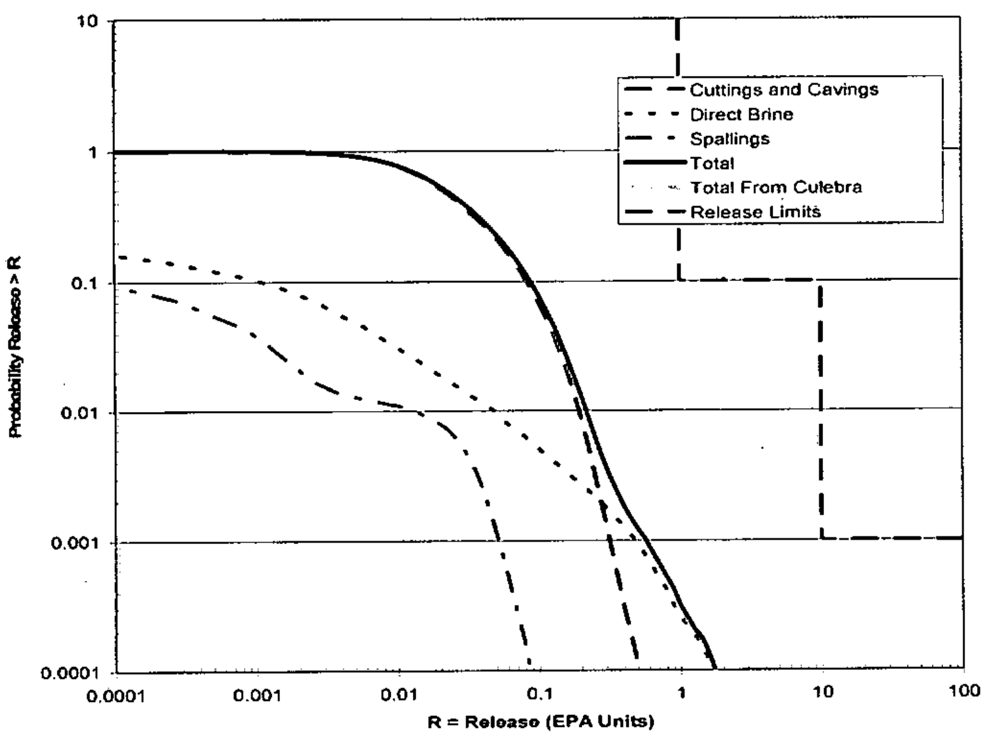

Figure 4. 8. Mean CCDFs for Components of Total Normalized Releases: Replicate R3 of CRA-2004 PABC

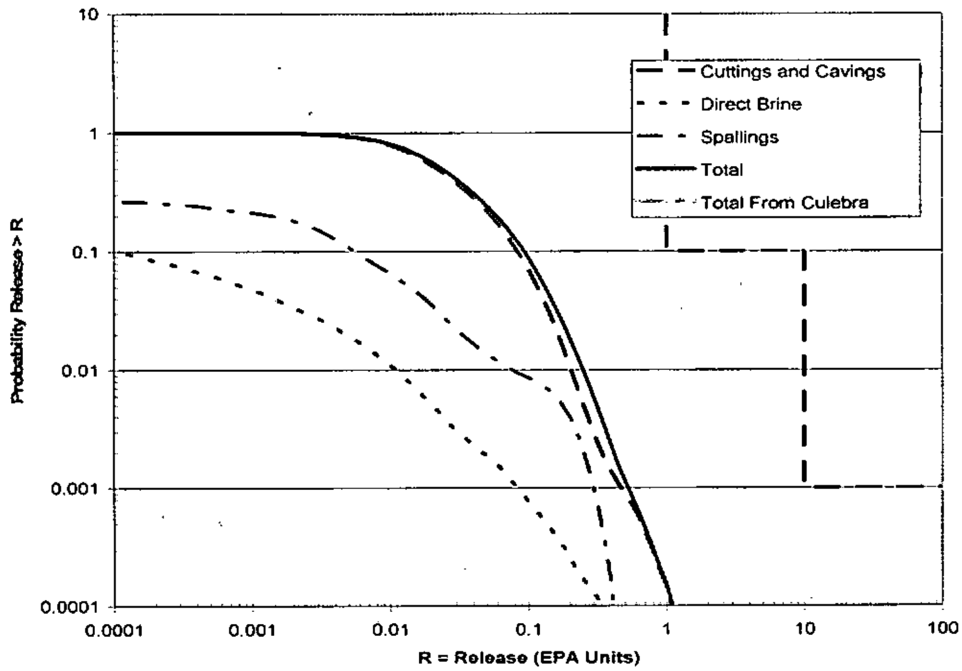

Figure 4. 9. Mean CCDFs for Components of Total Normalized Releases: Replicate R1 of CRA-2004

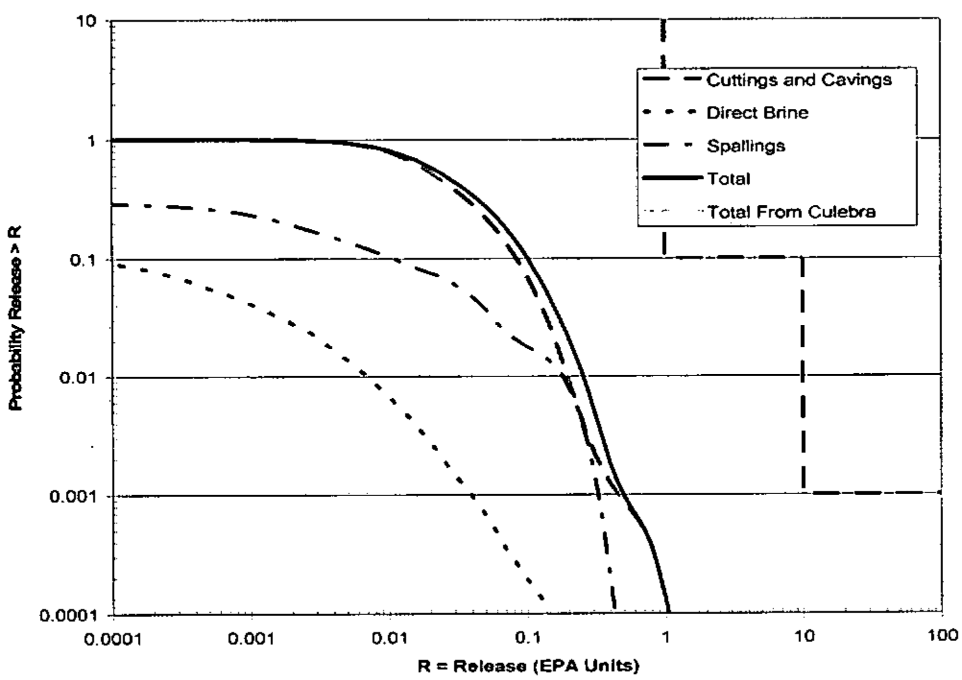

Figure 4. 10. Mean CCDFs for Components of Total Normalized Releases: Replicate R2 of CRA-2004

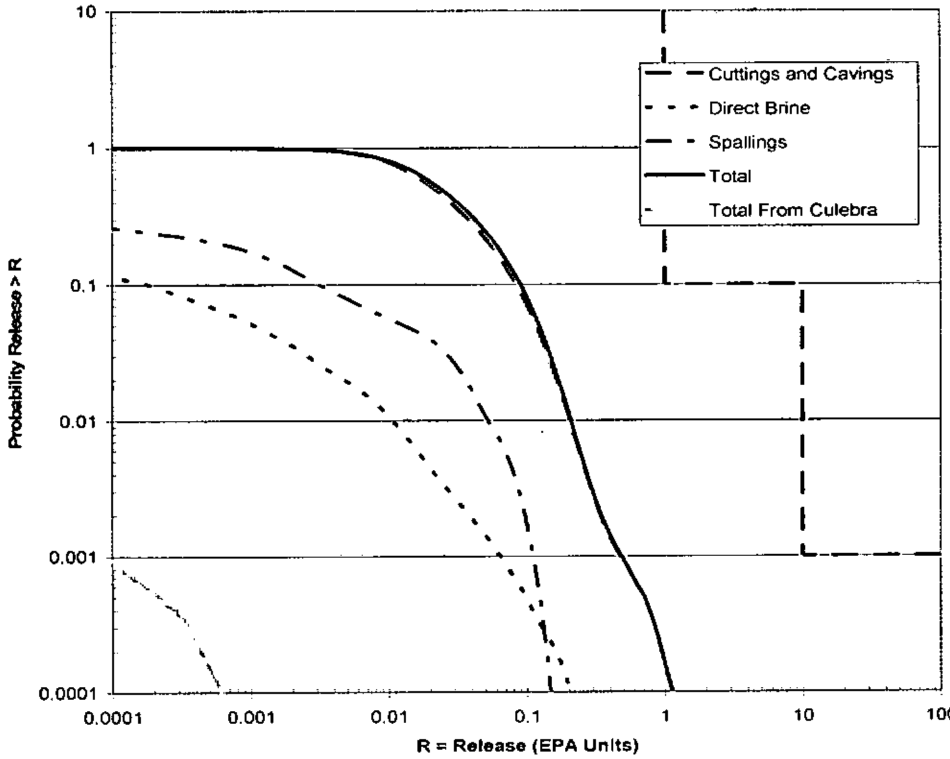

Figure 4. 11. Mean CCDFs for Components of Total Normalized Releases: Replicate R3 of CRA-2004

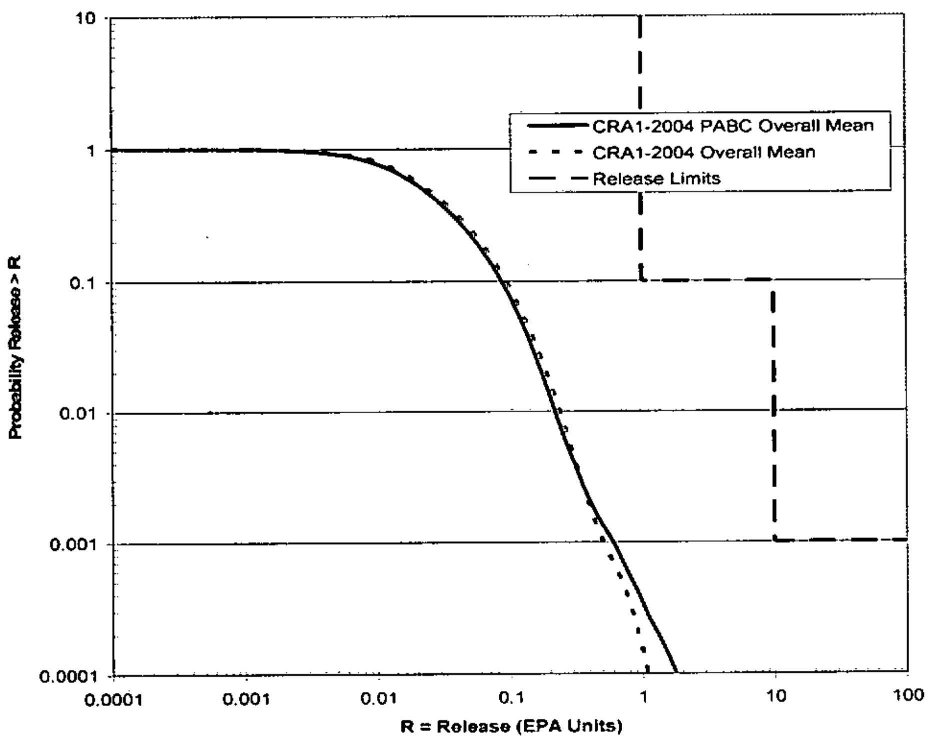

Figure 4. 12. Overall Mean CCDFs for Total Normalized Releases: CRA-2004 PABC and CRA-2004

Table 4. 1 CCA PAVT, CRA-2004, and CRA-2004 PABC Statistics on the Overall Mean for Total Normalized Releases at Probabilities of 0.1 and 0.001, All Replicates Pooled. CCA PAVT and CRA-2004 data was initially reported in Vugrin (2004b and 2004c).

