West Valley Demonstration Project

Doc. ID Number	WVDP-579
Revision Number	0
Revision Date	09/05/19

VITRIFICATION FACILITY AIR EMISSIONS DURING OPEN-AIR DEMOLITION

MEASURED VS. PREDICTED

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WEST VALLEY DEMONSTRATION PROJECT

Vitrification Facility Air Emissions during Open-Air Demolition

Measured vs. Predicted

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Revision History

Revision	Changes	Date
A	Issued for review	12/18/2017
B	Additional demo data added. Issued for review	10/02/2018
C	Incorporate DOE comments	01/08/2019
D	Incorporate EPA comments	05/13/2019
0	Initial Issue	7/27/2019

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Page numbers reflect original document BC-RP-0117, Rev. 0.

1 Summary

Revision 0 of the Alternative Method [Blunt 2016a] produced predicted values that are realistic, but slightly conservative for Mechanical Shearing, Load operations and Rubble Pile emissions. Predicted emissions from Hydraulic Hammering operations are extremely conservative and the methodology has been revised. Hot cutting[1] has a limited data set, but the Physical State factor proposed appears to be conservative for radionuclides that have higher boiling points and non-conservative for radionuclides with lower boiling points. A revised set of Physical State factors is provided in revision 1 of the Alternative Method.

Based on the validation study, the emission factors in revision 1 of the Alternative Method are representative of actual emissions, but still conservative. Revision 1 is provided as Appendix F of this document.

2 Background

The U.S. Environmental Protection Agency (EPA) granted the West Valley Demonstration Project (WVDP) approval to use "*Methodology for Radionuclide Source Term Calculations for Air Emissions from Demolition Activities, Rev. 0,*" authored by B. C. Blunt and submitted to EPA on January 25, 2016, as an alternative method (AM) for calculating emissions from the demolition of the Vitrification Facility (VF). The approved method can be used in lieu of 40 CFR 61 Appendix D, however, before the alternative calculation method can be used for other demolition actions, a study must be conducted to validate that the method does not significantly underestimate emissions[2].

Demolition of the VF was done with a three-phased approach based in part on the building's structural features, remaining equipment and radiological conditions. Dismantlement and demolition using a graded approach minimizes risk to personnel performing the work and those personnel surrounding the demolition site. It also allows for implementation of area specific controls, thus minimizing emissions and reducing negative impacts to the environment.

Phase 1 of demolition considered those portions of the facility which presented the least radiological hazards. These areas include the operating aisles, control room, break room, rest rooms, truck bays, stairways, tool and equipment storage rooms, etc.

Phase 2 of demolition consisted of the Vitrification Process Cell (VC) and constituted the greatest radiological hazards. The VC consisted of a stainless steel lined reinforced concrete structure with interior dimensions of 34-ft by 63-ft by approximately 46-ft tall. Interior surfaces of the VC as well as equipment contained therein were coated with fixative prior to beginning open air demolition.

Phase 3 of demolition contained both contaminated areas as well as areas with a low potential for contamination. This phase includes the Crane Maintenance Room (CMR), CMR Shield Door, Transfer Tunnel, Secondary Filter Room, Diesel Generator Room, and HVAC Operator Station.

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[1] As discussed in the AM, the emission rate for Hot Cutting is determined with 40CFR61 Appendix D method, but with a new Physical State Factor.

[2] 40 CFR 61.93(d) Allows for emissions to be estimated by approved alternative methods that do not significantly underestimate emissions.

3 Discussion

The objective of the post-demolition modeling is to validate that the AM does not significantly under estimate emissions. This is accomplished by observing how well radioactivity levels measured by actual sampling is replicated by air dispersion modeling using the actual meteorological conditions. EPA's AERMOD[3] software was used for the modeling analysis. AERMOD is the EPA's required dispersion model for a wide range of regulatory applications in all types of terrain for receptors within 50 km of the source; the model incorporates the latest understanding of atmospheric dispersion, and it explicitly accounts for building wake effects for point sources [EPA 2017]. In the case of the VF, located on the north end of the Main Plant Processing Buildings (MPPB) (see Figure 1), wake affects will be primarily due to the main plant buildings. To account for the building wake effects, each emission source is modelled as a virtual point source. AERMOD incorporates the Plume Rise Model Enhancements (PRIME) model via BPIPPRM (Building Profile Input Program for PRIME) to account for building wake effect calculations for point source emissions (EPA 2017). The PRIME model can model the downwind cavity (near wake) and the far wake areas on a three-dimensional scale. See Section 4.3 for additional discussion of the AERMOD modeling system.

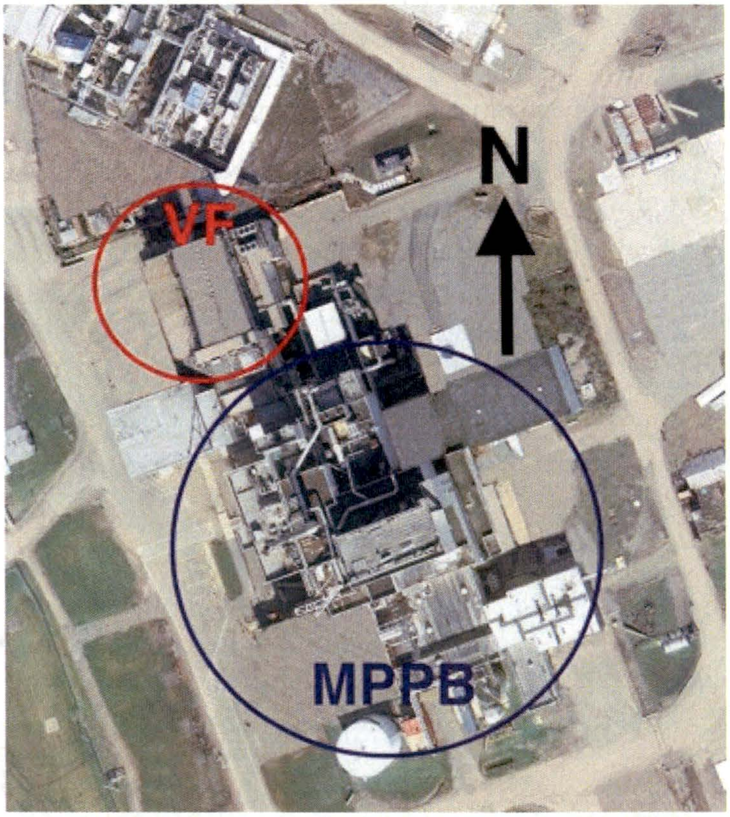

Figure 1: VF location relative to the MPPB

[3] American Meteorological Society/U.S. Environmental Protection Agency (USEPA) Regulatory Model (AERMOD)

Two low-volume ambient air samplers operating at approximately 80 liters per minute were used to collect weekly samples. The samplers, designated as ANVDEMO1 and ANVDEMO2, were located based on the projected airborne pathways expected during open-air demolition (see Figure 2). ANVDEMO1 was located approximately 50 meters to the northwest of the demolition activities and ANVDEMO2 was located approximately 70 meters to the northeast of the demolition activities. EPA [EPA 2017, 2018a, 2018b] states that AERMOD is the preferred model for distances up to 50 kilometers but has set no minimum distance between a source and a receptor for a point source[4]. The details for siting the samplers are included as Appendix A of this report.

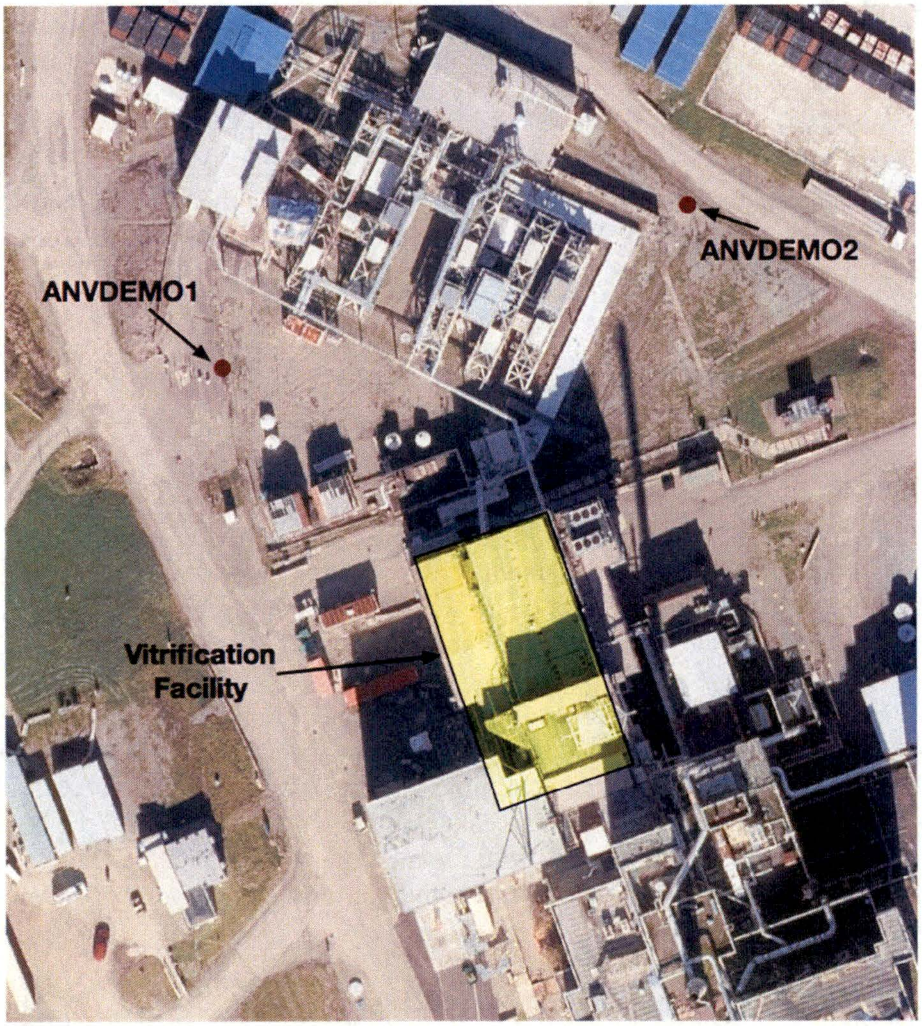

Figure 2: On-site ambient air sampler locations

[4] For an Area Source EPA states that receptors can even be located within the Area source, but since the numerical integration is not performed for portions of the area that are closer than 1.0 meter upwind of the receptor, caution should be used when placing receptors within or adjacent to areas that are less than a few meters wide.

