560074

Sandia National Laboratories

Waste Isolation Pilot Plant

Analysis Package for CCDFGF: 2014 Compliance Recertification Application Performance Assessment (CRA-2014 PA)

Revision 0

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WIPP:1.2.5:PA:QA-L:559199

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1 Introduction

The Waste Isolation Pilot Plant (WIPP), located in southeastern New Mexico, has been developed by the U.S. Department of Energy (DOE) for the geologic (deep underground) disposal of transuranic (TRU) 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), Part 191. The DOE demonstrates compliance with the containment requirements according to the Certification Criteria in Title 40 CFR Part 194 by means of performance assessment (PA) calculations performed by Sandia National Laboratories (SNL). WIPP PA calculations estimate the probability and consequence of potential radionuclide releases from the repository to the accessible environment for a regulatory period of 10,000 years after facility closure. The models used in PA are maintained and updated with new information as part of an ongoing process. Improved information regarding important WIPP features, events, and processes typically results in refinements and modifications to PA models and the parameters used in them. Planned changes to the repository and/or the components therein also result in updates to WIPP PA models. WIPP PA models are used to support the repository recertification process that occurs at five-year intervals following the receipt of the first waste shipment at the site in 1999.

PA calculations were included in the 1996 Compliance Certification Application (CCA) (U.S. DOE 1996), and in a subsequent Performance Assessment Verification Test (PAVT) (MacKinnon and Freeze 1997a, 1997b and 1997c). Based in part on the CCA and PAVT PA calculations, the EPA certified that the WIPP met the regulatory containment criteria. The facility was approved for disposal of transuranic waste in May 1998 (U.S. EPA 1998). PA calculations were an integral part of the 2004 Compliance Recertification Application (CRA-2004) (U.S. DOE 2004). During their review of the CRA-2004, the EPA requested an additional PA calculation, referred to as the CRA-2004 Performance Assessment Baseline Calculation (PABC) (Leigh et al. 2005), be conducted with modified assumptions and parameter values (Cotsworth 2005). Following review of the CRA-2004 and the CRA-2004 PABC, the EPA recertified the WIPP in March 2006 (U.S. EPA 2006).

PA calculations were completed for the second WIPP recertification and documented in the 2009 Compliance Recertification Application (CRA-2009). The CRA-2009 PA resulted from continued review of the CRA-2004 PABC, including a number of technical changes and corrections, as well as updates to parameters and improvements to the PA computer codes (Clayton et al. 2008). To incorporate additional information which was received after the CRA-2009 PA was completed, but before the submittal of the CRA-2009, the EPA requested an additional PA calculation, referred to as the 2009 Compliance Recertification Application Performance Assessment Baseline Calculation (CRA-2009 PABC) (Clayton et al. 2010), be undertaken which included updated information (Cotsworth 2009). Following the completion and submission of the CRA-2009 PABC, the WIPP was recertified in 2010 (U.S. EPA 2010).

The Land Withdrawal Act (U.S. Congress 1992) requires that the DOE apply for WIPP recertification every five years following the initial 1999 waste shipment. The 2014 Compliance Recertification Application (CRA-2014) is the third WIPP recertification application submitted by the DOE for EPA approval. The PA executed by SNL in support of the CRA-2014 PA is detailed in AP-164 (Camphouse 2013a). The CRA-2014 PA includes a number of technical changes and parameter refinements, as well as a redesigned WIPP panel closure system. Results found in the CRA-2014 PA are compared to those obtained in the CRA-2009 PABC in order to assess repository performance in terms of the current regulatory baseline. This analysis package documents the CCDF creation component of the CRA-2014 PA analysis.

2 Methodology

The performance assessment methodology accommodates both aleatory (i.e. stochastic) and epistemic (i.e. subjective) uncertainty in its constituent models. Aleatory uncertainty pertains to unknowable future events such as intrusion times and locations that may affect repository performance. It is accounted for by the generation of random sequences of future events. Epistemic uncertainty concerns parameter values that are assumed to be constants and the constants' true values are uncertain due to a lack of knowledge about the system. An example of a parameter with epistemic uncertainty is the permeability of a material. Epistemic uncertainty is accounted for by sampling of parameter values from assigned distributions. One set of sampled values required to run a WIPP PA calculation is termed a vector. The performance assessment models are executed for three replicates of 100 vectors, each vector being a realization resulting from a particular set of parameter values. A sample size of 10,000 possible sequences of future events is used in the calculations to estimate an exceedance probability of 0.001 (Helton et al., 1998). The releases for each of 10,000 possible sequences of future events are tabulated for each of the 300 vectors, totaling 3,000,000 possible sequences.

For a random variable, the complementary cumulative distribution function (CCDF) provides the probability of the variable being greater than a particular value. By regulation, performance assessment results are presented as a distribution of CCDFs of releases (U.S. EPA 1996). Each individual CCDF summarizes the likelihood of releases across all futures for one vector of parameter values. The uncertainty in parameter values results in a distribution of CCDFs.

The overall mean CCDF is computed as the arithmetic mean of the three mean CCDFs from each replicate. Confidence limits are computed about the overall mean CCDF using the Student's t-distribution, the mean CCDFs from each replicate, and the standard error based on the three replicate means. Confidence limits as they are implemented in PA are defined vertically about the mean, rather than horizontally. An artifact of this convention is that lower confidence limits can sometimes assume negative values, which can not be plotted on a logarithmic scale. When this occurs, the resulting lower confidence curve appears incomplete.

CCDF curves and statistics are generated using the CCDFGF Analysis database utility. A description of this utility can be found in Kirchner (2010). A CD containing the data loaded into this utility resulting from the CRA-2014 PA CCDFGF calculations, and SigmaPlot plots, are included as an attachment to this document and in LIBCRA14_CCGF.

2.1 Code Version

PRECCDFGF version 2.0 and CCDFGF version 6.0 were used for the CRA-2014 PA.

2.2 Random Seed in the CCDFGF Control Files

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

For the CRA-2014 PA, the same random seeds for CCDFGF were used as in the CRA-2009 PABC. This was done to allow a vector by vector comparison of the results of the CRA-2009 PABC to those obtained in the CRA-2014 PA. As the random seeds used to initialize the sampling of the epistemic parameters were unchanged in the CRA-2009 PABC and the CRA-2014 PA, any differences between the analyses can be attributed solely to the changes in the parameters, modeled processes, and repository reconfiguration and not the random seed choice. Random seeds used in the CRA-2014 PA calculations are specified in the files CCGF_CRA14_CONTROLRr.inp, where r = 1,2,3. These files are located in class CRA14-0 in CMS library LIBCRA14_CCGF.

2.3 CRA-2014 PA Cases and Run Control

Changes incorporated into the CRA-2014 PA include planned changes as well as parameter and implementation changes. As discussed in AP-164 (Camphouse 2013a), the approach taken in the CRA-2014 PA is to reasonably isolate impacts associated with these changes, and then to assess the combined impact when all are included in the PA. To that end, four individual cases are investigated in the CRA-2014 PA. Each case is treated as a separate analysis during code execution to ensure that the sequential implementation of change described in AP-164 is done correctly. The first three cases consist of a single replicate, while the fourth case consists of three replicates. All four of the cases impact CCDFGF results (although not all release components are different among all four cases), and are described below.

The first case considered in the CRA-2014 PA is used to compare the impact of a baseline set of changes relative to the CRA-2009 PABC. The name given to this case is CRA14-BL (for CRA-2014 Baseline). A single replicate (Replicate 1) is executed for

Case CRA14-BL and used to ascertain regulatory compliance impacts associated with a set of baseline changes. Changes included in Case CRA14-BL that impact CCDFGF results as compared to the CRA-2009 PABC are:

- Replacement of Option D with the Run-of-Mine Panel Closure System (ROMPCS)
- Additional excavation in the WIPP experimental area
- Updated waste inventory parameters
- Updated radionuclide solubilities and uncertainty, colloid parameters
- Updated drilling rate and plugging pattern parameters

Case CRA14-TP is the second case considered and incorporates all changes included in Case CRA14-BL, as well as the following changes:

- BOREHOLE:TAUFAIL (TAUFAIL hereafter) and GLOBAL:PBRINE (PBRINE hereafter) parameter distribution refinements

Case CRA14-BV is the third case considered and incorporates all changes included in Case CRA14-TP, as well as the following change:

- Variable Brine Volume Implementation, which eliminates a physically impossible situation where a quantity of radionuclides greater than the repository contents is assumed to be dissolved in the brine

Case CRA14-0 is the fourth case considered and incorporates all changes included in the CRA-2014 PA. Case CRA14-0 includes the changes implemented in Case CRA14-BV listed above, as well as the following changes:

- Update to parameter STEEL:CORRMCO2 ("steel corrosion rate" hereafter)
- Refinement to Repository Water Balance Implementation

Three replicates are executed for Case CRA14-0, and are used to determine regulatory compliance impacts associated with the full set of changes implemented in the CRA-2014 PA.

In addition to a description of the CRA-2014 PA results, this report contains comparisons with another PA calculation performed since the CRA-2009 PABC, the PCS-2012 PA calculation. The PCS-2012 PA calculation consists of an update from the CRA-2009 PABC calculation (3 replicates) to include an updated panel closure system and is discussed in AP-161 (Camphouse 2012).

Run control for the CRA-2014 PA is documented in Long (2013).

3 Analysis and Results

Results of the CRA-2014 PA calculations are described in subsections for each release component. Means with 95 percent confidence limits are presented for each component.

At the conclusion of each subsection, results of the CRA-2014 PA are compared to those found in the CRA-2009 PABC.

Normalized releases for cuttings and cavings are discussed in Subsection 3.1. Spallings releases are presented in Subsection 3.2. Results found for direct brine releases are discussed in Subsection 3.3. Normalized transport releases are presented in Subsection 3.4. Finally, total normalized releases are shown in Subsection 3.5.

3.1 Cuttings and Cavings Normalized Releases

CRA-2014 PA cuttings and cavings releases are presented in this section and compared to results obtained in the CRA-2009 PABC. Figure 3-1 shows the cuttings and cavings releases for replicate 1 of the CRA-2009 PABC, Case CRA14-BL, and Case CRA14-0 calculations. Figure 3-2 shows cuttings and cavings volumes for the same calculations.

For replicate 1, the PCS-2012 PA releases are identical to the CRA-2009 PABC releases because the updated panel closure system has no effect on cuttings and cavings releases (Zeitler 2012). Although the cuttings and cavings areas stay the same from the CRA-2009 PABC to Case CRA14-BL (Kicker 2013), the volumes increase due to an increased drilling rate (which results in an increased number of drilling events). The increased volumes lead to an increase in releases due to increased waste inventory.

The cuttings and cavings releases decrease from Case CRA14-BL to Case CRA14-TP due to the updated TAUFAIL parameter (the effective shear strength of waste erosion) distribution. The minimum, median, and mean values of TAUFAIL all increased from CRA-2009 PABC to the CRA-2014 PA. The increased waste shear strength leads to smaller cuttings and cavings volumes (and releases). The updated brine volume calculation (Case CRA14-BV) and iron corrosion parameter (Case CRA14-0) do not affect cuttings and cavings releases, so Case CRA14-BV and Case CRA14-0 cuttings and cavings releases are identical to Case CRA14-TP releases.

Figure 3-3, Figure 3-4, and Figure 3-5 show the CRA-2014 PA cuttings and cavings release CCDFs for replicates 1, 2, and 3, respectively. Figure 3-6 shows the 95 percent confidence limits about the overall cuttings and cavings mean.

The CRA-2009 PABC and the CRA-2014 PA cuttings and cavings CCDFs are plotted together in Figure 3-7 and Figure 3-8 for the overall mean and volume, respectively. Overall, cuttings and cavings normalized releases and volumes calculated for the CRA-2014 PA were smaller than those for the CRA-2009 PABC. Although the changes in waste inventory and drilling rate serve to increase the cuttings and cavings releases (as shown for replicate 1 in Figure 3-1), the effect of the changes to the TAUFAIL parameter is to reduce the overall cuttings and cavings volumes and mean releases to levels below the CRA-2009 PABC results.

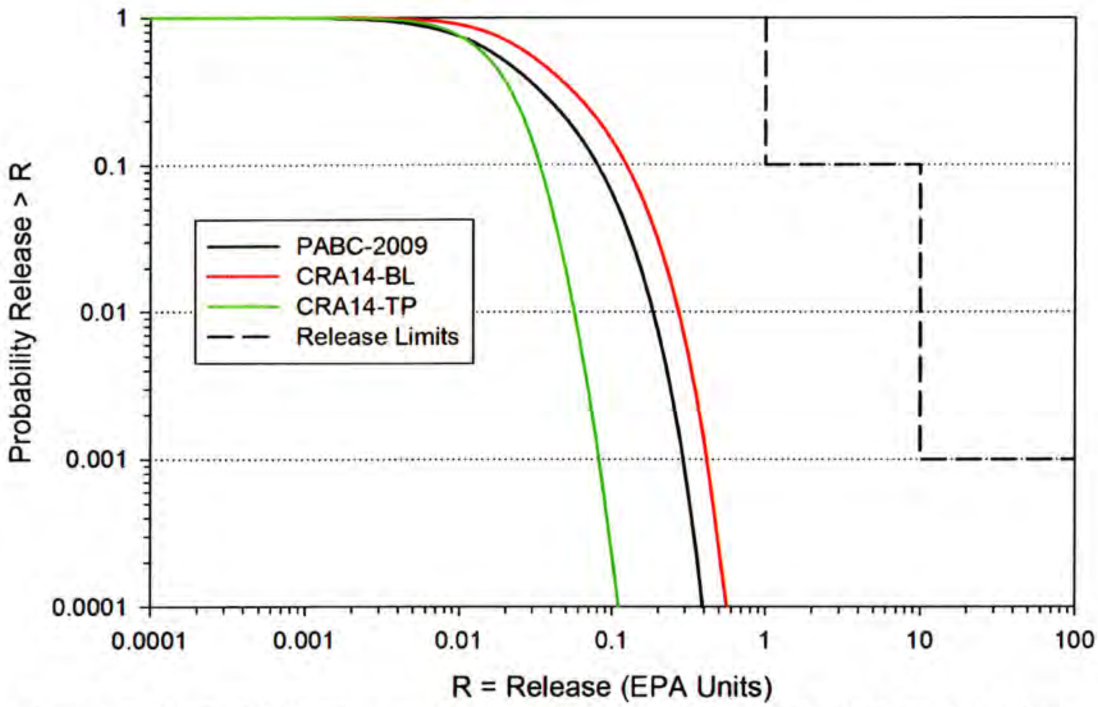

Figure 3-1: Replicate 1 Cuttings and Cavings Normalized Releases (the PCS-2012 PA releases are identical to the CRA-2009 PABC releases; Case CRA14-BV and Case CRA14-0 releases are identical to Case CRA14-TP releases)

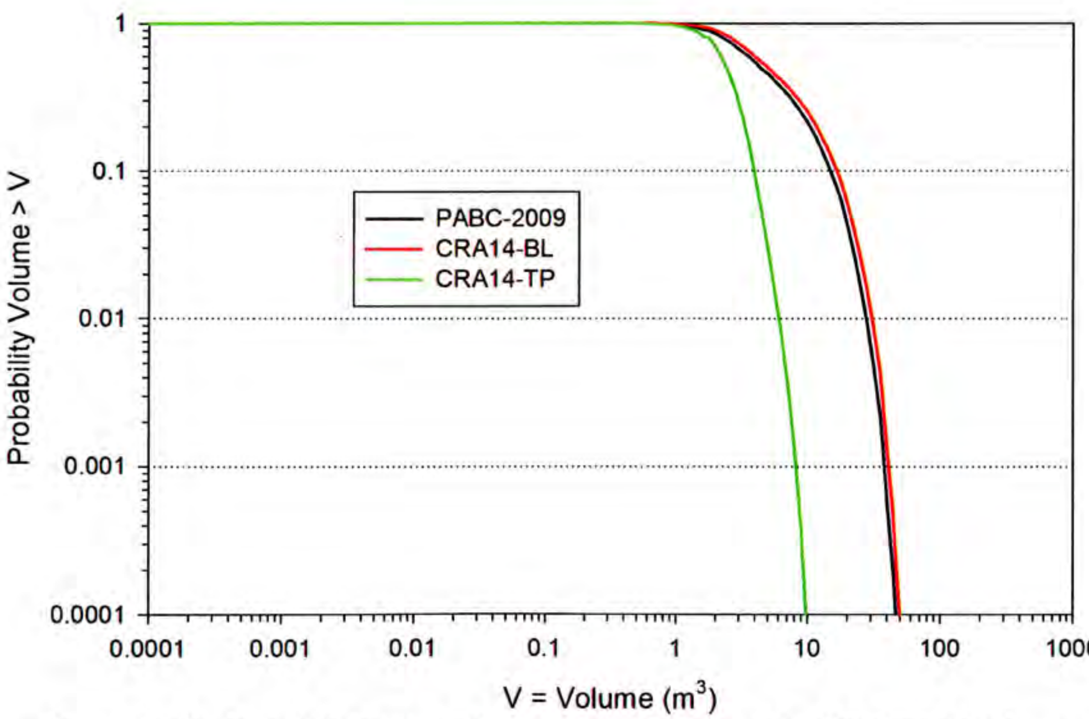

Figure 3-2: Replicate 1 Cuttings and Cavings Release Volumes (the PCS-2012 PA volumes are identical to the CRA-2009 PABC volumes; Case CRA14-BV and Case CRA14-TP volumes are identical to Case CRA14-0 volumes)