Probability	Analysis	Mean Total Release	90th Quantile Total Release	Lower 95% CL	Upper 95% CL
0.1	CCA PAVT	1.237E-1	1.916E-1	1.231E-1	1.373E-1
	CRA-2004	9.565E-2	1.571E-1	8.070E-2	1.104E-1
	CRA-2004 PABC	8.770E-2	1.480E-1	8.471E-2	9.072E-2
0.001	CCA PAVT	3.819E-1	3.907E-1	2.809E-1	4.357E-1
	CRA-2004	5.070E-1	8.582E-1	2.778E-1	5.518E-1
	CRA-2004 PABC	6.006E-1	8.092E-1	5.175E-1	6.807E-1

4.2 Cuttings and Cavings Normalized Releases

Figure 4.13, Figure 4.14, and Figure 4.15 show the CCDFs for cuttings and cavings releases for replicates 1, 2, and 3 of the CRA-2004 PABC, respectively. Figure 4.16 shows the mean CCDFs for cuttings and cavings releases for replicates 1, 2, and 3 of the CRA-2004 PABC. The releases in each replicate are very similar.

Figure 4.17 compares the mean, median, 90th, 50th, and 10th quantiles for each replicate's distribution of CCDFs for cuttings and cavings releases. Figure 4.17 shows that each replicate's distribution is quite similar. Figure 4.18 shows the 95 percent confidence intervals about the overall cuttings and cavings mean. The confidence interval is extremely tight.

Figure 4.19 shows the mean CCDFs for cuttings and cavings releases for all replicates of the CRA-2004. For further comparison, the overall mean CCDFs for cuttings and cavings releases from both analyses are shown in Figure 4.20. These resulting overall mean CCDFs are very similar, with the only significant differences occurring at probabilities less than approximately 0.003. These differences are due to modifications of the inventory implemented in the CRA-2004 PABC since the overall mean CCDFs for cuttings and cavings volumes from the two analyses are nearly identical (Figure 4.21), and releases are calculated by multiplying the cuttings and cavings volume by the average activity of three randomly sampled waste streams.

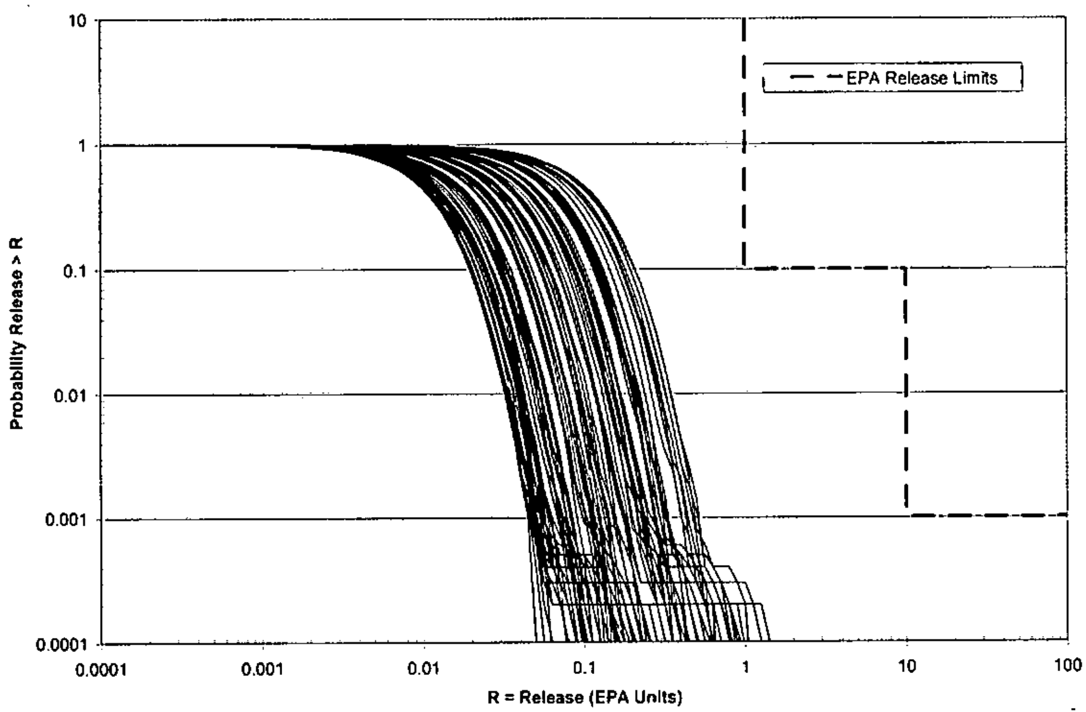

Figure 4.13. Cuttings and Cavings Normalized Releases: Replicate 1 of the CRA-2004 PABC

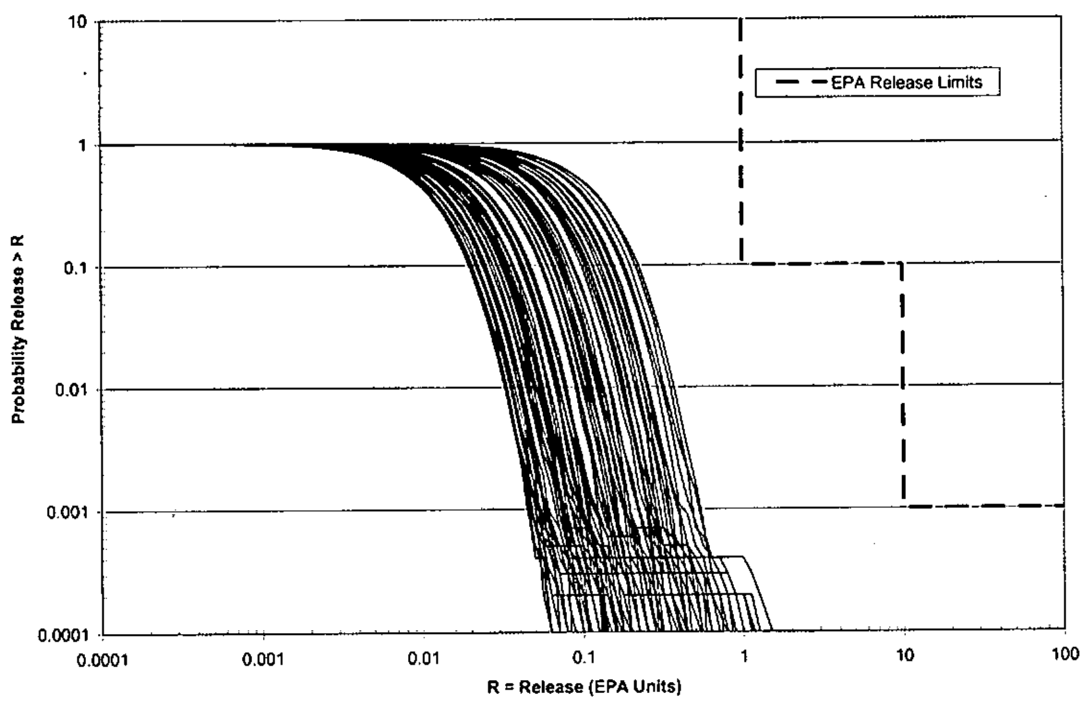

Figure 4.14. Cuttings and Cavings Normalized Releases: Replicate 2 of the CRA-2004 PABC

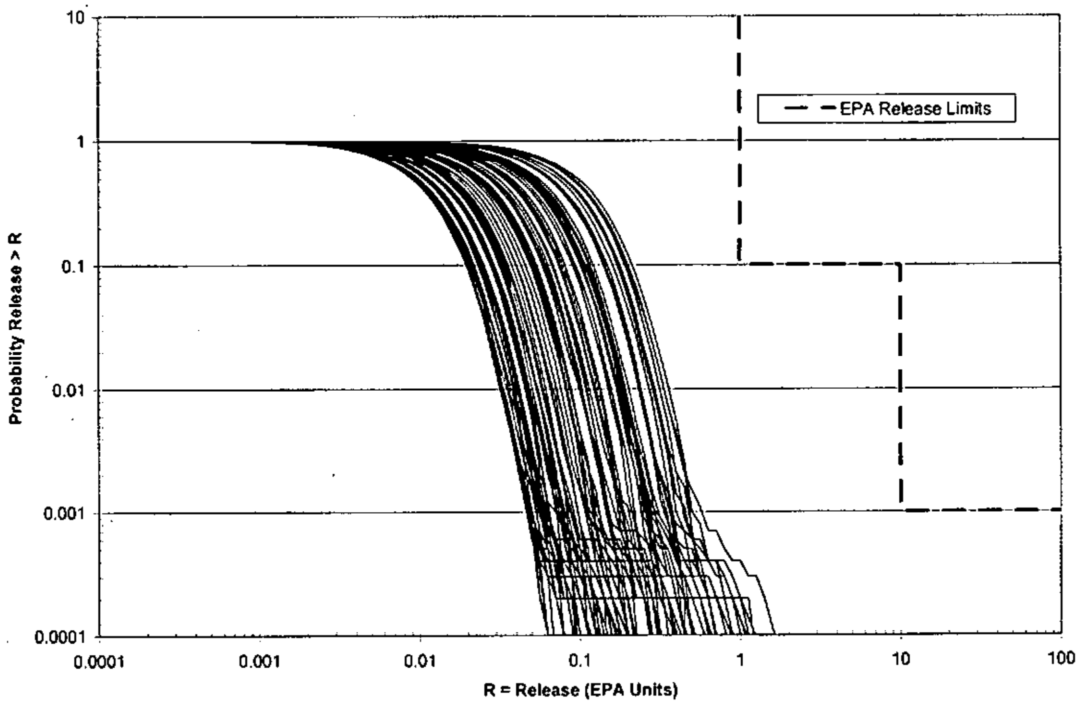

Figure 4.15. Cuttings and Cavings Normalized Releases: Replicate 3 of the CRA-2004 PABC