Meteorological data from the on-site meteorological tower, supplemented with data from the National Weather Service at the Cattaraugus County Olean Airport, were used for the study.

The study compares results of ambient monitoring conducted during demolition of the VF to predicted values using a source term derived with the approved AM. The Material at Risk (MAR), based on actual measured radiological conditions at the time of demolition, was used as the input to the approved AM to establish a source term. The modeling analysis compares atmospheric concentration sampling results measured during open-air demolition with modeling results based on this source term and the actual meteorological conditions measured during demolition.

Baseline sampling was conducted prior to the start of open-air demolition. A statistical approach is used to determine if sampling results are significant; i.e. are the sample results at each sample location due to demolition activities or are they near baseline values. Weather conditions and specific demolition activities that occurred during a sample period will affect which sampler, if any, was in a direct plume path. It was expected that not every sample would be statistically significant when compared to baseline data with the statistical test. Statistically significant samples based on the baseline data were found on ANVDEMO1 some weeks, on ANVDEMO2 other weeks, on both samplers some weeks, and other weeks no statistically significant results were observed.

Sample analysis was performed at an on-site laboratory using established procedures. For gross alpha/beta determinations, a low-background counter was used. In all cases, radiological analysis was carried out using calibrated instruments verified periodically to be in control.

4 Methodology

The objective of the post-demolition modeling is to validate that the AM does not significantly under estimate emissions or conversely identify methods in the AM that grossly over-estimate emissions. This will be accomplished by observing how well plume concentration in the air sampling data collected during demolition are replicated by air dispersion modeling using the actual meteorological conditions.

A detailed test plan[5] [Blunt 2016b] was prepared to provide an outline for conducting the validation testing. The test plan includes the location of the samplers, the dispersion modeling system to be used in the study and the statistical methodology to determine if samples results are statistically different than those collected during a baseline period. This test plan has been prepared to meet the intent of the EPA document EPA/240/B-06/001 (EPA QA/G-4) with regard to the use of the Data Quality Objectives (DQO) process. The test plan was followed in the conduct of the study, as well as the preparation of the validation report.

4.1 Statistical evaluation during demolition to baseline data

The results obtained during demolition can be deemed statistically significant using the disaggregation method presented by Strom, et al. [Strom 2012], to produce a probability density function (PDF) of possible true results. Statistical variances observed in environmental sampling results arise from a combination of measurement uncertainty and population variability. The method presented by Strom provides a technique to disaggregate measurement uncertainty from population variability.

[5] A copy of the test plan is included in this document as Appendix E.

This technique makes the following assumptions:

- The measurements are unbiased.
  The study used measurements as reported by the analytical laboratory. Negative values were not adjusted.
- The measurement uncertainties are normally distributed.
  The uncertainties reported from the laboratory are calculated assuming a normal distribution.
- The measurements are independent.
  Each filter was collected separately, with no overlap in sample period.
- The measurements are lognormally distributed.
  This assumption is proven with the data, as the mathematical development assumes a lognormal distribution for the population variability. This is frequently observed in both occupational and environmental radiological measurements [Strom 2012].
- Minimal structure and operational changes occur near the sampler locations.
  Other than the demolition activities, there were no operational changes that occurred between the baseline period and the demolition period. For ANVDEMO2 towards the middle of the baseline, two tanks and a compressor were installed near the sampler. There were structural changes that occurred near ANVDEMO2 between the baseline period and the demolition period. Based on the data from the baseline period before the installations, there was no effect on the results for the sampler operations. There were no structural changes that occurred for ANVDEMO1 between the baseline period and the demolition period.

In this case the population is the group or set of sampler filters, and the measured value can be represented as

$$x_i = t_i + e_i$$

where

x_i	=	measured or reported value
t_i	=	true value
e_i	=	measured or observable error

Assuming that all values are independent, then using traditional methods the variance of the measured values is found as

$$S_m^2 = \frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2$$

where

S_m^2	=	variance of the set or group of measured values
N	=	number of measurements
$\bar{x}$	=	sample mean, which is defined as:

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i$$

where

x_i	=	an individual measurement or sample result

For this study, the variance of the set or group of measured values is comprised of two components:

- the variability among the populations (pre-demo and open-air demo), and
- the variability due to measurement uncertainty.

The expected value of the sample variance, $E(S_m^2)$, is represented by

$$E(S_m^2) = \sigma^2 + \frac{1}{N}\sum_{i=1}^{N} u_i^2$$

where

σ^2	=	variance within the population
u_i^2	=	standard uncertainty (measurement variance squared)

The variance within the population can be found by rearrangement,

$$\sigma^2 = S_m^2 - \frac{1}{N}\sum_{i=1}^{N} u_i^2$$

The mean and the standard deviation of the lognormal distribution can be calculated as follows:

$$\mu_{ln} = ln(\bar{x}_{ln}) - \left(\sigma_{ln}^2/_2\right)$$

and

$$\sigma_{ln} = \sqrt{ln\left(1 + \sigma^2/_{\bar{x}^2}\right)}$$

Once the data are disaggregated, a plot of the lognormal PDF of the population for the baseline period can be produced for each of samplers ANVDEMO1 and ANVDEMO2. Using Bayes' theorem, this PDF would be termed the "prior" PDF. Using the same techniques and assumptions a PDF of the population portion of the results can be produced for each sample collected during demolition, which in effect is a "posterior" PDF.

To test for significance a null hypothesis is made that samples will represent baseline emissions. The alternate hypothesis would be that the sample represents emissions from the demolition activities. In order to reject the null hypothesis for a sample the peak of the posterior PDF would fall to the right of the 95-pecentile location of the prior PDF. Any sample that meets this test is considered significant and the emissions represent demolition activities (i.e., the null hypothesis is rejected).

The lognormal PDF, *P(x),* is given by

$$P(x) = \frac{1}{x\sigma_{ln}\sqrt{2\pi}} \, exp\left[-0.5\left(\frac{ln(x) - \mu_{ln}}{\sigma_{ln}}\right)^2\right]$$

and can be calculated using the excel® function "LOGNORMAL.DIST".

See Section 5.1 for the application of this method.

4.2 Direct comparison of measured to AERMOD predicted results

Theoretical average weekly air concentrations that correlated with the ambient air filter sample periods were determined using air dispersion modeling and a source term calculated with the AM. Details of the AERMOD runs are provided in the following section "AERMOD Modeling Methodology." A **Predicted** average air concentration was then determined by adding the **Background** air concentration that also correlated with the week the sample was collected to the **Theoretical** average weekly air concentration produced with AERMOD. The **Background** concentrations were determined from a sampler located approximately 2000 meters from the demolition activities. The **Predicted** average air concentration was compared to the measured results from the on-site ambient air samplers.

4.3 AERMOD Modeling Methodology

The EPA model, AERMOD[6], was used to estimate atmospheric concentrations for released radiological material due to demolition activities. Surrounding buildings were input into the model to account for building wake effects and downwash. Structures in the path of a plume can modify the air concentrations around and behind the building due to effects such as eddy or cavity formation, and channeling. The AERMOD family of models contains preprocessors (BPIPPRM) that account for these building wake effects for point sources. For the VF demolition, the blue areas in Figure 3 represent all the structures that are in the AERMOD building files. The buildings and areas that comprise the VF are input as separate buildings. The advantage to inputting the facility being demolished in sections or areas is that when a section is removed during demolition the AERMOD file can be easily reconfigured and the BPIPPRM preprocessor routine rerun to establish correct building wake effects for the next demolition activities.

Source emissions data is based on the survey data collected during the characterization of the facility and maintained in the site Characterization Database. Data is available for building sections, rooms, piping sections, individual equipment and walls, as was deemed appropriate for the expected contamination level of the building. Therefore, as the building is demolished, the radiological MAR for that section of the building was determined by summing the corresponding database files. An emission factor from the AM for the method used to demolish a section of the building was multiplied by the MAR to determine the curies released. The MAR released was determined on a daily basis and was converted to grams per second on an hourly basis for input into the AERMOD software.

The AERMOD software was run for a one-week period that corresponded to each filter collection period. The resulting average period concentration ($\mu g/m^3$) was then converted back to a $\mu Ci/ml$ basis for comparison to the average filter concentration. Conversion between mass and curies was accomplished with specific activities and isotopic ratios as provided in the site Characterization Database.

