EEG-85

ANALYSIS OF EMPLACED WASTE DATA AND IMPLICATIONS OF NON-RANDOM EMPLACEMENT FOR PERFORMANCE ASSESSMENT FOR THE WIPP

Lawrence E. Allen
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FOREWORD

The purpose of the New Mexico Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the Waste Isolation Pilot Plant (WIPP) Project to ensure the protection of the public health and safety and the environment of New Mexico. The WIPP Project, located in southeastern New Mexico, became operational in March 1999 for the disposal of transuranic (TRU) radioactive wastes generated by the national defense programs. The EEG was established in 1978 with funds provided by the U.S. Department of Energy (DOE) to the State of New Mexico. Public Law 100-456, the National Defense Authorization Act, Fiscal Year 1989, Section 1433, assigned the EEG to the New Mexico Institute of Mining and Technology and continued the original contract DE-AC04-79AL10752 through DOE contract DE-AC04-89AL58309. The National Defense Authorization Act for Fiscal Year 1994, Public Law 103-160, and the National Defense Authorization Act for Fiscal Year 2000, Public Law 106-65, continued the authorization.

The EEG performs independent technical analyses on a variety of issues. Now that the WIPP is operational, these issues include facility modifications and waste characterization for future receipt and emplacement of remote-handled waste, generator site audits, contact-handled waste characterization issues, the suitability and safety of transportation systems, mining of new panels, and analysis of new information as part of the five year recertification cycles as mandated by the WIPP Land Withdrawal Act. Review and comment is provided on the annual Safety Analysis Report and Proposed Modifications to the Hazardous Waste Facility Permit. The EEG also conducts an independent radiation surveillance program which includes a radiochemical laboratory.

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The analysis described in this report was reviewed by Dr. Bruce Davis of Centennial, Colorado. Dr. Davis is a consulting geostatistician with extensive experience in statistical and geostatistical applications to problems in the environmental, mining, and petroleum industries. The authors wish to thank Dr. Davis for his comments and suggestions.

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ACRONYMS

CCA	Compliance Certification Application
CCDF	Complimentary Cumulative Distribution Function
DOE	US Department of Energy
EEG	Environmental Evaluation Group
EPA	US Environmental Protection Agency
GSLIB	Geostatistical Software Library
LWA	Land Withdrawal Act
PE-Ci	Plutonium-239 Equivalent Curie
POC	Pipe Overpack Container
SNL	Sandia National Laboratories
SWB	Standard Waste Box
TDOP	Ten-Drum Overpack
TRU	Transuranic
WIPP	Waste Isolation Pilot Plant
WTS	Washington TRU Solutions
WWIS	WIPP Waste Information System

EXECUTIVE SUMMARY

The WIPP Land Withdrawal Act recognized that after the initial certification of the WIPP and start of disposal operations, operating experience and ongoing research would result in new technical and scientific information. The Environmental Evaluation Group (EEG) has previously reported on issues that it considers important as the Department of Energy (DOE) works towards the first recertification. One of these issues involves the assumption of random emplacement of waste used in the performance assessment calculations in support of the initial certification application. As actual waste emplacement data are now available from four years of disposal, the EEG performed an analysis to evaluate the validity of that initial assumption and determine implications for performance assessment.

Panel 1 was closed in March 2003. The degree of deviation between actual emplaced waste in Panel 1 and an assumption of random emplacement is apparent with concentrations of ^{239}Pu being 3.20 times, ^{240}Pu being 2.67 times, and ^{241}Am being 4.13 times the projected repository average for the space occupied by the waste.

A spatial statistical analysis was performed using available Panel 1 data retrieved from the WWIS and assigned room coordinates by Sandia National Laboratories. A comparison was made between the waste as emplaced and a randomization of the same waste. Conversely, the distribution of waste as emplaced is similar to the distribution of waste in the individual containers and can be characterized as bi-modal and skewed with a long high-concentration tail. The distribution of randomized waste is fairly symmetrical, as would be expected from classical statistical theory. In the event of a future drilling intrusion, comparison of these two distributions shows a higher probability of intersecting a high-concentration stack of the actual emplaced waste, over that of the same waste emplaced in a randomized manner as was assumed in the certified performance assessment calculations. This suggests that the methodology used during the certification performance assessment calculations underestimated potential releases by cuttings and cavings. That methodology sampled each layer in a stack separately and used the mean concentration for each waste stream.

The DOE performed a spallings release bounding analysis at the time of the initial certification. However, the selection of the statistical sample size of the bounding analysis assumed independence of samples, which is not characteristic of non-random waste emplacement. Instead it is demonstrated that the emplaced waste is spatially dependent. Therefore, the bounding analysis may not be adequate in the event of continued non-random emplacement. As for cuttings and cavings releases, the probability of a high-concentration intersection during an intrusion is increased because of non-random emplacement. Performance assessment calculations should either incorporate this increased probability or an adequate bounding calculation should be performed using spatial statistical methodology.

The use of Pipe Overpack Containers for isolation of the high ^{239}Pu waste may reduce the amount of material brought to the surface as a result of an intrusion. However, the integrity of these containers over the regulatory period has not yet been demonstrated. If the DOE wishes to take credit for the container, the DOE needs to provide an analysis of structural integrity and the potential effects resulting from the use of Pipe Overpack Containers.

1.0 INTRODUCTION

The Waste Isolation Pilot Plant (WIPP), built and operated by the US Department of Energy (DOE), serves as a geologic repository for disposal of defense transuranic (TRU) waste. The WIPP Land Withdrawal Act (LWA) required initial certification of compliance of the WIPP by the US Environmental Protection Agency (EPA) (LWA 1992). In addition, a recertification decision by EPA is required by the LWA at least every five years, dated from the initial receipt of waste. Recertification must consider new information resulting from operating experience of the facility and ongoing scientific investigation. The first recertification application is due to EPA by March 2004.

The Environmental Evaluation Group (EEG), in its role of providing independent technical oversight of the WIPP project on behalf of the State of New Mexico, previously identified ongoing issues relevant to the first recertification performance assessment calculations (Allen et al. 2002). These calculations attempt to represent the amount of radioactive material released as the result of some future drilling effort inadvertently penetrating a long forgotten repository. The performance assessment calculations for demonstration of compliance with EPA's standards assumed random emplacement of waste. Operational experience however, confirms non-random emplacement of waste.

In response to EEG's non-random emplacement concerns at the time of the initial certification (Neill 1997), the DOE provided a bounding analysis to demonstrate compliance, assuming contiguous emplacement of a high-activity waste stream (Dials 1997). This analysis was accepted by the EPA.

With the availability of operational data, this issue should be re-visited in the performance assessment calculations for the first recertification. Using emplaced waste data through September 2002, the EEG performed an analysis of the effects of non-random emplacement. This included: 1) comparison of emplaced activity for Panel 1 with the average activity, 2) analysis of the effects of random versus non-random emplacement on vertical stacking of waste containers, 3) analysis of volume/variance implications on the DOE bounding analysis, and 4) analysis of the potential positive effects of waste emplaced in pipe overpack containers.

The spatial distribution of waste in the repository is an issue for compliance because of the possibility of future human intrusions during the 10,000 year regulatory period. The WIPP is located in an area rich in oil, gas, and potash resources (Silva 1994). Performance assessment calculations include intrusion scenarios involving drilling into the repository which results in solids released due to cuttings, cavings and spallings (DOE 1996). Each intrusion is assumed to penetrate each container in a particular stack. For cuttings and cavings, it was assumed in the initial certification performance assessment that potential radioactivity that may be released into the environment can come from different waste streams, each having different amounts of activity at the time of the intrusion. This was accomplished by sampling the distribution of waste stream activity three times, once for each layer of waste in the stack, weighted by the waste stream volumes, and averaging to determine the released activity. Therefore, there was no correlation between layers of waste, which is inconsistent with the manner in which waste arrives and is actually emplaced. DOE's analysis resulted in cuttings and cavings releases that were greater than would occur from assuming average repository radionuclide concentrations, but were still a relatively small amount of allowed releases (Neill 1997).