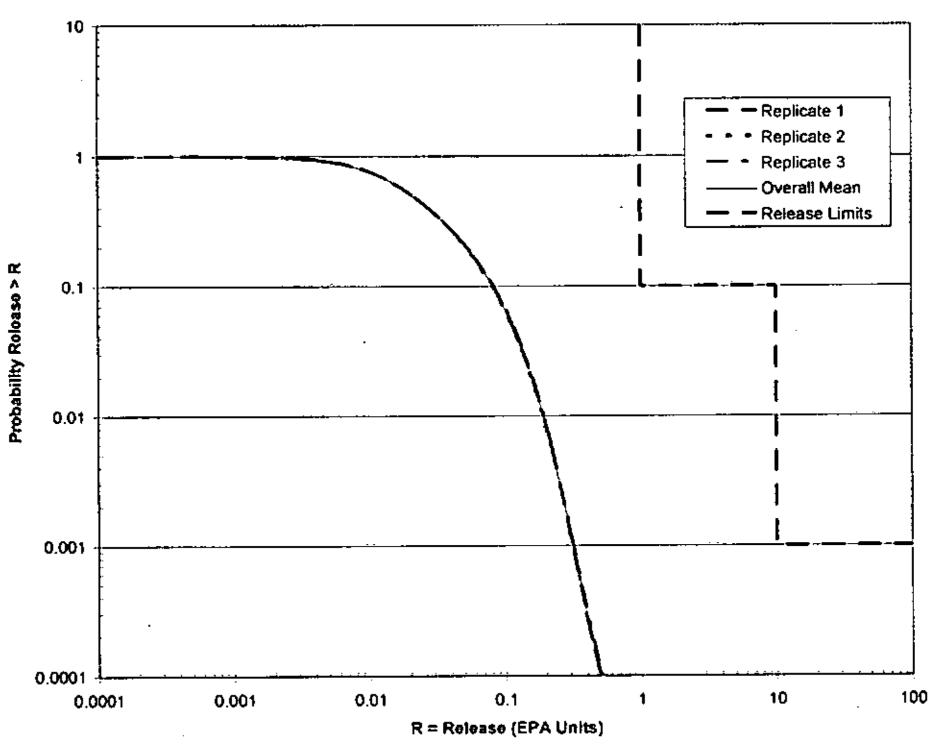

Figure 4.16. Mean CCDFS for Cuttings and Cavings Releases: All Replicates of the CRA-2004 PABC

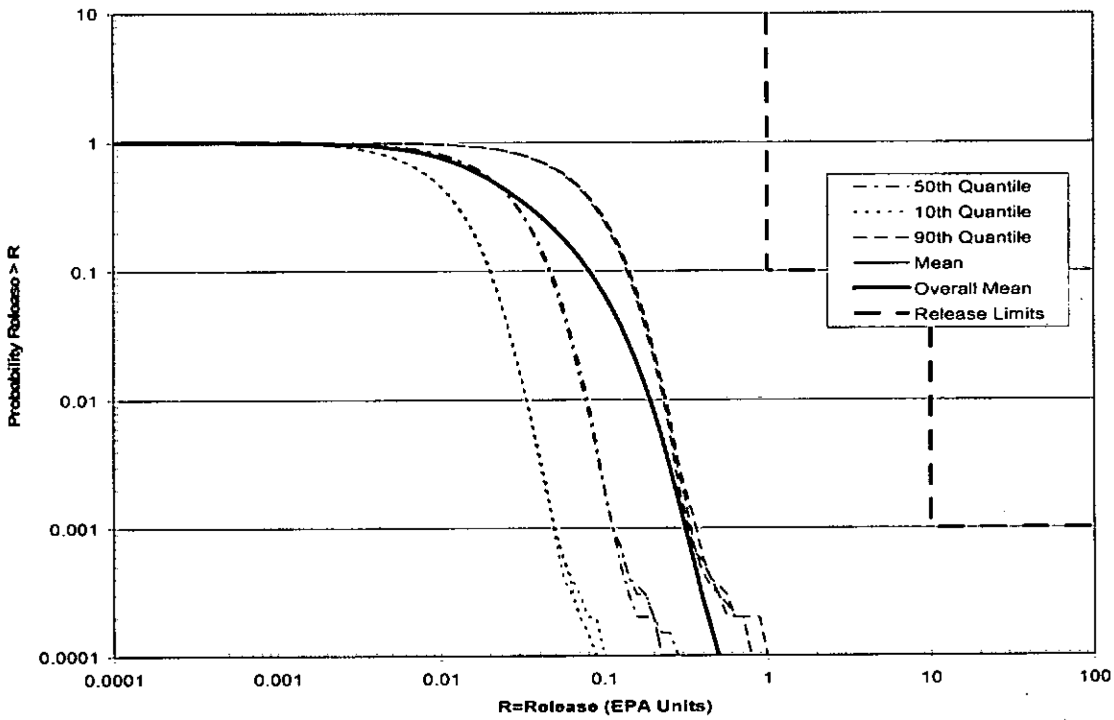

Figure 4.17. Mean and Quantile CCDFs for Cuttings and Cavings Normalized Releases: All Replicates of the CRA-2004 PABC

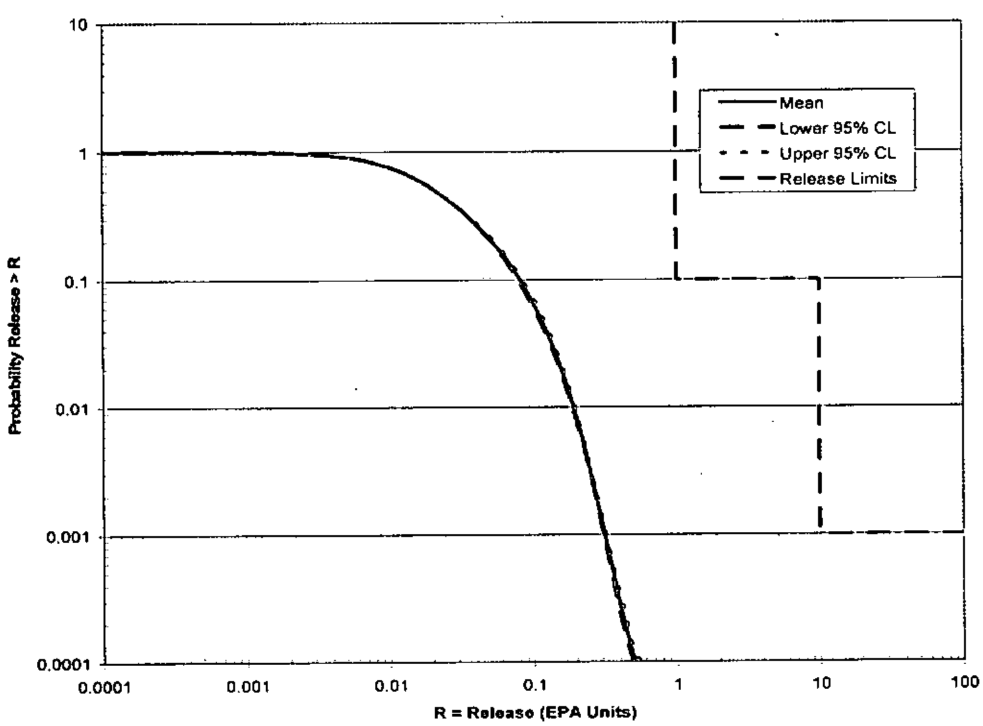

Figure 4.18. Confidence Interval on Overall Mean CCDF for Cuttings and Cavings Normalized Releases: CRA-2004 PABC

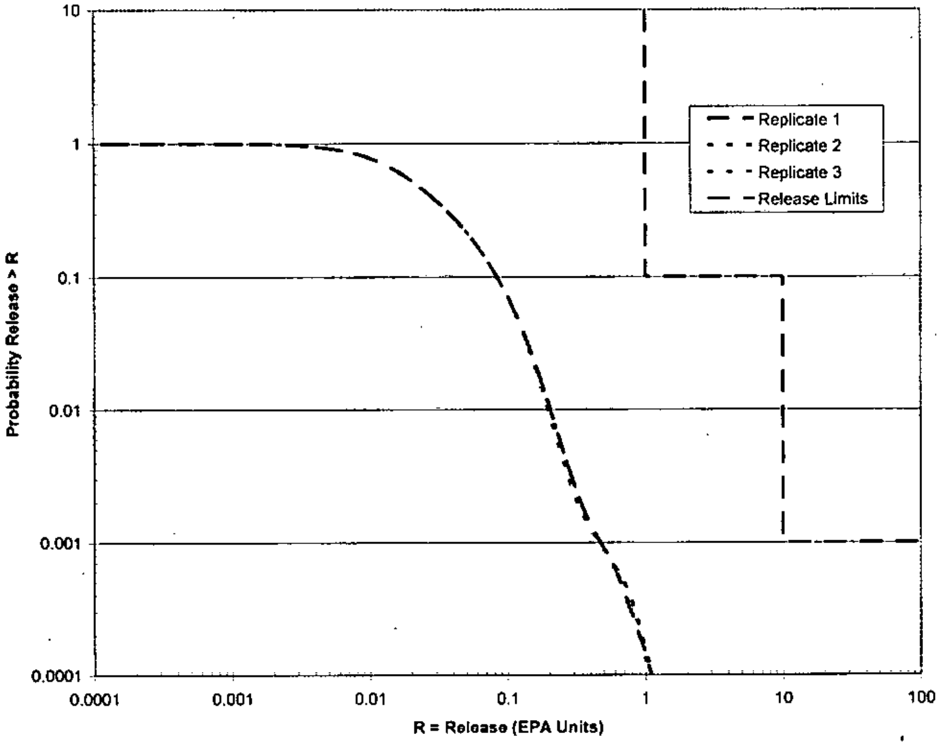

Figure 4.19. Mean CCDFS for Cuttings and Cavings Releases: All Replicates of the CRA-2004

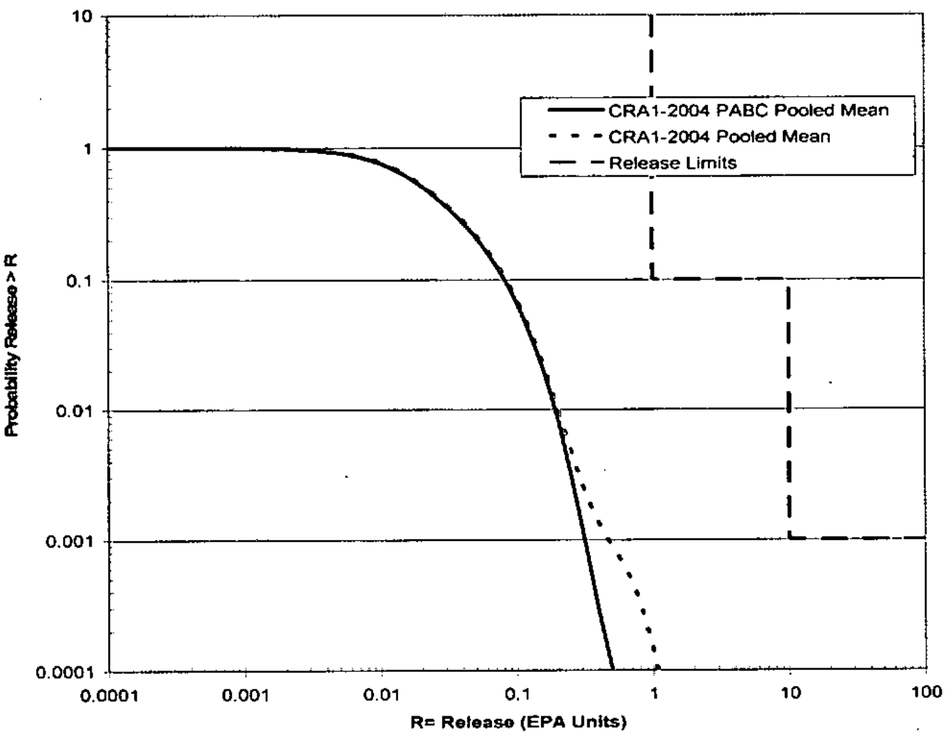

Figure 4.20. Overall Mean CCDFs for Cuttings and Cavings Releases: CRA-2004 PABC and CRA-2004