Virtual point sources[7] were placed at each area of demolition, load out areas and rubble pile areas. The height of virtual point sources representing demolition was established at half the height of the area being demolished. In the case of the Vitrification facility, the height of all the structures demolished were constant at about 6.1 m (20 ft.), therefore the heights of the virtual point sources for Demo_W, Demo_E, Demo_N and VITCELL were set at 3.05 m (10 ft). The diameter for the demolition virtual point sources was set to 1 meter. The virtual point sources representing load out emissions were set to a height of 1.524 m (5 ft), which is the approximate height of the boxes that debris was being loaded into, and the diameter was set to 2 m. For the rubble piles, the pile heights varied throughout the demolition period. There was no data available on the day to day height of the pile, which could vary between near ground level and approximately 3.048 m (10 ft). Therefore, a constant height of 3.048 m (10 ft) was used for the virtual point source with a diameter of 1 meter. During the hot cutting work the material

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[6] Lakes Environmental Software AERMOD View, which consists of the AERMOD model (FORTRAN executable), obtained from EPA and compiled to run on a Windows operating system, and a custom graphical user interface that facilitates the manipulation of model input and output was for this evaluation. The latest version of AERMOD, Version 18081 was used for the calculations.

[7] A point source is the only type of source for which AERMOD will include building wake effects.

was placed on blocks. The virtual point source was assumed to be approximately 1 m (3.3 ft) in height with a diameter of 1 meter.

The temperature for all sources was set to ambient and the exit gas velocity was set to 0.0001 m/s. For hot cutting, the exit gas, which would have been at a temperature hotter than ambient was forced through a water curtain, which is assumed to cool the gases to ambient or near ambient temperature. See Section 5.2.3 for a more detailed discussion of the model assumptions used for the limited hot cutting data set.

Figure 3: Structures in AERMOD file for VF Demolition

4.4 Alternative Methodology revision 0 (AM) calculations

The AM approved by EPA on January 25, 2016 contains emission factors that correspond to various demolition methods. The emission factors are summarized in Table 1.

Table 1: Emission Factors for Demolition Methods

Method	Emission Factor (Ci released per Ci processed)
Shearing	5.0E-05
Hydraulic Hammer	1.0E-03
Diamond Wire Saw	$(5.0E-05)\dfrac{(Length\ of\ cuts)(width\ of\ kerf)}{Area\ Slab}$
Wall Saw	$(5.0E-03)\dfrac{(Length\ of\ cuts)(width\ of\ kerf)}{Area\ Slab}$
Rubble Pile Emissions a)	$(0.0016)\dfrac{\left(Wind\ Speed/_{2.2}\right)^{1.3}}{\left(Moisture\ content/_{2}\right)^{1.4}}$
Load Out Emissions	2.9E-05
Hot Cutting b)	Physical State Factor = 0.07

a) Wind Speed units are m/s
Moisture content units are %

b) Note that as discussed in the AM, the emission rate for Hot Cutting is determined with 40CFR61 Appendix D method, but with a new Physical State Factor.

The mass of material removed during demolition was obtained from the waste tracking database. A demolition rate was calculated by dividing the total material packaged, as given in the waste tracking database, by the total hours of demolition that produced the waste packaged.

$$demolition\ rate = \frac{pounds\ of\ waste\ loaded}{demolition\ time\ that\ produced\ the\ waste\ loaded}$$

Demolition varied through the project based on the demolition method being used and the removal of special interest items, such as crane rails or chillers. For the project there were 5 demolition rates used, which are present Table 2

Table 2: Demolition rates

Demo Rate Number	Demolition Period	Waste Loading Period	Hours of Demolition	Pounds of Waste Loaded	Demo rate (lb/hr)
1	9/13/17 to 10/31/17	9/13/17 to 11/3/17	119.28	1702320	14271.2
2	11/1/17 to 11/13/17	11/4/17 to 11/28/17	13.75	23790	1730.2
3	11/29/17 to 3/25/18	11/29/17 to 3/25/18	47.35	835440	17643.9
4	3/26/18 to 5/29/18	3/26/18 to 5/29/18	105.07	3038573	28920.4
5	5/29/18 to 6/20/18	5/29/18 to 6/20/18	33.33	562470	16874.1

The mass of material for each activity and at each location could then be calculated. The demolition rate on a daily basis was calculated as the product of the demolition rate given in Table 2 by the number of hours of demolition during that day. The mass of material loaded each day was taken from the site waste tracking database. The mass of material remaining in the pile each day was calculated as the sum of the material in the pile from the previous day, plus the mass of material produced during demolition that day, minus the material loaded in containers that day. For days when the logbooks indicated that waste loading occurred, but the waste tracking database did not list a container as filled, the time for that day was prorated with the time during the days that the waste tracking database indicated containers were filled.

The radiological MAR for each section of the demolition was obtained from the site's characterization database and converted to mass using the Specific Activity of each radionuclide. The Specific Activities used are presented in Table 3. The masses for each radionuclide were summed based on its characteristic as a beta or alpha emitter. Finally, the total mass of MAR was divided by the mass of material produced during demolition to arrive at an average gram of activity per pound of demolition waste material. The average gram of activity per pound of demolition waste material was multiplied by the mass of material processed with each activity (demolition, loading and pile) each day to produce a number of grams of MAR processed each day by that activity.

The emission rate for each activity and at each location could then be calculated by multiplying the grams of MAR processed that day by the emission factor for the demolition method used. Similarly, the emissions for loading rubble in a waste container was determined by multiplying the emission factor by grams of MAR loaded that day. For the rubble pile, the average daily wind speed was used based on the on-site metrological data files. The moisture content was assumed to be 2%. This is assumed to be a conservative value[8], as the material was wetted during demolition and a fixative was applied each night.

[8] The lower the moisture content, the higher the emissions.

Table 3: Specific Activities

Radionuclide	Sp. Activity (Ci/g)
Am-241	3.43E+00
Cm-243	5.17E+01
Cm-244	8.33E+01
Cs-137	8.70E+01
Np-237	7.05E-04
Pu-238	1.71E+01
Pu-239	6.22E-02
Pu-240	2.28E-01
Pu-241	1.03E+02
Sr-90	1.37E+02
U-232	2.14E+01
U-233	9.65E-03
U-234	6.24E-03
U-235	2.16E-06
U-238	3.35E-07

The time each day that demolition and waste loading occurred was determined from the entry logs maintained by the Radiological Operations Department. This allowed for development of an hourly emission rate file to load into the AERMOD program.

4.5 Alternative Methodology (AM) calculations, revised emission factors

As is discussed in the next section, it was found that the emission factors presented in the AM, as originally written, worked well for shearing, loading and the rubble pile. However, emission factors for hydraulic hammering were found to be very conservative. It was also noted by the demolition crews that the rubble piles produced by hydraulic hammering were maintained extremely moist. The equation used to estimate emissions from rubble piles allows for changing the moisture content without changing the AM. To develop a more realistic emission factor for hydraulic hammering a two-step process, discussed in section 5.4.1, was used. One of the steps involved changing the moisture content in the rubble pile. The net result of the two-step process was to revise the emission factor for hydraulic hammering from 1E-03 to 1E-05. All other factors remained the same. A copy of the Alternative Method with these changes is presented in Appendix F.

Changes were also made to the Hot Cutting factors. See sections 5.2.3 and 5.4.2 for more detail.

5 Discussion of results

Collection of baseline data at the two sampler locations began on October 12, 2016, nearly one year prior to beginning open-air demolition of the VF. The sampler located to the northwest of the VF is designated as ANVDEMO1 and is located about 50 meters from the VF. The sampler located to the northeast of the VF is designated as ANVDEMO2 and is located about 70 meters from the VF. The baseline data are presented in Appendix B.

Open air-demolition of the VF began on September 11, 2017. However, the September 13 filter only contained a few hours of demolition and is included in the baseline data. The filter collected on September 20, 2017 is the first filter where demolition occurred during the entire collection period and as such is where the validation study begins. A summary of the demolition activities is provided in Appendix C.

The predicted emission values are based on the demolition methods only and do not include the background concentrations. The concentration values determined at the demo samplers (ANVDEMO1 and ANVDEMO2) do include background concentrations. Therefore, the first step in making a comparison between predicted and measured emissions is to determine the appropriate background concentration to add to the predicted emission valves. At WVDP there are 17 potential samplers that could be used for this background value. The first location is a background sampler that has been routinely collected by the WVDP staff at a location approximately 20 miles south of the site designated as AFGRVAL. The other 16 samplers at the WVDP would the ambient air sampler ring where one sampler is located in each of the 16-sectors around the site ranging in distance of about 1000 meters to 3400 meters from the demolition activities. The first step in selection of the background site was a relative percent difference comparison of the gross alpha and gross beta for each potential background locations against the data from demo samplers ANVDEMO1 and ANVDEMO2[9] during the baseline period. Since the potential background samples are two-week samples and the ANVDEMO1 and ANVDEMO2 samples are one-week samples, the corresponding two filters from ANVDEMO1 and ANVDEMO2 are averaged for this comparison. The results of that evaluation are presented in Table 4.

[9] Data from the baseline period is presented for both ANVDEMO1 and ANVDEMO2 in Appendix B. Note that for ANVDEMO1 the sample collected on 3/15/17 was voided due to the sample paper being misaligned.

Table 4: Percent Difference Between ANVDEMO1/ANVDEMO2 and the Sampler at the Specific Location during the Baseline Period

Location	Direction from Site	Approximate Distance (m)	Percent Difference [a)]	
			Gross Alpha	Gross Beta
AF01	N	2400	-29%	1%
AF02	NNE	2700	-19%	5%
AF03	NE	2000	-16%	8%
AF04	ENE	2200	-20%	9%
AF05	E	2400	-29%	3%
AF06	ESE	2300	-27%	9%
AF07	SE	3000	-17%	13%
AF08	SSE	3400	-27%	0%
AF09	S	2200	-27%	6%
AF10	SSW	2800	-28%	4%
AF11	SW	2300	-27%	6%
AF12	WSW	2100	-24%	10%
AF13	W	1800	-26%	6%
AF14	WNW	1000	-27%	10%
AF15	NW	1200	-34%	8%
AF16	NNW	1625	-25%	15%
AFGRVAL	S	32000	-39%	4%

a) A negative value indicates that the ANVDEMO1 and/or ANVDEMO2 sample results were less than the corresponding potential background sampler results.