A spallings release, which results from a pressurized repository, may be much larger. The initial performance assessment assumed that a spallings event would release material from multiple drums and multiple waste streams and could be approximated by the average activity of all contact-handled waste at the time of the intrusion. This is essentially an assumption of a homogenous distribution of radionuclides throughout the repository. It was calculated that the material removed by a spallings release would be between two and nineteen times the internal volume of a 55-gallon drum.

2.0 EMPLACEMENT OF WASTE

The underground WIPP facility design includes eight panels for disposal of transuranic waste (see Figure 1). Each panel consists of seven disposal rooms. Haulage drifts may be utilized as Panels 9 and 10 following emplacement of waste in the eight designed panels. Panel 1 was partially filled and closed by March 2003. At the present time waste is being emplaced in Panel 2 and excavation of Panel 3 is underway.

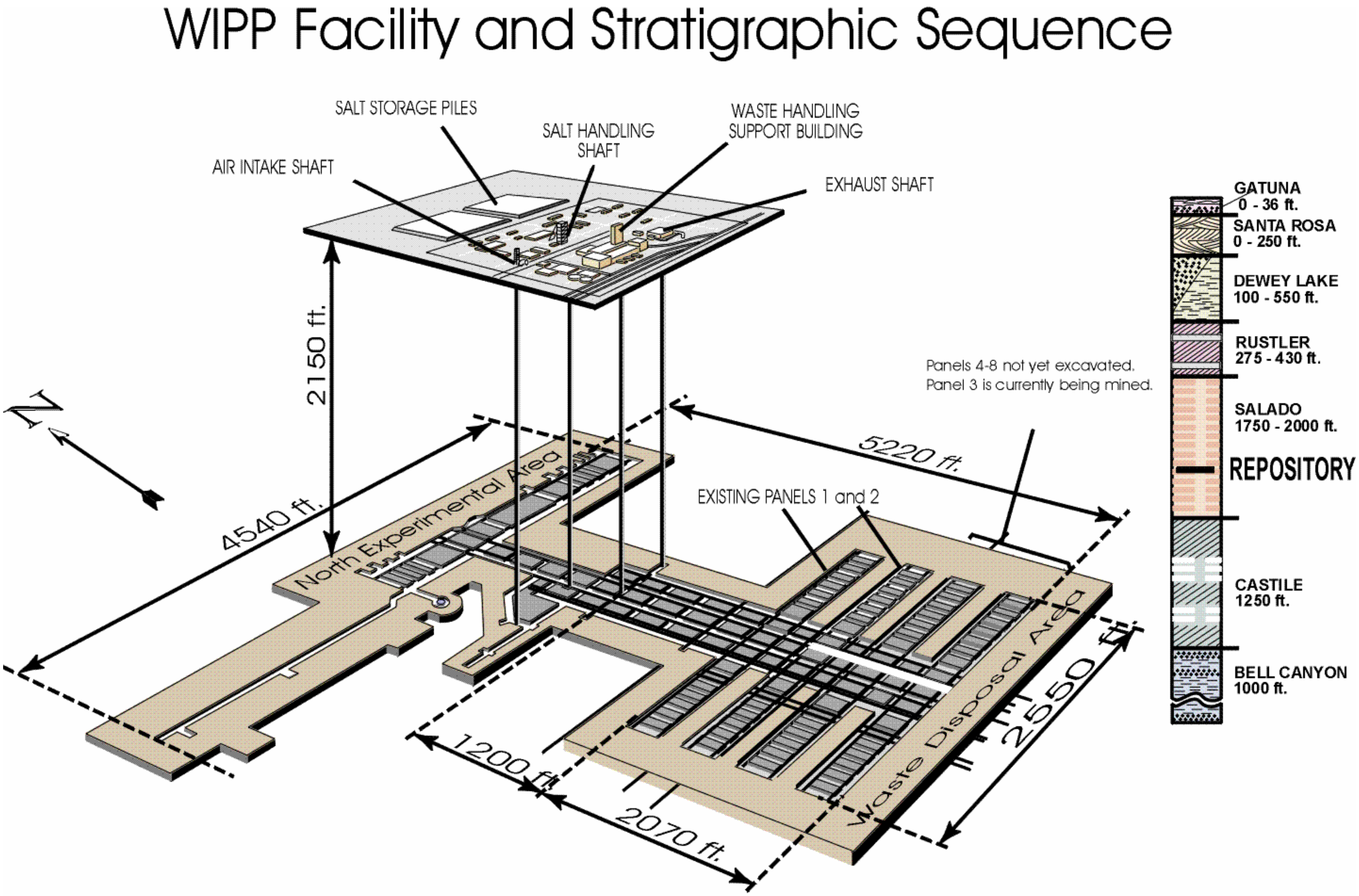


Figure 1. The WIPP facility and stratigraphic sequence. Panel 2 is currently in use. Waste emplacement was completed in Panel 1 during March 2003 Source of Figure: DOE.

Waste emplaced in Panel 1 was contained in: 1) drums, 2) standard waste boxes (SWB), 3) pipe overpack containers (POC), or 4) the recently permitted ten drum overpack (TDOP). Figure 2 shows schematics of these containers. Panel 1 drums are a 55-gallon drum which are constructed of steel and have an internal volume of 0.208 m^3. Seven drums are typically banded together for transportation to WIPP and emplacement in the underground (7 pack).

A SWB is also constructed of steel and has an internal volume of 1.88 m^3. If used for overpacking, each SWB contains up to the equivalent volume of four 55-gallon drums. However, more waste volume may be emplaced into a SWB if directly loaded. POCs fit within a 55 gallon drum, providing additional isolation of the waste. These were used for the high ^{239}Pu residues emplaced in Panel 1 (WTS 2002). TDOPs were used only recently and were not included in the Panel 1 data available at the time of analysis. To date these have been used for lower concentration TRU waste.

SWBs and drums are emplaced in stacks of three containers. Figure 3 shows a stack of three SWBs (center) and two 7 packs with a SWB on top (reader's right).

3.0 ANALYSIS OF WASTE EMPLACEMENT DATA

The EEG analysis of waste emplacement data included:

1) Comparison of emplaced activity for Panel 1 with the average activity.
2) Analysis of the effects of random versus non-random emplacement on vertical compositing of waste container activity.
3) Analysis of volume/variance implications on the DOE bounding analysis.
4) Analysis of the potential positive effects on performance assessment of waste emplaced in POCs.