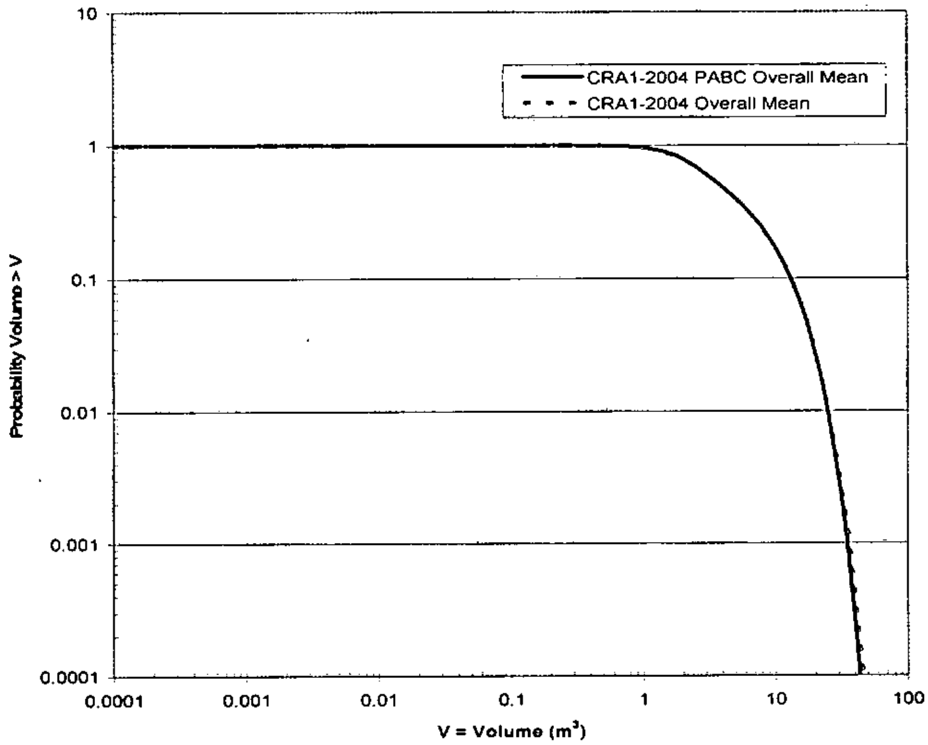

Figure 4.21. Overall Mean CCDFs for Cuttings and Cavings Volumes: CRA-2004 PABC and CRA-2004

The increase in CRA-2004 cuttings and cavings releases at a probability of 0.003 in each replicate was due to a single waste stream, LA-TA-55-48, with very high radioactivity that was present in the CRA-2004 inventory. These waste streams maintain significant radioactivity during the 10,000-year period. The volume of the LA-TA-55-48 waste stream in the CRA-2004 inventory (31 m^3) implies that if a waste stream were selected at random, the probability of selecting the LA-TA-55-48 waste stream is 31/168,500 = 0.00018. However, in any future of the repository, roughly six intrusions are expected (Dunagan 2003), implying that 18 waste streams are selected for cuttings and cavings releases. The mean probability that the LA-TA-58-48 waste stream is selected at least once for CRA-2004 cuttings and cavings releases is estimated to be

$$1-(1-0.00018)^{18}=0.0033\,;$$

During the inventory update for the CRA-2004 PABC, it was noted that given the radionuclide concentrations reported for this volume of waste, the fissile gram equivalents (FGE) per container were approximately ten times that allowed for shipment to WIPP. As a result, the Los Alamos National Laboratories (LANL) site was contacted and asked to re-examine their reporting of this waste stream. Upon review, LANL reported revised data for LA-TA-55-48. The new data for LA-TA-55-48 had reduced radionuclide concentrations so that the FGE for LA-TA-55-48 for CRA-2004 PABC are within the FGE limits for waste that is shippable to WIPP. As a result, the CRA-2004 cuttings and cavings releases exceed CRA-2004 PABC releases at probabilities less than 0.003.

4.3 Spallings Normalized Releases

Figure 4.22, Figure 4.23, and Figure 4.24 show the CCDFs for spallings releases for replicates 1, 2, and 3 of the CRA-2004 PABC.

Figure 4.25 compares the mean and 90th quantiles for each replicate's distribution of CCDFs for spallings releases. Figure 4.26 shows the 95 percent confidence intervals about the overall spallings mean.

Figure 4.27 shows the mean spallings release CCDFs for all replicates of the CRA-2004 PABC. For comparison, the mean spallings release CCDFs from the CRA-2004 are shown in Figure 4.28, and Figure 4.29 shows the overall mean spallings release CCDFs for both analyses.

At all probabilities, CRA-2004 PABC overall mean spallings releases are significantly smaller than overall mean spallings releases from the CRA-2004. At a probability of 0.1, CRA-2004 PABC releases are approximately two orders of magnitude smaller (approximately 10^{-4} versus 10^{-2}), and at a probability of 0.001, CRA-2004 PABC releases are one order of magnitude smaller (approximately 10^{-2} versus 10^{-1}).

This decrease in overall mean spallings release values can be directly attributed to a decrease in overall mean spallings volumes (Figure 4.30). Spallings releases are calculated by multiplying spallings volume by the average repository activity at the time of the release. For any given probability shown in Figure 4.29 and Figure 4.30, the overall mean spallings release decreased by approximately the same order of magnitude as the overall mean spallings volume.

As indicated in Vugrin (2005a), the distributions of spallings volumes from a single intrusion calculated by DRSPALL from the CRA-2004 PABC and CRA-2004 were similar. CUTTINGS_S interpolates the DRSPALL volumes using repository pressures calculated by BRAGFLO to calculate the spallings volume released from a single intrusion for the WIPP PA intrusion scenarios. As shown in Vugrin (2005b), the frequency of nonzero spallings intrusions calculated by CUTTINGS_S decreased significantly. This reduction is directly attributed to the reduced microbial gas generation rates implemented in BRAGFLO for the CRA-2004 PABC (Nemer at al. 2005). In fact, about two thirds of all CRA-2004 PABC vectors did not have CCDFs that predicted a release of 10^{-4} EPA units at any probability. This compares with approximately one half of all CRA-2004 vectors.

The decreased mean spallings releases for the CRA-2004 PABC had a direct impact on the confidence intervals for the overall mean CCDF for total releases. Of cuttings and cavings, spallings, and DBRs, the mean CCDFs for spallings releases showed the greatest variability in the CRA-2004. This variability directly contributed the variability of the mean CCDFs for total releases which affects the size of the confidence intervals on the overall mean CCDF. Since the CRA-2004 PABC mean spallings CCDFs decreased in magnitude, the spallings mean variability has less of an impact on the variability of total releases. Little variability is observed between replicates of DBR mean CCDFs and cuttings and cavings mean CCDFs for the CRA-2004 PABC, and the result was narrower confidence intervals on the overall mean for total releases.