The AF02, AF03 and AF07 all have less than 20% difference when comparing the gross alpha for that location to demo samplers. Of these three samplers, both AF02 and AF03 have less than a 10% difference for the gross beta, while the difference for AF07 is 13%.

From the prospective of wind direction, both of these samplers are located in sectors where the frequency of time that the wind blows towards these samplers is low. During the actual demolition activities, the wind blows in the direction of AF02 and AF03 less than 2% of the time as depicted by the wind rose (wind blowing from) presented as Figure 4.

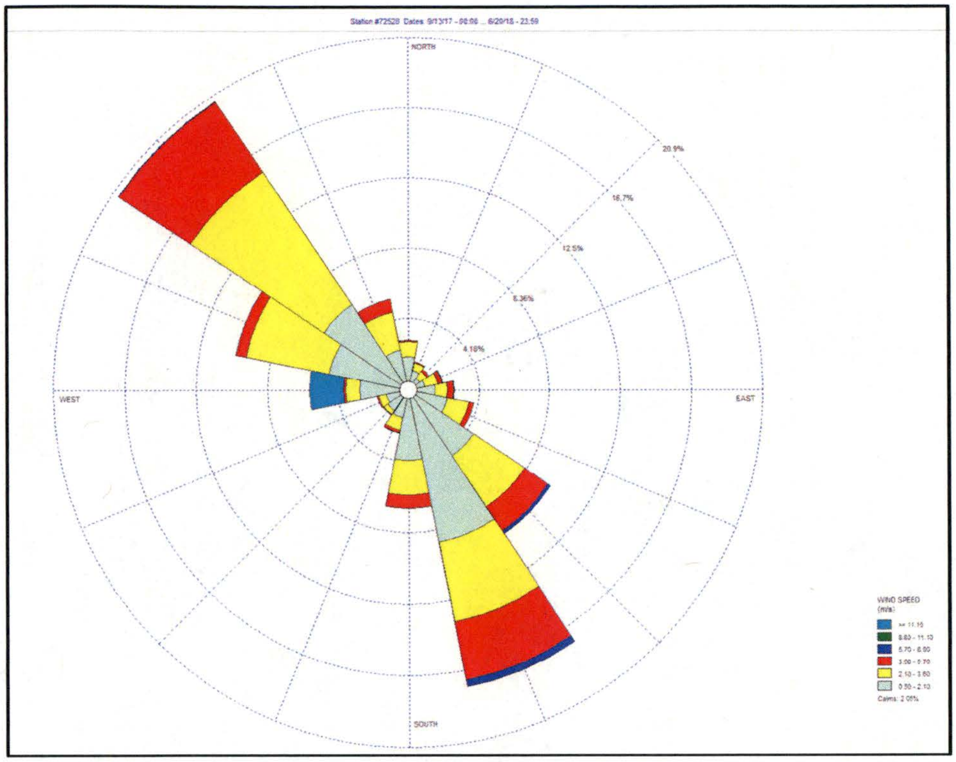
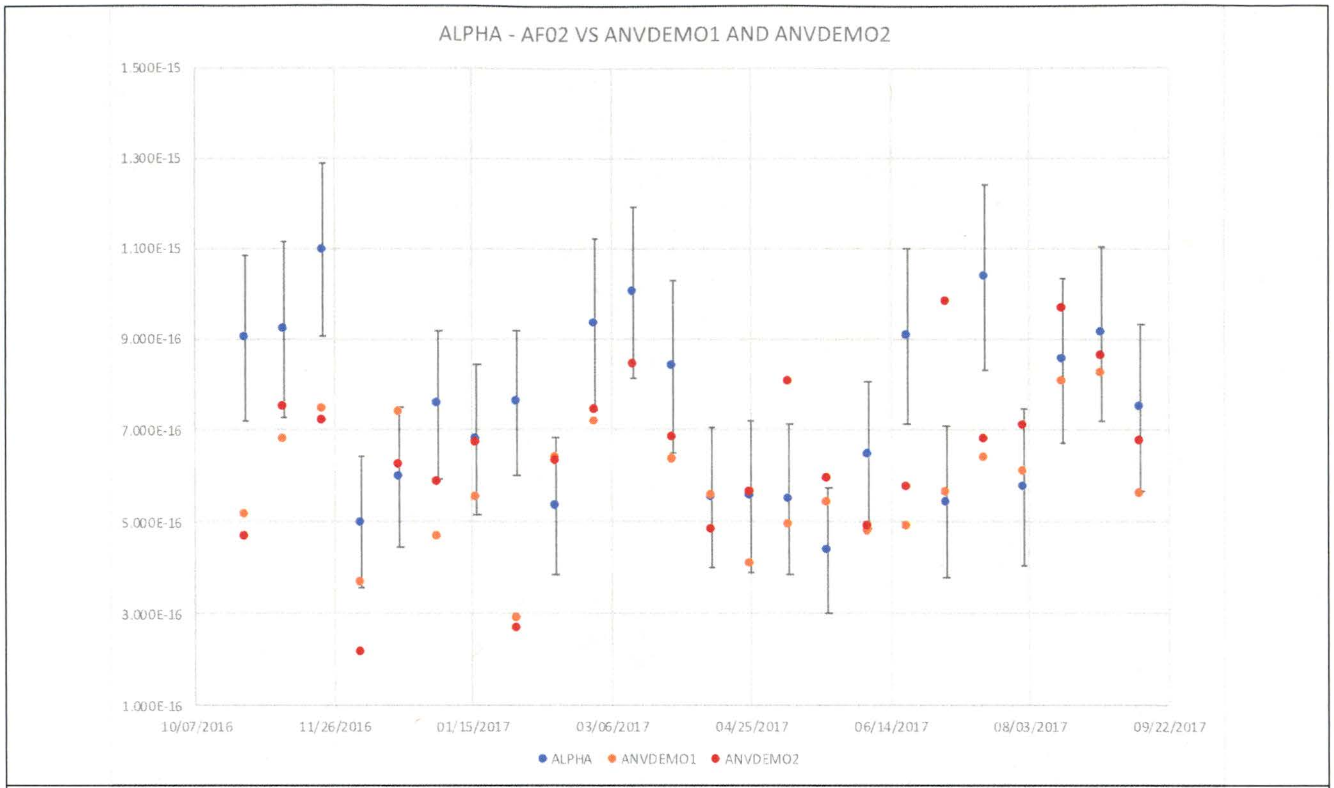


Figure 4: Wind Rose during demolition period 9/13/17 to 6/20/18 (wind blowing from)

Figure 5 presents a plot of the gross alpha for each of AF02 and AF03 with error bands that are the length of the uncertainty for each sample collected. The gross alpha results for ANVDEMO1 and ANVDEMO2 have been plotted on the same graphs. In general, the AF03 data seems to more closely match the demo samplers results for the baseline period.



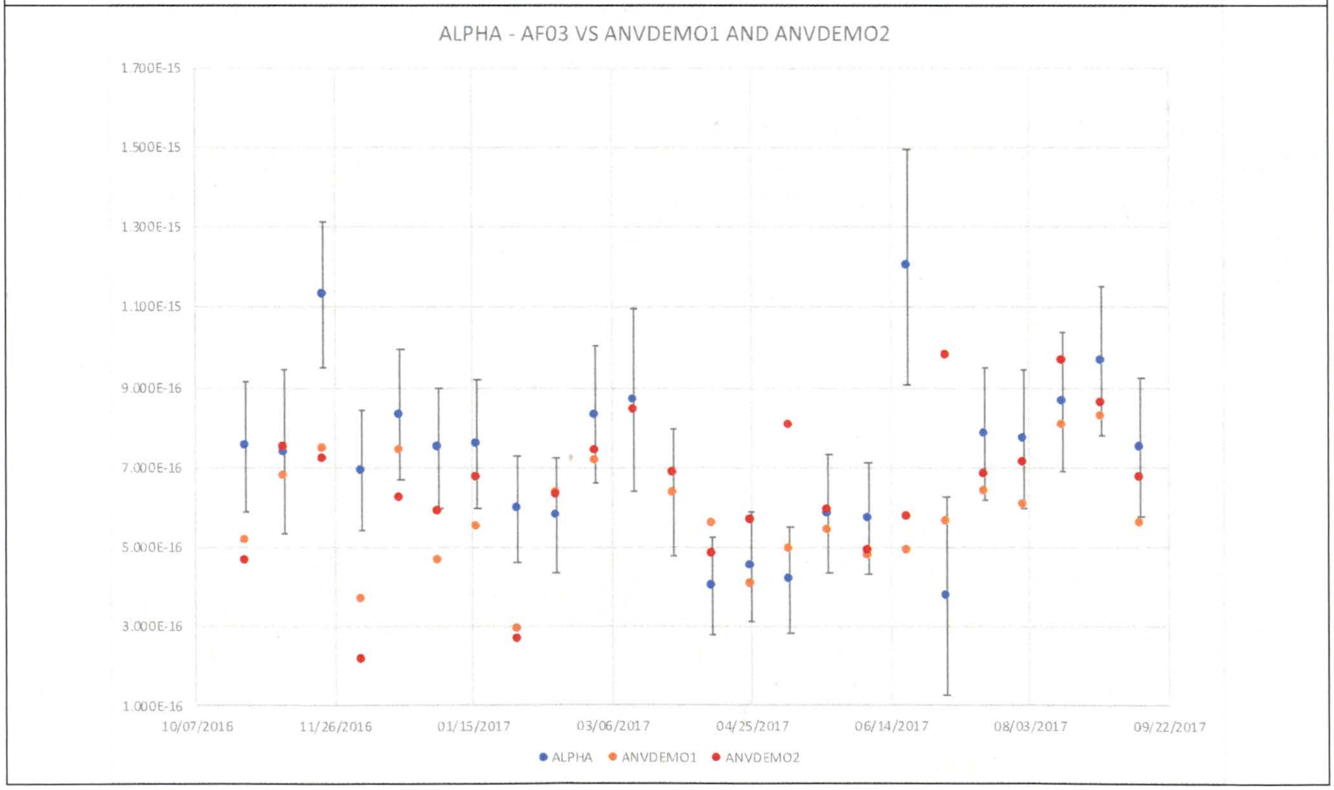


Figure 5: Gross Alpha comparison of AF02 and AF03 with error bands versus ANVDEMO1 and ANVDEMO2

Finally, AF03 is a little closer to the demolition activities and will be used as the background sample source for the demolition period. The AF03 background samples are two-week samples. The background data for the demolition period is presented in Table 5.