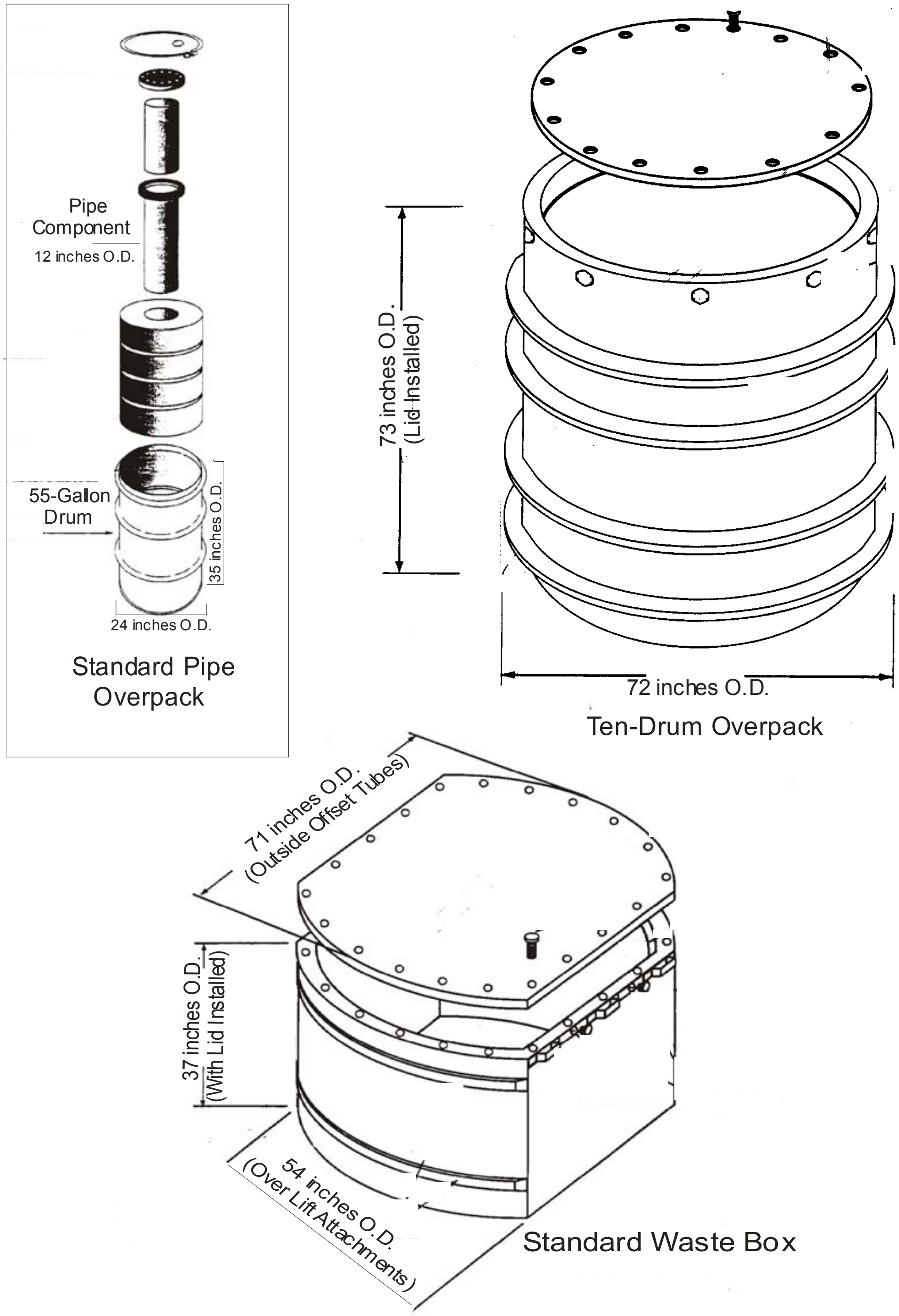


Figure 2. Waste containment packages used in Panel 1 (WTS 2002).

Figure 3. Waste being emplaced in Panel 1. Note stacks of three containers with MgO on top of each stack.

The first analysis was done using all emplaced waste data for Panel 1. The final three analyses used data provided by the DOE during January 2003 and consisted of emplaced waste through September 2002. These data were retrieved from the WIPP Waste Information System (WWIS) and assigned room coordinates by Sandia National Laboratories (SNL) (Stein 2002). Data were complete for rooms three and seven, for about one-half of room two, the intake drifts for rooms four through six, and the exit drifts for rooms two, three, and seven. Waste was only emplaced in the intake drift portion of rooms four through six because of degrading room condition resulting from the time interval between mining and first receipt of waste.

The exact size of each containment package (7 pack or standard waste box) and the exact spacing between packages is not recorded. Therefore, "real" coordinates were not available from SNL. For this analysis, the EEG took the SNL room coordinates and transformed them into a master grid containing all rooms. It was assumed that grid points have a spacing of seven feet. Each grid location is a stack of containment packages in which three layers of waste are emplaced: top, middle, and bottom.

3.1 Emplaced Activity in Panel 1

Non-random emplacement of waste results from the campaigning of specific waste streams to the WIPP depending on the DOE's agreements with the various states which host TRU waste and the readiness of particular waste streams for shipment from the other sites (DOE 2000). Table 1 compares important emplaced radionuclides to date with the average concentration assumed for the repository (DOE 2003). With the final emplacement of waste in Panel 1 during March 2003, the degree of deviation between actual emplaced waste and an assumption of random emplacement is apparent. ^{239}Pu is 3.20 times, ^{240}Pu is 2.67 times, and ^{241}Am is 4.13 times the projected repository average for the space occupied by waste. These averages are based on a total volume of waste of 10,496 m^3.

Table 1

Comparison of Emplaced Panel 1 Ci with Compliance Certification Application Projections

Radionuclide	Curies (Ci)	Ci/m^3	CCA[*] Ci/m^3	Actual/CCA
^{239}Pu	152,000	14.48	4.52	3.20
^{240}Pu	34,290	3.27	1.22	2.67
^{241}Am	120,200	11.45	2.77	4.13
^{238}Pu	6,186	0.59	11.02	0.05
^{241}Pu[**]	482,024	45.92		

[*] Table 4-6, CCA (DOE 1996)

[**] Not a tracked radionuclide but important because of its daughter product, ^{241}Am

It is worth noting that only a very small fraction of the high wattage ^{238}Pu has been shipped and emplaced. This suggests the possibility of some future shipping campaign for the waste streams containing primarily ^{238}Pu, although the relatively short half-life is unlikely to have a significant effect on repository performance.

3.2 Analysis of Effects on Vertical Stacking

For each layer at each grid location, the total number of Plutonium-239 equivalent Curies (PE-Ci) was computed from the contents of each container according to the formula and weighting factors (DOE 2002):

$$PE-Ci=\frac{^{233}U}{3.9}+\frac{^{237}Np}{1.0}+\frac{^{236}Pu}{3.2}+\frac{^{238}Pu}{1.1}+\frac{^{239}Pu}{1.0}+\frac{^{240}Pu}{1.0}+\frac{^{241}Pu}{51.0}+\frac{^{242}Pu}{1.1}+\frac{^{241}Am}{1.0}+\frac{^{243}Am}{1.0}+\frac{^{242}Cm}{30.0}+\frac{^{244}Cm}{1.9}+\frac{^{252}Cf}{3.9}.$$

PE-Ci were used in this analysis, eliminating the need to analyze multiple radionuclides. However, for performance assessment calculations it is necessary to use individual radionuclide data.

Using the internal volume of each waste container (drum, POC, or SWB), the volume of waste was computed at each grid point. Finally, the total concentration (PE-Ci/m^3) was calculated for each stack of three containers. Figure 4a shows the spatial distribution of emplaced waste as expressed by PE-Ci/m^3.

To compare the actual emplaced waste with what could have been emplaced had the waste been emplaced in a random fashion, the following methodology was employed:

1) The concentration (PE-Ci/m^3) at each grid point for each layer (top, middle, and bottom) was calculated.
2) Using a random number generator, the order of each grid location was randomized by layer.
3) The combined concentration was then recalculated for each stack of three containers.

Figure 4b shows this hypothetical spatial distribution of random emplacement. When compared to Figure 4a it may be observed, at least qualitatively, that there are no longer specific areas of high or low activity, but a spatially uniform distribution of concentration.

Emplaced waste and randomized waste distributions were plotted and are shown in Figure 5. The means of the two distributions are essentially the same, but the distribution of actual emplaced waste is bi-modal with a higher standard deviation with a long high-concentration tail. This results from the physical process of non-random emplacement. High-concentration containers will likely be stacked together vertically, as will low-concentration containers.