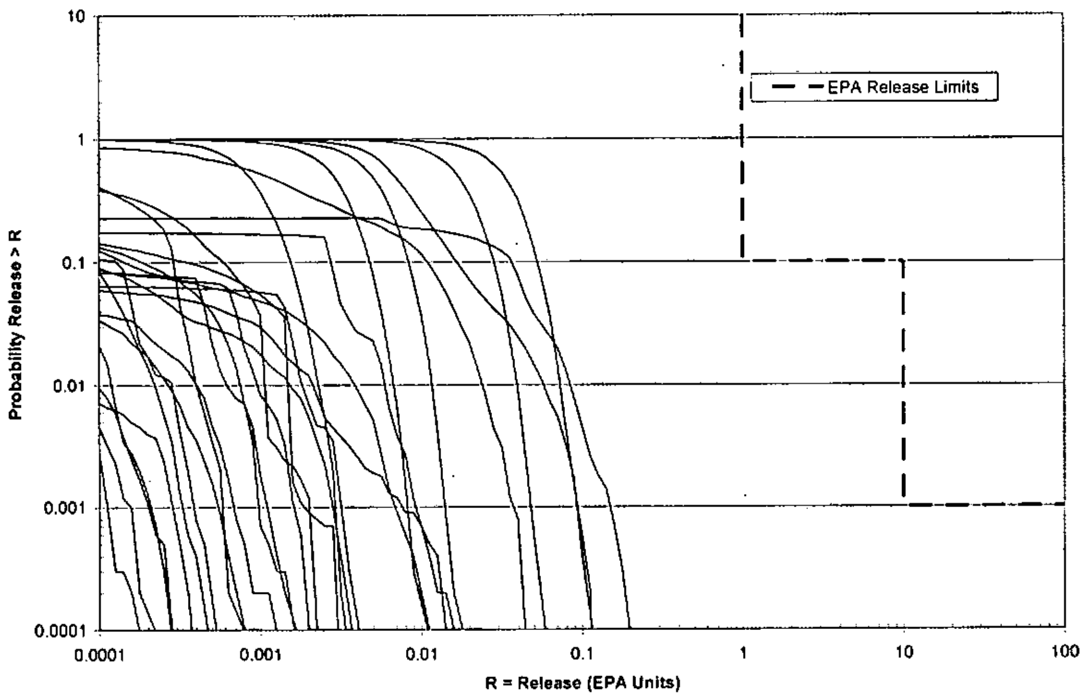

Figure 4.22. Spallings Normalized Releases: Replicate 1 of the CRA-2004 PABC

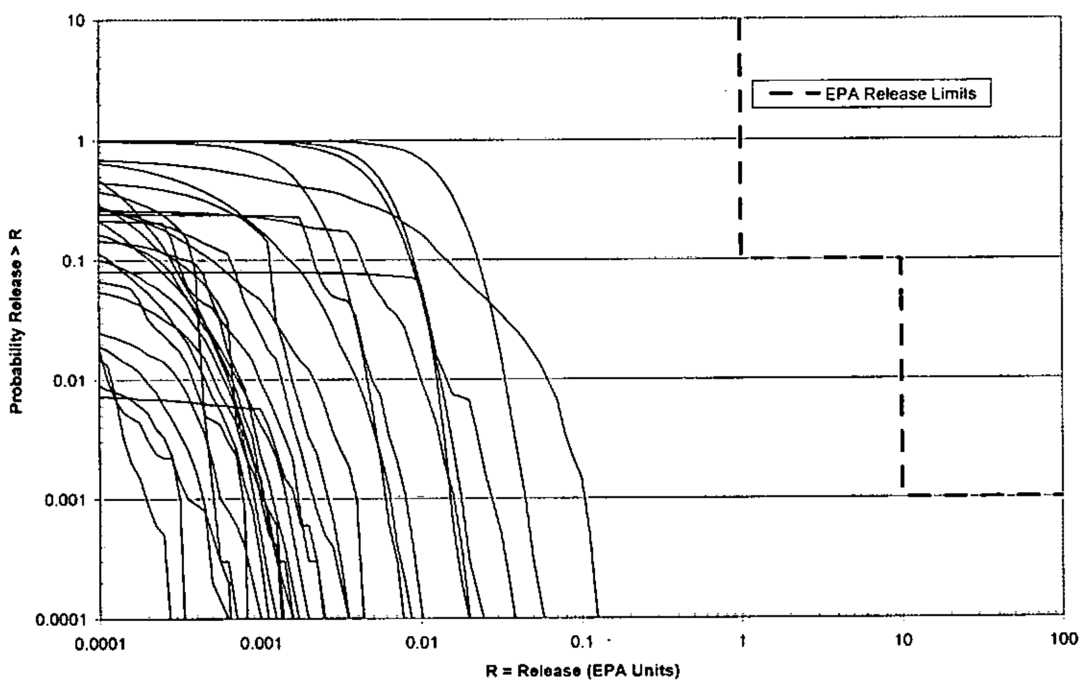

Figure 4.23. Spallings Normalized Releases: Replicate 2 of the CRA-2004 PABC

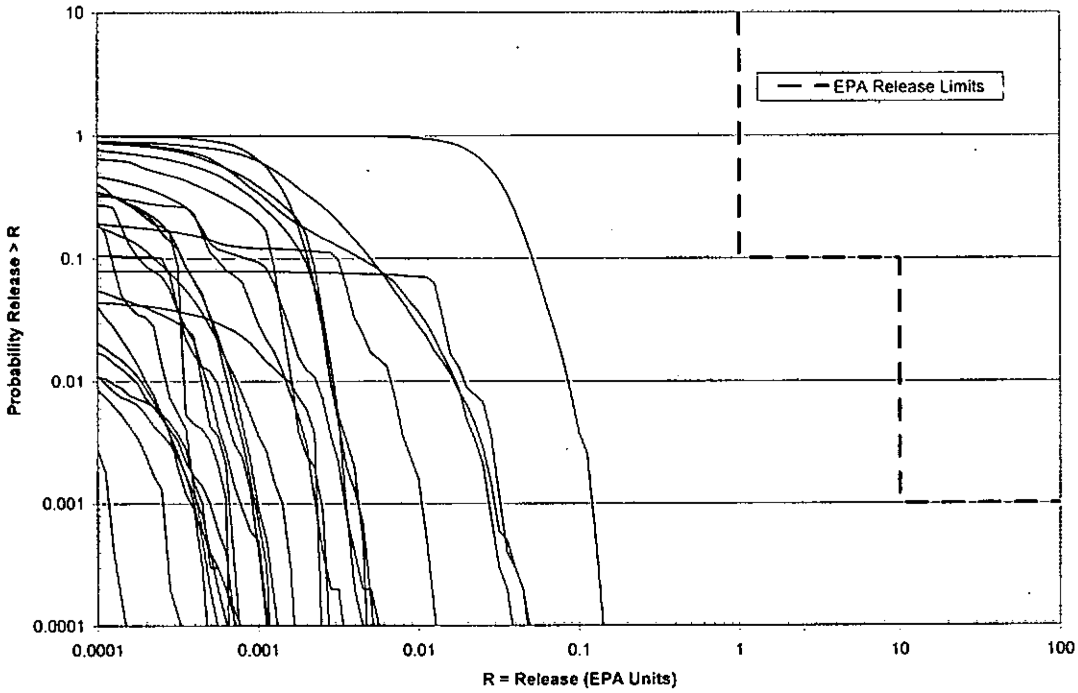

Figure 4.24. Spallings Normalized Releases: Replicate 3 of the CRA-2004 PABC

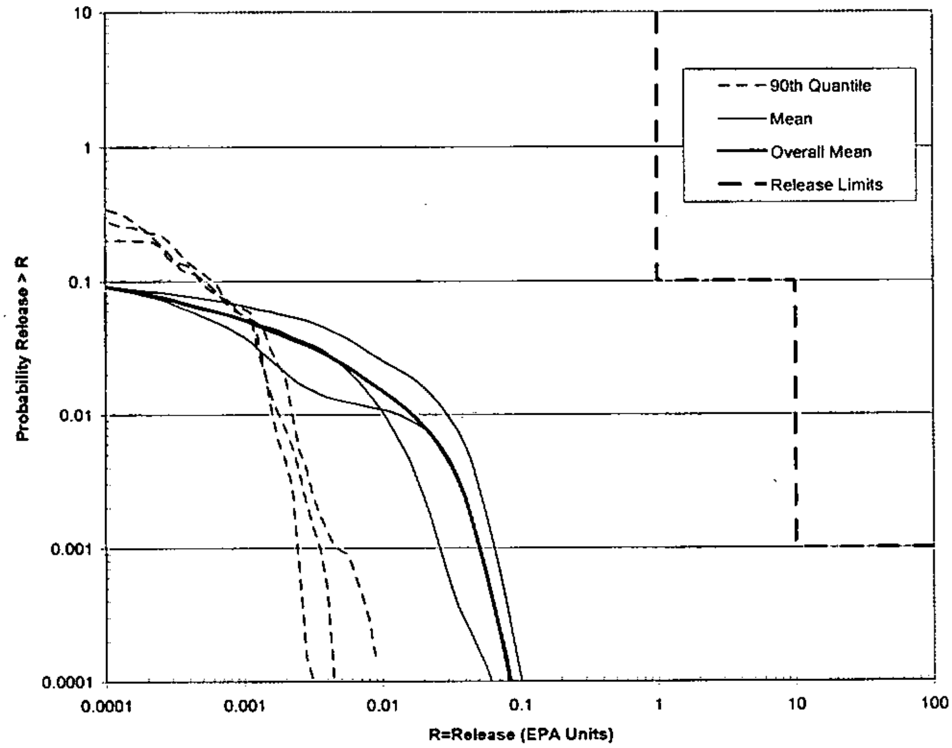

Figure 4.25. Mean and Quantile CCDFs for Spallings Normalized Releases: All Replicates of the CRA-2004 PABC

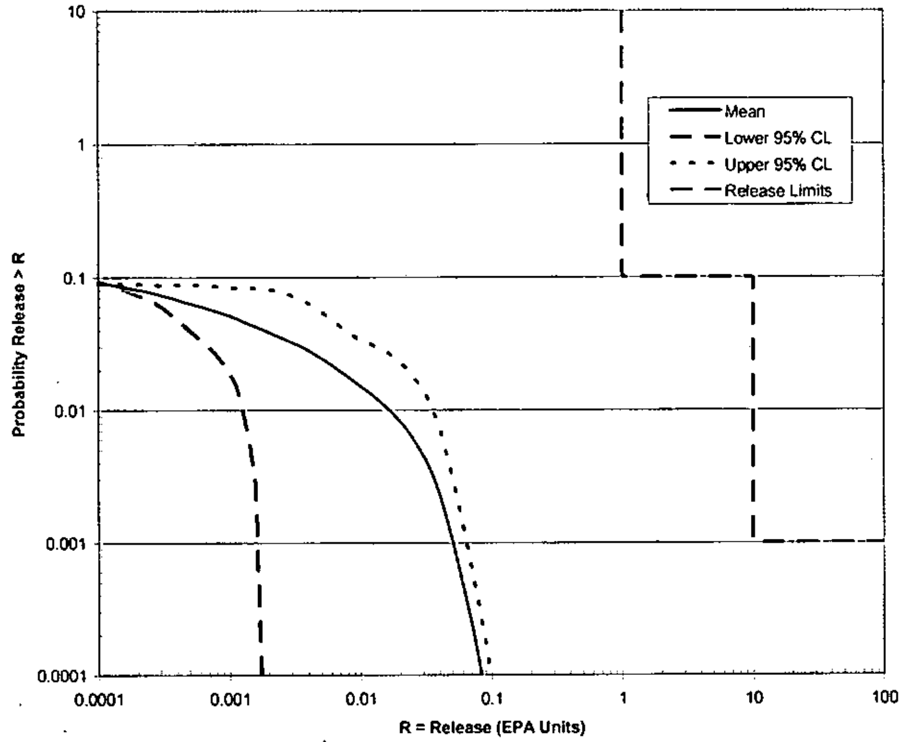

Figure 4.26. Confidence Interval on Overall Mean CCDF for Spallings Normalized Releases: CRA-2004 PABC

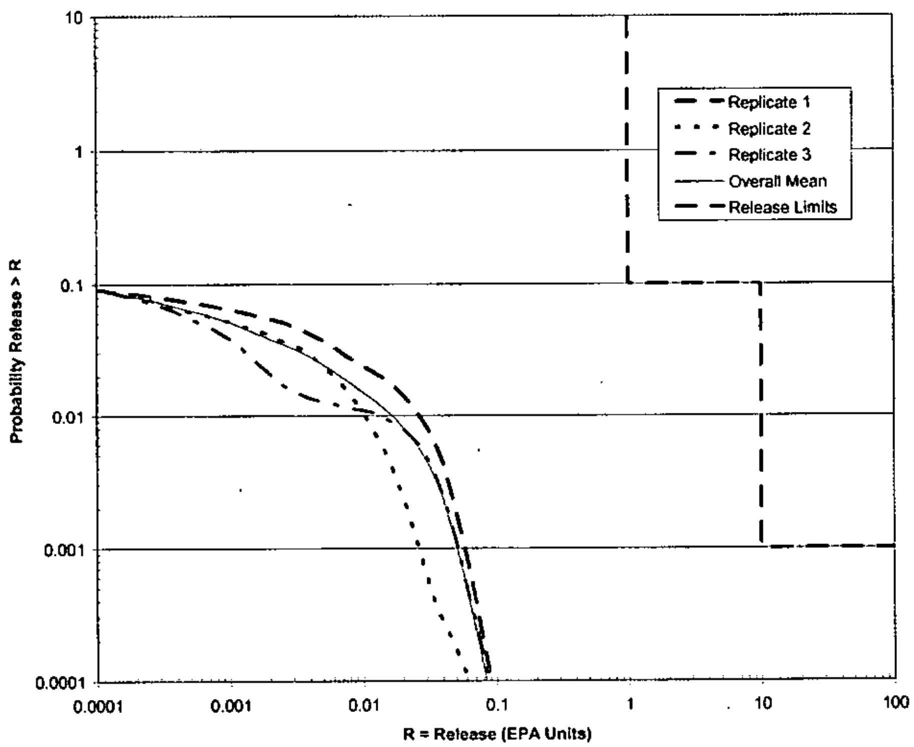

Figure 4.27. Mean CCDFS for Spallings Releases: All Replicates of the CRA-2004 PABC