Samples were collected weekly from both ANVDEMO1 and ANVDEMO2 samplers. After 7 days, the samples are counted for both alpha and beta. The sample results for filters collected during demolition are presented in Table 6 and Table 7.

Table 5: Background Data During Demolition (from AF03 sampler)

Collection Date	Gross alpha (μCi/ml)	Uncertainty (μCi/ml)	Gross beta (μCi/ml)	Uncertainty (μCi/ml)
09/26/2017	9.55E-16	1.84E-16	2.48E-14	7.81E-16
10/10/2017	1.01E-15	1.84E-16	1.91E-14	6.94E-16
10/24/2017	9.78E-16	1.75E-16	2.28E-14	7.45E-16
11/07/2017	6.44E-16	1.48E-16	1.35E-14	5.84E-16
11/21/2017	1.21E-15	2.20E-16	1.79E-14	7.45E-16
12/05/2017	9.71E-16	1.75E-16	2.22E-14	7.22E-16
12/19/2017	7.26E-16	1.64E-16	1.50E-14	6.15E-16
01/02/2018	8.39E-16	1.68E-16	1.65E-14	6.49E-16
01/16/2018	1.10E-15	1.88E-16	1.77E-14	6.70E-16
01/30/2018	8.66E-16	1.71E-16	2.17E-14	7.07E-16
02/13/2018	7.19E-16	1.61E-16	1.85E-14	6.56E-16
02/27/2018	6.39E-16	1.57E-16	1.61E-14	6.26E-16
03/13/2018	9.76E-16	2.68E-16	1.51E-14	9.26E-16
03/27/2018	1.02E-15	1.69E-16	1.46E-14	5.46E-16
04/10/2018	7.09E-16	1.50E-16	1.31E-14	5.33E-16
04/24/2018	7.82E-16	1.55E-16	1.46E-14	5.55E-16
05/08/2018	1.10E-15	1.89E-16	1.59E-14	6.38E-16
05/22/2018	6.11E-16	1.68E-16	1.25E-14	5.73E-16
06/05/2018	6.83E-16	1.60E-16	1.54E-14	6.26E-16
06/19/2018	5.24E-16	1.45E-16	1.12E-14	5.44E-16

Table 6: Sample Data for ANVDEMO1

Collection Date	Collection Time	Gross alpha (µCi/ml)	Uncertainty (µCi/ml)	Gross beta (µCi/ml)	Uncertainty (µCi/ml)
9/20/17	1523	9.32E-16	2.77E-16	2.34E-14	1.12E-15
9/27/17	1621	1.15E-15	3.00E-16	3.22E-14	1.28E-15
10/4/17	1116	5.63E-16	2.37E-16	1.69E-14	9.56E-16
10/11/17	1345	6.78E-16	2.42E-16	2.10E-14	1.03E-15
10/18/17	1525	5.55E-16	2.36E-16	1.54E-14	9.16E-16
10/25/17	1349	1.01E-15	2.79E-16	2.56E-14	1.14E-15
11/1/17	826	4.45E-16	2.02E-16	1.36E-14	8.81E-16
11/8/17	1411	6.80E-16	2.08E-16	1.53E-14	8.89E-16
11/15/17	956	8.61E-16	2.80E-16	2.11E-14	1.05E-15
11/22/17	1320	4.79E-16	2.19E-16	1.53E-14	9.07E-16
11/29/17	1422	7.19E-16	2.56E-16	2.14E-14	1.04E-15
12/6/17	1058	8.28E-16	2.56E-16	2.48E-14	1.13E-15
12/13/17	1054	6.20E-16	2.13E-16	1.83E-14	9.87E-16
12/20/17	1359	5.66E-16	2.19E-16	1.80E-14	9.66E-16
12/27/17	1021	6.16E-16	2.34E-16	1.54E-14	9.22E-16
1/3/18	1157	9.60E-16	2.60E-16	1.89E-14	9.81E-16
1/10/18	1241	9.36E-16	2.70E-16	2.54E-14	1.18E-15
1/17/18	1054	5.70E-16	2.23E-16	1.84E-14	9.49E-16
1/24/18	1634	6.18E-16	2.10E-16	2.61E-14	1.07E-15
1/31/18	1427	6.12E-16	2.32E-16	2.00E-14	9.86E-16
2/7/18	1325	6.76E-16	2.28E-16	1.67E-14	9.24E-16
2/14/18	1254	6.43E-16	2.22E-16	2.76E-14	1.12E-15
2/21/18	1316	6.69E-16	2.28E-16	2.04E-14	1.01E-15
2/28/18	924	7.27E-16	2.48E-16	1.43E-14	8.99E-16
3/7/18	1636	7.94E-16	2.24E-16	2.21E-14	1.01E-15
3/14/18	1314	4.59E-16	2.03E-16	8.43E-15	7.49E-16
3/21/18	1524	1.00E-15	2.57E-16	2.12E-14	1.03E-15
3/28/18	1328	6.62E-16	2.46E-16	1.40E-14	8.87E-16
4/5/18	742	8.92E-16	2.48E-16	1.89E-14	9.52E-16
4/11/18	1402	1.12E-15	2.87E-16	1.90E-14	1.06E-15
4/18/18	1456	6.99E-16	2.42E-16	1.39E-14	8.85E-16
4/25/18	1138	1.13E-15	2.87E-16	2.51E-14	1.12E-15
5/2/18	1048	6.65E-16	2.44E-16	1.64E-14	9.53E-16
5/9/18	1131	7.85E-16	2.77E-16	2.07E-14	1.03E-15
5/16/18	1613	6.44E-16	2.40E-16	1.53E-14	9.23E-16
5/23/18	1228	2.93E-16	2.03E-16	1.38E-14	8.96E-16
5/30/18	1530	8.75E-16	2.65E-16	2.78E-14	1.15E-15
6/6/18	1137	3.51E-16	2.18E-16	1.02E-14	8.16E-16
6/13/18	1415	5.44E-16	2.17E-16	1.59E-14	9.19E-16
6/20/18	1018	6.47E-16	2.38E-16	1.65E-14	9.76E-16

Table 7: Sample Data for ANVDEMO2

Collection Date	Collection Time	Gross alpha (μCi/ml)	Uncertainty (μCi/ml)	Gross beta (μCi/ml)	Uncertainty (μCi/ml)
9/20/17	1618	7.06E-16	2.68E-16	2.42E-14	1.19E-15
9/27/17	1618	1.31E-15	3.39E-16	3.41E-14	1.40E-15
10/4/17	1110	6.34E-16	2.67E-16	1.69E-14	1.03E-15
10/11/17	1349	6.46E-16	2.58E-16	2.34E-14	1.15E-15
10/18/17	1529	5.32E-16	2.51E-16	1.79E-14	1.03E-15
10/25/17	1354	7.65E-16	2.69E-16	3.40E-14	1.36E-15
11/1/17	835	6.68E-16	2.45E-16	1.34E-14	9.31E-16
11/8/17	1414	7.03E-16	2.21E-16	1.67E-14	9.62E-16
11/15/17	959	6.92E-16	2.73E-16	2.06E-14	1.07E-15
11/22/17	1324	5.45E-16	2.39E-16	1.56E-14	9.58E-16
11/29/17	1427	6.63E-16	2.63E-16	2.16E-14	1.08E-15
12/6/17	1100	8.56E-16	2.71E-16	2.45E-14	1.17E-15
12/13/17	1059	7.76E-16	2.43E-16	1.85E-14	1.04E-15
12/20/17	1320	5.32E-16	2.26E-16	2.10E-14	1.07E-15
12/27/17	1028	6.91E-16	2.55E-16	1.92E-14	1.05E-15
1/3/18	1203	8.64E-16	2.61E-16	3.26E-14	1.28E-15
1/10/18	1237	9.08E-16	2.65E-16	2.85E-14	1.23E-15
1/17/18	1056	7.45E-16	2.62E-16	1.94E-14	1.04E-15
1/24/18	1642	6.58E-16	2.30E-16	2.76E-14	1.17E-15
1/31/18	1433	7.25E-16	2.66E-16	1.92E-14	1.05E-15
2/7/18	1318	1.46E-15	3.32E-16	3.56E-14	1.36E-15
2/14/18	1300	7.22E-16	2.50E-16	2.87E-14	1.22E-15
2/21/18	1323	8.24E-16	2.60E-16	2.62E-14	1.18E-15
2/28/18	933	5.15E-16	2.36E-16	1.35E-14	9.24E-16
3/7/18	1632	1.02E-15	2.80E-16	2.15E-14	1.13E-15
3/14/18	1324	2.85E-16	1.95E-16	9.22E-15	8.33E-16
3/21/18	1520	9.76E-16	2.74E-16	1.93E-14	1.07E-15
3/28/18	1334	8.20E-16	2.84E-16	1.37E-14	9.49E-16
4/5/18	746	7.44E-16	2.41E-16	1.45E-14	8.98E-16
4/11/18	1410	1.26E-15	3.23E-16	1.85E-14	1.13E-15
4/18/18	1500	5.38E-16	2.41E-16	1.34E-14	9.36E-16
4/25/18	1143	1.14E-15	3.08E-16	2.04E-14	1.11E-15
5/2/18	1040	7.01E-16	2.66E-16	2.33E-14	1.15E-15
5/9/18	1137	6.48E-16	2.86E-16	4.15E-14	1.46E-15
5/16/18	1617	7.38E-16	2.71E-16	1.79E-14	1.05E-15
5/23/18	1231	6.81E-16	2.76E-16	1.60E-14	1.03E-15
5/30/18	1533	1.74E-15	3.71E-16	4.34E-14	1.51E-15
6/6/18	1139	1.38E-16	2.09E-16	1.56E-14	1.01E-15
6/13/18	1418	7.77E-16	2.65E-16	3.04E-14	1.27E-15
6/20/18	1021	5.18E-16	2.39E-16	1.76E-14	1.07E-15