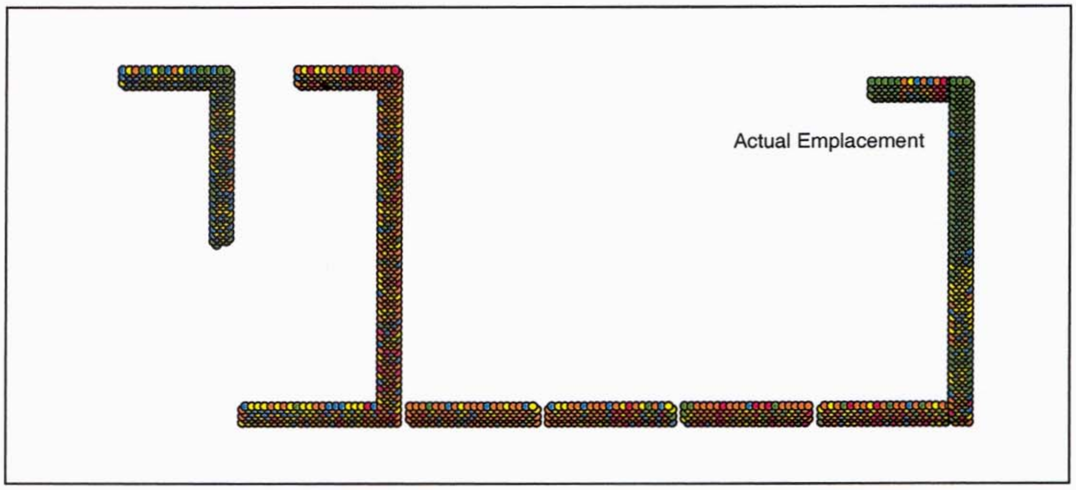


Fig 4a

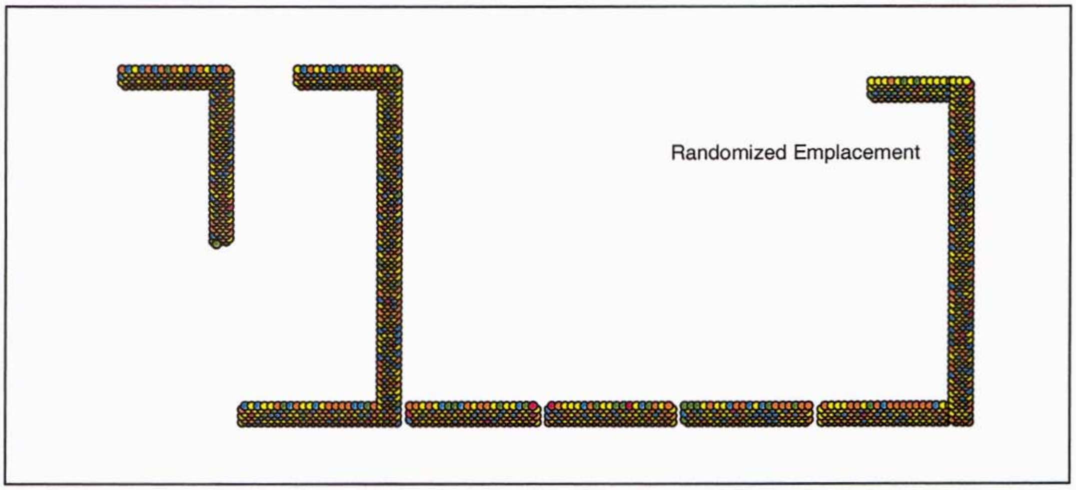


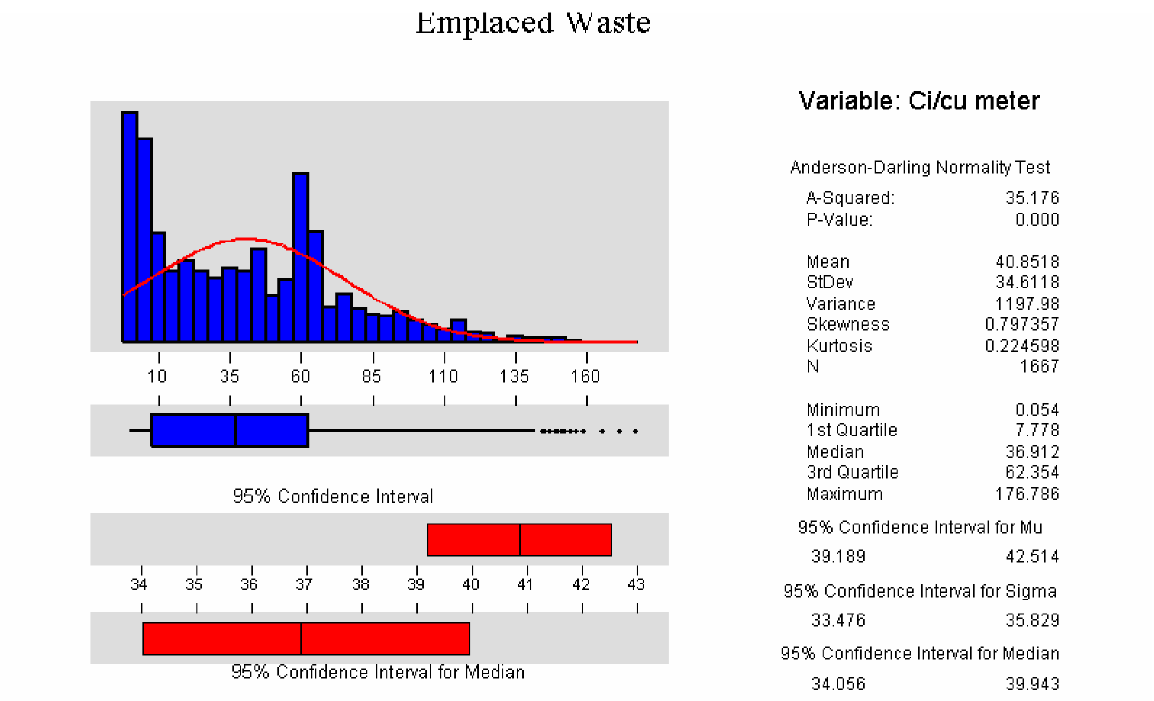
Fig 4b

Figure 4. Panel 1. Actual and randomized emplacement.