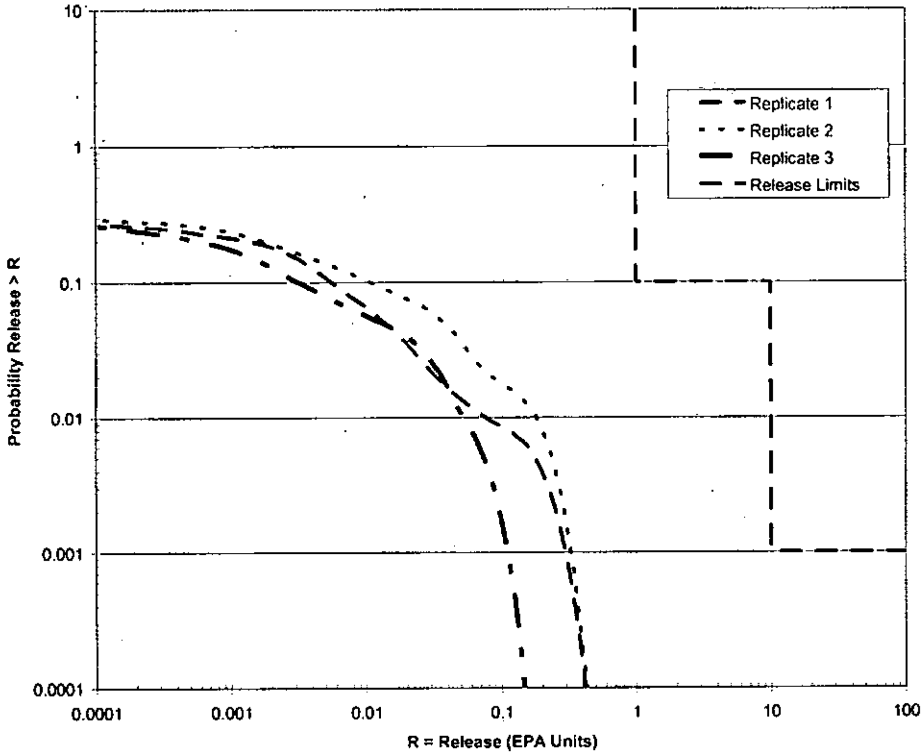

Figure 4.28. Mean CCDFS for Spallings Releases: All Replicates of the CRA-2004

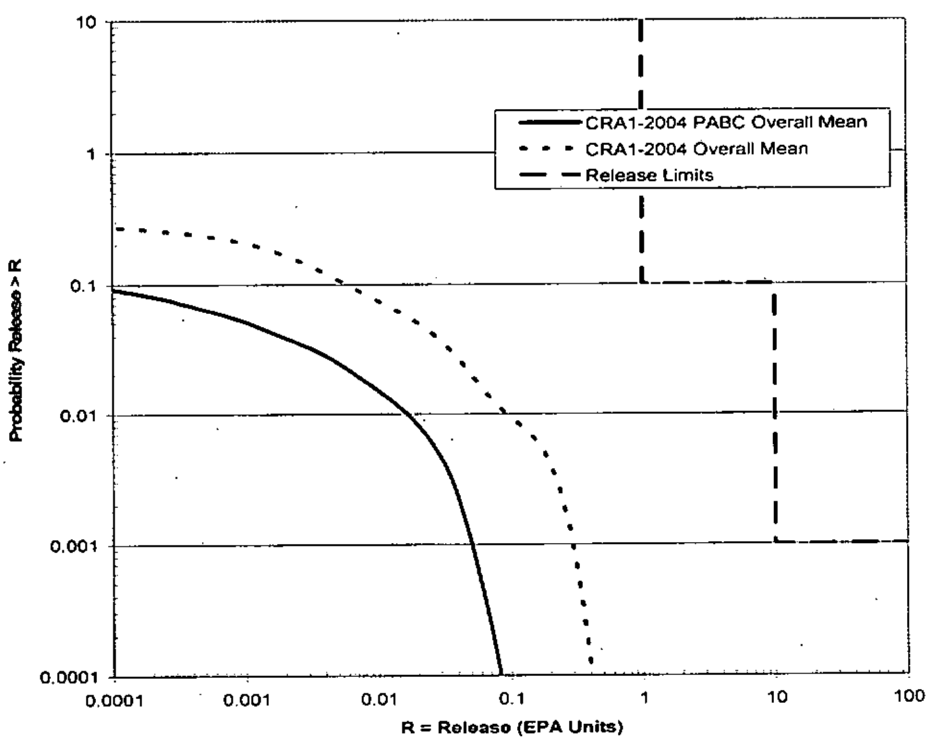

Figure 4.29. Overall Mean CCDFs for Spallings Releases: CRA-2004 PABC and CRA-2004

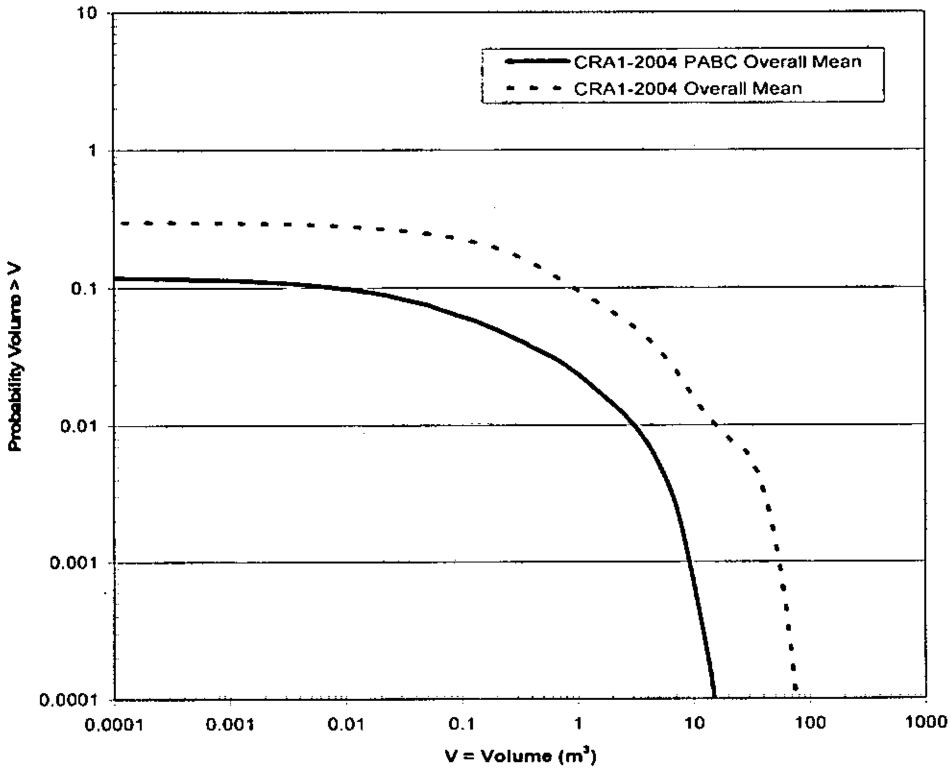

Figure 4.30. Overall Mean CCDFs for Spallings Volumes: CRA-2004 PABC and CRA-2004

4.4 Normalized Direct Brine Releases

Figure 4.31, Figure 4.32, and Figure 4.33 show the CCDFs for DBR releases for replicates 1, 2, and 3 of the CRA-2004 PABC. Figure 4.34 compares the mean, median, 90th, 50th, and 10th quantiles for each replicate's distribution of CCDFs for DBR releases. Figure 4.35 shows the 95 percent confidence intervals about the overall DBR mean.

Figure 4.36 shows the mean DBR CCDFs for all replicates of the CRA-2004 PABC. For comparison, the mean DBR CCDFs for the CRA-2004 are shown in Figure 4.37, and Figure 4.38 shows the overall mean DBR CCDFs from both analyses. At all probabilities, CRA-2004 PABC mean DBRs increased from the CRA-2004 values. In fact, DBRs are now the second largest contributor to total releases at most probabilities, and the dominant contributor at very low probabilities (Figure 4. 6, Figure 4. 7, and Figure 4. 8).

Calculation of DBRs can be primarily affected by two sources: the volume of the DBR and the solubility of actinides in the brine. Two significant changes were made to WIPP PA that affected calculation of DBRs. The first was implementation of the new probability for microbial activity and reduced microbial microbial gas generation rates in the BRAGFLO model (Nemer et al. 2005). These changes affect both pressure and the amount of brine in the repository, so the new rates impacted the volumes of DBRs.

The second set of changes that affected DBRs involve modifications of actinide solubilities. The EPA specified that a revised estimate of 1×10^{-3} M be used for the solubility of U(+VI) in WIPP brines for the CRA-2004 PABC source term. This solubility is approximately two orders of magnitude larger than the value used for the CRA-2004. Additionally, new uncertainty ranges for +III and +IV oxidation states were implemented for the CRA-2004 PABC. In comparison the CRA-2004 ranges, the CRA-2004 PABC ranges were expanded. For further discussion of these changes and other more minor modifications to actinide solubilities, see Garner and Leigh (2005).

The overall mean CCDFs for DBR volumes from the two analyses are shown in Figure 4.39. The overall mean CCDF for CRA-2004 PABC volumes exceeds that of the CRA-2004 for probabilities greater than 0.02, and for smaller probabilities, the CRA-2004 overall mean CCDF for DBR volumes predicts slightly larger volumes. Implementation of the changes to the microbial gas generation model may have had some impact at large probabilities. However, it is clear that the changes to the actinide solubilities played a large factor in the increase of DBR releases. At probabilities less than 0.01, the CRA-2004 overall mean for DBR volumes exceeds the CRA-2004 PABC overall mean for DBR volumes, the CRA-2004 PABC overall mean for DBRs exceeds the the CRA-2004 overall mean for DBRs at all probabilities. Thus, it is certain, that at least at probabilities less than 0.01, the changes to actinide solubilities are responsible for the increase in DBRs.