5.1 Statistical test discussion

A typical probability density function (PDF) was plotted for the baseline period and then using the method described in Section 4.1 a PDF for each sample was plotted against the baseline PDF. This produced a series of plots presented in their entirety in Appendix D.

As shown in Figure 6, an example of the PDF plots for the baseline and the samples collected during demolition, the baseline PDF (prior) is presented as a bold red peak on the plot.. A vertical dashed line at the location of the 95-percentile location (x_p – see below for an explanation of how to calculate x_p) for the baseline PDF has been added to each plot. The 95-percentile represents the location at which a sample PDF to the left of that line indicates that there is a 95% chance that the sample filter represented by that peak could be part of baseline emissions. Any posterior PDF peak (peaks that are labeled with a date) to the right would have less than a 5% chance of being a baseline value and would be considered emissions due to demolition activities. Weather conditions and specific demolition activities that occurred during a sample period will affect which sampler, if any, was in a direct plume path. It was expected that not every sample would be statistically significant. Statistically significant samples based on the baseline data were found on ANVDEMO1 some weeks, on ANVDEMO2 other weeks, on both samplers some weeks and other weeks no statistically significant results were observed.

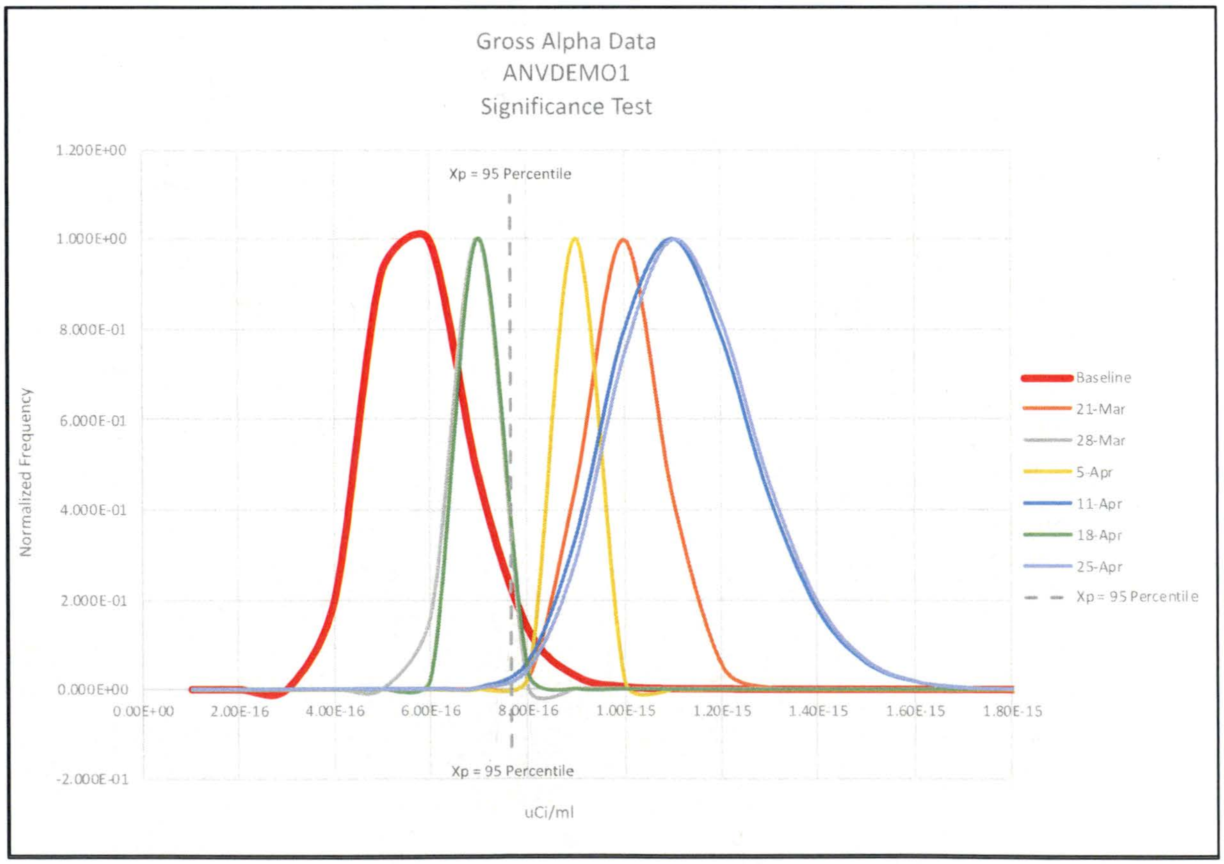


Figure 6: Example Significance Test PDF Plot

The x_p percentile represents the value at which the probability percent of the population is below that value. For example, at the 95-percentile the probability percent is 95% that a given value is below x_p for the subject population. The x_p percentile can be used to determine if a sample value is outside the baseline data and thus due to demolition activities. The percentile can be found from the standard deviation of a dataset.

For example, 68.26% of the population is within one standard deviation of the mean and 15.87% of the values are on the lower end of the PDF and 15.87% are on the upper end of the PDF. For the case of baseline samples vs demolition samples only the upper end is considered as outside of the baseline data and due to demolition activities. With this approach, at one standard deviation the percentile would be 84.13%. A Z-table is often used to find the value of Z which represents the number of standard deviations needed to obtain a specific percentile.

The value of x_p at a specific percentile can be found from the Z formula. For a lognormal distribution the Z formula is

$$Z = \frac{ln(x_p) - \mu_{ln}}{\sigma_{ln}}$$

Where: x_p = value of variable "x" at a specific percentile.
μ_{ln} = lognormal of the mean
σ_{ln} = lognormal of the standard deviation

Then, solving for x_p

$$x_p = exp[(Z)(\sigma_{ln}) + \mu_{ln}]$$

Values of Z are:

- 95-percentile = 1.645
- 99-percentile = 2.326

For the baseline data presented in Appendix B, the lognormal of mean and the lognormal of the standard deviation were determined with Excel® functions. These values, along with the calculated valves of x_p at the 95 and 99 percentiles are presented in Table 8.

Table 8: Baseline Statistical Data

Variable	Gross Alpha		Gross Beta	
	ANVDEMO1	ANVDEMO2	ANVDEMO1	ANVDEMO2
μ_{ln}	-35.095	-34.983	-31.794	-31.7692
σ_{ln}	0.1777	0.1620	0.2415	0.2451
$x_{p=95}$	7.680E-16	8.368E-16	2.315E-14	2.387E-14
$x_{p=99}$	8.669E-16	9.345E-16	2.728E-14	2.821E-14

Using this approach, there were 21 weeks out of the 41-week[10] demolition period when one or more samplers registered statistically significant data at the 95-percentile level. Seventeen (17) of those weekly samples were actually at the 99-percentile level. Details on a week by week basis is provided in Table 9.

[10] The week of Christmas is not counted in the evaluation. The project was closed for that week in 2017.

Table 9: Weekly evaluation of statistical significance and the associate percentile ranking

Sample Date	ANVDEMO1 alpha	ANVDEMO1 beta	ANVDEMO2 alpha	ANVDEMO2 beta
9/20/17	99 %			95 %
9/27/17	99 %	99 %	99 %	99 %
10/4/17				
10/11/17				
10/18/17				
10/25/17	99 %	95 %		99 %
11/1/17				
11/8/17				
11/15/17	95 %			
11/22/17				
11/29/17				
12/6/17	95 %	95 %	95 %	95 %
12/13/17				
12/20/17				
12/27/17	Off for Christmas holidays from 12/22/17 through 1/1/18.			
1/3/18	99 %		95 %	99 %
1/10/18	99 %	95 %	95 %	99 %
1/17/18				
1/24/18		95 %		95 %
1/31/18				
2/7/18			99 %	99 %
2/14/18		99 %		99 %
2/21/18				95 %
2/28/18				
3/7/18	95%		99 %	
3/14/18				
3/21/18	99 %		99 %	
3/28/18				
4/5/18	99 %			
4/11/18	99 %		99 %	
4/18/18				
4/25/18	99 %	95 %	99 %	
5/2/18				
5/9/18				99 %
5/16/18				
5/23/18				
5/30/18	95 %	99 %	99 %	99 %
6/6/18				
6/13/18				99 %
6/20/18				
8/01/18	99 %	99 %		99 %
8/08/18	99 %	99 %	99 %	99 %

5.2 Predicted vs. Measured test discussion for revision 0 of the Alternative Method

The next step in the evaluation of results, and the step that determines if the AM is providing reasonable data that do not significantly underestimate or grossly overestimate emissions, is the direct comparison to air dispersion calculations. The data has been separated into three groups; one group for mechanical shearing, a second group for hydraulic hammering, and the third group for hot cutting.