Legend

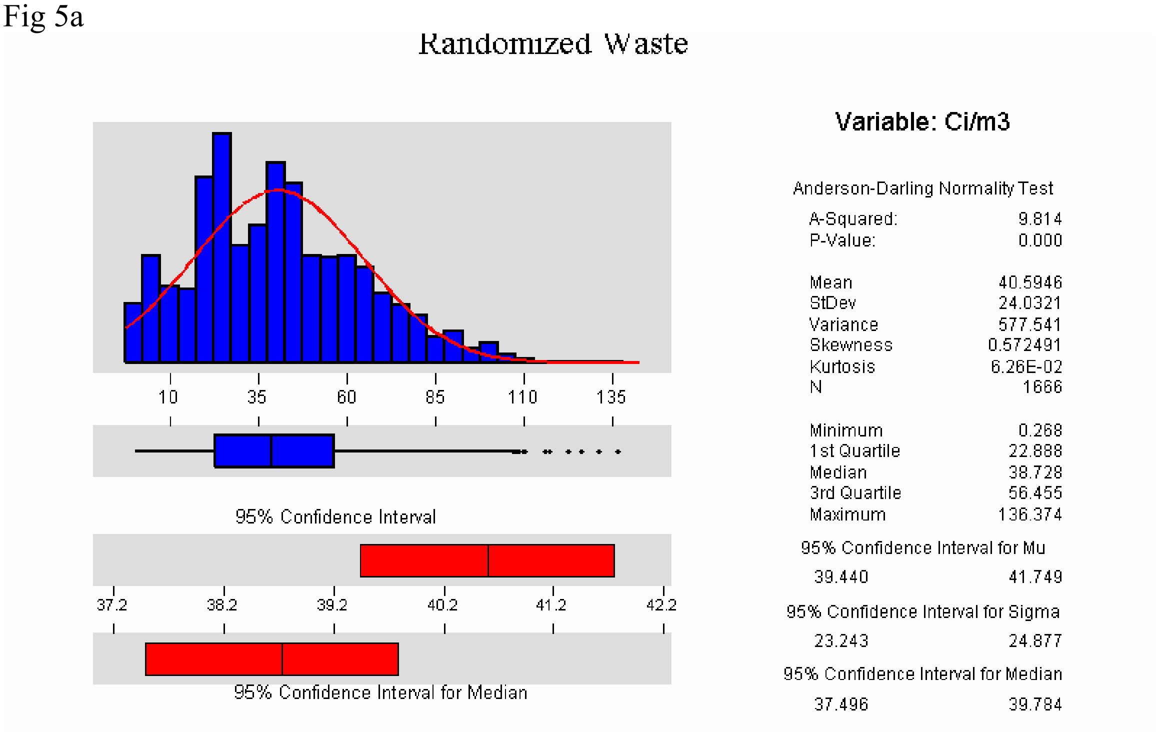
PECi/m3

- ● 0. - 10.
- ● 10. - 25.
- ● 25. - 50.
- ● 50. - 100.
- ● 100. - 200.



```
Variable: Ci/cu meter

Anderson-Darling Normality Test
 A-Squared:              35.176
 P-Value:                 0.000

 Mean                   40.8518
 StDev                  34.6118
 Variance               1197.98
 Skewness              0.797357
 Kurtosis              0.224598
 N                         1667

 Minimum                  0.054
 1st Quartile             7.778
 Median                  36.912
 3rd Quartile            62.354
 Maximum                176.786

95% Confidence Interval for Mu
 39.189                  42.514

95% Confidence Interval for Sigma
 33.476                  35.829

95% Confidence Interval for Median
 34.056                  39.943
```

Fig 5a

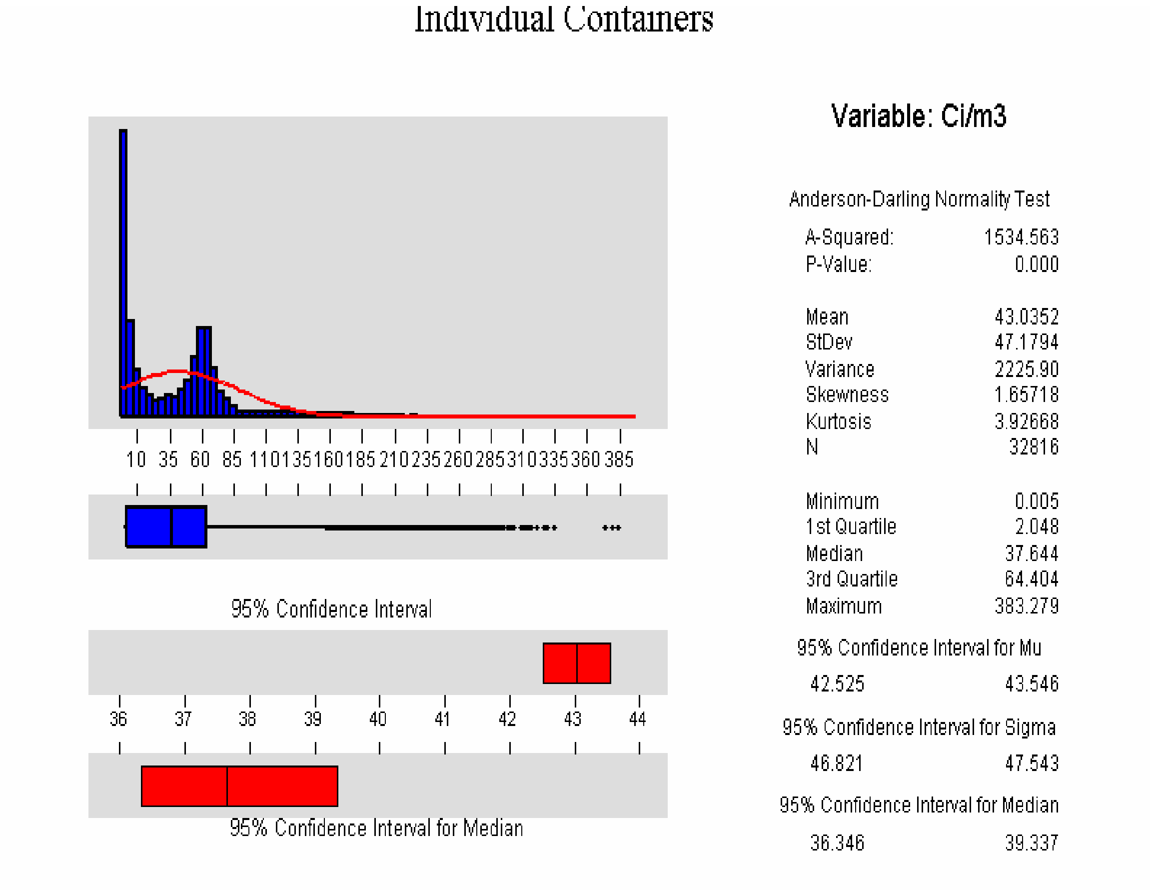


```
Variable: Ci/m3

Anderson-Darling Normality Test
 A-Squared:               9.814
 P-Value:                 0.000

 Mean                   40.5946
 StDev                  24.0321
 Variance               577.541
 Skewness              0.572491
 Kurtosis              6.26E-02
 N                         1666

 Minimum                  0.268
 1st Quartile            22.888
 Median                  38.728
 3rd Quartile            56.455
 Maximum                136.374

95% Confidence Interval for Mu
 39.440                  41.749

95% Confidence Interval for Sigma
 23.243                  24.877

95% Confidence Interval for Median
 37.496                  39.784
```

Fig 5b

Figure 5. Histograms and statistical summaries of actual and randomized emplaced waste.

Figure 6 shows the distribution PE-Ci in individual containers used in this analysis. This distribution is similar to that of the stacks of actual emplaced waste. As was seen in Figure 5, randomizing the spatial location prior to stacking results in a distribution of stacks that is closer to a normal distribution, or a state of maximum entropy as would be predicted from classical statistical theory. Non-random loading results in a skewing of that randomized distribution, with a lower median value but a longer high-concentration tail, more closely resembling the distribution of individual containers.



Variable: Ci/m3

Anderson-Darling Normality Test

A-Squared:	1534.563
P-Value:	0.000
Mean	43.0352
StDev	47.1794
Variance	2225.90
Skewness	1.65718
Kurtosis	3.92668
N	32816
Minimum	0.005
1st Quartile	2.048
Median	37.644
3rd Quartile	64.404
Maximum	383.279

95% Confidence Interval for Mu

42.525	43.546

95% Confidence Interval for Sigma

46.821	47.543

95% Confidence Interval for Median

36.346	39.337

Figure 6. Distribution of individual containers used in the analysis.

The change of shape from the distribution of individual containers (Figure 6) to the stacks of randomized containers (Figure 5b) results from a change in volume, or statistical support. This volume change causes a change in variation that is affected by the spatial correlation of the containers. The similarity between the distribution of individual containers and that of actual stacks of emplaced waste (Figure 5a), i.e. permanence of distribution (Journel and Huijbregts

1978), and their deviation from the randomized distribution, illustrates the degree of non-random emplacement practiced in Panel 1. As the data are randomized and become spatially uncorrelated, classical statistics (independence of samples) would predict the empirical results demonstrated in Figure 5b. That is, that the distribution of emplaced waste would become more symmetrical.