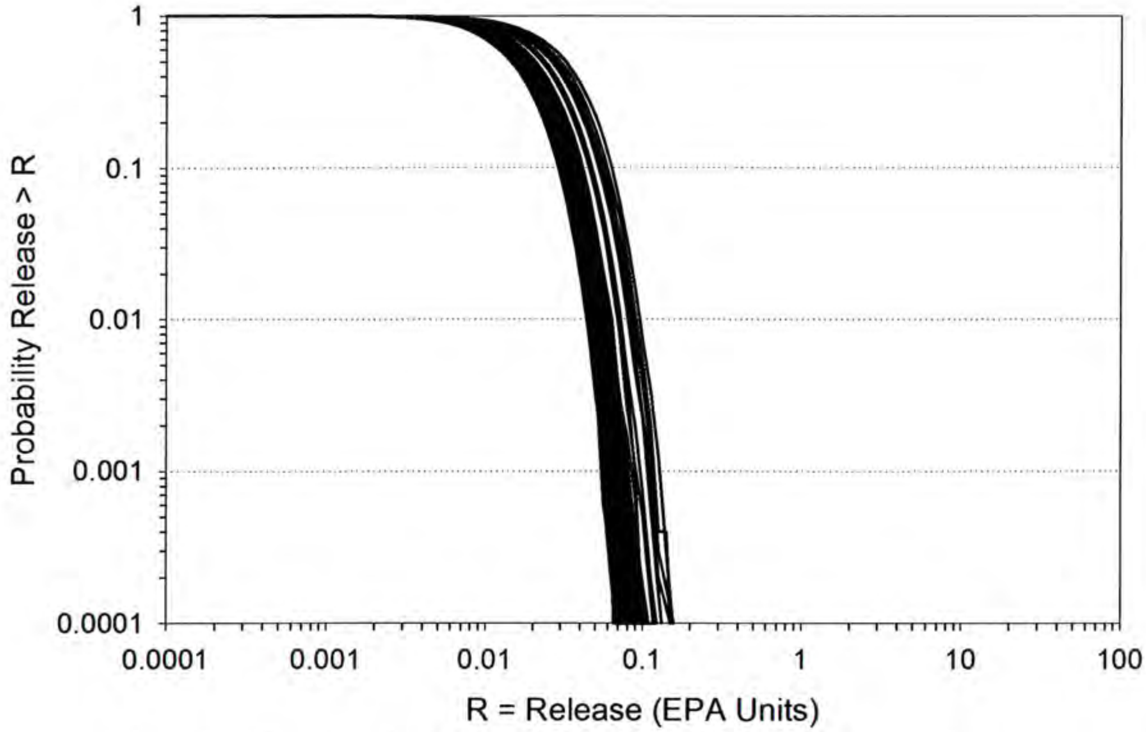

Figure 3-3: CRA-2014 PA Replicate 1 Cuttings and Cavings Normalized Releases

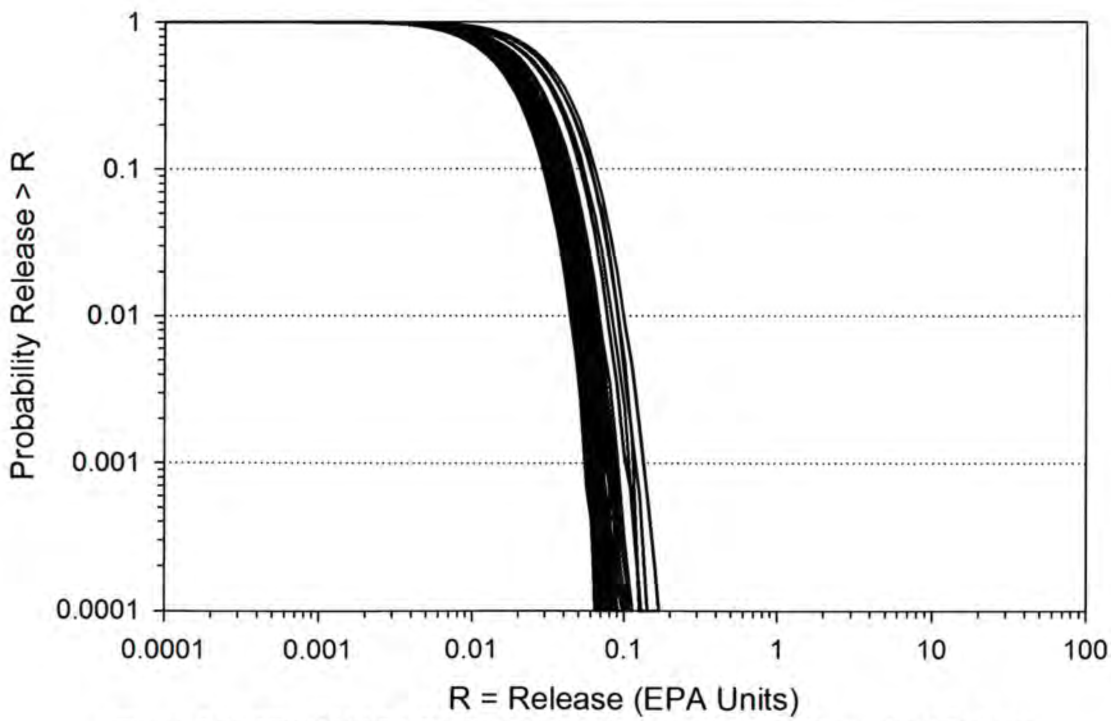

Figure 3-4: CRA-2014 PA Replicate 2 Cuttings and Cavings Normalized Releases

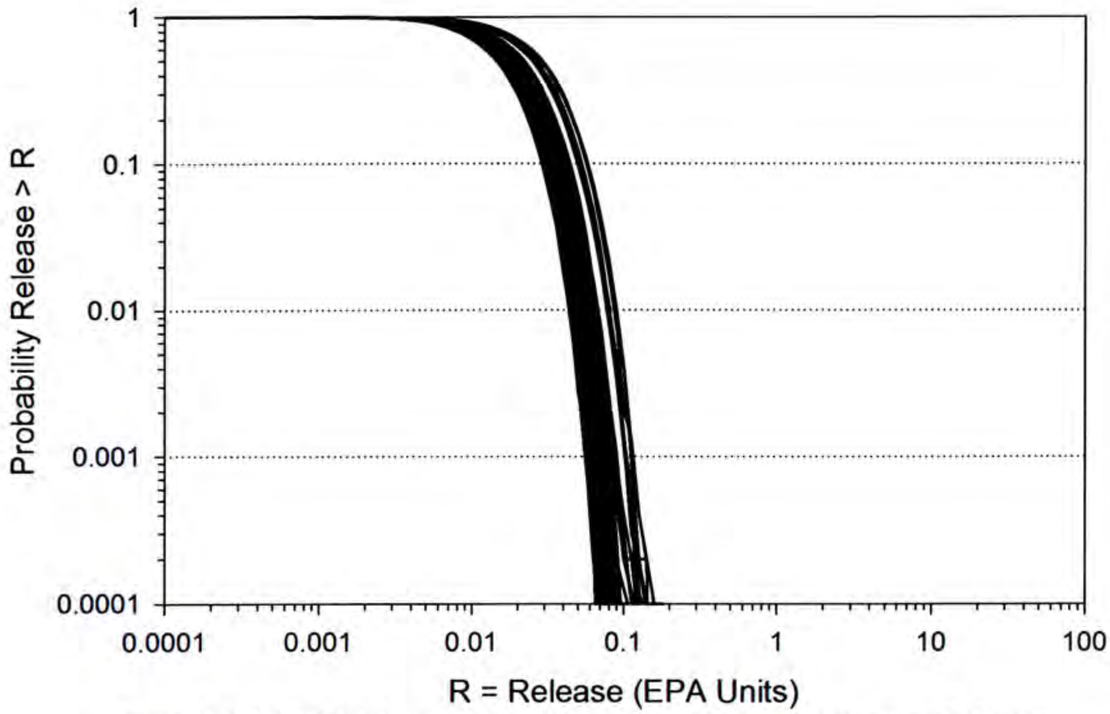

Figure 3-5: CRA-2014 PA Replicate 3 Cuttings and Cavings Normalized Releases

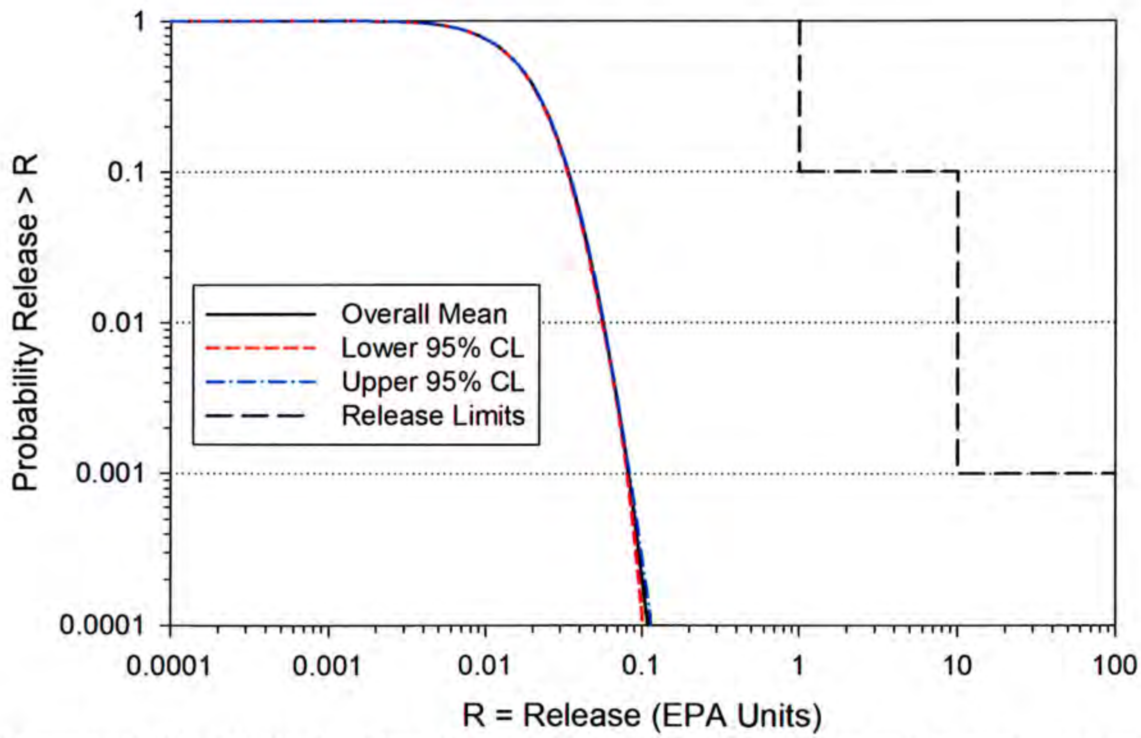

Figure 3-6: CRA-2014 PA Confidence Limits on Overall Mean for Cuttings and Cavings Normalized Releases

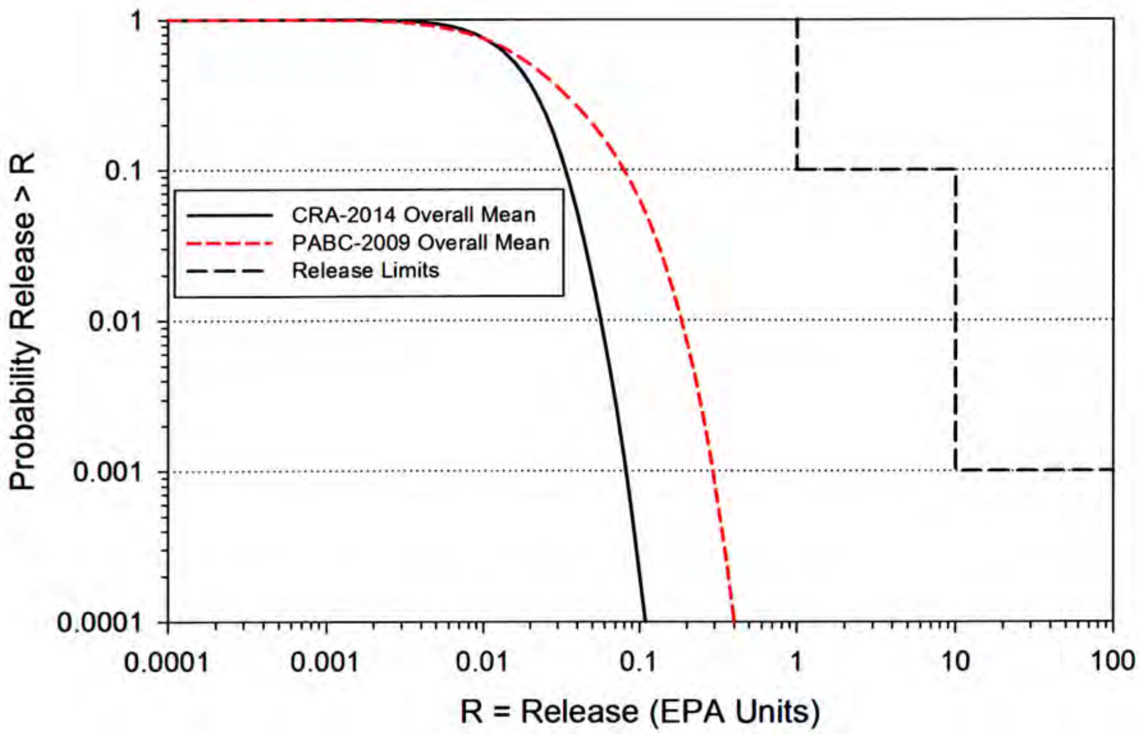

Figure 3-7: CRA-2014 PA and CRA-2009 PABC Overall Mean CCDFs for Normalized Cuttings and Cavings Releases

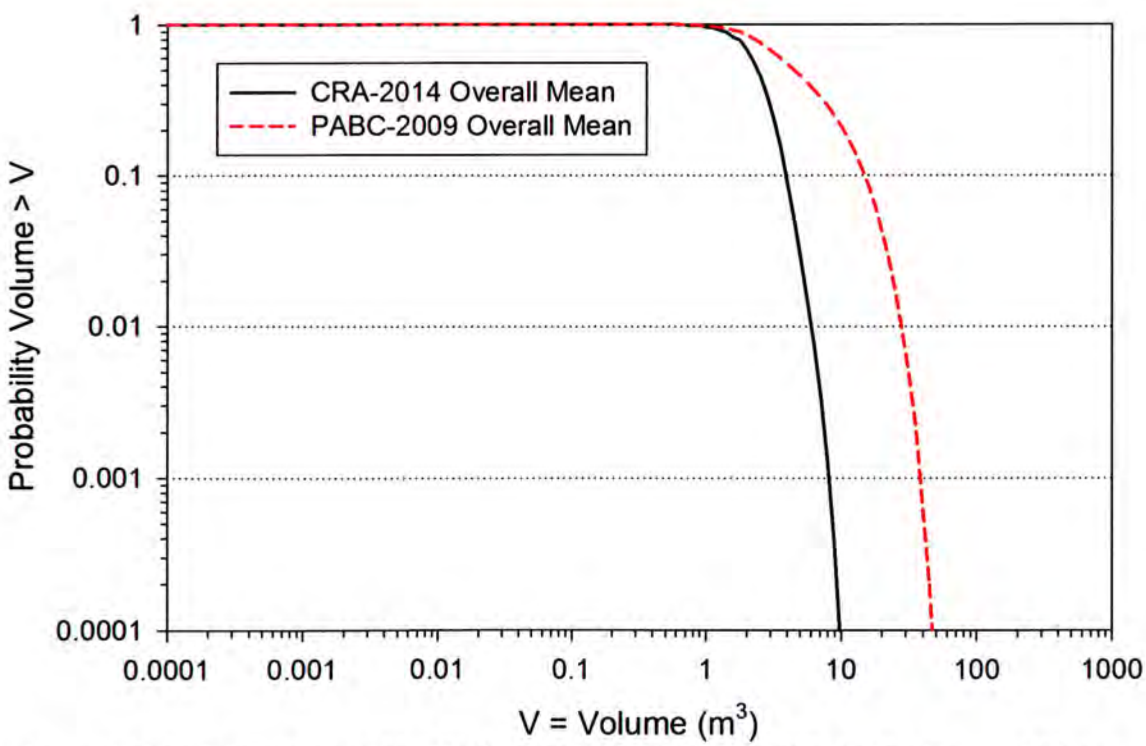

Figure 3-8: CRA-2014 PA and CRA-2009 PABC Overall Mean CCDFs for Cuttings and Cavings Release Volumes

3.2 Spallings Normalized Releases

CRA-2014 PA spallings releases are presented in this section and compared to results obtained in the CRA-2009 PABC. Figure 3-9 shows the spallings releases for replicate 1 of the CRA-2009 PABC, the PCS-2012 PA, Case CRA14-BL, Case CRA14-TP and Case CRA14-0 calculations. Figure 3-10 shows spallings releases with Cases CRA14-BL and CRA14-TP data excluded for clarity. Figure 3-11 shows spallings releases with the CRA-2009 PABC and PCS-2012 data excluded for clarity. Figure 3-12 shows spallings volumes for the same calculations. Figure 3-13 shows volumes with Cases CRA14-BL and CRA14-TP data excluded for clarity). Figure 3-14 shows spallings volumes with the CRA-2009 PABC and PCS-2012 data excluded for clarity.

For replicate 1, spallings releases and volumes increase from the CRA-2009 PABC to the PCS-2012 PA at probabilities greater than ~0.03 due to the updated ROMPCS, which decreases closure permeability after 200 years and thus increases pressurization in a waste panel (Zeitler 2012). In Zeitler (2012), the mean spallings release was shown to increase for all probabilities from the CRA-2009 PABC to the PCS-2012 PA.

From the PCS-2012 PA to Case CRA14-BL, spallings volumes decrease to approximately the levels of the CRA-2009 PABC due to additional excavated volume and decreased iron and cellulosics, plastics and rubber (CPR) inventories, which caused decreases in waste panel pressures. Spallings releases decrease at probabilities greater than ~0.03 and increase at probabilites less than ~0.03 due to increased waste inventory, as well as updated drilling rate and plugging pattern parameters. Spallings releases are nearly identical between Case CRA14-BL and Case CRA14-TP. The Case CRA14-BV releases are identical to the Case CRA14-TP releases as the brine volume correction does not affect spallings releases. Spallings volumes and releases decreased from Case CRA14-BV to the Case CRA14-0 due to a decrease in waste panel pressure following changes to the steel corrosion parameter and the updated repository water balance implementation.

Figure 3-15, Figure 3-16, and Figure 3-17 show the CRA-2014 PA spallings release CCDFs for replicates 1, 2, and 3, respectively. Figure 3-18 shows the 95 percent confidence limits about the overall spallings mean.

The CRA-2009 PABC and the CRA-2014 PA spallings CCDFs are plotted together in Figure 3-19 and Figure 3-20 for the overall mean and volume, respectively. A reduction in repository pressure translates into smaller spallings volumes as these volumes depend directly on repository pressure. Despite the modified panel closure system, which serves to increase waste panel pressures, the updated steel corrosion rate, additional excavation in the WIPP experimental area, and the updated repository water balance implementation each contribute to a decrease in waste panel pressures (Kicker 2013). Summed together, there is an overall decrease in pressures that directly leads to a decrease in spallings volumes from the CRA-2009 PABC to the CRA-2014 PA. There is also an overall reduction in spallings releases, despite an increase in waste inventory activity, due to a decrease in the number of nonzero spallings volumes.

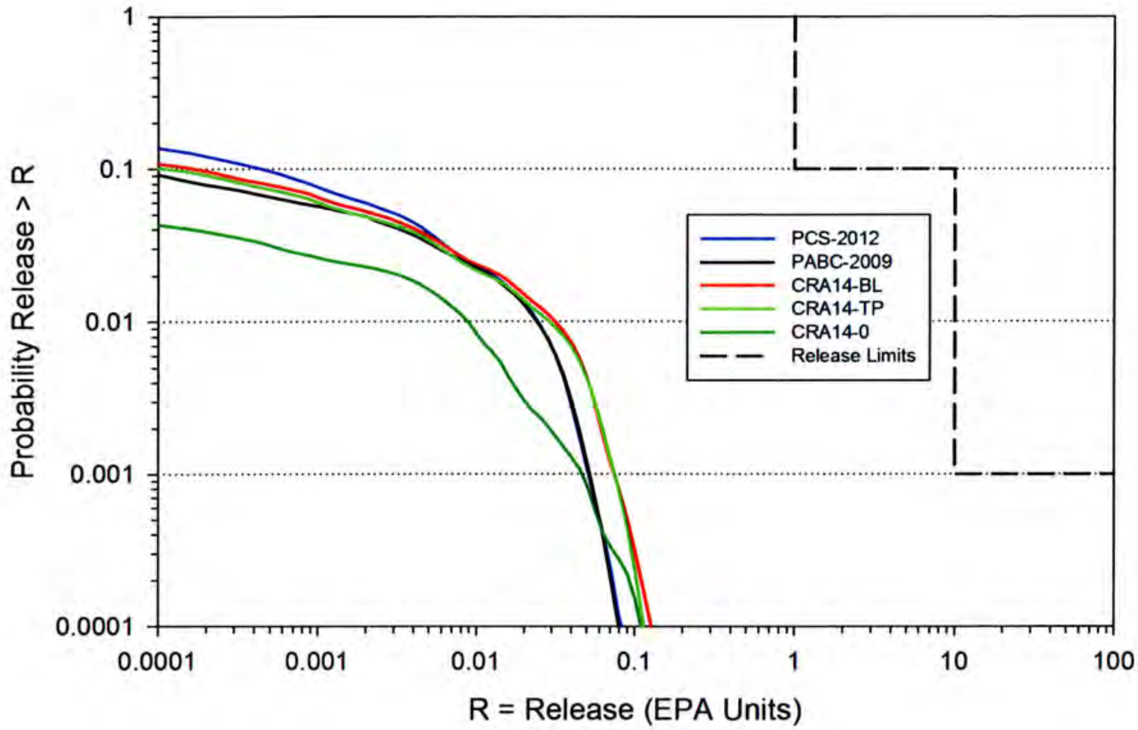

Figure 3-9: Replicate 1 Spallings Normalized Releases (Case CRA14-BV releases are identical to Case CRA14-TP releases)

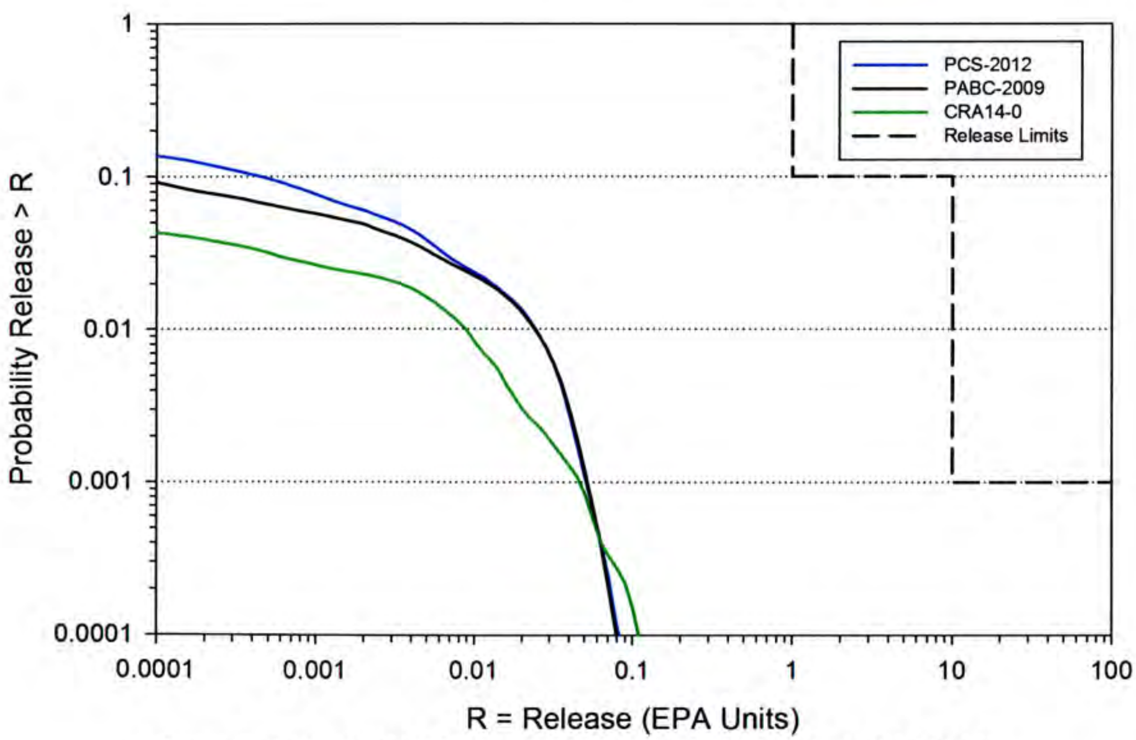

Figure 3-10: Replicate 1 Spallings Normalized Releases (2009, 2012, 2014)

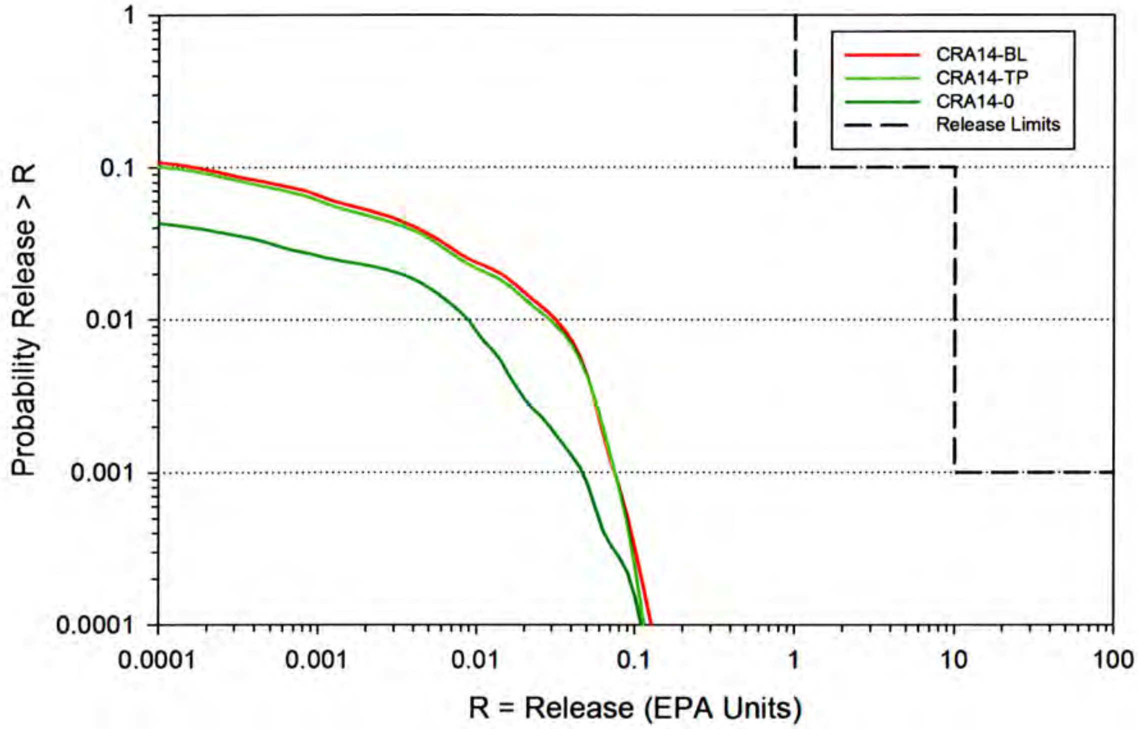

Figure 3-11: Replicate 1 Spallings Normalized Releases (2014) (Case CRA14-BV releases are identical to Case CRA14-TP releases)