5.2.1 Shearing data sets

Results from the AERMOD modeling software for the sampling period of each filter is presented in the "AERMOD Predicted Concentration" column of Table 10, Table 11, Table 12 and Table 13. The "Total Predicted Concentration" is the sum of the "AERMOD Predicted Concentration" and the "Background Concentration" columns. The "Filter Measured Concentration" column is the average concentration as measured on the filter collected on the indicated date; these data have been presented previously and is reproduced here for simplicity.

There are 5 Total Predicted alpha results that are less than the alpha values measured on the filters – 2 out of 11 for ANVDEMO1 and 3 out of 11 for ANVDEMO2. For the beta results there are few cases – 3 out 11 for ANVDEMO1 and 5 out of 11 for ANVDEMO2 – where the predicted result is less than the measured value from the filter. A visual representation of these results is presented in Figure 7, Figure 8, Figure 9, and Figure 10.

Table 10: Predicted vs. Measured alpha concentrations at ANVDEMO1 for Shearing

Sample Collection Date	AERMOD Predicted Concentration (μCi/ml)	Background Concentration (μCi/ml)	Total Predicted Concentration (μCi/ml)	Filter Measured Concentration (μCi/ml)
9/20/17	2.99E-17	9.55E-16	9.85E-16	9.32E-16
9/27/17	2.82E-17	9.55E-16	9.84E-16	1.15E-15
10/4/17	4.93E-17	1.01E-15	1.06E-15	5.63E-16
10/11/17	5.88E-17	1.01E-15	1.07E-15	6.78E-16
10/18/17	1.10E-16	9.78E-16	1.09E-15	5.55E-16
10/25/17	9.34E-17	9.78E-16	1.07E-15	1.01E-15
11/1/17	4.18E-17	6.44E-16	6.85E-16	4.45E-16
11/8/17	1.13E-17	6.44E-16	6.55E-16	6.80E-16
11/15/17	3.83E-18	1.21E-15	1.21E-15	8.61E-16
11/22/17	4.49E-18	1.21E-15	1.21E-15	4.79E-16
11/29/17	2.22E-17	9.71E-16	9.93E-16	7.19E-16

Table 11: Predicted vs. Measured beta concentrations at ANVDEMO1 for Shearing

Sample Collection Date	AERMOD Predicted Concentration (μCi/ml)	Background Concentration (μCi/ml)	Total Predicted Concentration (μCi/ml)	Filter Measured Concentration (μCi/ml)
9/20/17	3.71E-15	2.48E-14	2.85E-14	2.34E-14
9/27/17	3.50E-15	2.48E-14	2.83E-14	3.22E-14
10/4/17	6.12E-15	1.91E-14	2.52E-14	1.69E-14
10/11/17	7.29E-15	1.91E-14	2.64E-14	2.10E-14
10/18/17	1.36E-14	2.28E-14	3.64E-14	1.54E-14
10/25/17	1.16E-14	2.28E-14	3.44E-14	2.56E-14
11/1/17	5.19E-15	1.35E-14	1.87E-14	1.36E-14
11/8/17	1.40E-15	1.35E-14	1.49E-14	1.53E-14
11/15/17	4.75E-16	1.79E-14	1.84E-14	2.11E-14
11/22/17	5.57E-16	1.79E-14	1.85E-14	1.53E-14
11/29/17	2.76E-15	2.22E-14	2.50E-14	2.14E-14

Table 12: Predicted vs. Measured alpha concentrations at ANVDEMO2 for Shearing

Sample Collection Date	AERMOD Predicted Concentration (μCi/ml)	Background Concentration (μCi/ml)	Total Predicted Concentration (μCi/ml)	Filter Measured Concentration (μCi/ml)
9/20/17	4.03E-18	9.55E-16	9.59E-16	7.06E-16
9/27/17	1.51E-17	9.55E-16	9.71E-16	1.31E-15
10/4/17	7.24E-18	1.01E-15	1.02E-15	6.34E-16
10/11/17	2.77E-17	1.01E-15	1.04E-15	6.46E-16
10/18/17	1.96E-17	9.78E-16	9.98E-16	5.32E-16
10/25/17	3.24E-17	9.78E-16	1.01E-15	7.65E-16
11/1/17	1.55E-17	6.44E-16	6.59E-16	6.68E-16
11/8/17	1.16E-18	6.44E-16	6.45E-16	7.03E-16
11/15/17	1.22E-18	1.21E-15	1.21E-15	6.92E-16
11/22/17	9.64E-19	1.21E-15	1.21E-15	5.45E-16
11/29/17	1.13E-17	9.71E-16	9.82E-16	6.63E-16

Table 13: Predicted vs. Measured beta concentrations at ANVDEMO2 for Shearing

Sample Collection Date	AERMOD Predicted Concentration (μCi/ml)	Background Concentration (μCi/ml)	Total Predicted Concentration (μCi/ml)	Filter Measured Concentration (μCi/ml)
9/20/17	5.00E-16	2.48E-14	2.53E-14	2.53E-14
9/27/17	1.88E-15	2.48E-14	2.67E-14	2.67E-14
10/4/17	8.99E-16	1.91E-14	2.00E-14	2.00E-14
10/11/17	3.44E-15	1.91E-14	2.26E-14	2.26E-14
10/18/17	2.44E-15	2.28E-14	2.52E-14	2.52E-14
10/25/17	4.01E-15	2.28E-14	2.68E-14	2.68E-14
11/1/17	1.93E-15	1.35E-14	1.54E-14	1.54E-14
11/8/17	1.44E-16	1.35E-14	1.36E-14	1.36E-14
11/15/17	1.51E-16	1.79E-14	1.81E-14	1.81E-14
11/22/17	1.20E-16	1.79E-14	1.81E-14	1.81E-14
11/29/17	1.41E-15	2.22E-14	2.36E-14	2.36E-14

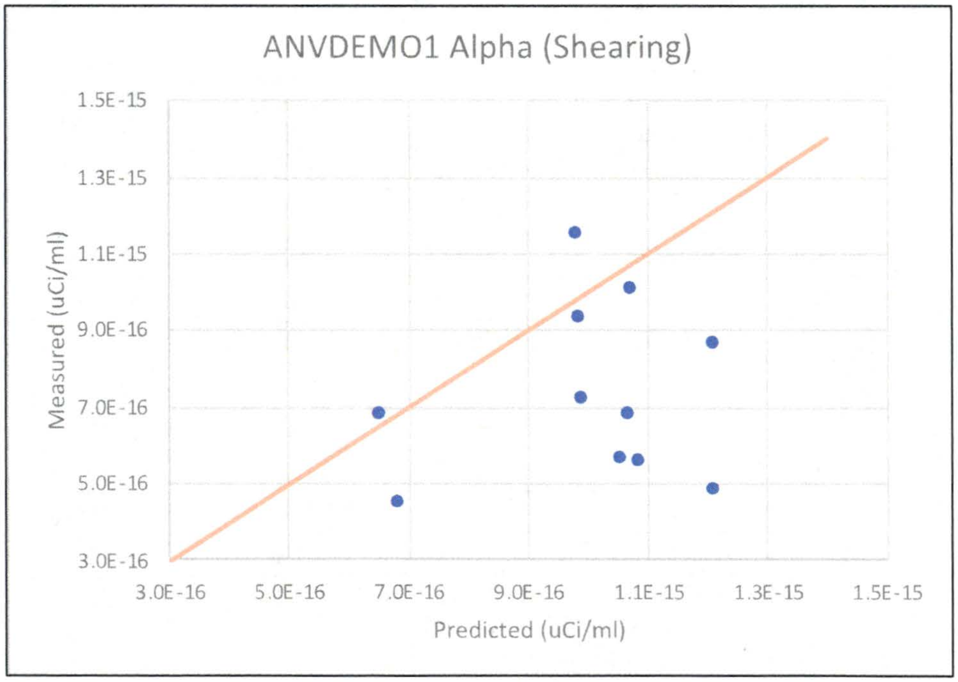


Figure 7: ANVDEMO 1 alpha -comparison of Predicted to Measured values for Shearing