The degree to which the distribution deviates from a randomized case is dependent on the actual data, but the probability of intersecting a high-concentration stack of three containers will increase because of the nature of non-random emplacement. This is shown for the Panel 1 actual and randomized distributions in a probability plot (Figure 7). It shows that the probability of intersecting high-concentration stacks is significantly higher in the non-random distribution versus the randomized distribution. For example, computing the projected average concentration of the Rocky Flats residues from the CCA information and assuming 20,100 drum equivalents of volume results in a value of 84.2 PE-Ci/m^3. From Figure 7, the probability of intersecting a stack greater than this average is 5% for the randomized case, but is 11% for actual emplacement.

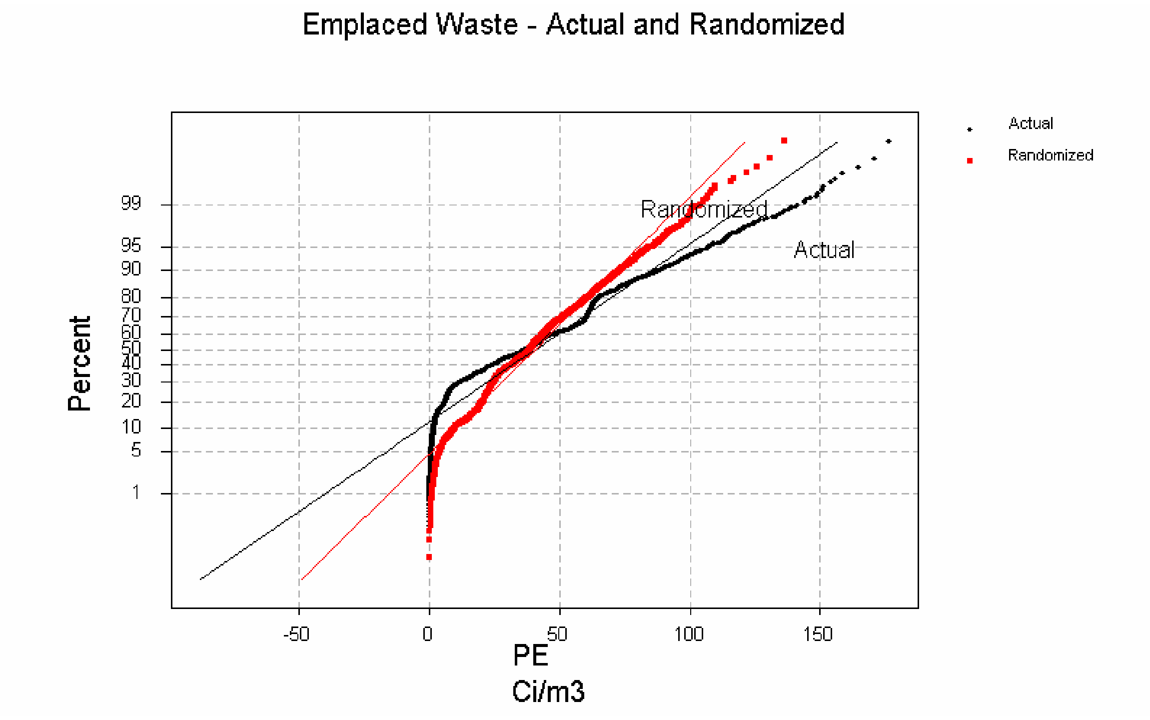


Figure 7. Probability plots of actual and randomized distributions.

Chapter 4 of the CCA (DOE 1996) states that, "A sampling of 10,000 futures is large enough that the *relatively low* probability combination of three of the waste streams with higher activity loading occurring in a single drilling event is captured in the CCDFs presented …" (italics added). It goes on to state, "… the CCDF is not impacted by sampling uncertainty so the assumption of random emplacement of containers is not important to the location of the CCDF and a load management plan is not necessary to support performance assessment assumptions". The change in distribution away from randomness caused by non-random emplacement of waste, and the subsequent increase in probability of high concentration intersection during an intrusion, casts doubt on these performance assessment assumptions.

3.3 Volume/Variance Implications of Non-Random Emplacement

In response to the EEG's concerns about the random emplacement assumption in the Compliance Certification Application (DOE 1996), the DOE performed a bounding analysis which assumed contiguous emplacement of the Rocky Flats residue waste (Dials 1997). This waste stream was selected because it was the highest activity contact-handled waste that had at least 810 drum equivalents volume. The 810 value was one one-thousandth of the total number of drum equivalents to be emplaced in the WIPP. Therefore, this waste stream would have a probability (conditional on the occurrence of a single intrusion) of intersection of more than 0.001, the probability limit established in 40 CFR § 191.13(a) (CFR 2002). However, this probability was based on the assumption of independence of samples and would therefore be a bounding case for random emplacement, not non-random emplacement.

As discussed in Section 3.1, about 11 percent of the emplaced three-layer stacks have average concentrations over the Rocky Flats residue average. The spatial distribution of these stacks are shown in Figure 8. The actual average emplaced value of the residues was only about 76 PE-Ci/m^3. If the actual value had been 84.2 PE-Ci/m^3, the discrepancy between randomized and actual would have been even greater. The probability of intersecting high-concentration stacks can be examined for the distribution of a spallings-sized event versus the distribution of an 810 drum-sized unit. The use of the spall-sized volume in an intrusion scenario is similar to the concept of a selective mining unit (smu) in ore reserve estimation (Journel and Huijbregts 1978) or a volume of selective remediation (vsr) in environmental cleanup (Desbarats 1995).

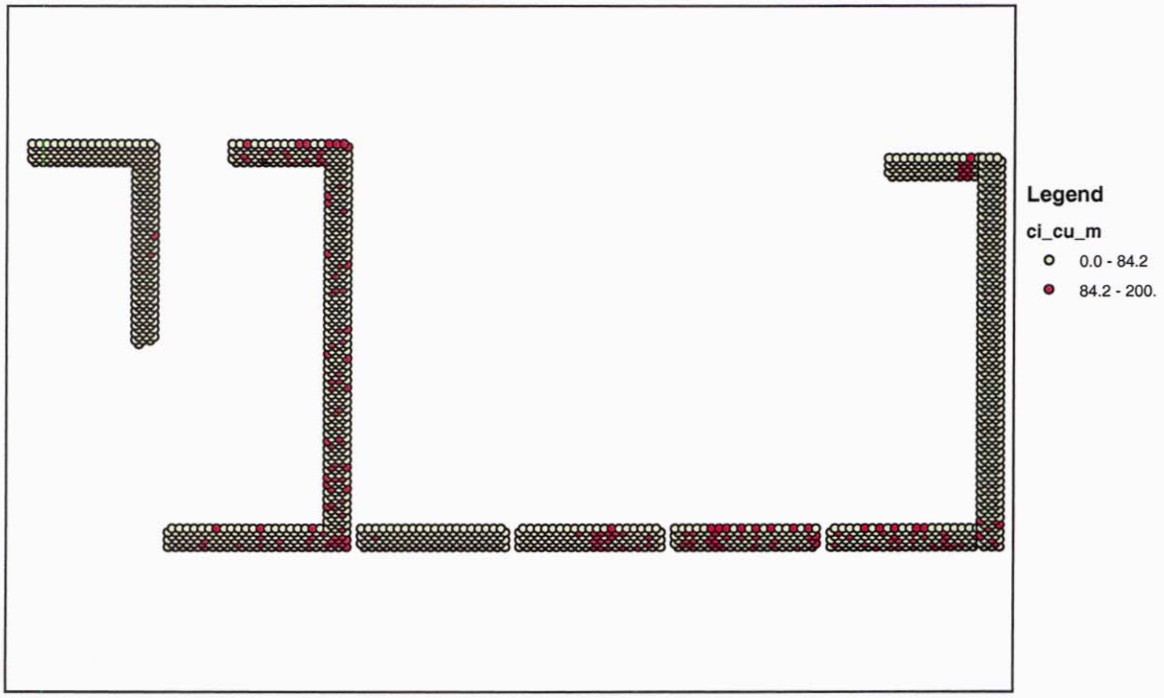


Figure 8. Panel 1. Emplaced PE-Ci over residue average.