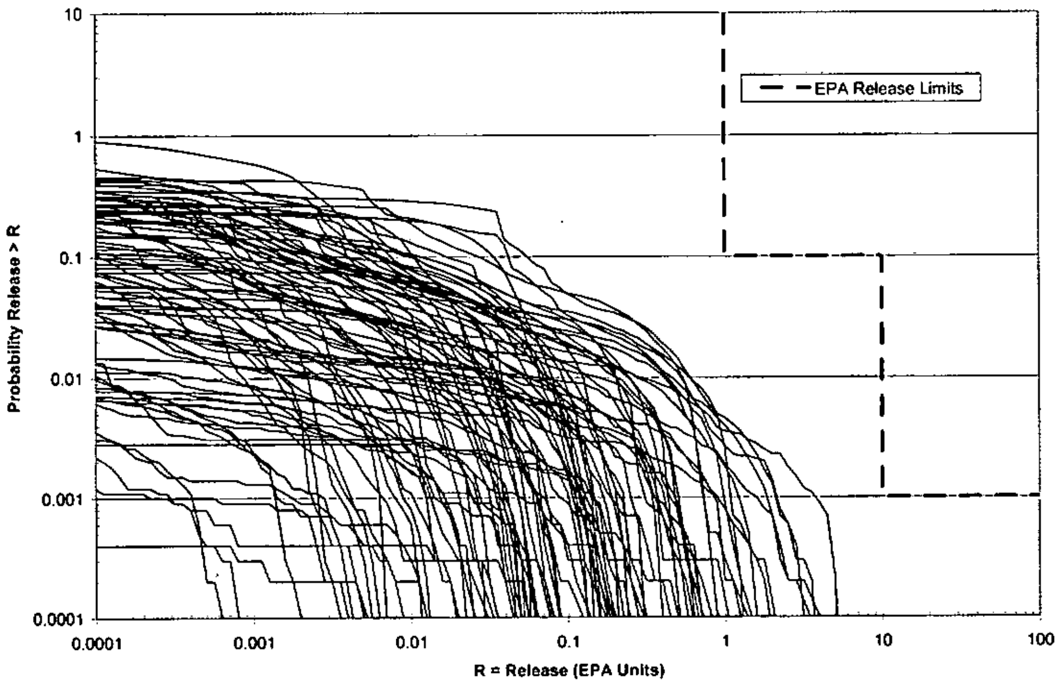

Figure 4.31. DBR Normalized Releases: Replicate 1 of the CRA-2004 PABC

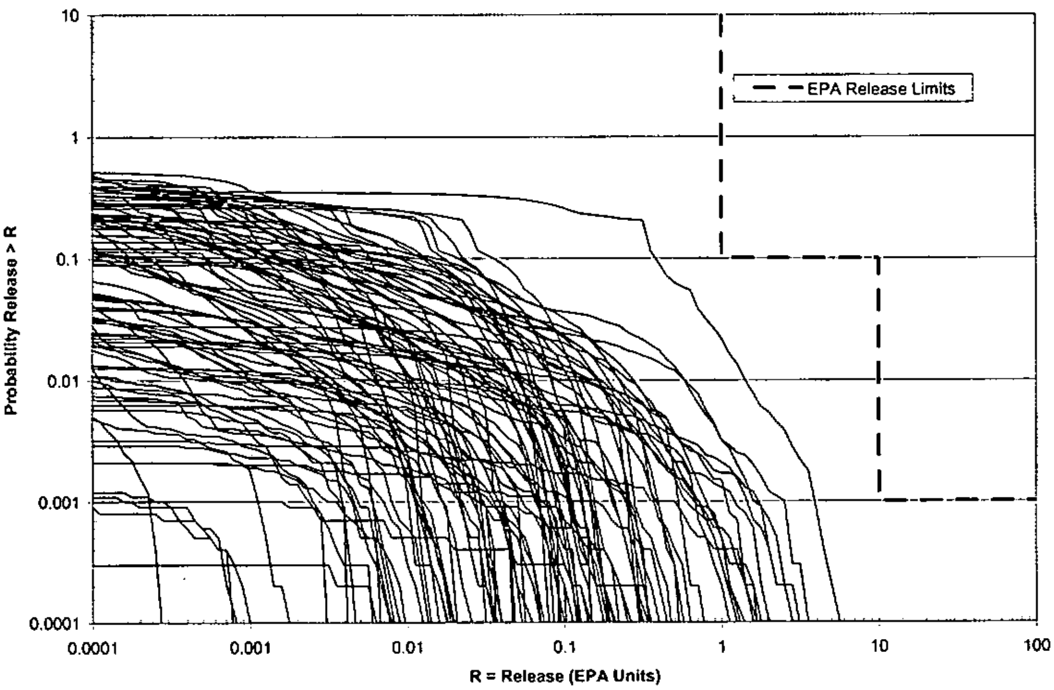

Figure 4.32. DBR Normalized Releases: Replicate 2 of the CRA-2004 PABC

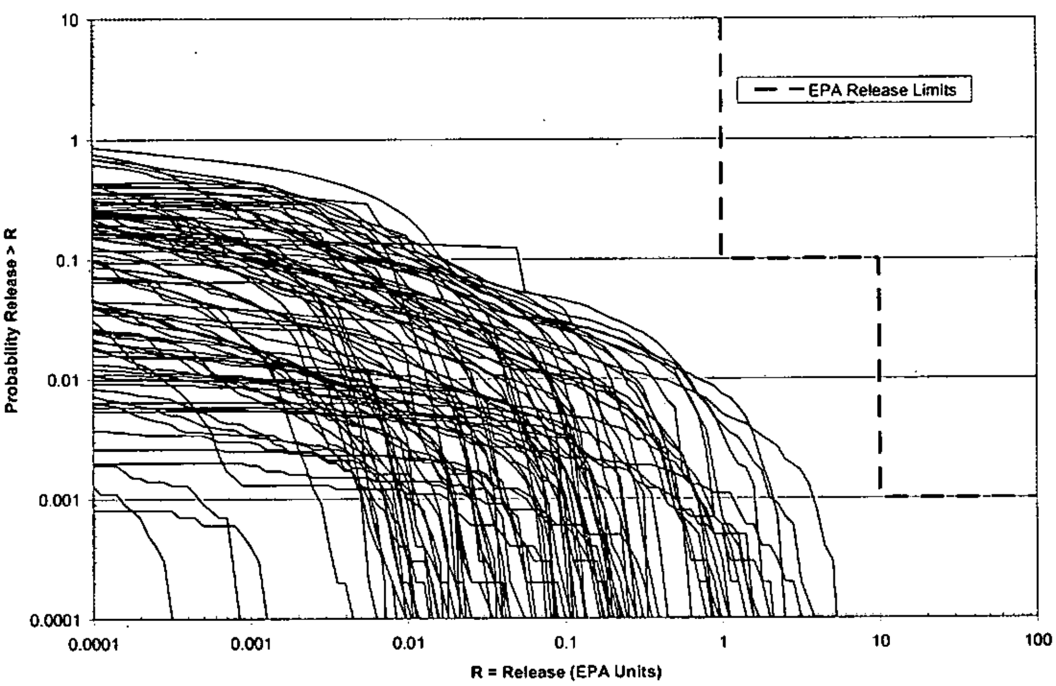

Figure 4.33. DBR Normalized Releases: Replicate 3 of the CRA-2004 PABC

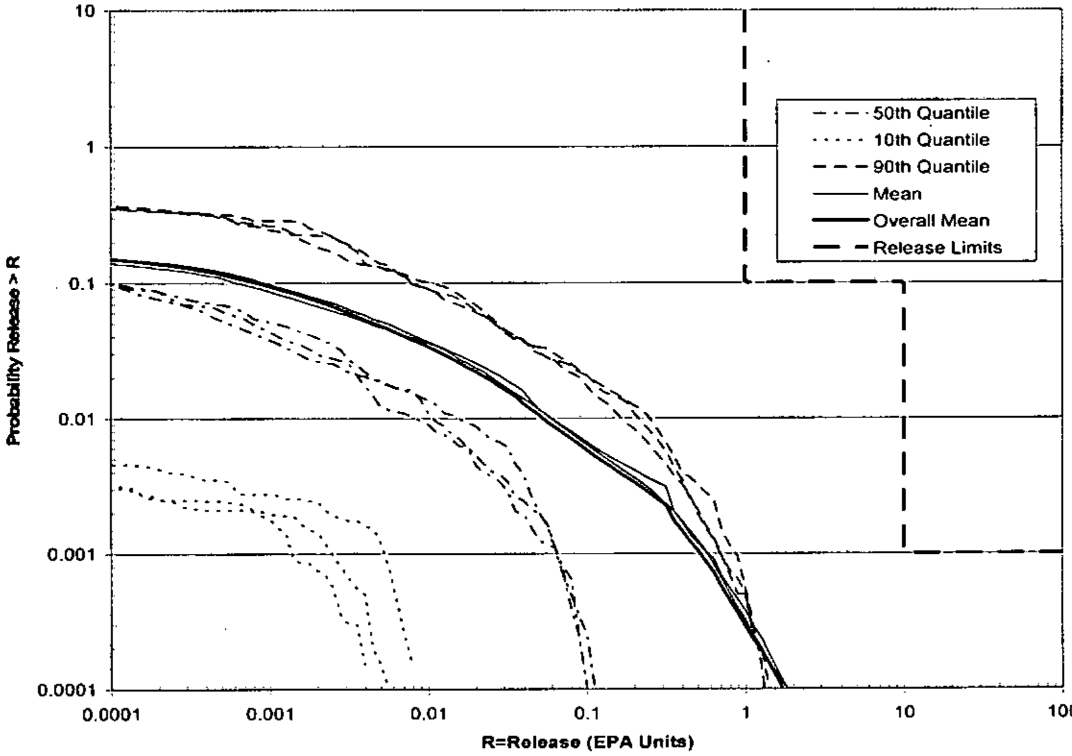

Figure 4.34. Mean and Quantile CCDFs for DBR Normalized Releases: All Replicates of the CRA-2004 PABC

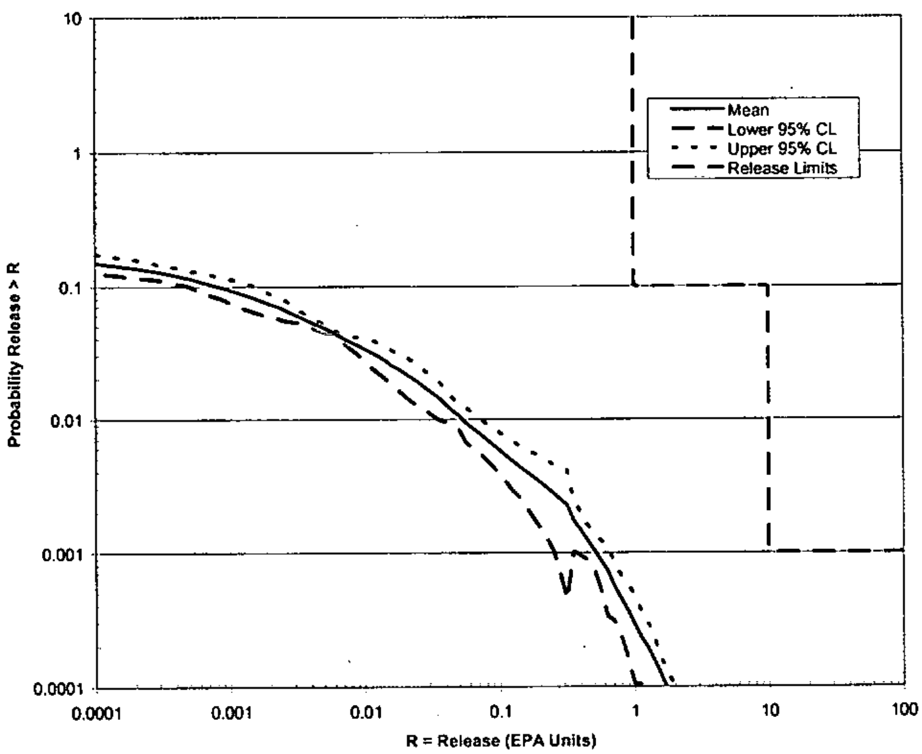

Figure 4.35. Confidence Interval on Overall Mean CCDF for DBR Normalized Releases: CRA-2004 PABC