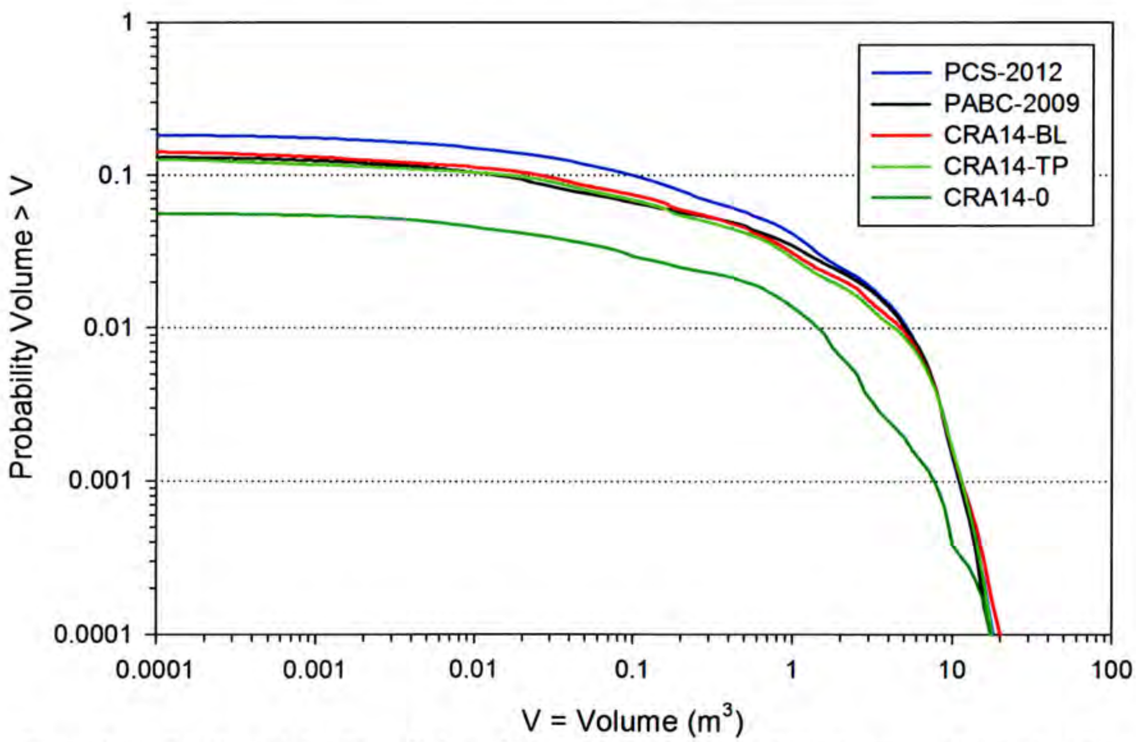

Figure 3-12: Replicate 1 Spallings Release Volumes (Case CRA14-BV release are identical to Case CRA14-TP releases)

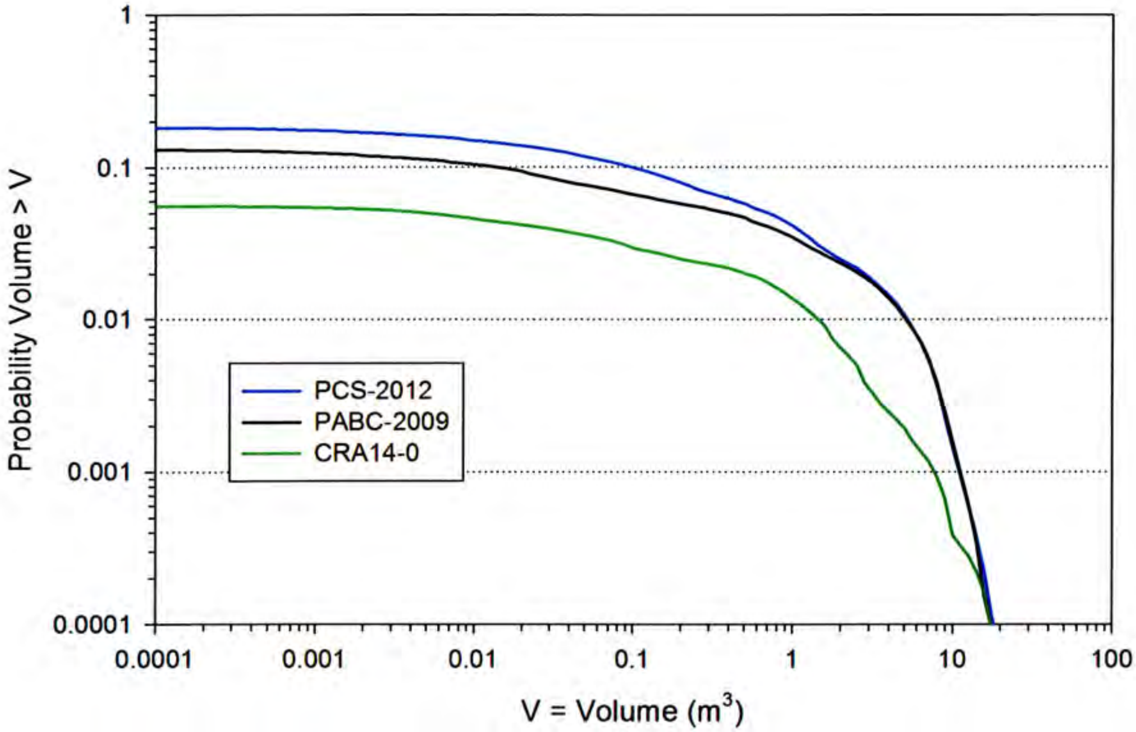

Figure 3-13: Replicate 1 Spallings Release Volumes (2009, 2012, 2014)

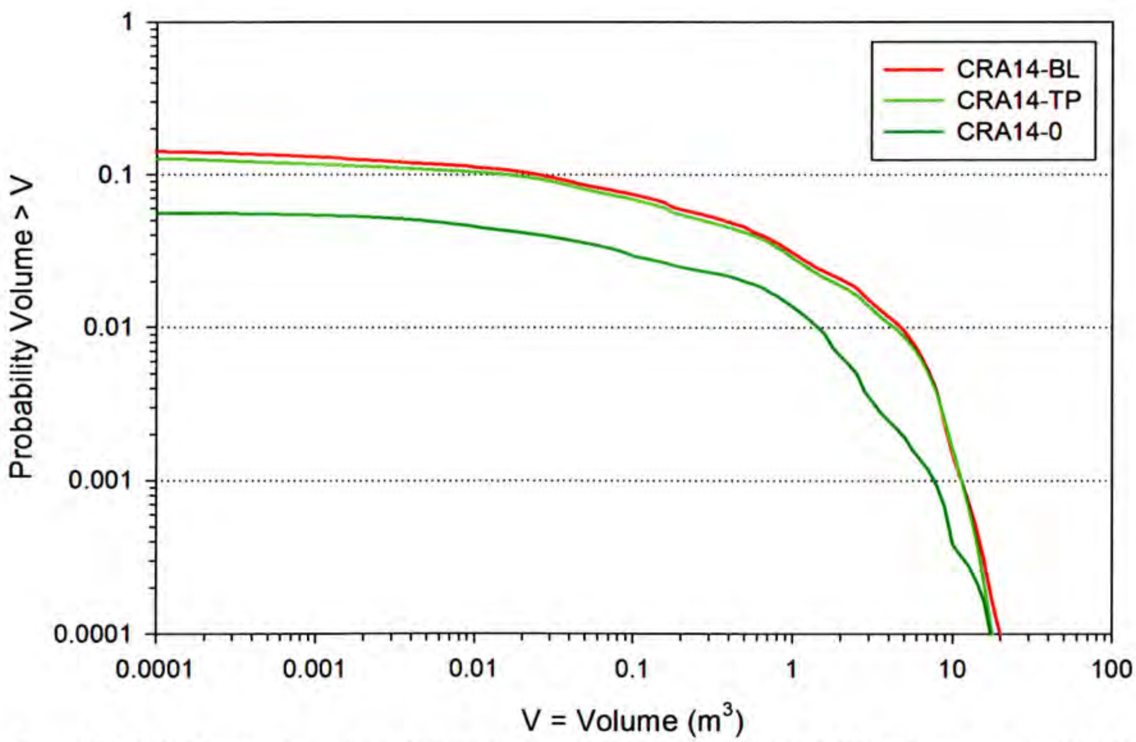

Figure 3-14: Replicate 1 Spallings Release Volumes (2014) (Case CRA14-BV release are identical to Case CRA14-TP releases)

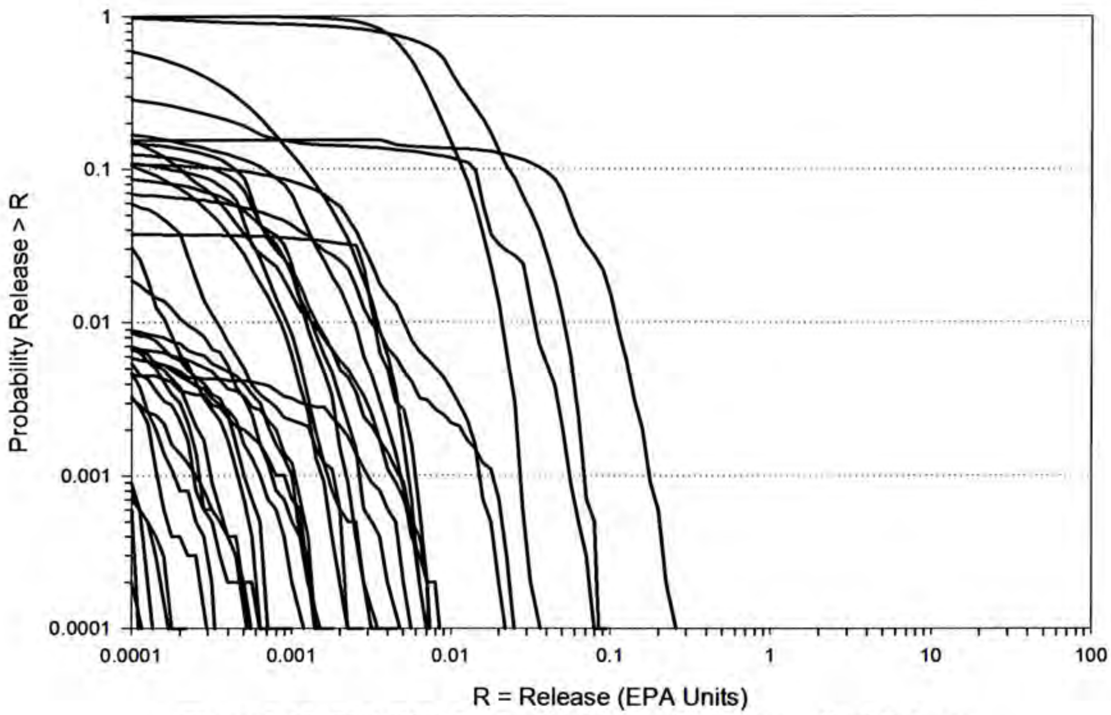

Figure 3-15: CRA-2014 PA Replicate 1 Spallings Normalized Releases

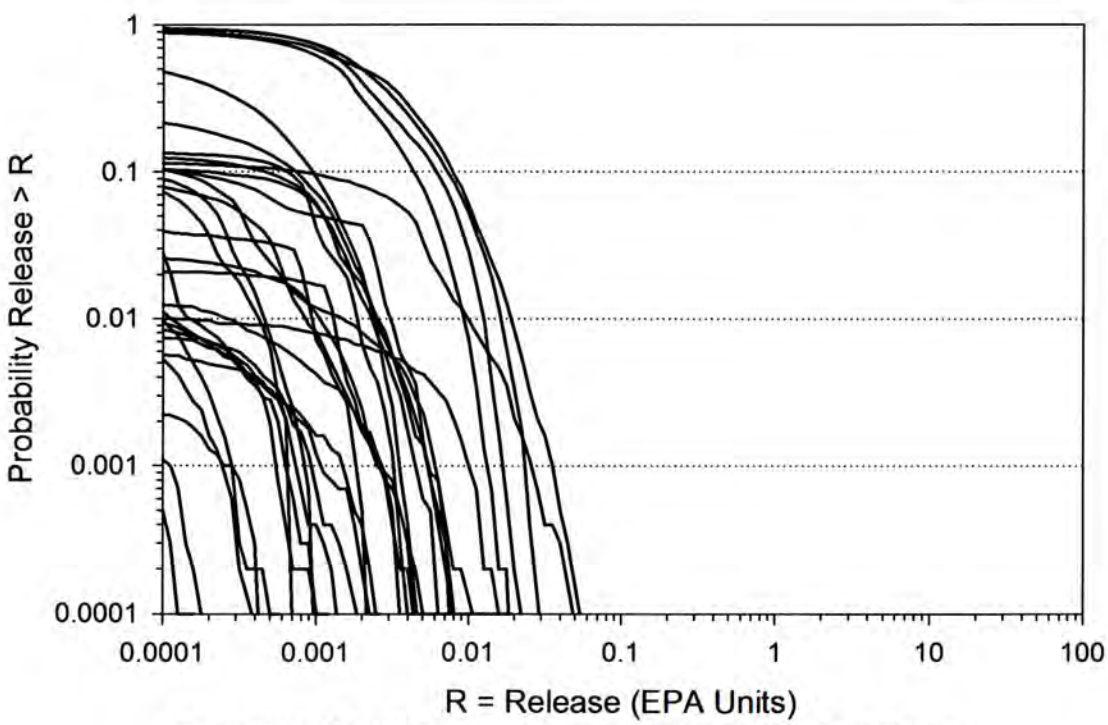

Figure 3-16: CRA-2014 PA Replicate 2 Spallings Normalized Releases

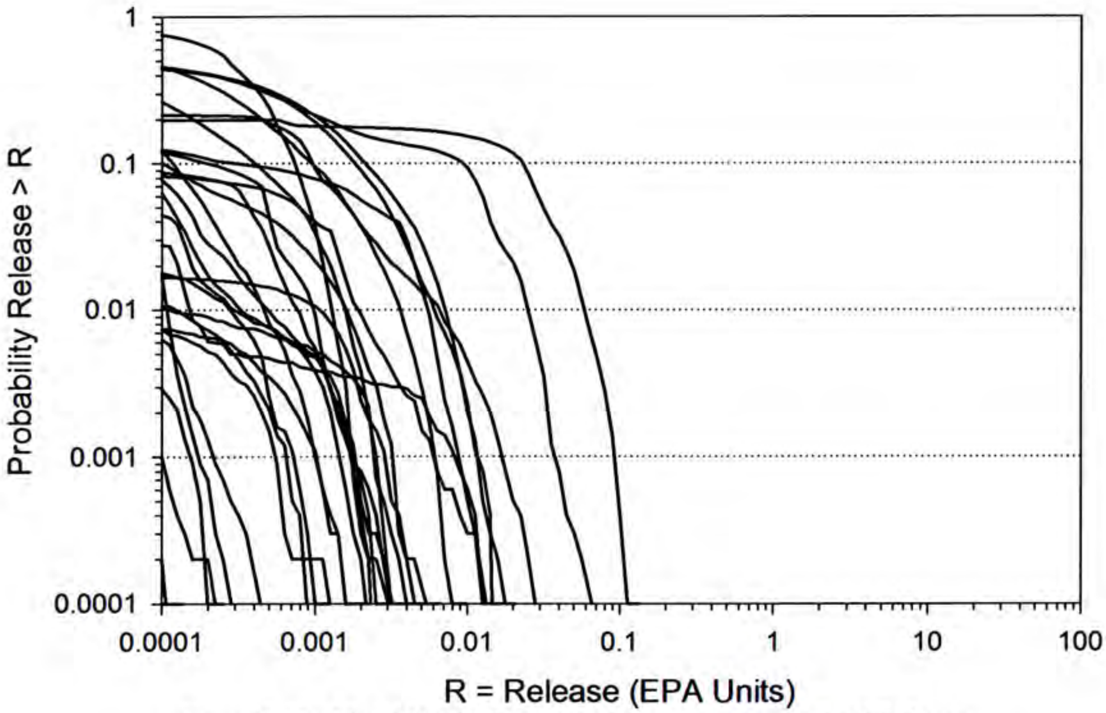

Figure 3-17: CRA-2014 PA Replicate 3 Spallings Normalized Releases

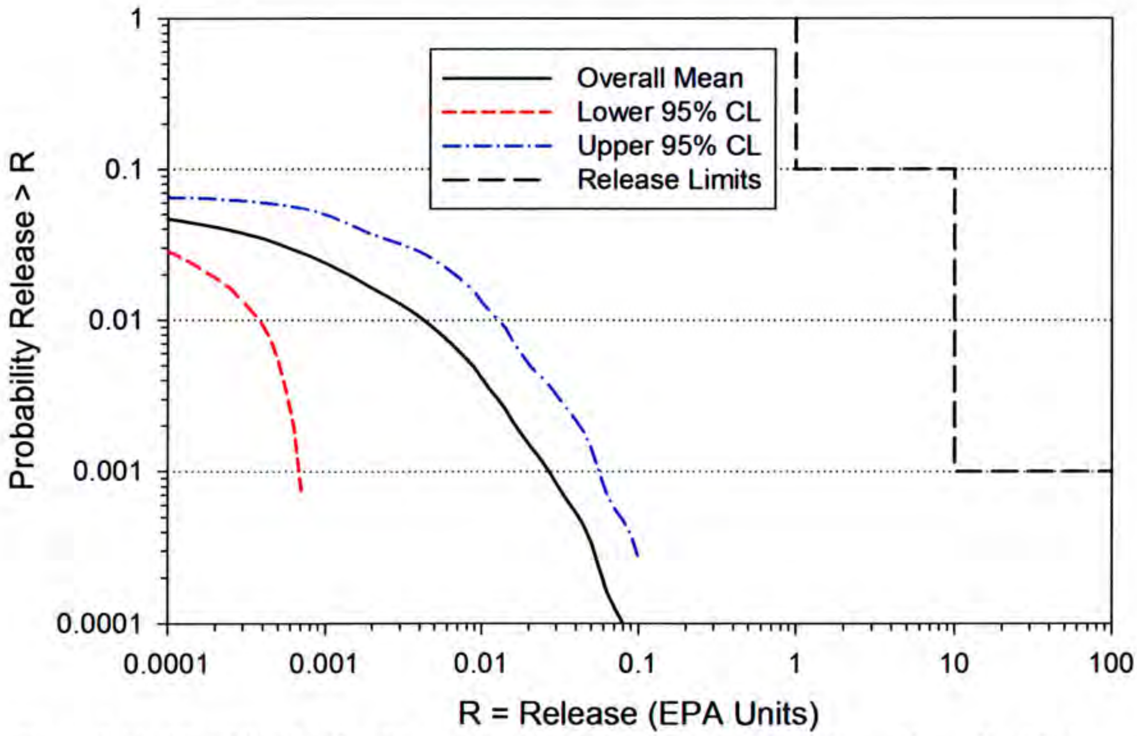

Figure 3-18: CRA-2014 PA Confidence Limits on Overall Mean for Spallings Normalized Releases

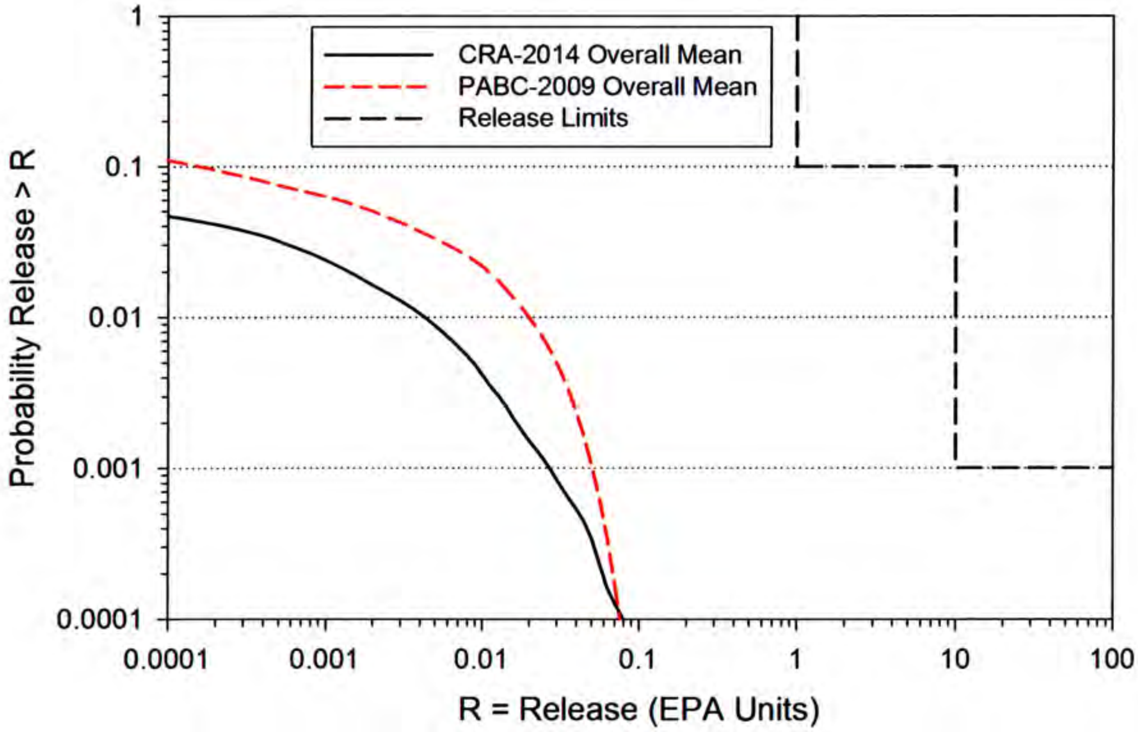

Figure 3-19: CRA-2014 PA and CRA-2009 PABC Overall Mean CCDFs for Normalized Spallings Releases