The distribution of a spallings-sized event can be approximated by the distribution of stacks, already shown in Section 3.1. Assuming the volume of three stacked 7-packs, each grid node (or stack) would equal 4.4 m^3. The actual value may be slightly less because of the use of SWB and TDOP as overpack containers. Therefore, the volume of each stack would be close to the 4 m^3 volume in a maximum spallings event. A volume of 810 drums is approximately 40.5 times the volume of a stack of containers. This could be represented by a block with dimensions of square root of 40.5 times the assumed grid size representing a stack, or 7 ft. This would result in a block of 44.5 ft. by 44.5 ft. The distribution of these blocks could be calculated from a change of support technique such as Hermite Polynomial Transformation (Journel and Huijbregts 1978).

Hermite Polynomial Transformation requires a variance reduction factor which can be computed after deriving the variance between blocks (810 drum units) and the overall domain. This variance between blocks is computed (Isaaks and Srivastava 1989):

$$\sigma^2(v,V) = \sigma^2(.,V) - \sigma^2(.,v)$$

where:

$\sigma^2(v,V)$ = variance between blocks of size v within domain V.

$\sigma^2(.,V)$ = variance of a point within the domain.

$\sigma^2(.,v)$ = variance of a point within a block of size v, or dispersion variance.

The total variance is shown in Figure 5a as 1198 (PE-Ci/m^3)^2. The dispersion variance may be estimated from a variogram model of the samples, or stacked containers (David 1977).

An experimental variogram of the emplaced waste was computed using the GSLIB program GAMV (Deutsch and Journel 1998). This variogram was fitted with a spherical model as shown in Figure 9. The dispersion variance for a point within the 810 drum unit was computed with kriging program subroutines in GSLIB, using this variogram function, and resulted in the variance reduction factor, $\sigma^2(.,v)/\sigma^2(.,V)$, equal to 0.18.

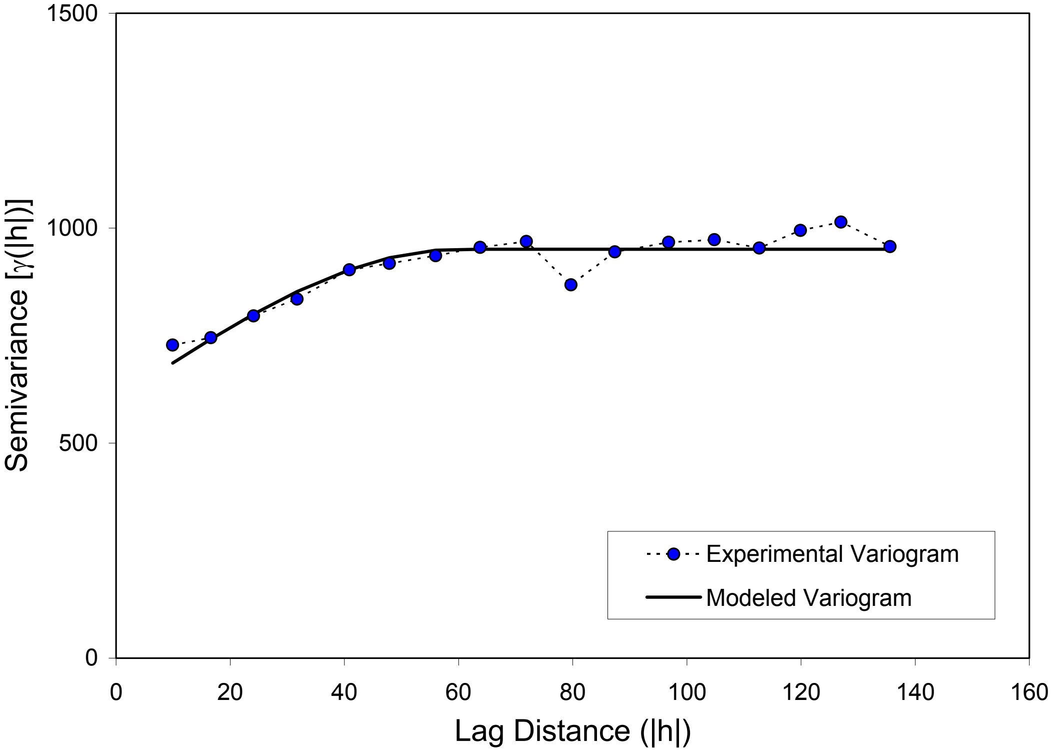


Figure 9. Experimental variogram fitted with spherical model: Co = 600, C1 = 350, R = 60 ft.

Using a program for Hermite Polynomial Change of Support (Guertin 1984) a hypothetical distribution of 810 drum units was constructed from the distribution of stacked containers. The probability plots for this distribution as well as the original distribution of stacked containers (spall units) are shown in Figure 10. As can be seen, the probability of intersection of a high-concentration stack during an intrusion scenario will be underestimated by assuming volumes of 810 drum units. Therefore, an analysis conditional on a minimum of 810 drums may not represent an adequate bounding case for non-random emplacement of waste.

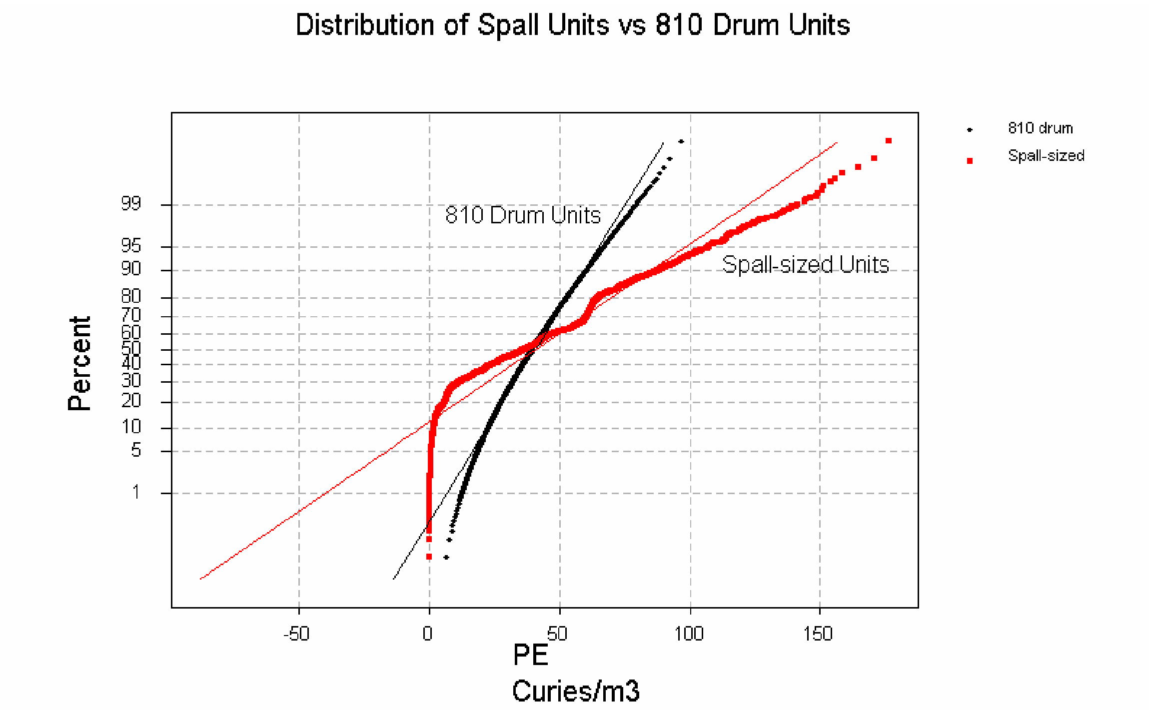


Figure 10. Distribution of stacked containers (approximate spall units) and the hypothetical distribution of units containing 810 drums.