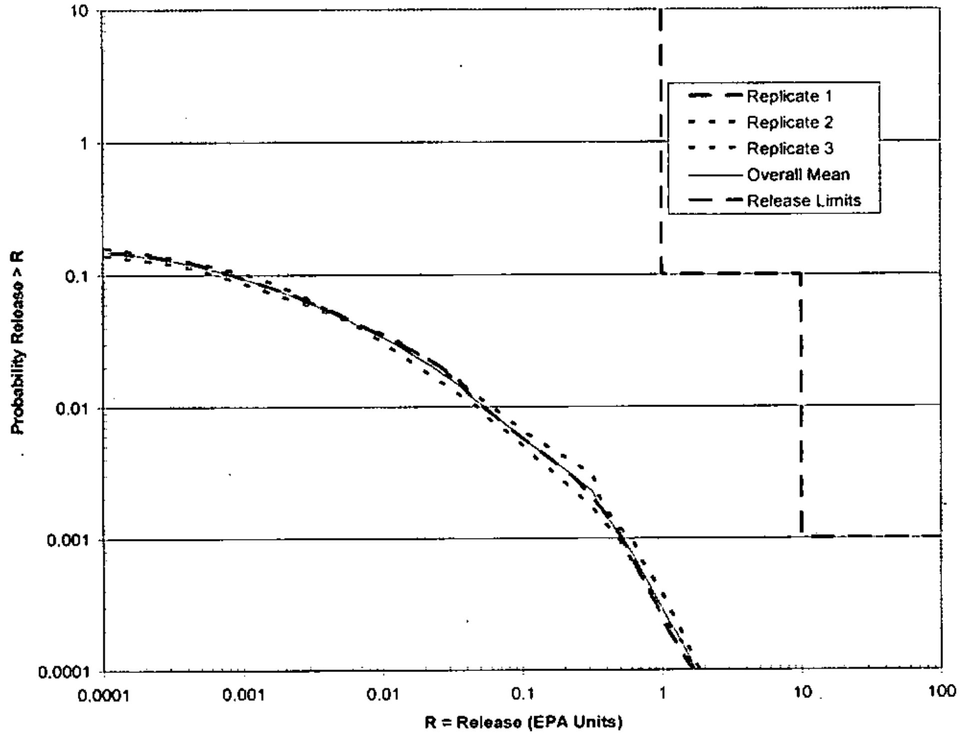

Figure 4.36. Mean CCDFS for DBRs: All Replicates of the CRA-2004 PABC

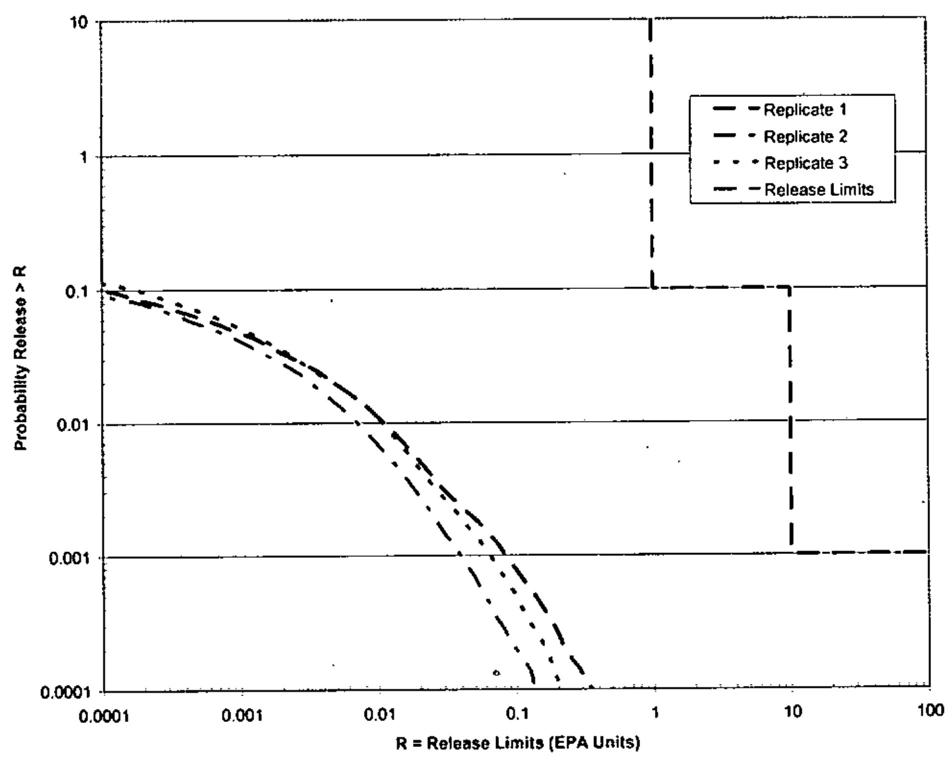

Figure 4.37. Mean CCDFS for DBRs: All Replicates of the CRA-2004

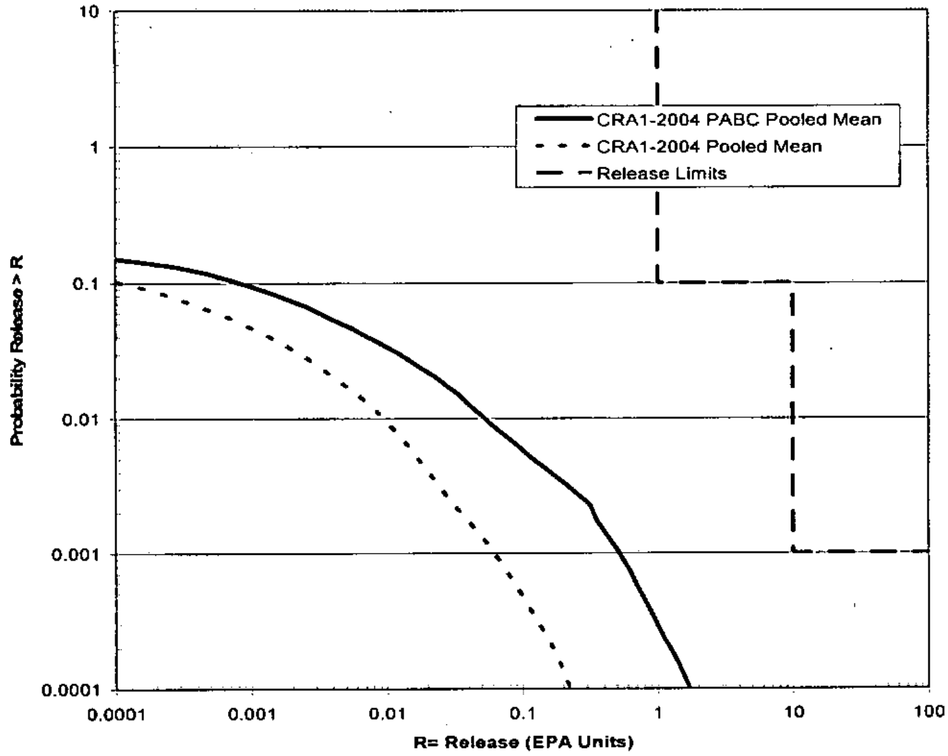

Figure 4.38. Overall Mean CCDFs for DBRs: CRA-2004 PABC and CRA-2004

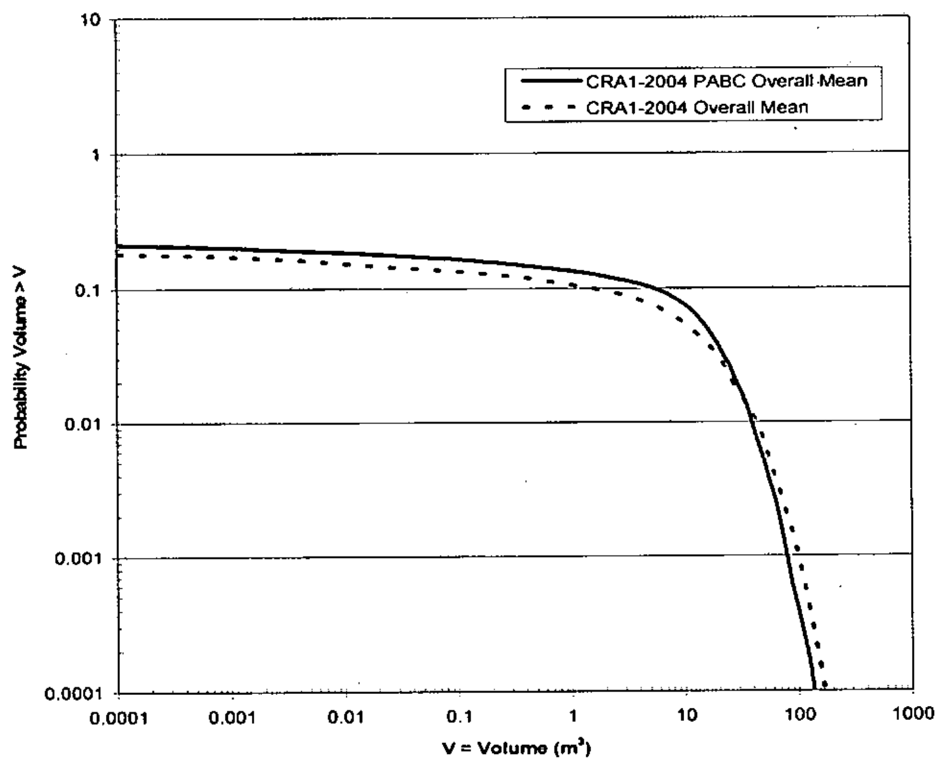

Figure 4.39. Overall Mean CCDFs for DBR Volumes: CRA-2004 PABC and CRA-2004

4.5 Normalized Transport Releases

Figure 4.40 shows the mean CCDF for normalized releases due to transport through the Culebra for replicate R2 (No transport releases larger than 10^{-6} EPA units occurred in replicates R1 and R3).

Normalized transport releases for the CRA-2004 PABC are qualitatively similar to the CRA-2004 results in that only one replicate exhibits releases that are significantly larger than the numerical error inherent in the transport calculations. Overall, fewer vectors had releases in the CRA-2004 PABC than were observed in the CRA-2004. This decrease is attributed to the increase in mean advective travel times that occurred when the exclusion zone around oil and gas boreholes was removed from the mining-modified Culebra T-fields.

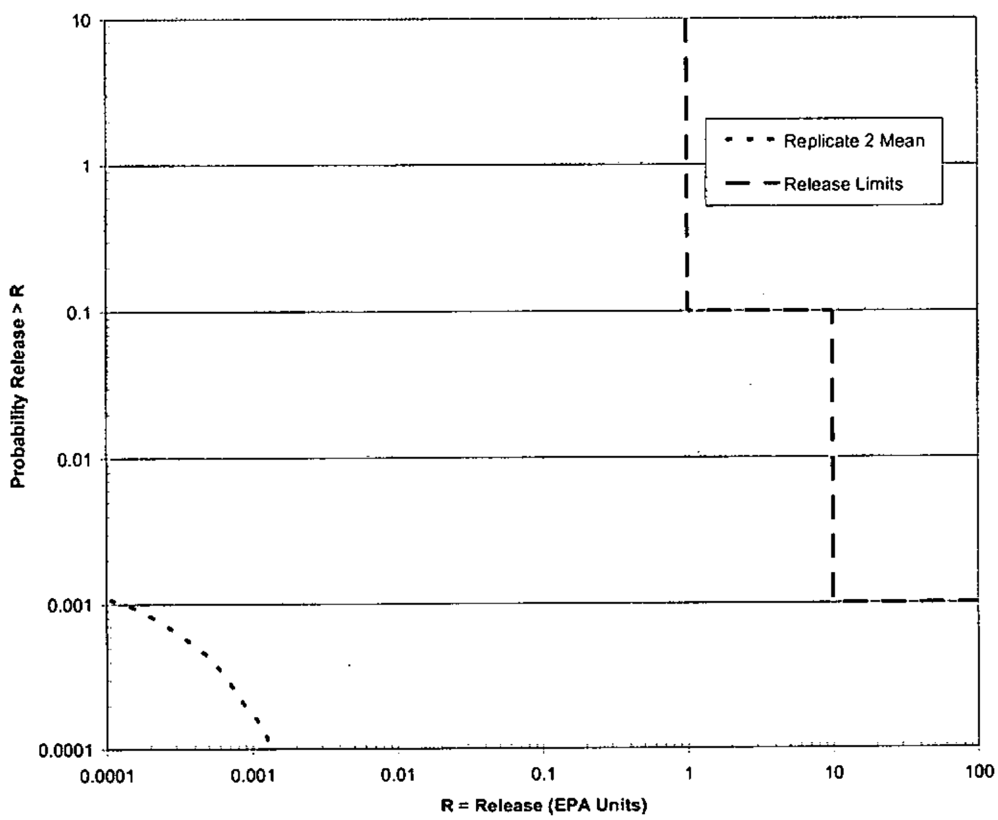

Figure 4.40. Mean CCDF for Releases from the Culebra for Replicate 2 of the CRA-2004 PABC

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9/6/05

Vugrin, Eric D

From: Dunagan, Sean
Sent: Tuesday, September 06, 2005 3:47 PM
To: Vugrin, Eric D; Chavez, Mario Joseph
Subject: Signature authority

Eric Vugrin has my signature authority for "Analysis Package for CCDFGF:CRA-2004 Performance Assessment Baseline Calculation" and its associated documents.

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