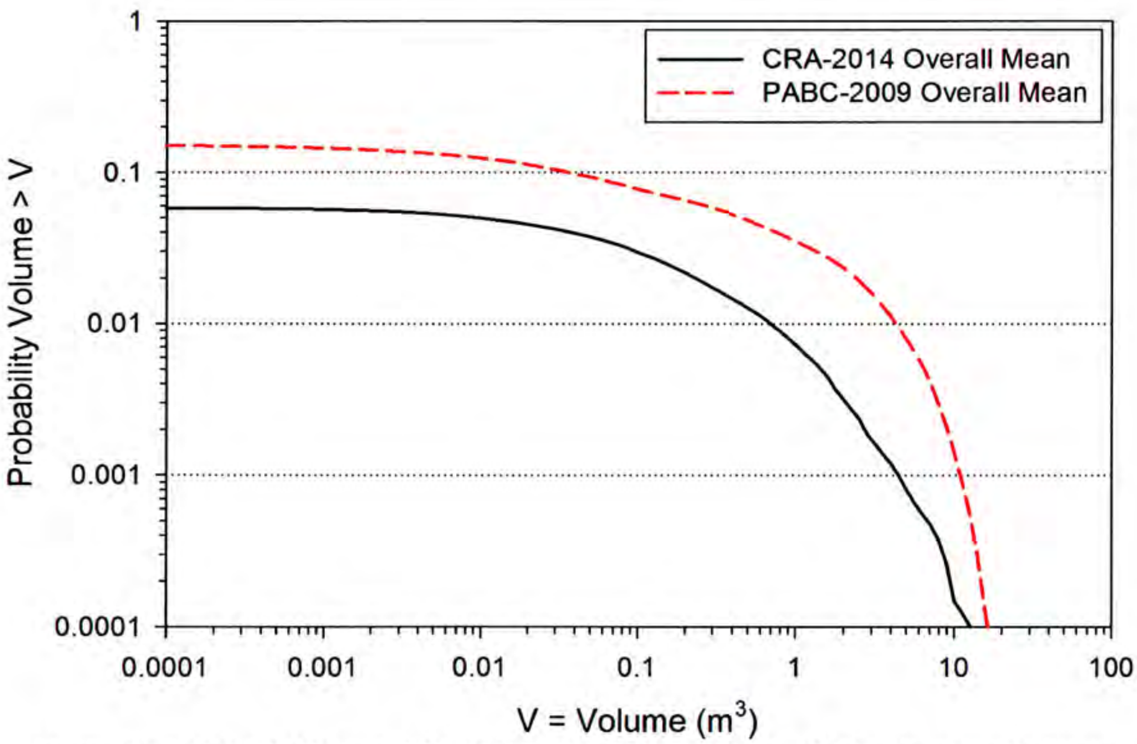

Figure 3-20: CRA-2014 PA and CRA-2009 PABC Overall Mean CCDFs for Spallings Volumes

3.3 Normalized Direct Brine Releases

CRA-2014 PA normalized direct brine releases are presented in this section and compared to results obtained in the CRA-2009 PABC. Figure 3-21 shows the direct brine releases (DBRs) for replicate 1 for all cases (Figure 3-22 and Figure 3-23 show the same data with fewer plots per figure for clarity). Figure 3-24 shows DBR volumes for all cases (Figure 3-25 and Figure 3-26 show the same data with fewer plots per figure for clarity).

Figure 3-27, Figure 3-28, and Figure 3-29 show the CRA-2014 PA CCDFs for DBRs in replicates 1, 2, and 3, respectively. Figure 3-30 shows the 95 percent confidence limits about the DBR overall mean.

For replicate 1, DBRs and DBR volumes are different for each of the six cases. DBRs showed some increase from the CRA-2009 PABC to the PCS-2012 PA due to increased DBR volumes, which are a result of increases in average waste panel pressure, as well as increased brine saturation for intrusion scenarios that involve drilling into a pressurized brine region beneath the repository (Malama 2012).

From the PCS-2012 PA to Case CRA14-BL, DBRs increase at low probabilities due to increased radionuclide solubilities (DBR volumes were nearly identical). DBRs decrease from Case CRA14-BL to Case CRA14-TP due to changes in the PBRINE parameter (probability of encountering a brine pocket) that reduced DBR volumes. DBRs decrease from Case CRA14-TP to Case CRA14-BV due to decreased brine saturations stemming from the brine volume correction (DBR volumes did not change). DBRs and DBR volumes decrease from Case CRA14-BV to Case CRA14-0 due to reduced waste panel pressure stemming from reduction in steel corrosion and the water balance implementation (Malama 2013 and Camphouse 2013b).

The CRA-2009 PABC and the CRA-2014 PA DBR CCDFs are plotted together in Figure 3-31 and Figure 3-32 for the overall mean and volume, respectively. Overall, there was a decrease in DBR volumes and DBRs from CRA-2009 PABC to the CRA-2014 PA. Despite increases in waste inventory and solubilities, DBR releases decreased overall primarily due to changes in the PBRINE parameter (which decreased the probability of encountering a brine pocket) and the brine volume correction. The updated steel corrosion rate and water balance implementation also contributed to decreased DBRs compared to the CRA-2009 PABC.

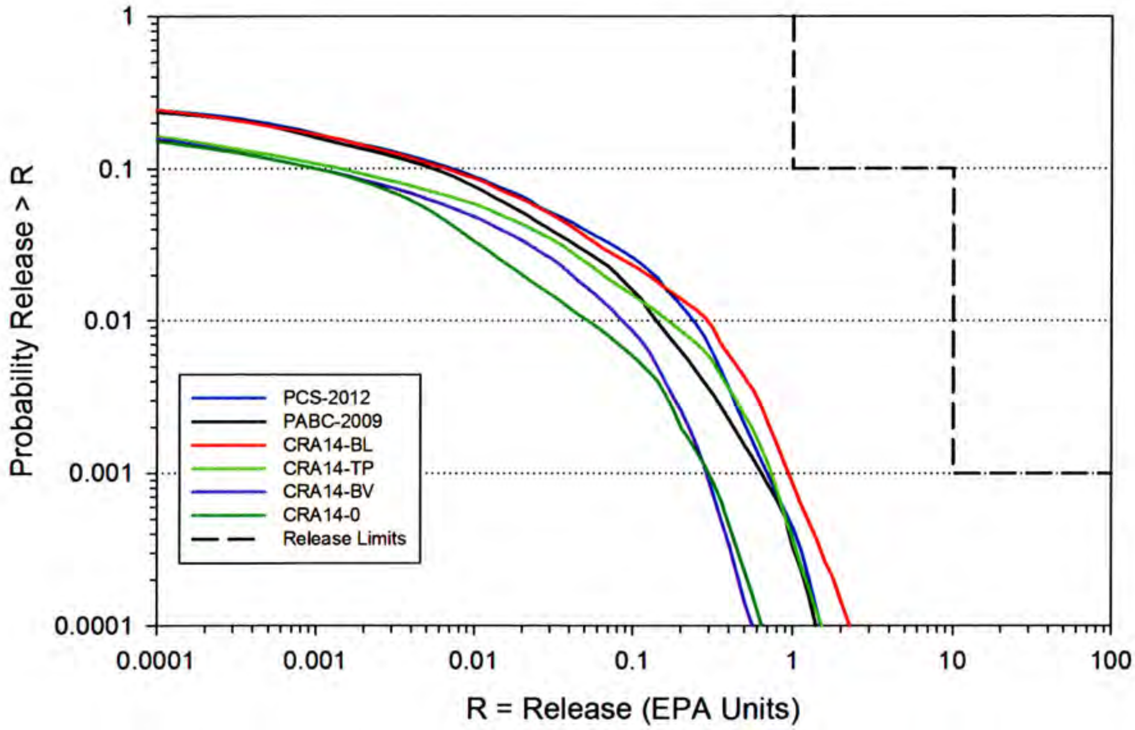

Figure 3-21: Replicate 1 Direct Brine Normalized Releases

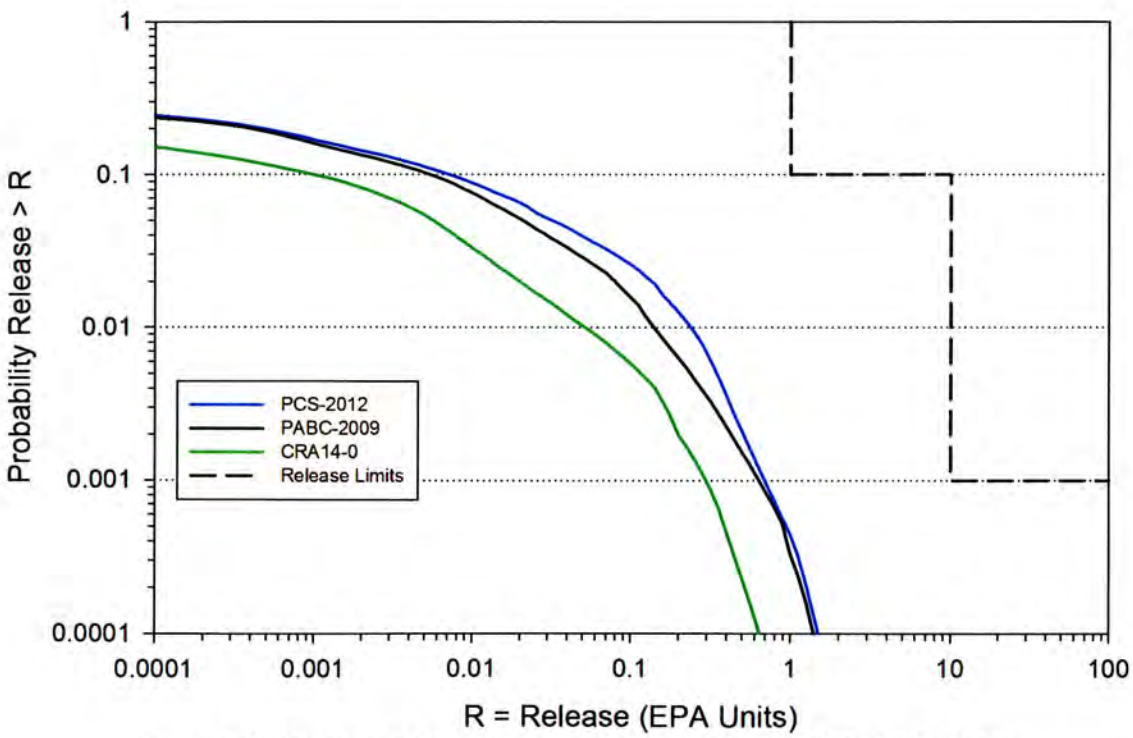

Figure 3-22: Replicate 1 Direct Brine Normalized Releases (2009, 2012, 2014)

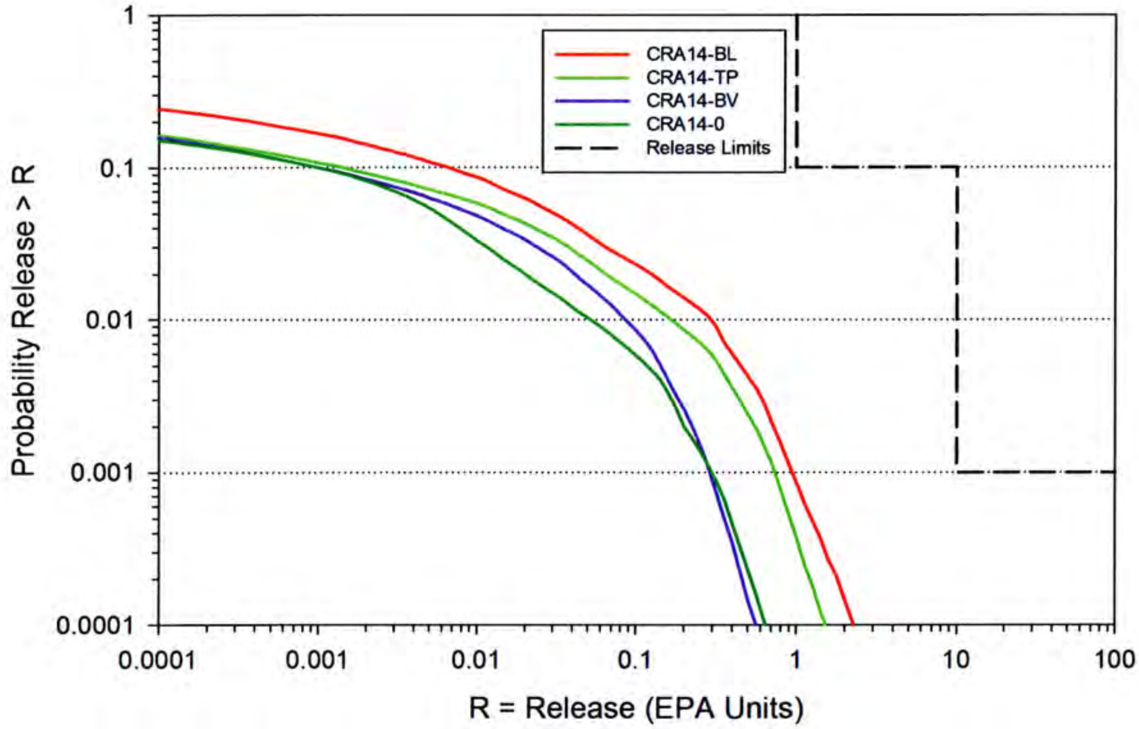

Figure 3-23: Replicate 1 Direct Brine Normalized Releases (2014)

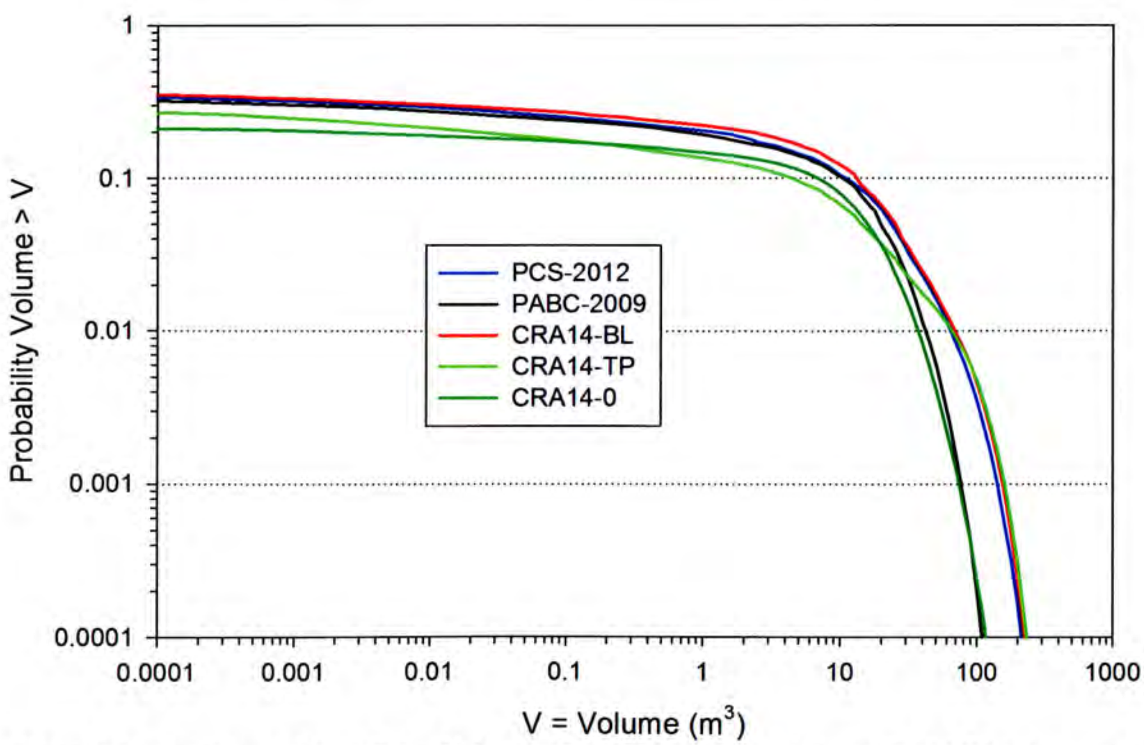

Figure 3-24: Replicate 1 Direct Brine Volumes (Case CRA14-BV and Case CRA14-TP volumes are equivalent)

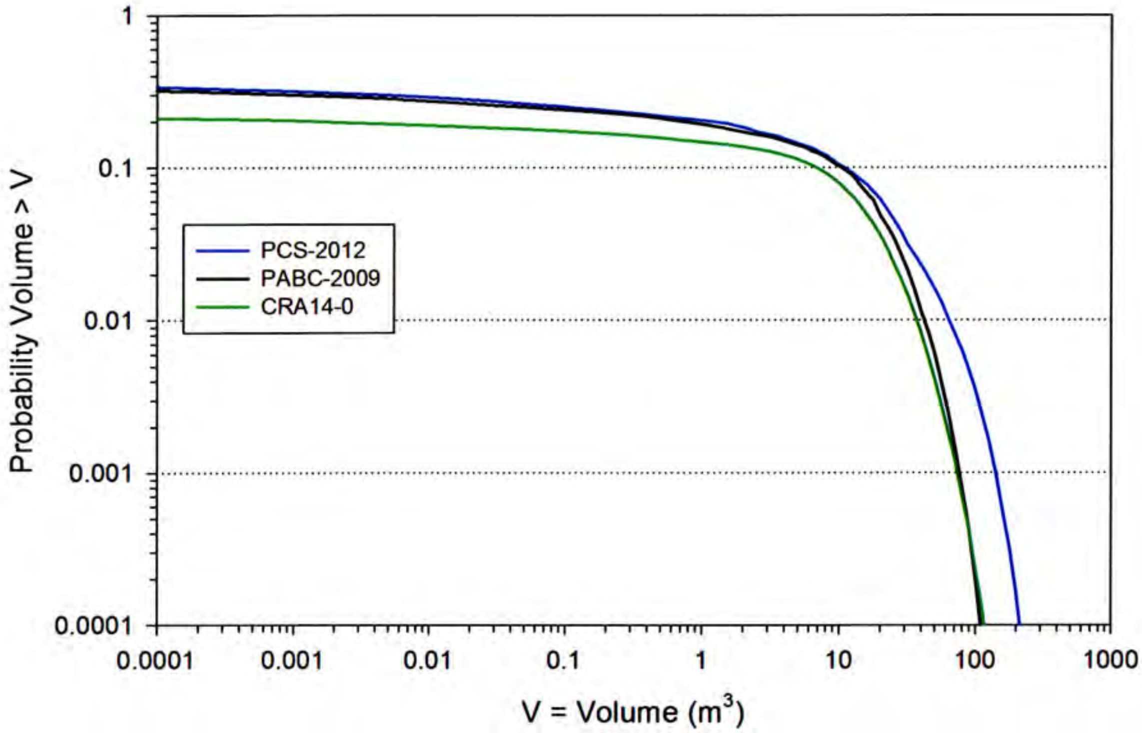

Figure 3-25: Replicate 1 Direct Brine Volumes (2009, 2012, 2014)

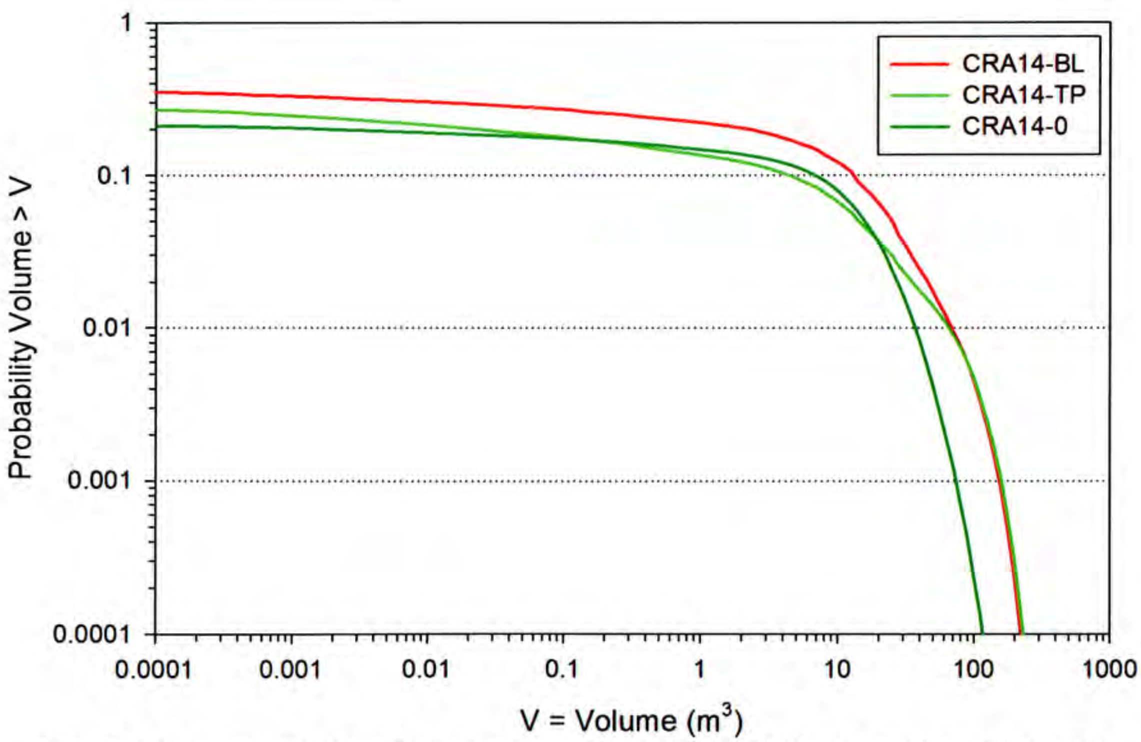

Figure 3-26: Replicate 1 Direct Brine Volumes (2014) (Case CRA14-BV and Case CRA14-TP volumes are equivalent)