3.4 Pipe Overpack Containers

POCs have been used to isolate much of the high ^{239}Pu waste emplaced in Panel 1. No credit has been suggested or taken for the use of these POCs in performance assessment. Further, EEG is unaware of any studies conducted to determine the effect of the POC during an intrusion scenario.

However, if it could be demonstrated by the DOE that POCs retain their integrity and effectively reduce the potential of activity release over the regulatory period, they could be a means of reducing the amount of material brought to the surface from an intrusion into a high-concentration stack. This is shown in Figure 11 where all emplaced material contained in POCs was removed prior to calculation of the probability plot. In addition, the probability of intersecting waste would be slightly reduced because of differences in volume between the actual drum and the POC contained within.

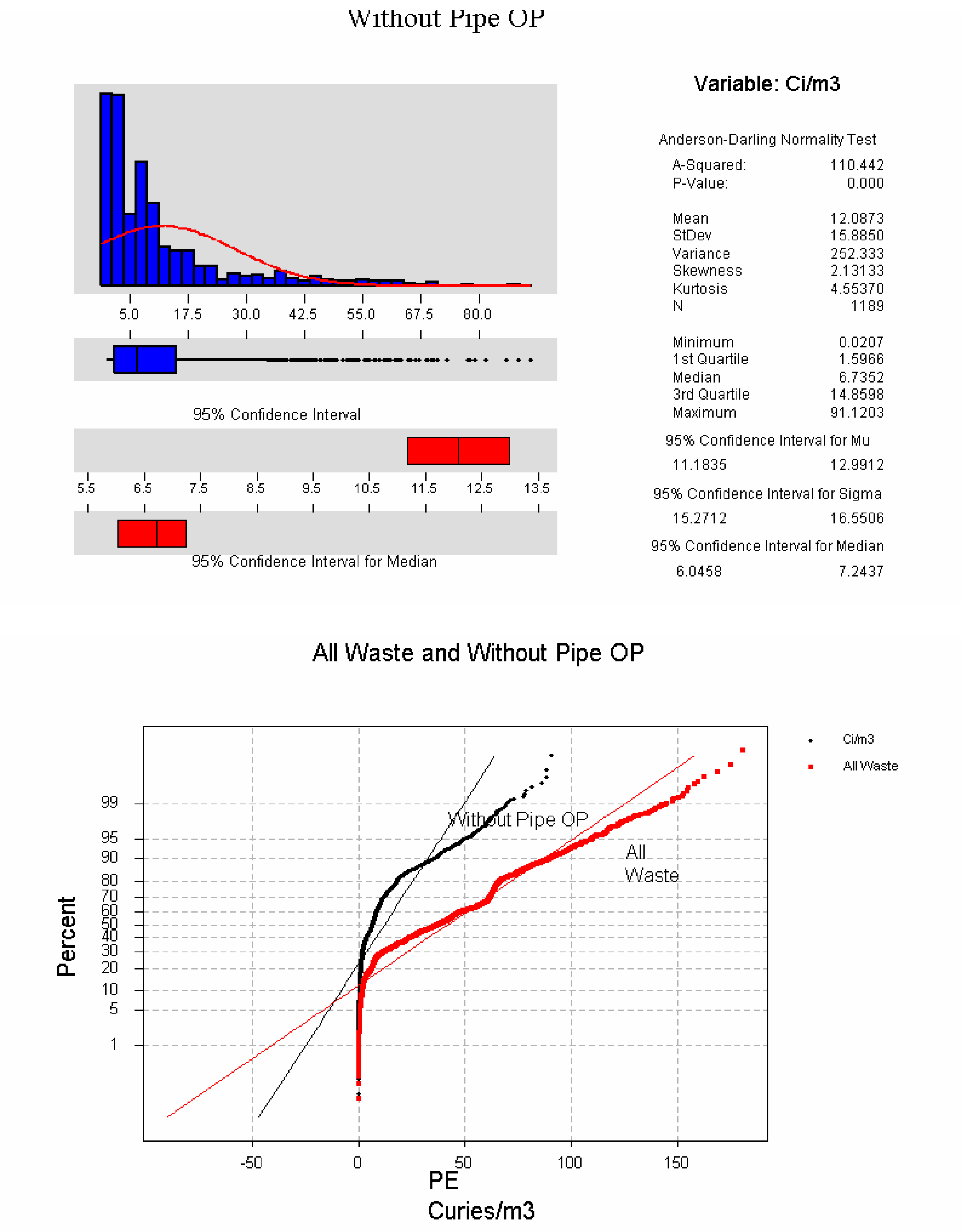


Figure 11. Histogram and probability plot of emplaced waste disregarding that contained in POCs.

4.0 CONCLUSIONS

The shipping campaign priority of residues from Rocky Flats has resulted in the non-random emplacement of waste in Panel 1 and in elevated emplaced activity. ^{239}Pu is 3.20 times, ^{240}Pu is 2.67 times, and ^{241}Am is 4.13 times the projected repository average for the space occupied by waste. Moreover, the non-random emplacement process skews the distribution of emplaced waste, as compared with a randomized case, resulting in higher concentration tails and increasing the probability that an intrusion will intersect a high-concentration stack. This suggests that for cuttings and cavings scenarios, the practice of sampling waste streams independently (and using their means) for each layer in a stack would underestimate the potential releases.

Furthermore, the practice of non-random emplacement may invalidate the premise of the performance assessment bounding analysis for spallings. The DOE bounding analysis assumed independence of samples for selection of the minimum waste stream volume to be analyzed. Independence of samples is not inherent in non-random emplacement, which results in the spatial dependence between sample locations. The hypothetical distribution of potentially spalled units shows an increased probability of high-concentration intersection over the distribution of volumes assumed in the bounding case.

It has been demonstrated that the practice of non-random emplacement of waste results in spatial dependence of waste containers. Therefore, classical statistical techniques do not properly address this issue. Instead, spatial statistical (geostatistical) methods are necessary for analysis, performance assessment implementation, and bounding calculations.

5.0 RECOMMENDATIONS

The EEG recommends that:

1) The DOE should develop a waste loading scheme for performance assessment which is based upon their shipping schedule. While this schedule will change over time, it is the best information currently available and presents a more realistic assumption than random emplacement. A spallings event should then be based upon this spatial distribution of waste instead of the mean value of waste.

Alternatively, the DOE should develop a bounding case based on the distribution of potentially spalled units, recognizing the effects of skewed distributions which results from the non-random emplacement process. One possibility would be to use geostatistical simulation with different variograms (with a range of spatial correlations) to show the consequences of different emplacement sequences for the future.

2) The DOE should develop and use, in the recertification performance assessment calculations, a methodology for non-random waste emplacement for cuttings and cavings scenarios. This methodology should recognize the likelihood of similar material occurring for a stack of three containers instead of randomly sampling for each layer in the stack and be based on anticipated shipping schedules. It should also acknowledge the increased probability of high-concentration intercepts, which result from non-random loading instead of using mean values of entire waste streams.

3) If the DOE wishes to take credit for the container, the DOE needs to provide an analysis of the potential effects resulting from the use of pipe overpacks, which may provide a more secure containment of radionuclides within the repository.

4) The DOE should continue to build a spatial data base of emplaced waste for ongoing analysis and for use during future recertifications.

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