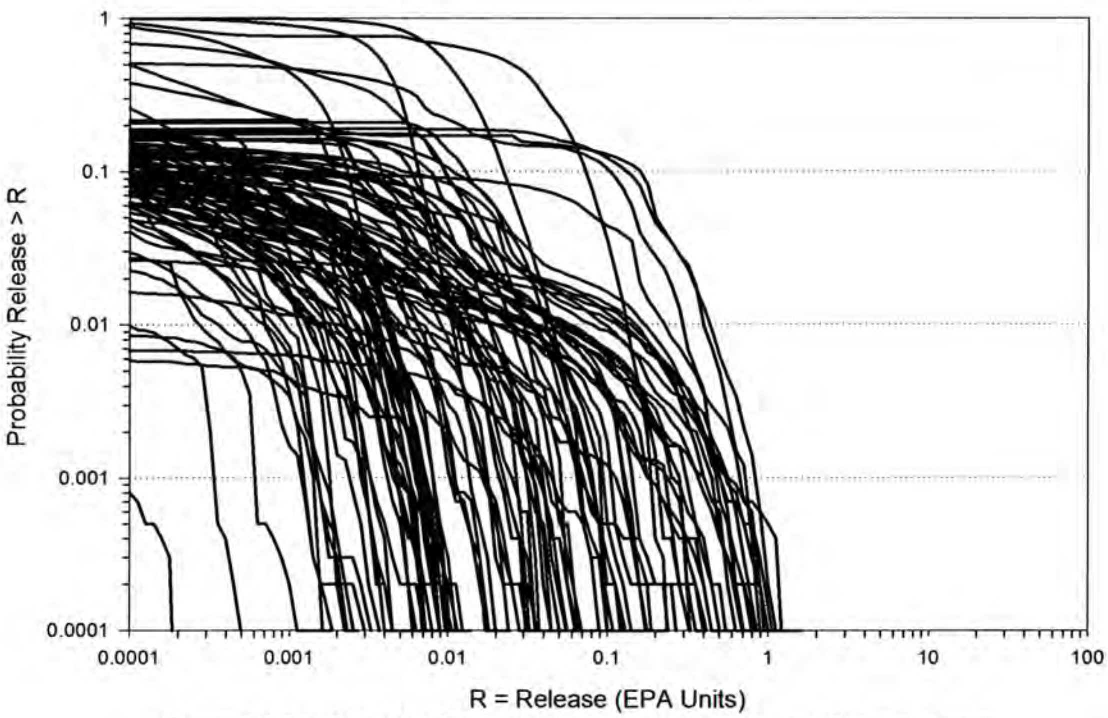

Figure 3-27: CRA-2014 PA Replicate 1 Normalized Direct Brine Releases

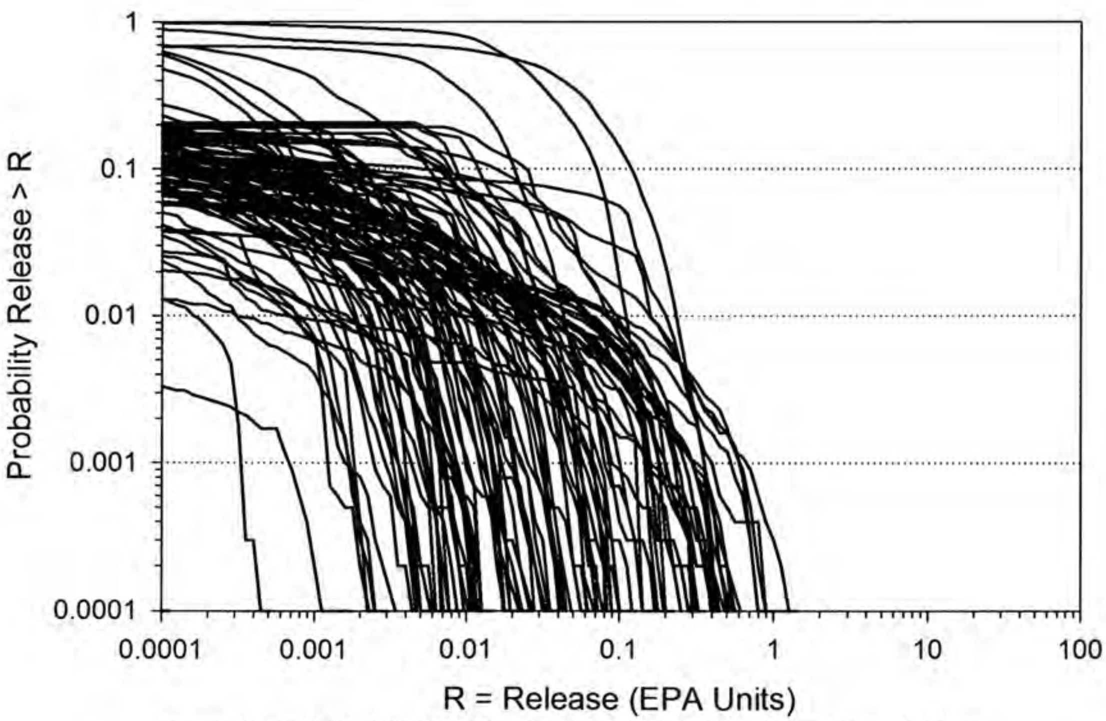

Figure 3-28: CRA-2014 PA Replicate 2 Normalized Direct Brine Releases

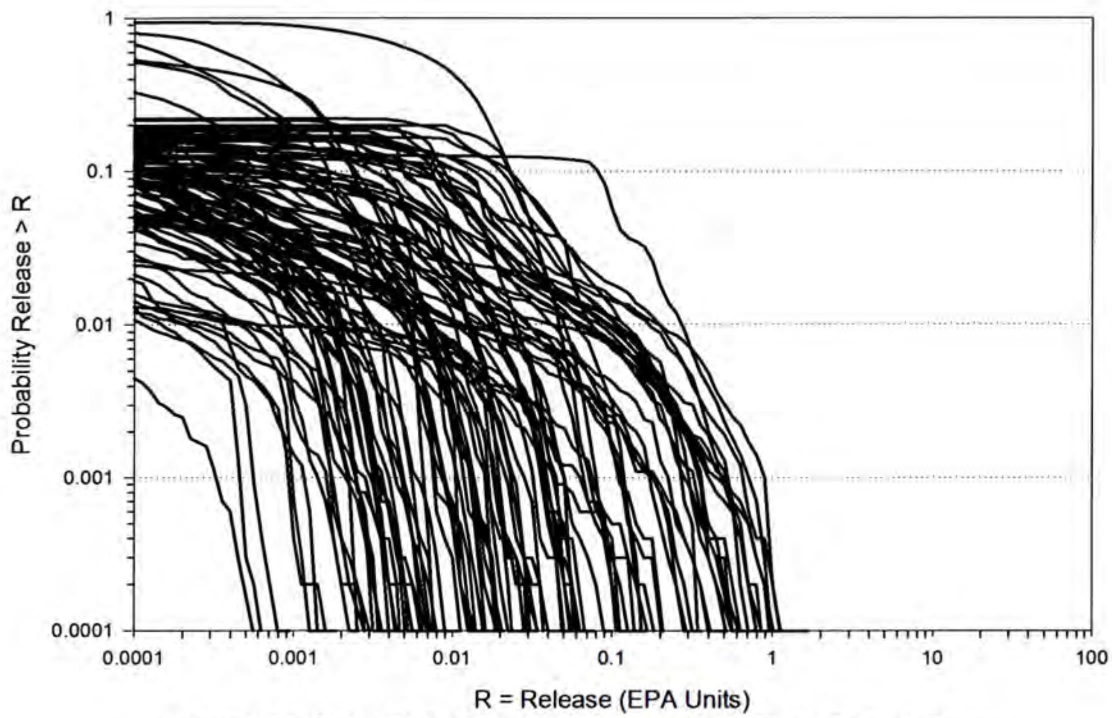

Figure 3-29: CRA-2014 PA Replicate 3 Normalized Direct Brine Releases

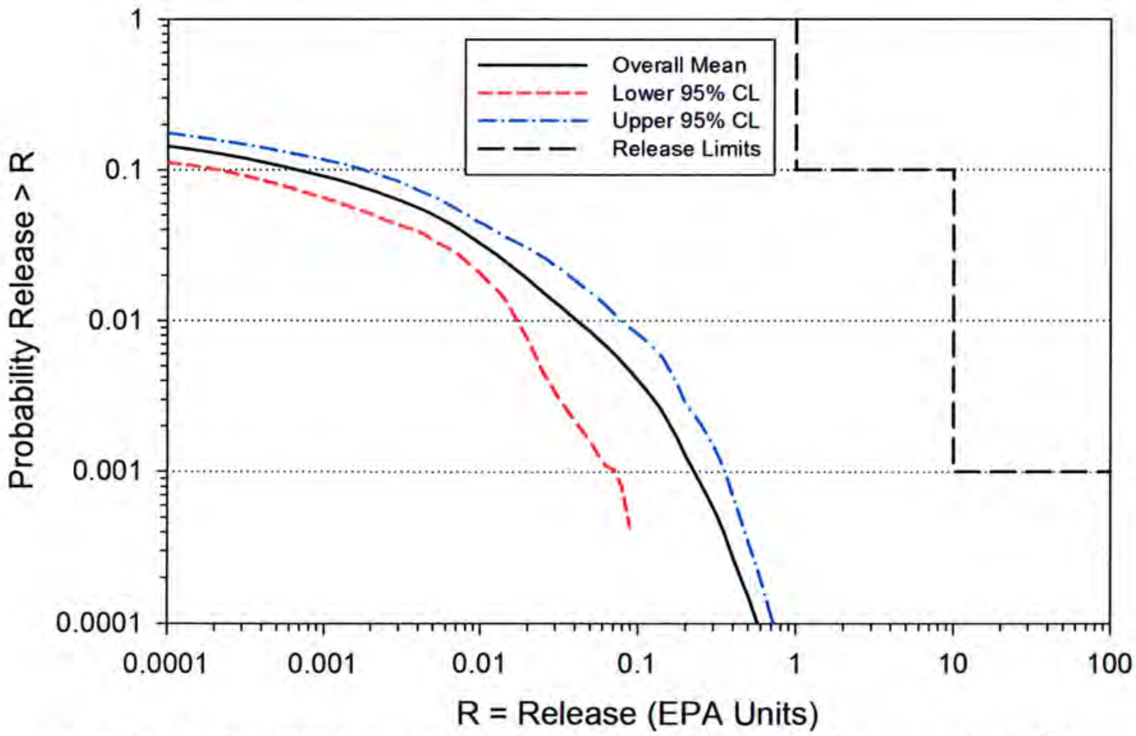

Figure 3-30: CRA-2014 PA Confidence Limits on Overall Mean for Normalized Direct Brine Releases

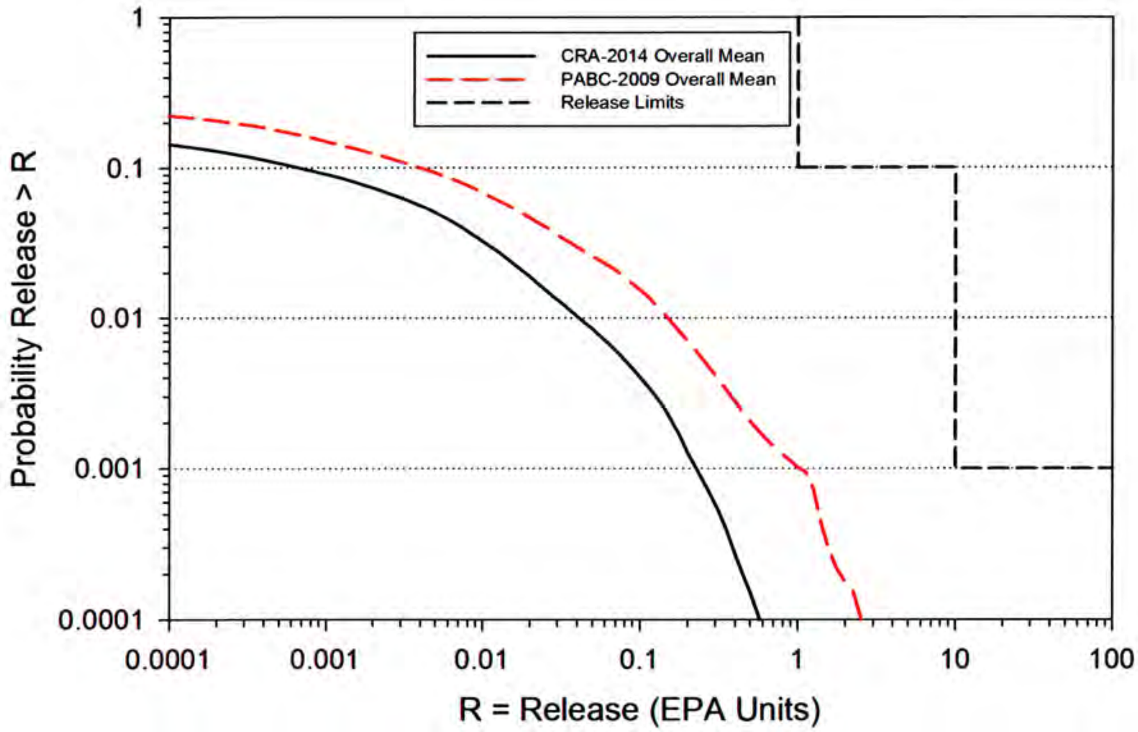

Figure 3-31: CRA-2014 PA and the CRA-2009 PABC Overall Mean CCDFs for Normalized Direct Brine Releases

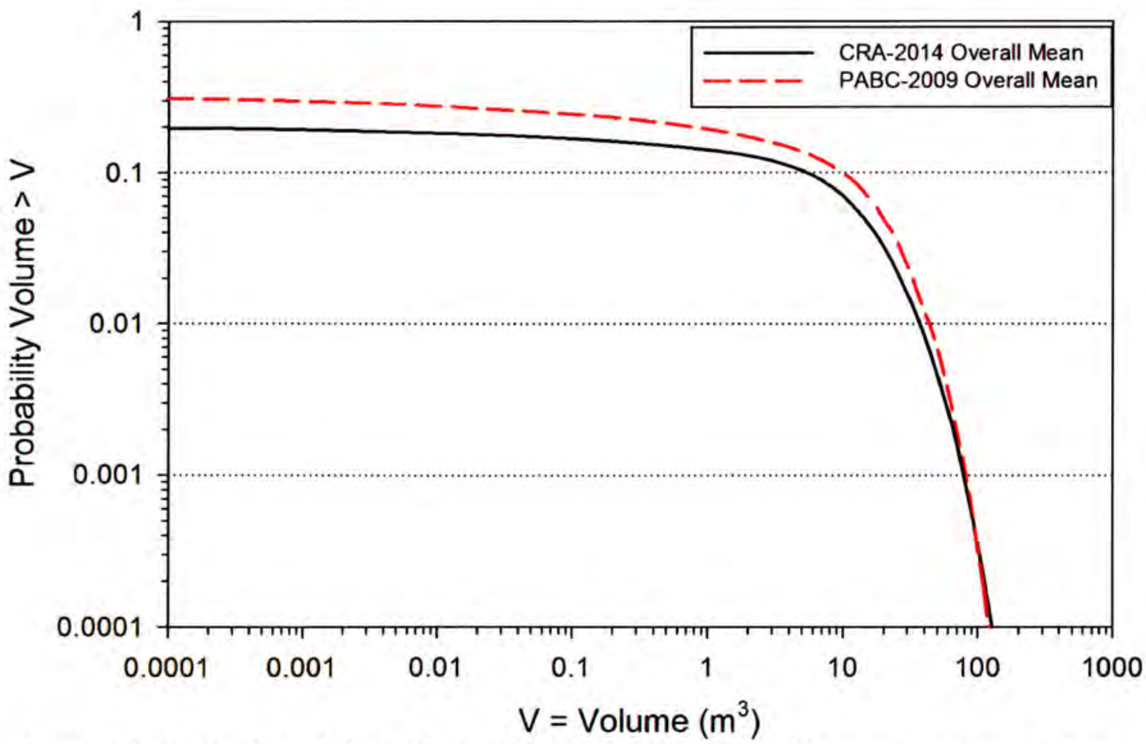

Figure 3-32: CRA-2014 and the CRA-2009 PABC Overall Mean CCDFs for Direct Brine Volumes

3.4 Normalized Transport Releases from the Culebra

CRA-2014 PA normalized transport releases from the Culebra are presented in this section and compared to results obtained in the CRA-2009 PABC. Figure 3-33, Figure 3-34, and Figure 3-35 show the CRA-2014 PA CCDFs for Culebra releases to the land withdrawal boundary (LWB) for replicates 1, 2, and 3, respectively. Figure 3-36 shows the 95 percent confidence limits about the overall Culebra transport mean. The lower 95 percent confidence limit on the mean release has an unusual shape (it is relatively far from the mean for releases between 0.001 and 0.01 EPA Units, but is close to the mean at around 0.03 EPA Units) due to a coincidence of the three replicate means at around 0.03 EPA Units (Figure 3-37).

The CRA-2009 PABC and the CRA-2014 PA CCDFs for Culebra releases are plotted together in Figure 3-38 and Figure 3-39 for the overall mean releases from and to the Culebra, respectively. The mean releases from the Culebra decrease from the CRA-2009 PABC to the CRA-2014 PA. However, this overall decrease is the sum of an increase in the replicate 1 mean along with decreases in the means of replicates 2 and 3 (Figure 3-37). The difference in mean CCDF *changes* from the CRA-2009 PABC and the CRA-2014 PA among the replicates can be attributed to the effect of the PBRINE parameter changes, as well as the relatively small number of vectors that contribute nonzero releases to the mean releases.

Although the upper limit of the PBRINE parameter distribution has decreased from the CRA-2009 PABC to the CRA-2014 PA, the lower limit has increased, which has led to some vectors having greater releases in the CRA-2014 PA. The PBRINE parameter determines when the repository becomes flooded; once it is flooded, the repository remains flooded for the rest of that future. So a small change in the PBRINE parameter can change the releases signficantly for a given vector when the state of the repository is a factor, as is the case for releases from the Culebra.

Because so few nonzero vectors contribute to a replicate mean, changes in a few vectors can have a relatively large impact on the mean. Case CRA14-TP outlined in AP-164 only considers changes to replicate 1 vectors. Because so few vectors contribute nonzero releases (~10 percent), the changes to the PBRINE parameter make it possible that the observed change to the replicate 1 mean release CCDF can be in opposition to the change in the overall mean. In the cases of the other release mechanisms discussed above (cuttings and cavings, spallings, DBRs), many more vectors contribute to each replicate mean, which decreases the probability of a single replicate mean changing in opposition to the overall mean.

Figure 3-40, Figure 3-41, and Figure 3-42 show the CRA-2009 PABC and CRA-2014 PA CCDFs for Culebra releases to the LWB for replicates 1, 2, and 3, respectively. Mean releases by replicate are shown in Figure 3-37 for the CRA-2009 PABC and CRA-2014 PA. From these plots, it is clear how a few vectors can have a great effect on a replicate mean for releases to the Culebra. For example, the relatively large decrease in replicate 2 mean releases from the Culebra can be traced to about 3-4 vectors (Figure 3-41), despite minimal changes in mean releases to the Culebra (Figure 3-43).

Figure 3-44 shows the releases from the Culebra for replicate 1 of the CRA-2009 PABC, Case CRA14-BL, Case CRA14-TP, and Case CRA14-0 calculations. Figure 3-45 shows the releases to the Culebra for the same replicate 1 calculations.

For replicate 1, the PCS-2012 PA Culebra releases are identical to the CRA-2009 PABC releases. Culebra releases decrease from PCS-2012 to Case CRA14-BL at probabilities below about 0.006 but increase at higher probabilities likely due to a combination of reduced waste inventory and increased drilling rate and radionuclide solubilities. Culebra releases decrease from Case CRA14-BL to Case CRA14-TP at probabilities below about 0.006 and increase at higher probabilities due to changes to the limits of the PBRINE parameter (see discussion above). A change in the PBRINE parameter from 0.015 to 0.070 for vector 98 (the vector with greatest releases shown in Figure 3-40 for both the CRA-2009 PABC and CRA-2014 PA) is largely responsible for the increase in mean release. Culebra releases are identical for Case CRA14-TP and Case CRA14-BV because multiple brine volumes were not calculated using NUTS—it only uses the minimum brine volume. In effect, this makes the calculated Culebra releases relatively conservative.

Culebra releases show a slight increase at higher probabilities from Case CRA14-BV to Case CRA14-0 due to changes in panel pressures and brine saturation caused by updates to the steel corrosion rate and water balance implementation. The releases increase from the CRA-2009 PABC to Case CRA14-0 for replicate 1, although the overall mean across three replicates decreases (Figure 3-38) (see discussion above regarding changes to the PBRINE parameter). Releases from the Culebra (Figure 3-44) for replicate 1 show a different trend than the releases to the Culebra (Figure 3-45) among the different cases, likely due to the time component of release; an increase to the drilling rate changes the times at which the repository becomes flooded, which then affect the times at which there are releases to the Culebra. The stochastic nature of the drilling times can thus result in different trends between releases to the Culebra and releases from the Culebra.

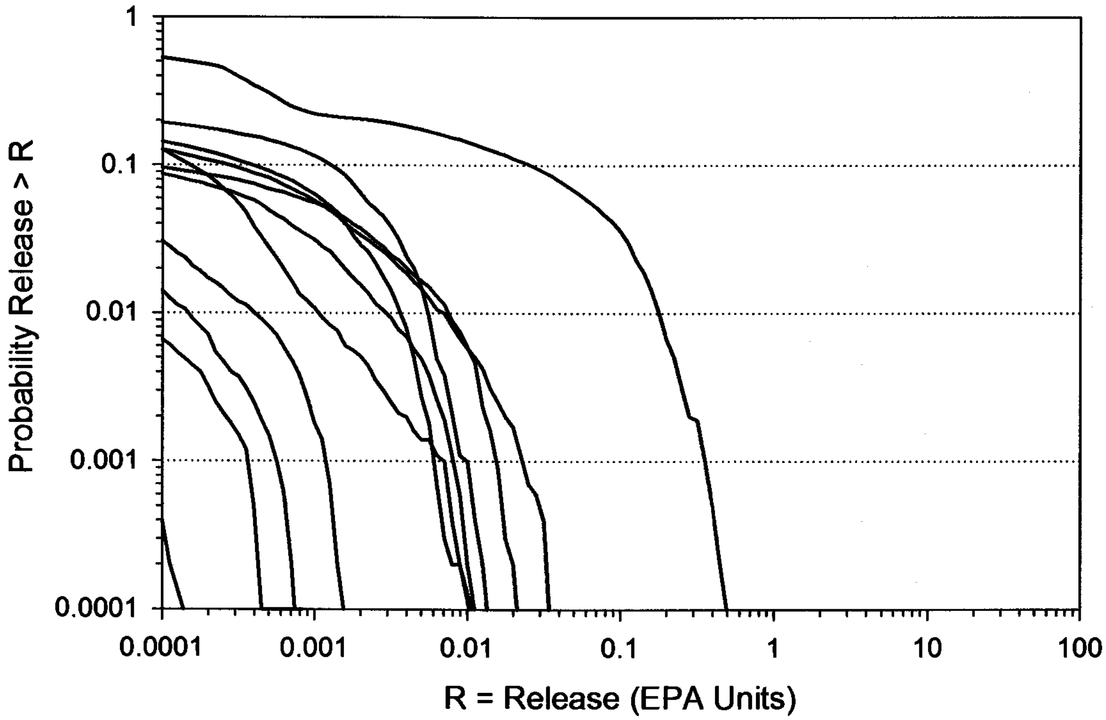

Figure 3-33: CRA-2014 PA Replicate 1 Normalized Culebra Transport Releases

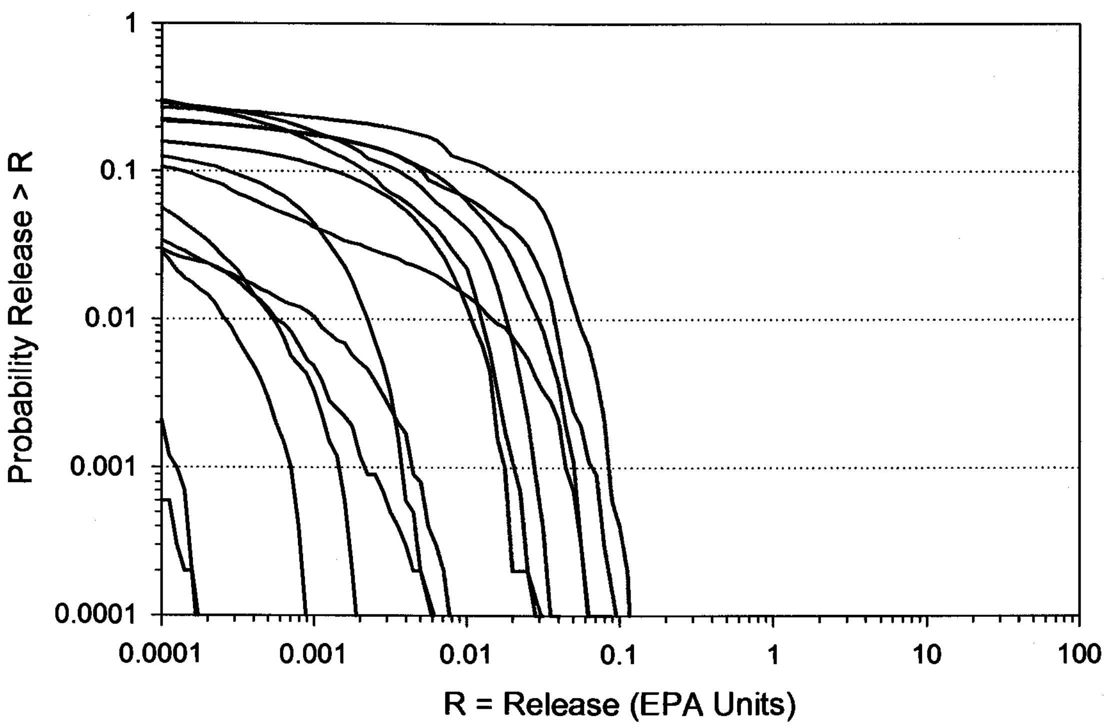

Figure 3-34: CRA-2014 PA Replicate 2 Normalized Culebra Transport Releases

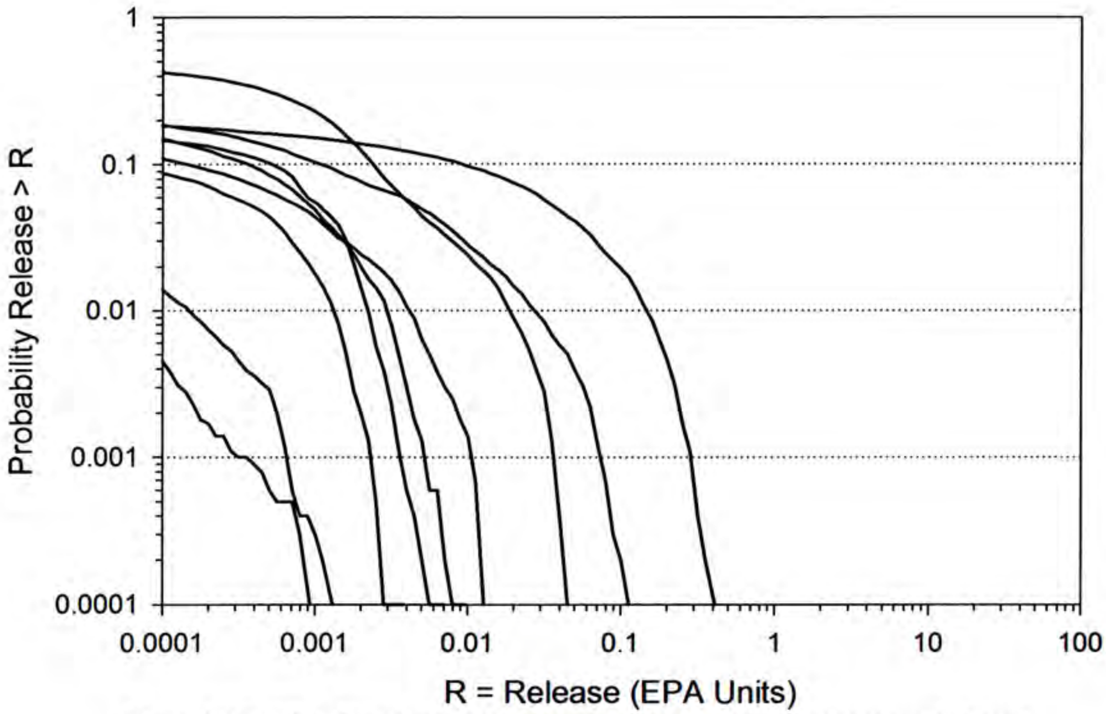

Figure 3-35: CRA-2014 PA Replicate 3 Normalized Culebra Transport Releases

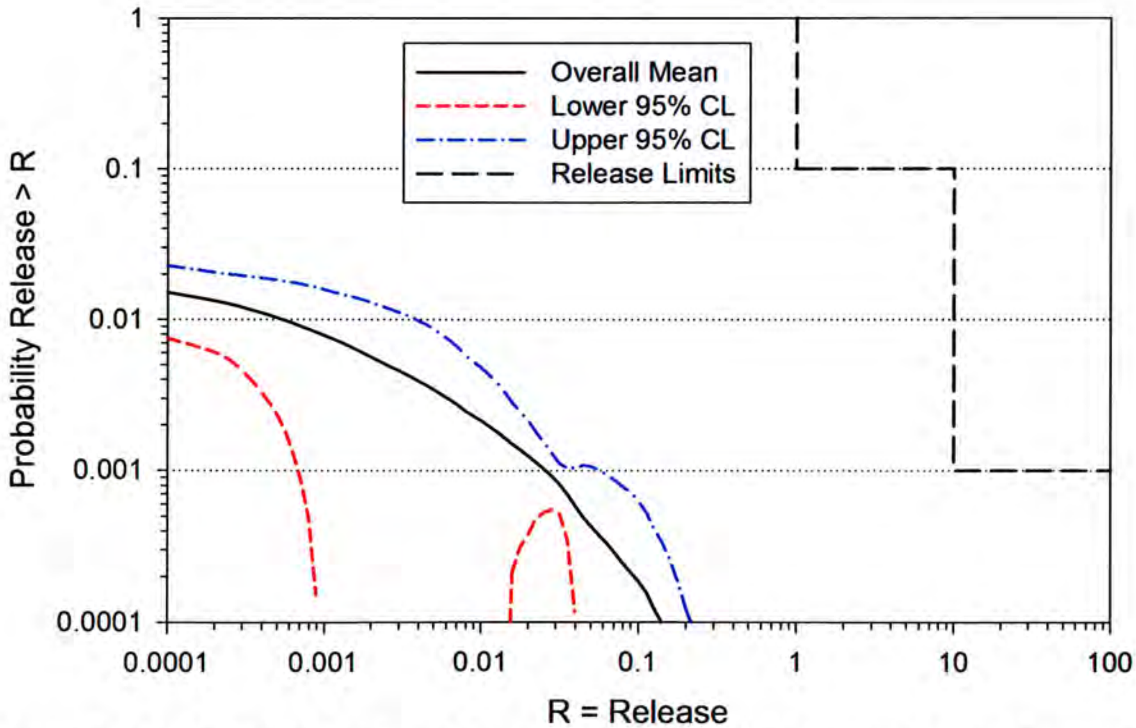

Figure 3-36: CRA-2014 PA Confidence Limits on Overall Mean for Normalized Culebra Transport Releases

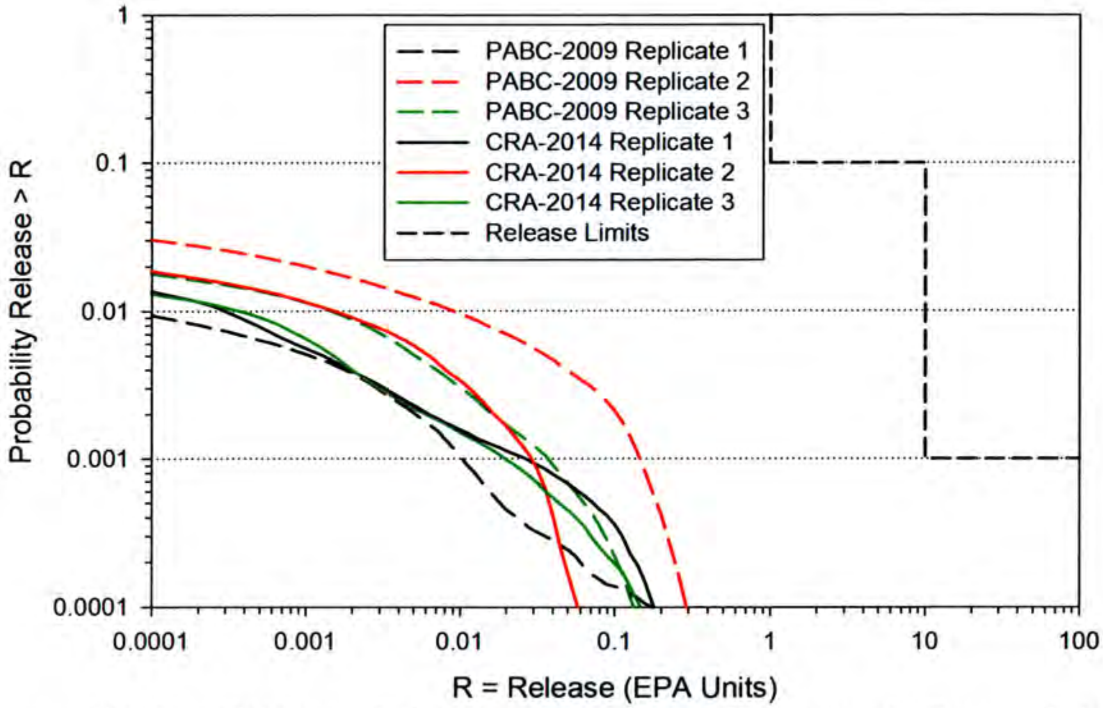

Figure 3-37: CRA-2014 PA and CRA-2009 PABC Mean CCDFs by Replicate for Transport Releases from the Culebra

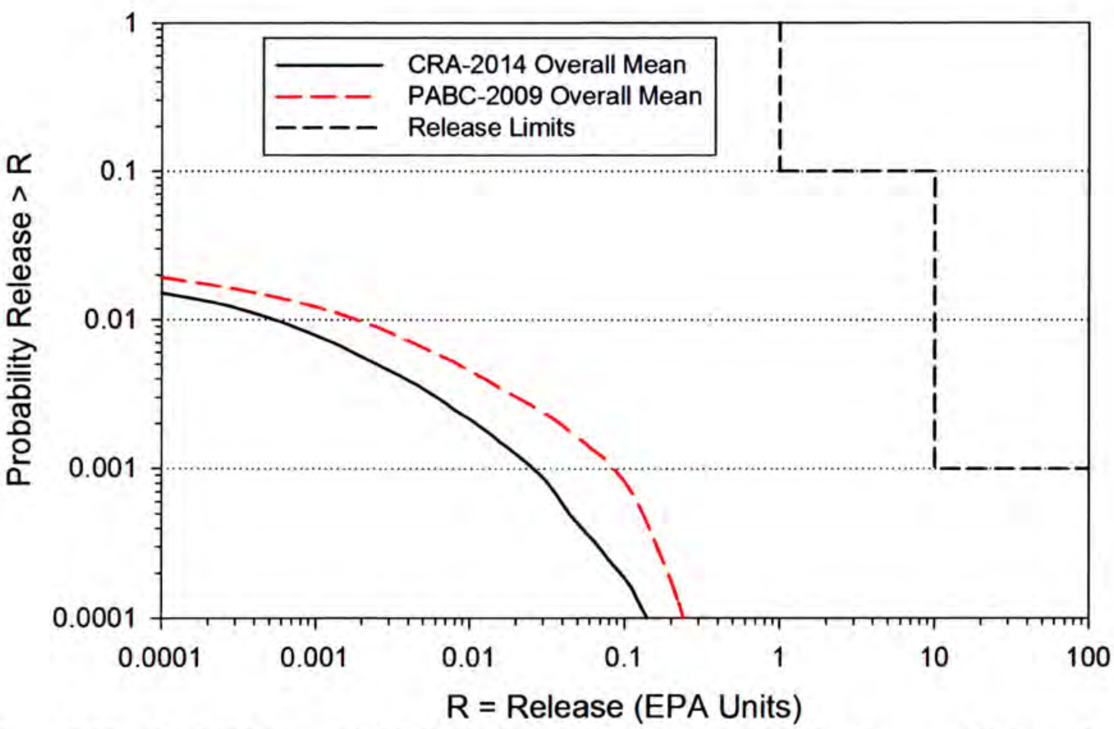

Figure 3-38: CRA-2014 PA and CRA-2009 PABC Overall Mean CCDFs for Transport Releases from the Culebra

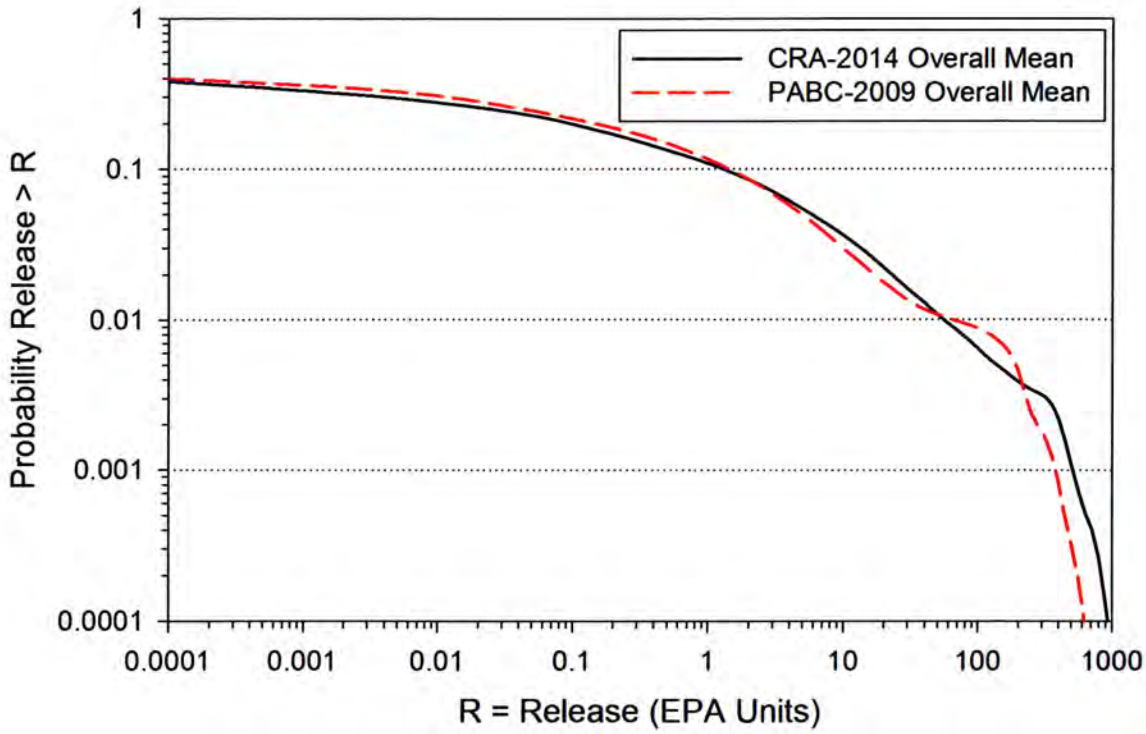

Figure 3-39: CRA-2014 and CRA-2009 PABC Overall Mean CCDFs for Transport Releases to the Culebra

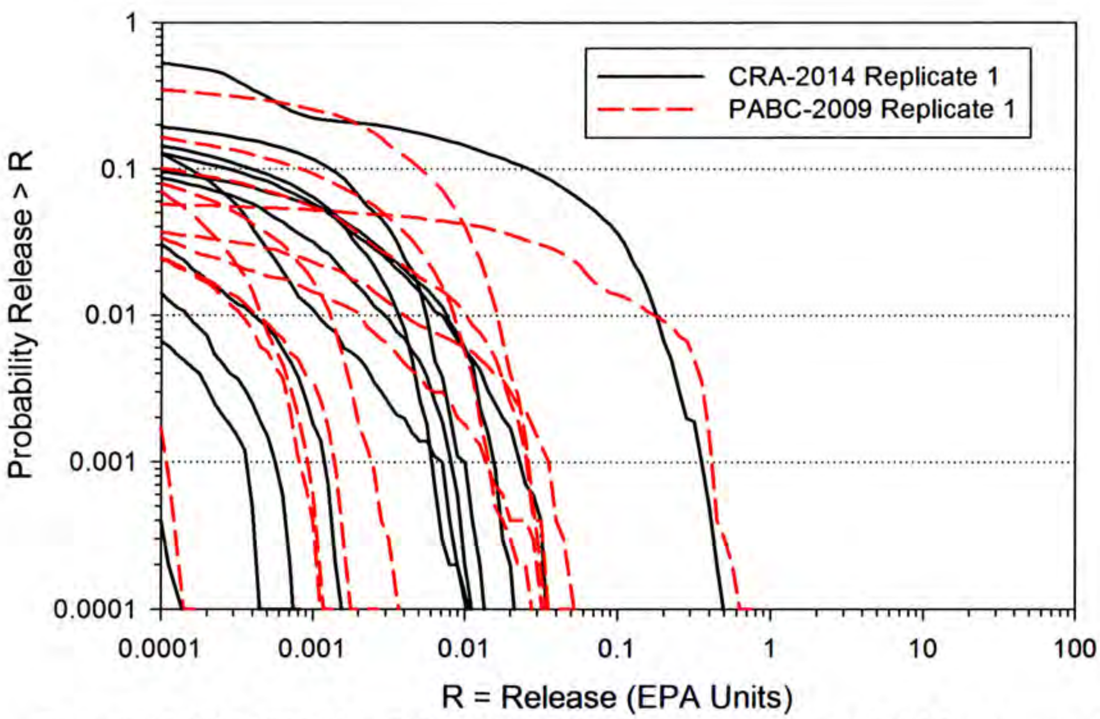

Figure 3-40: CRA-2014 PA and CRA-2009 PABC Replicate 1 Normalized Culebra Transport Releases

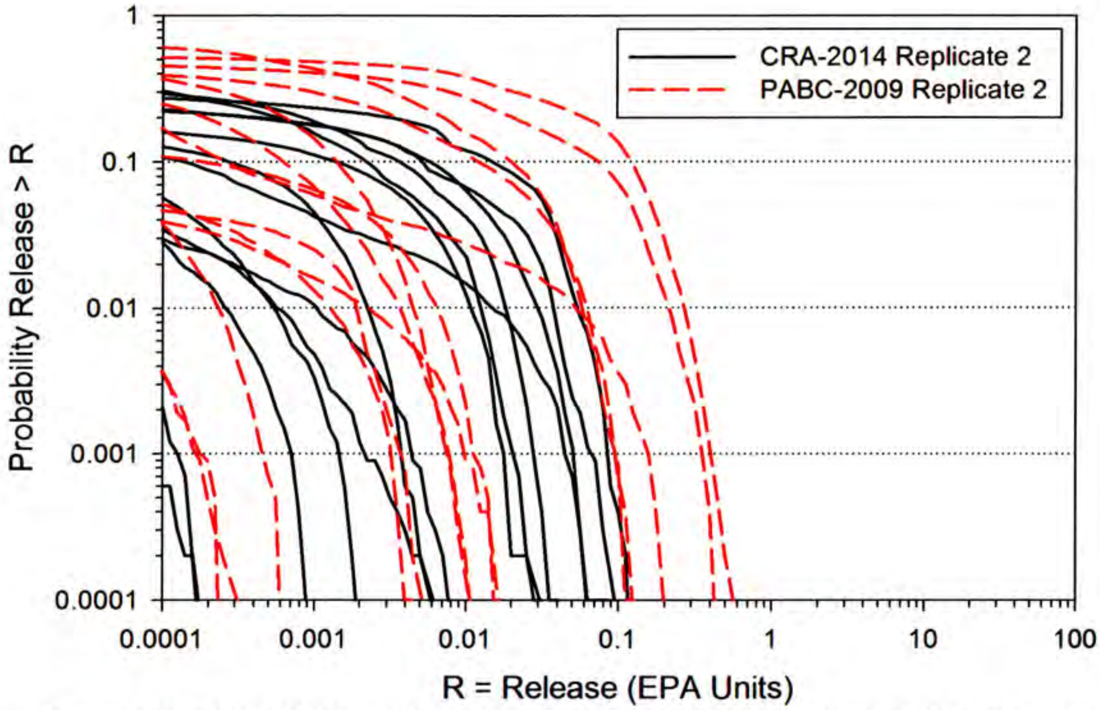

Figure 3-41: CRA-2014 PA and CRA-2009 PABC Replicate 2 Normalized Culebra Transport Releases

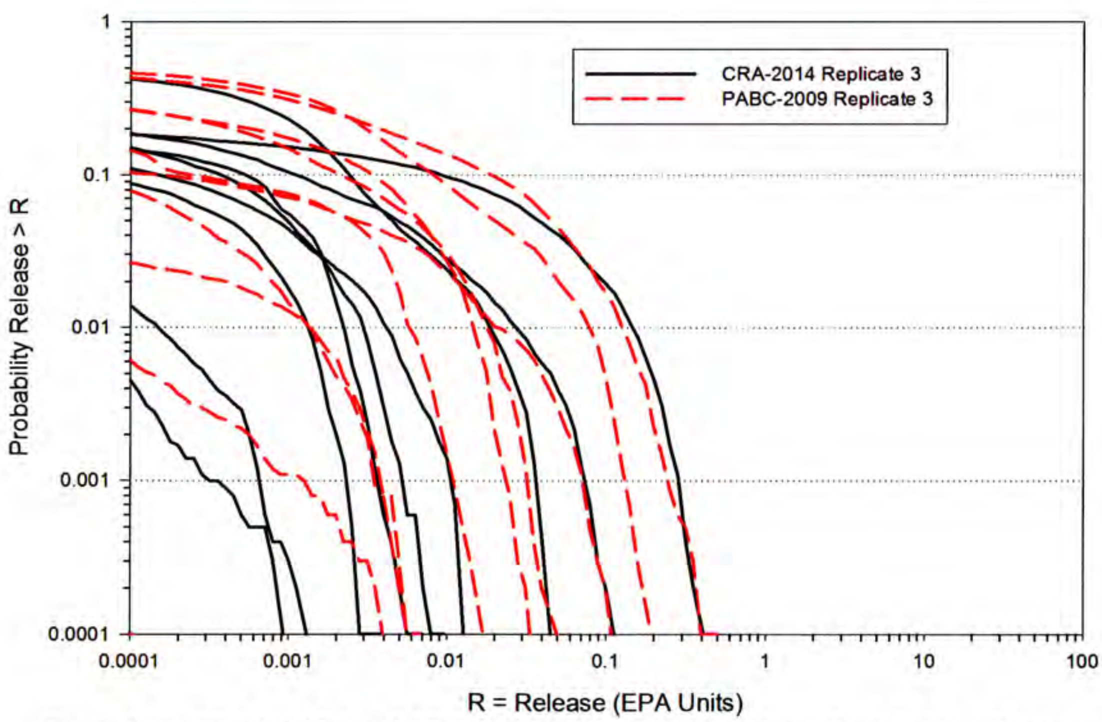

Figure 3-42: CRA-2014 PA and CRA-2009 PABC Replicate 3 Normalized Culebra Transport Releases

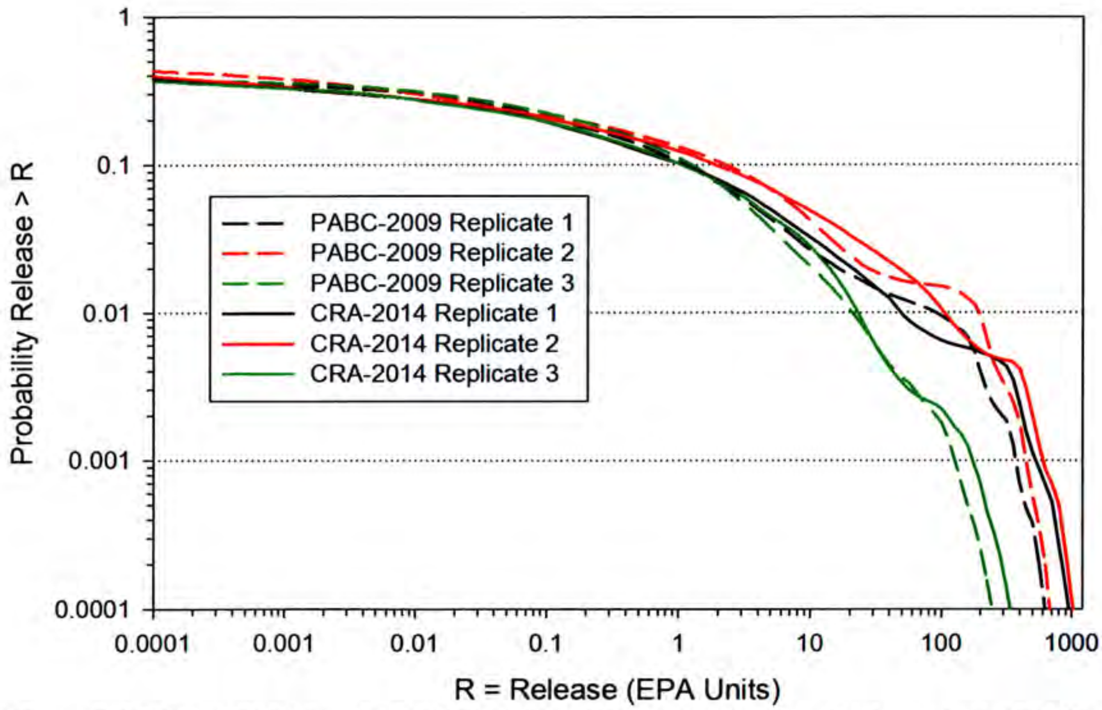

Figure 3-43: CRA-2014 PA and CRA-2009 PABC CCDFs for Transport Releases to the Culebra by Replicate

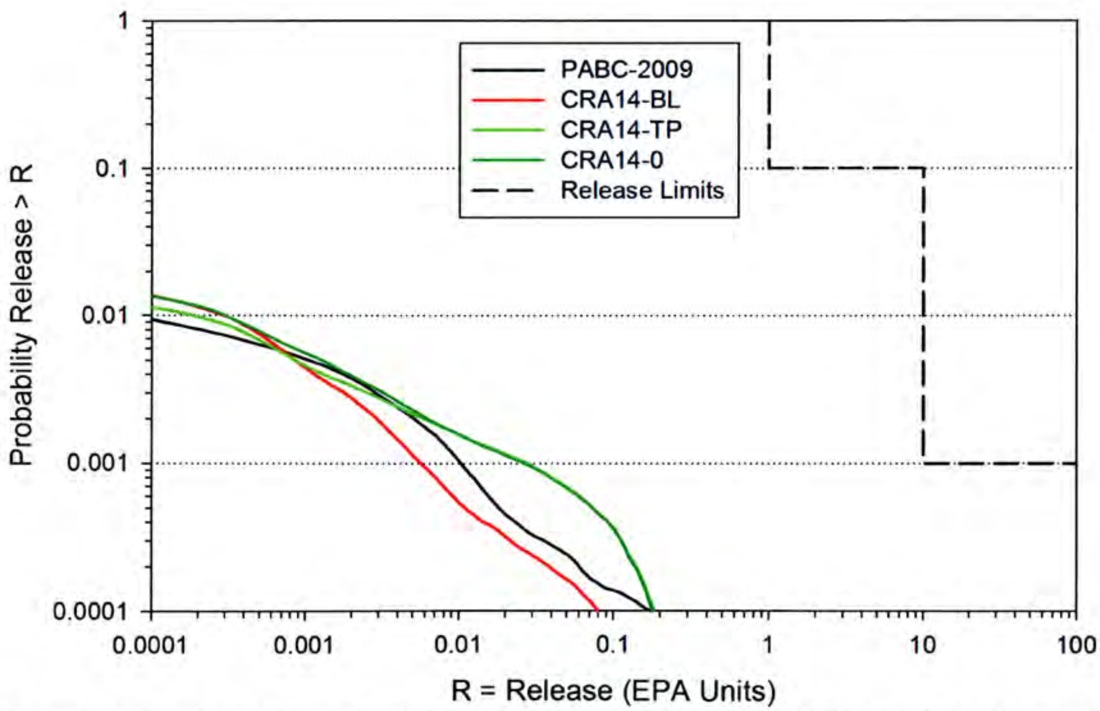

Figure 3-44: Replicate 1 Normalized Culebra Transport Releases (the PCS-2012 PA Culebra releases are identical to the CRA-2009 PABC releases; Culebra releases are the same for Case CRA14-TP and Case CRA14-BV.)

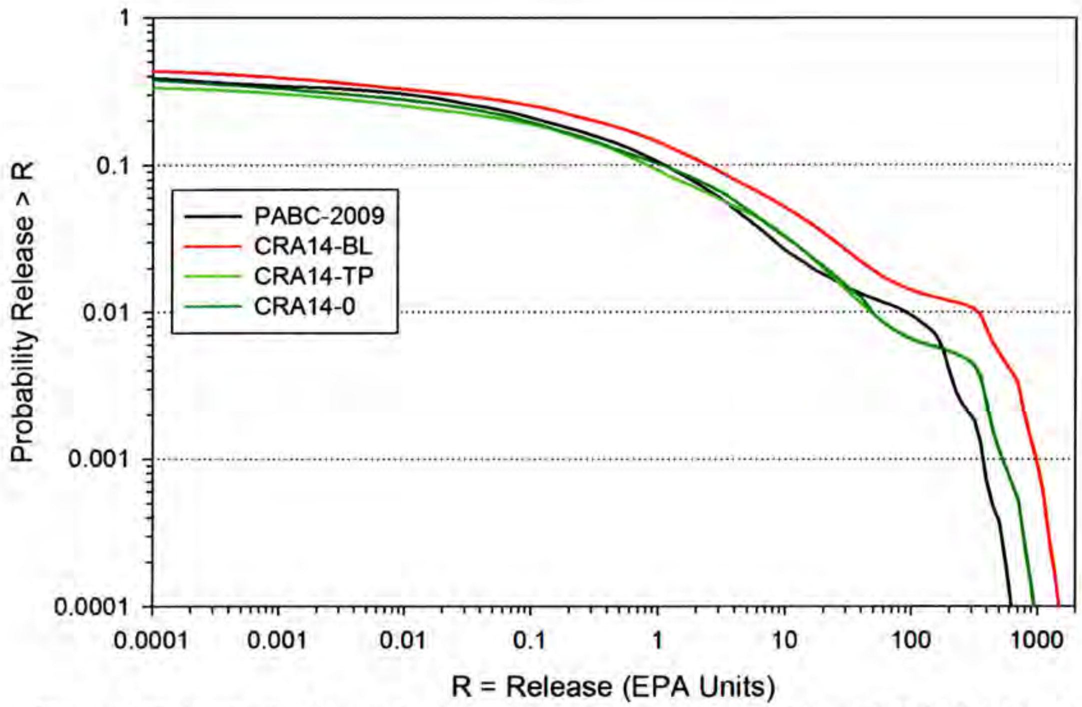

Figure 3-45: Replicate 1 Normalized Transport Releases to the Culebra (PCS-2012 PA Culebra releases are identical to CRA-2009 PABC releases; Culebra releases are the same for Case CRA14-TP and Case CRA14-BV.)

3.5 Total Normalized Releases

Total normalized releases for the CRA-2014 PA are presented in this section and compared to results obtained in the CRA-2009 PABC. Total releases are calculated by summing the releases across each potential release pathway, namely cuttings and cavings releases, spallings releases, direct brine releases, and transport releases. Figure 3-46 shows the total releases for replicate 1 for all cases. Figure 3-47, Figure 3-48, and Figure 3-49 show the CRA-2014 PA CCDFs for total releases in replicates 1, 2, and 3, respectively. Figure 3-50 shows the 95 percent confidence limits about the overall transport mean.

For replicate 1, total releases are different for each of the six cases. Total releases increase slightly from CRA-2009 PABC to the PCS-2012 PA due to increases in DBRs and spallings releases (Zeitler 2012). Total releases increase from the PCS-2012 PA to Case CRA14-BL due to increased cuttings and cavings releases and DBRs, as well as some mixed changes (across the probability scale) to spallings and Culebra releases. Total releases decrease from Case CRA14-BL to Case CRA14-TP due to decreased cuttings and cavings releases and DBRs. Total releases decrease from Case CRA14-TP to Case CRA14-BV due to decreased DBRs. Total releases are approximately the same from Case CRA14-BV to Case CRA14-0 PA due to decreases in spallings releases and DBRs combined with an increase in Culebra releases (which was not indicative of the observed decrease in the overall mean Culebra releases). Overall, total releases decrease from the CRA-2009 PABC to the CRA-2014 PA due to decreases in mean releases from all components analyzed here.

As seen in Figure 3-50, the overall mean for normalized total releases and its lower/upper 95% confidence limits are well below acceptable release limits. Accordingly, the WIPP remains in compliance with the containment requirements of 40 CFR Part 191. The overall means of the CRA-2014 PA release components contributing are compared to their CRA-2009 PABC counterparts in Figure 3-51. CRA-2014 PA and CRA-2009 PABC overall mean CCDFs for total releases are compared in Figure 3-53. As seen in Figure 3-53, overall mean CCDFs obtained in CRA-2009 PABC and the CRA-2009 PA are nearly identical only for release values less than approximately 0.005 EPA Units. For releases greater than 0.0005 EPA units, the difference between the overall means obtained in the two analyses becomes more obvious with CRA-2009 PABC total releases exceeding those seen in the CRA-2014 PA.

A comparison of the statistics on the overall mean for total normalized releases obtained in the CRA-2009 PABC (Camphouse 2009) and the CRA-2014 PA can be seen in Table 1. At probabilities of 0.1 and 0.001, values obtained for the mean total release are lower for the CRA-2014 PA.

Table 1: CRA-2014 PA and CRA-2009 PABC Statistics on the Overall Mean for Total Normalized Releases in EPA Units at Probabilities of 0.1 and 0.001

Probability	Analysis	Mean Total Release	Lower 95% CL	Upper 95% CL	Release Limit
0.1	CRA-2014 PA	0.0367	0.0352	0.0384	1
	CRA-2009 PABC	0.0937	0.0908	0.0959	1
0.001	CRA-2014 PA	0.261	0.109	0.384	10
	CRA-2009 PABC	1.10	0.372	1.77	10

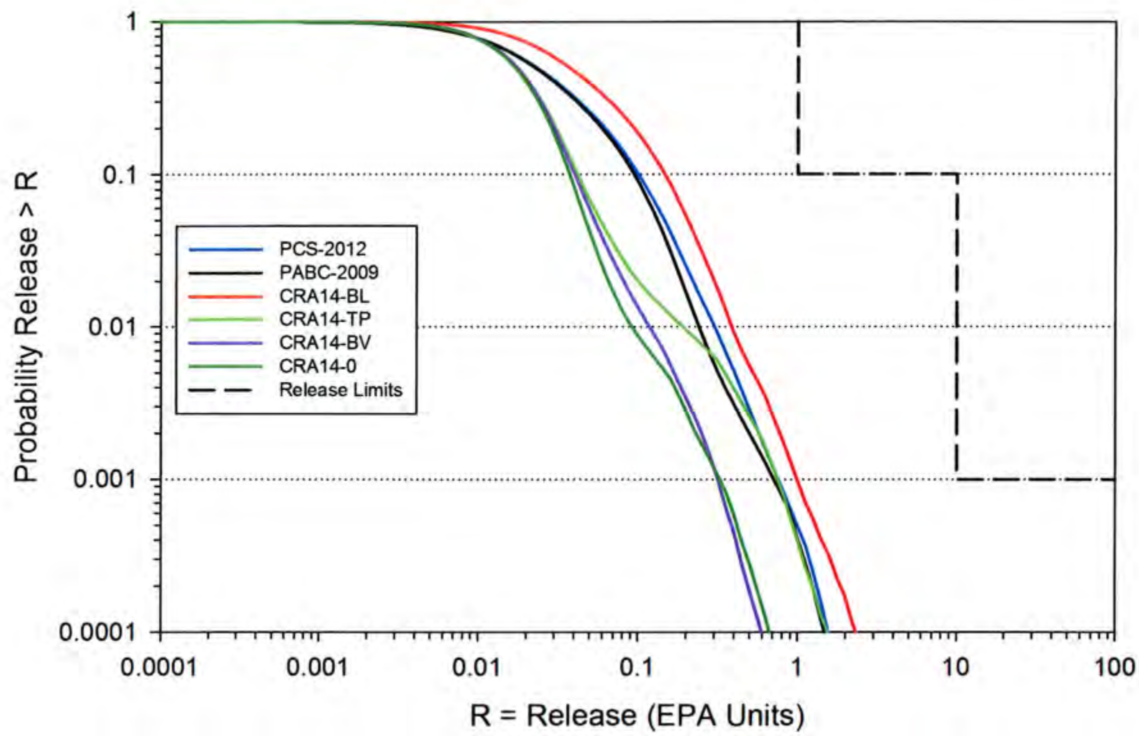

Figure 3-46: Replicate 1 Total Normalized Releases

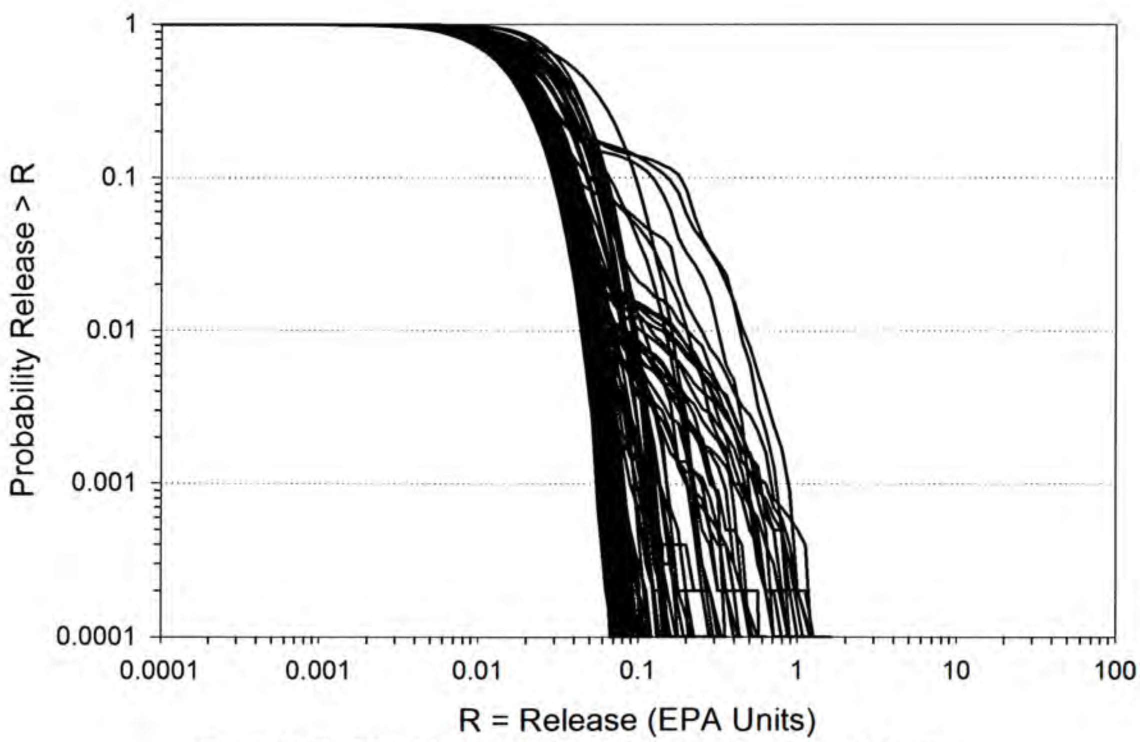

Figure 3-47: CRA-2014 PA Replicate 1 Total Normalized Releases

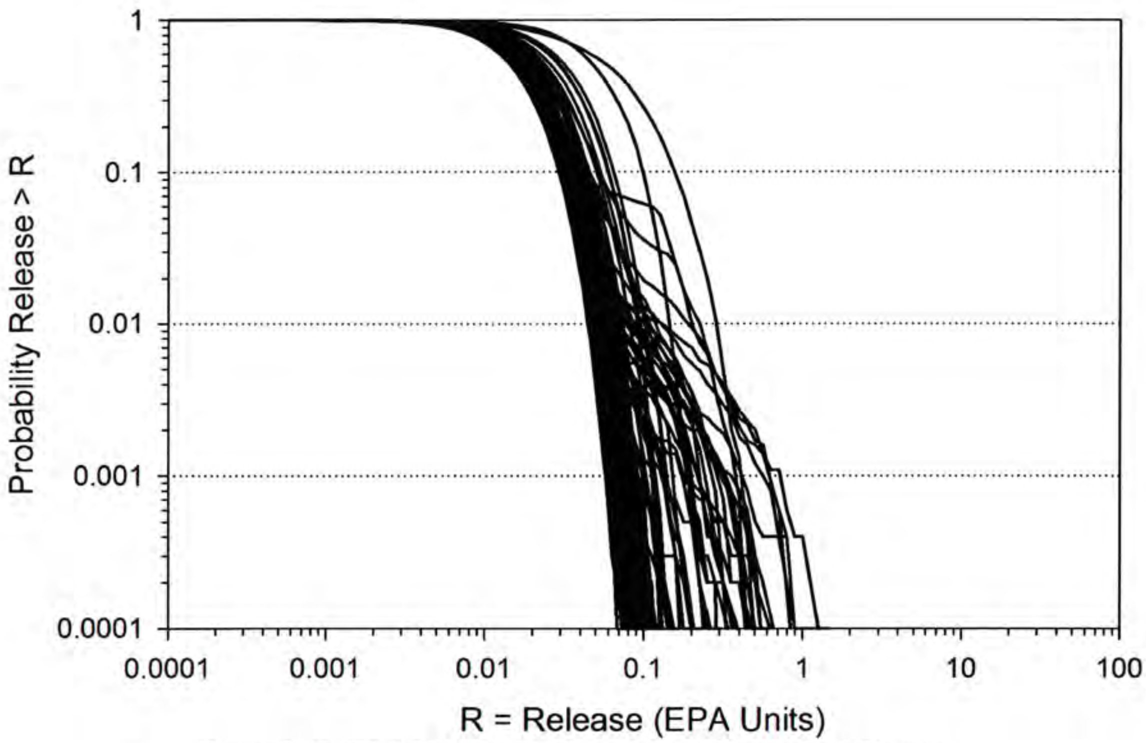

Figure 3-48: CRA-2014 PA Replicate 2 Total Normalized Releases

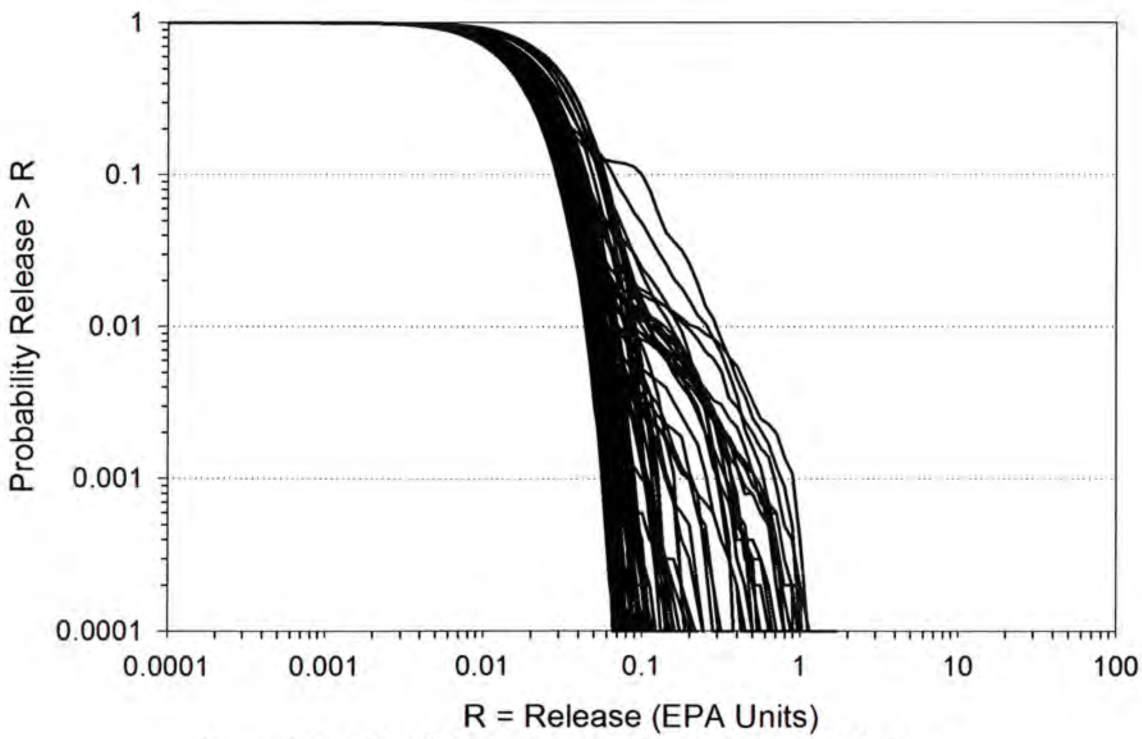

Figure 3-49: CRA-2014 PA Replicate 3 Total Normalized Releases

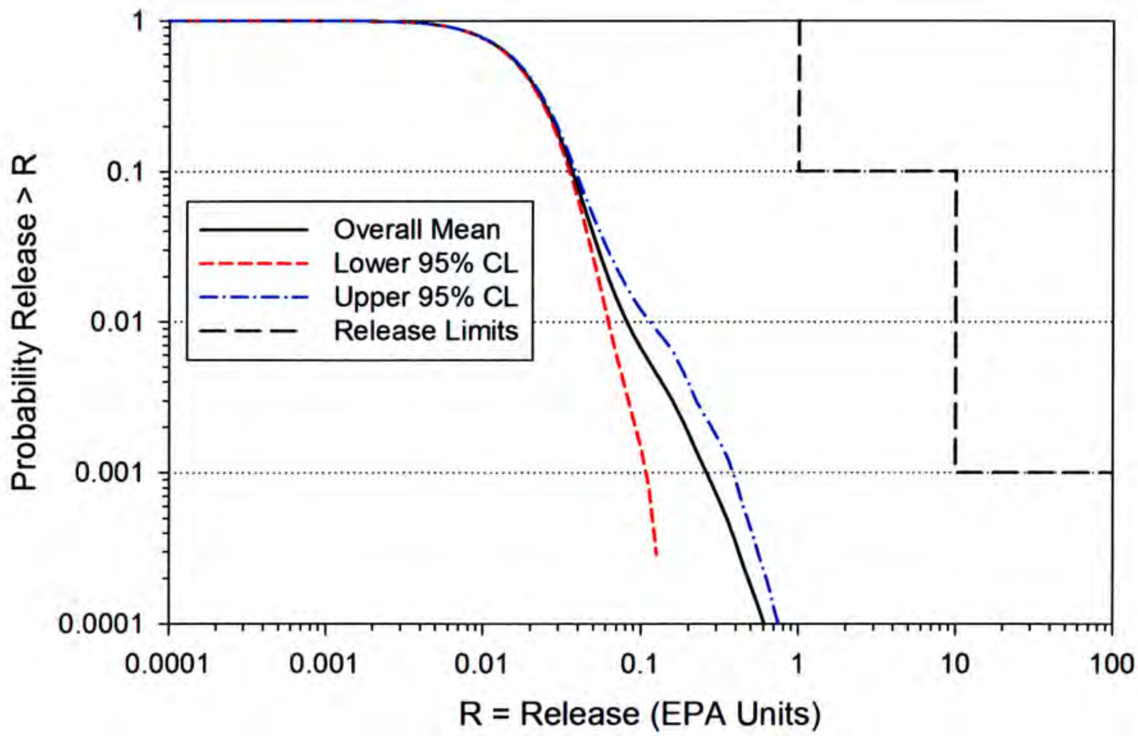

Figure 3-50: CRA-2014 PA Confidence Limits on Overall Mean for Total Normalized Releases

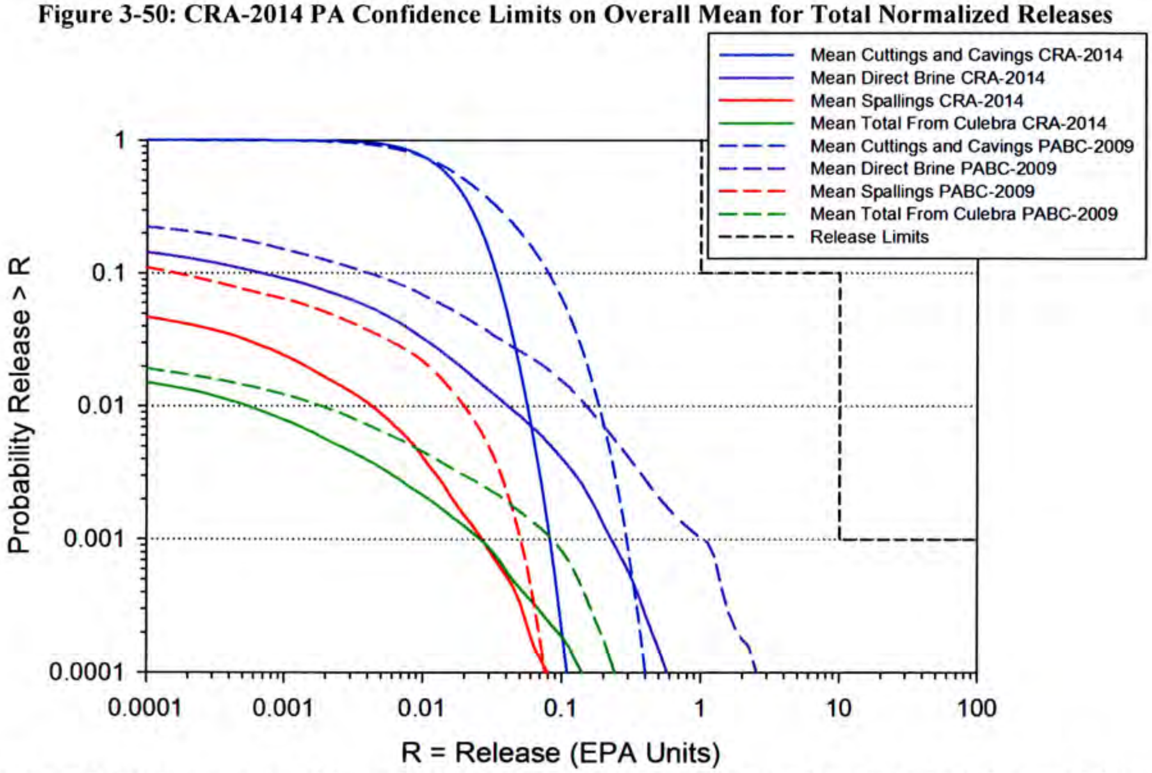

Figure 3-51: Comparison of Overall Means for Release Components of the CRA-2014 PA and CRA-2009 PABC

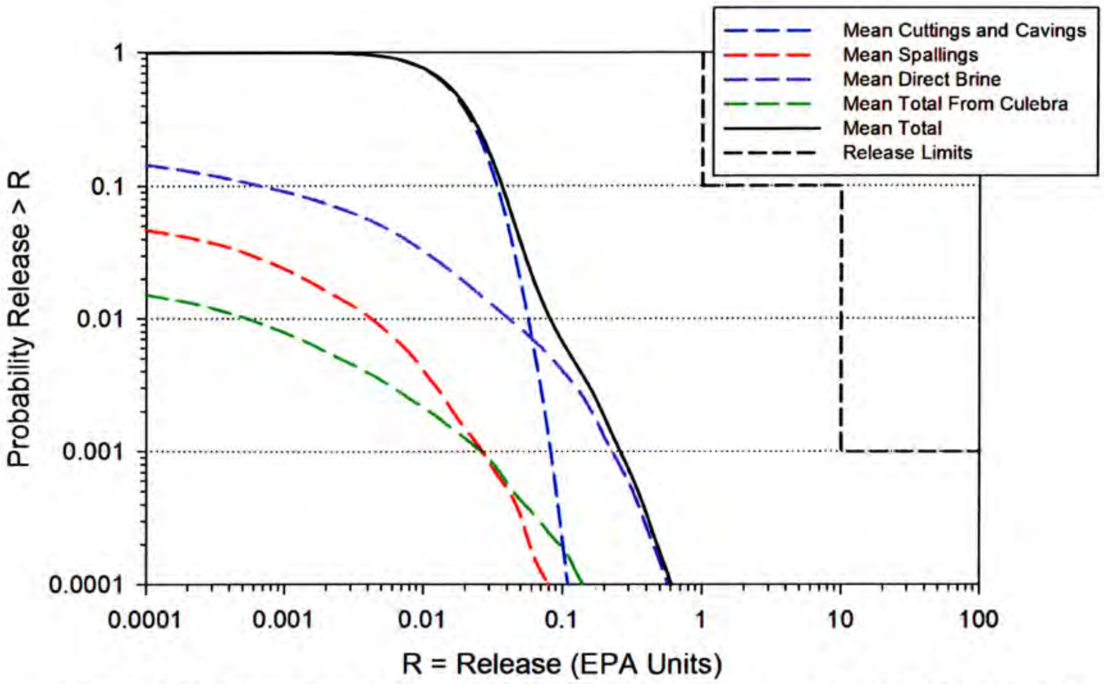

Figure 3-52: Comparison of Overall Means for Release Components of the CRA-2014 PA

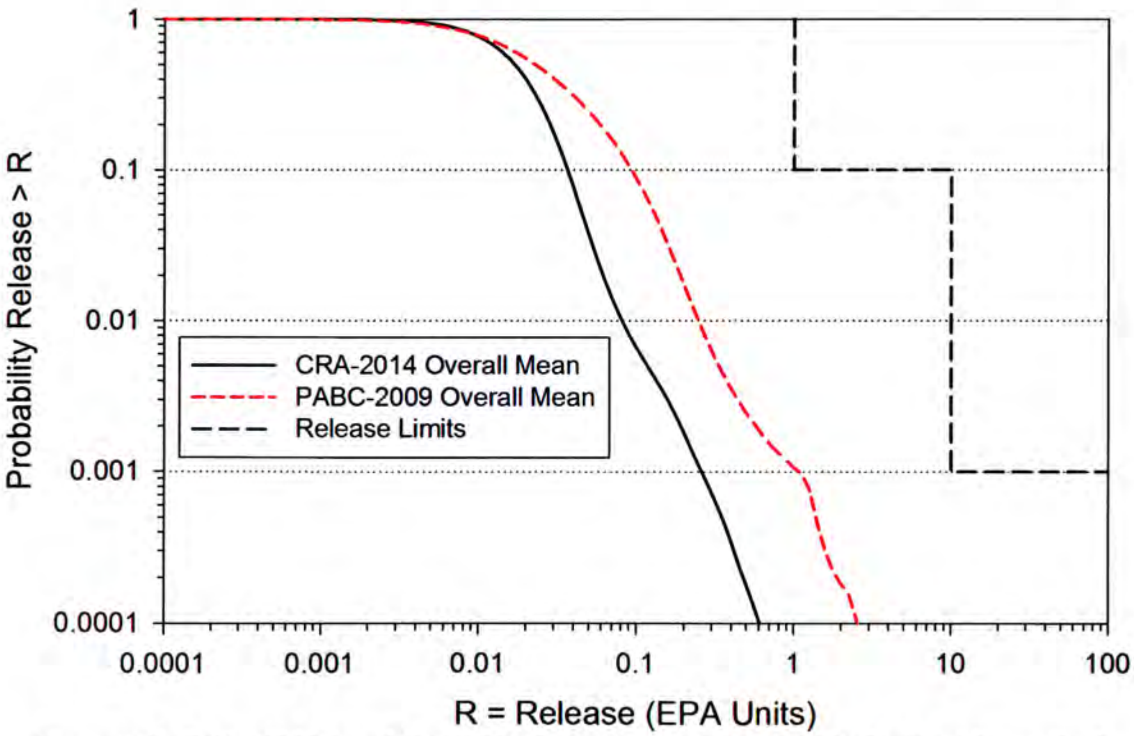

Figure 3-53: CRA-2014 PA and CRA-2009 PABC Overall Mean CCDFs for Total Normalized Releases

4 Summary

Total normalized releases calculated in the CRA-2014 PA remain below their regulatory limits. As a result, the WIPP remains in compliance with the containment requirements of 40 CFR Part 191. Releases to the surface continue to have greater probability than releases to the LWB.

CRA-2014 PA cuttings and cavings releases and volumes are lower than those seen in the CRA-2009 PABC primarily due to changes to the TAUFAIL parameter. CRA-2014 PA spallings volumes and releases are lower than those seen in the CRA-2009 PABC primarily due to a decrease in waste panel pressure following changes to the steel corrosion rate and the updated repository water balance implementation. Direct brine releases are lower than those seen in the CRA-2009 PABC results due to changes in the PBRINE parameter and the brine volume implementation, but also in part by the update to the steel corrosion rate and water balance correction. Releases to the LWB resulting from subsurface transport of radionuclides through the Culebra are lower in the the CRA-2014 PA, although the contribution to the overall mean releases is small, and due to the small number of nonzero release vectors, directly linking changes in mean releases to parameter changes is difficult.

5 References

Camphouse, R.C. 2009. Analysis Package for CCDFGF: CRA-2009 Performance Assessment Baseline Calculation. Sandia National Laboratories, Carlsbad, NM. ERMS 549013.

Camphouse, R.C. 2012. Analysis Plan for the 2012 WIPP Panel Closure System Performance Assessment A-161, Revision 0. Sandia National Laboratories, Carlsbad, NM. ERMS 557726.

Camphouse, R.C. 2013a. Analysis Plan for the 2014 WIPP Compliance Recertification Application Performance Assessment. Sandia National Laboratories, Carlsbad, NM. ERMS 559198.

Camphouse, R.C. 2013b. Analysis Package for Salado Flow Modeling Done in the 2014 Compliance Recertification Application Performance Assessment (CRA-2014 PA). Sandia National Laboratories, Carlsbad, NM. In Progress.

Clayton, D.J., R.C. Camphouse, J.W. Garner, A.E. Ismail, T.B. Kirchner, K.L. Kuhlman, M.B. Nemer. 2010. Summary Report of the CRA-2009 Performance Assessment Baseline Calculation. Sandia National Laboratories, Carlsbad, NM. ERMS 553039.

Clayton, D.J., S. Dunagan, J.W. Garner, A.E. Ismail, T.B. Kirchner, G.R. Kirkes, M.B. Nemer. 2008. Summary Report of the 2009 Compliance Recertification

Application Performance Assessment. Sandia National Laboratories, Carlsbad, NM. ERMS 548862.

Cotsworth, E. 2005. EPA Letter on Conducting the Performance Assessment Baseline Change (PABC) Verification Test. U.S. EPA, Office of Radiation and Indoor Air, Washington, D.C. ERMS 538858.

Cotsworth, E. 2009. EPA Letter on CRA-2009 First Set of Completeness Comments. U.S. EPA, Office of Radiation and Indoor Air, Washington, D.C. ERMS 551444.

Helton, J. et al. 1998. Uncertainty and Sensitivity Analysis Results Obtained in the 1996 Performance Assessment for the Waste Isolation Pilot Plant. Sandia National Laboratories, Albuquerque, NM. SAND98-0365.

Kicker, D. 2013. Analysis Package for Cuttings, Cavings, and Spallings: 2014 Compliance Recertification Application Performance Assessment (CRA-2014 PA) Sandia National Laboratories, Carlsbad, NM. In Progress

Kirchner, T. 2010. Sensitivity of the CRA-2009 Performance Assessment Baseline Calculation Releases to Parameters. Sandia National Laboratories, Carlsbad, NM. In Progress

Leigh, C.D., J.F. Kanney, L.H. Brush, J.W. Garner, G.R. Kirkes, T. Lowry, M.B. Nemer, J.S. Stein, E.D. Vugrin, S. Wagner, and T.B. Kirchner. 2005. 2004 Compliance Recertification Application Performance Assessment Baseline Calculation, Revision 0. Sandia National Laboratories, Carlsbad, NM. ERMS 541521.

Long, J. J. 2013. Execution of Performance Assessment Codes for the CRA-2014 Performance Assessment. Sandia National Laboratories, Carlsbad, N.M. In Progress

MacKinnon, R.J., and G. Freeze. 1997a. Summary of EPA-Mandated Performance Assessment Verification Test (Replicate 1) and Comparison With the Compliance Certification Application Calculations, Revision 1. Sandia National Laboratories, Carlsbad, NM. ERMS 422595

MacKinnon, R.J., and G. Freeze. 1997b. Summary of Uncertainty and Sensitivity Analysis Results for the EPA-Mandated Performance Assessment Verification Test, Rev. 1. Sandia National Laboratories, Carlsbad, NM. ERMS 420669.

MacKinnon, R.J., and G. Freeze. 1997c. Supplemental Summary of EPA-Mandated Performance Assessment Verification Test (All Replicates) and Comparison With the Compliance Certification Application Calculations, Revision 1. Sandia National Laboratories, Carlsbad, NM. . ERMS 414880.

Malama, B. 2012. Analysis Package for Direct Brine Releases: 2012 Panel Closure System Performance Assessment (PCS-2012 PA). Sandia National Laboratories, Carlsbad, NM. ERMS 558226.

Malama, B. 2013. Analysis Package for Direct Brine Releases: CRA-2014 Performance Assessment (CRA-2014 PA). Sandia National Laboratories, Carlsbad, NM. In Progress.

U.S. Congress. 1992. WIPP Land Withdrawal Act, Public Law 102-579, 106 Stat. 4777, 1992; as amended by Public Law 104-201, 110 Stat. 2422, 1996.

U.S. Department of Energy (DOE) 1996. Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot. U.S. Department of Energy Waste Isolation Pilot Plant, Carlsbad Area Office, Carlsbad, NM. DOE/CAO-1996-2184.

U.S. Department of Energy (DOE) 2004. Title 40 CFR Part 191 Compliance Recertification Application for the Waste Isolation Pilot Plant, , 10 vols., U.S. Department of Energy Waste Isolation Pilot Plant, Carlsbad Area Office, Carlsbad, NM. DOE/WIPP 2004-3231.

U.S. Environmental Protection Agency (EPA). 1993. 40 CFR Part 191: Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes; Final Rule. Federal Register, Vol. 58, 66398-66416.

U.S. Environmental Protection Agency (EPA). 1996. 40 CFR Part 194: Criteria for the Certification and Recertification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations; Final Rule. Federal Register, Vol. 61, 5223-5245.

US Environmental Protection Agency (EPA). 1998. 40 CFR 194, Criteria for the Certification and Recertification of the Waste Isolation Pilot Plant's Compliance with the Disposal Regulations: Certification Decision: Final Rule, Federal Register. Vol. 63, 27354-27406. ERMS 251924.

U.S. Environmental Protection Agency (EPA). 2006. 40 CFR 194, Criteria for the Certification and Recertification of the Waste Isolation Pilot Plant's Compliance with the Disposal Regulations: Certification Decision: Final Rule, Federal Register. Vol. 71, 18010-18021.

U.S. Environmental Protection Agency (EPA). 2010. 40 CFR Part 194 Criteria for the Certification and Recertification of the Waste Isolation Pilot Plant's Compliance With the Disposal Regulations: Recertification Decision, Federal Register No. 222, Vol. 75, pp. 70584-70595, November 18, 2010.

Zeitler, T.R. 2012. CCDFGF Analysis Package for the AP-161 (PCS-2012) Performance Assessment. Sandia National Laboratories, Carlsbad, NM. ERMS 558337.