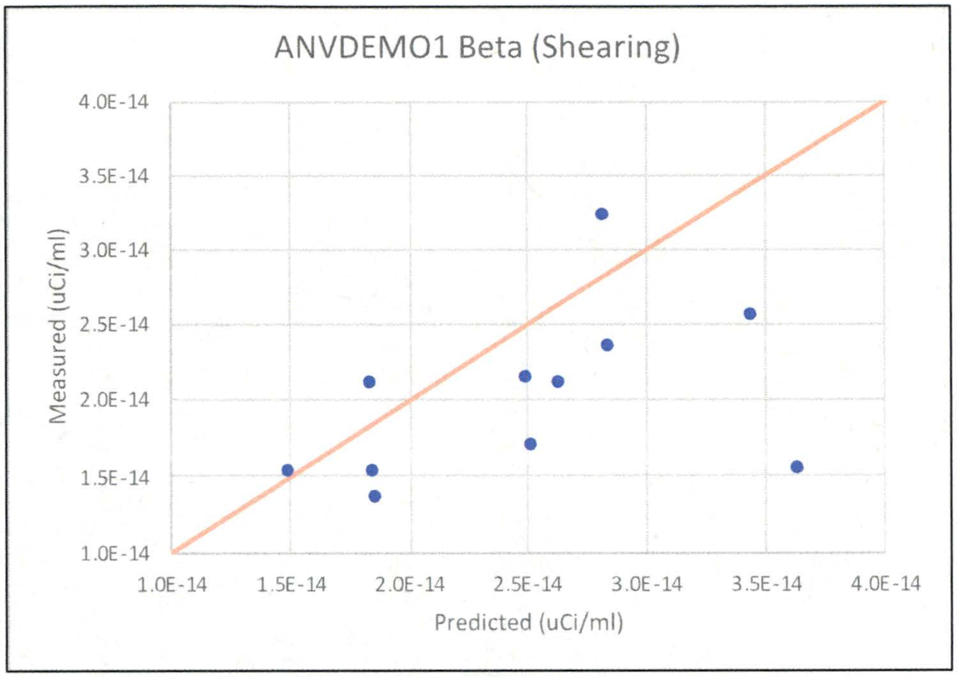


Figure 8: ANVDEMO 1beta -comparison of Predicted to Measured values for Shearing

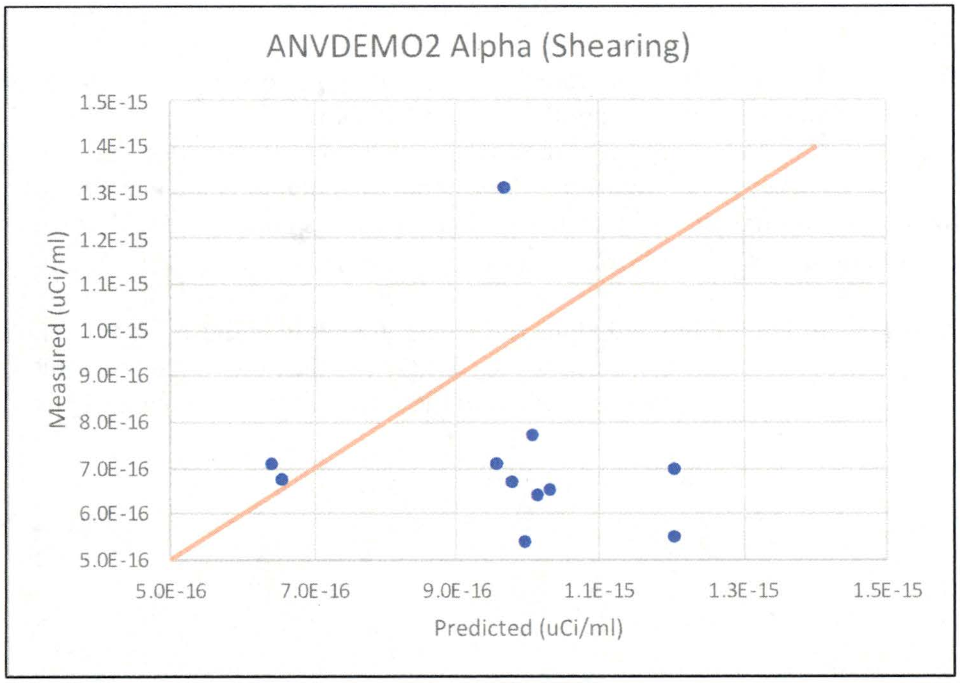


Figure 9: ANVDEMO 2 alpha -comparison of Predicted to Measured values for Shearing

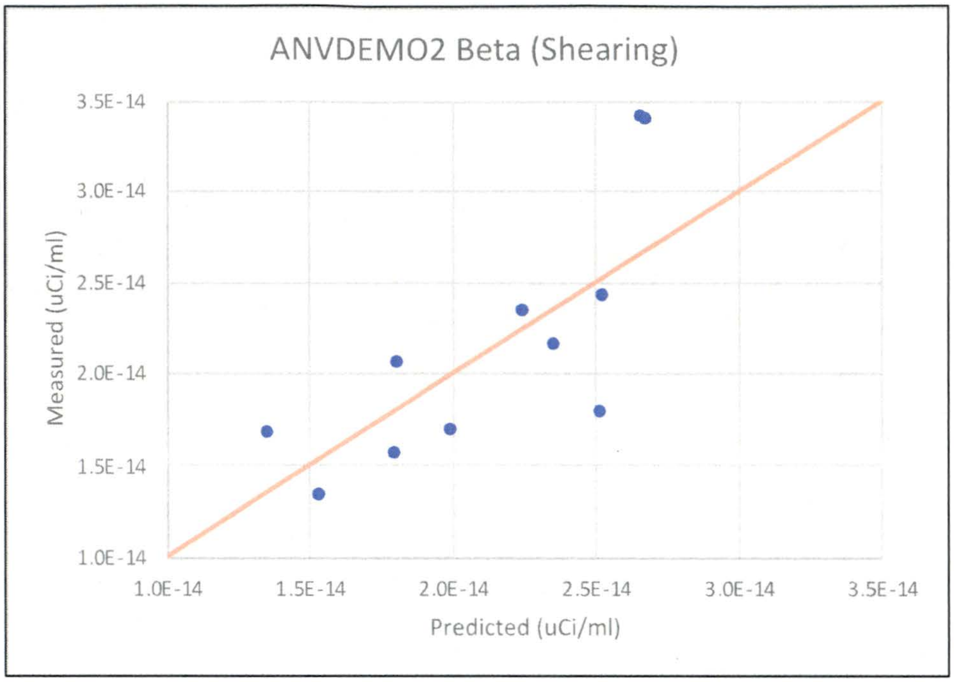


Figure 10: ANVDEMO 2 beta -comparison of Predicted to Measured values for Shearing

5.2.2 Hydraulic Hammer data sets

Results from the AERMOD modeling software for the sampling period of each filter are presented in the "AERMOD Predicted Concentration" column of Table 14, Table 15, Table 16 and Table 17. The "Total Predicted Concentration" is the sum of the "AERMOD Predicted Concentration" and the "Background Concentration" columns. The "Filter Measured Concentration" column is the average concentration as measured on the filter collected on the indicated date; this data has been presented previously and is reproduced here for simplicity.

In all but two cases of the Total Predicted alpha results are greater than the alpha values measured on the filters. For the beta results all of the predicted results are greater than the measured value from the filter. A visual representation of these results is presented in Figure 11, Figure 12, Figure 13, and Figure 14.

Table 14: Predicted vs. Measured alpha concentrations at ANVDEMO1 for Hydraulic Hammer

Sample Collection Date	AERMOD Predicted Concentration (μCi/ml)	Background Concentration (μCi/ml)	Total Predicted Concentration (μCi/ml)	Filter Measured Concentration (μCi/ml)
12/6/17	4.62E-15	9.71E-16	5.59E-15	8.28E-16
12/13/17	2.44E-15	7.26E-16	3.17E-15	6.20E-16
12/20/17	1.96E-15	7.26E-16	2.69E-15	5.66E-16
12/27/17 (a)	1.96E-15	8.39E-16	2.80E-15	6.16E-16
1/3/18 (a)	4.58E-15	8.39E-16	5.42E-15	9.60E-16
1/10/18	6.34E-15	1.10E-15	7.44E-15	9.36E-16
1/17/18	1.50E-14	1.10E-15	1.61E-14	5.70E-16
1/24/18	1.45E-14	8.66E-16	1.54E-14	6.18E-16
1/31/18 (a)	1.95E-14	8.66E-16	2.03E-14	6.12E-16
2/7/18 (a)	9.49E-15	7.19E-16	1.02E-14	6.76E-16
2/14/18 (a)	6.76E-15	7.19E-16	7.48E-15	6.43E-16
2/21/18 (a)	1.05E-15	6.39E-16	1.68E-15	6.69E-16
2/28/18 (a)	7.22E-16	6.39E-16	1.36E-15	7.27E-16
3/7/18 (a)	6.10E-16	9.76E-16	1.59E-15	7.94E-16
3/14/18 (a)	2.62E-16	9.76E-16	1.24E-15	4.59E-16
3/21/18 (a)	1.78E-16	1.02E-15	1.20E-15	1.00E-15
3/28/18	4.47E-15	1.02E-15	5.49E-15	6.62E-16
4/5/18	1.19E-14	7.09E-16	1.26E-14	8.92E-16
4/11/18	7.35E-15	7.09E-16	8.06E-15	1.12E-15
4/18/18	1.58E-15	7.82E-16	2.36E-15	6.99E-16
4/25/18	3.83E-15	7.82E-16	4.61E-15	1.13E-15
5/2/18	1.13E-15	1.10E-15	2.23E-15	6.65E-16
5/9/18	1.04E-14	1.10E-15	1.15E-14	7.85E-16
5/16/18	9.89E-15	6.11E-16	1.05E-14	6.44E-16
5/23/18	8.50E-15	6.11E-16	9.11E-15	2.93E-16
5/30/18	3.55E-15	6.83E-16	4.23E-15	8.75E-16
6/6/18	1.70E-15	6.83E-16	2.38E-15	3.51E-16
6/13/18	8.72E-15	5.24E-16	9.24E-15	5.44E-16
6/20/18	7.13E-16	5.24E-16	1.24E-15	6.47E-16

(a) Indicates weeks with pile only emissions.

Table 15: Predicted vs. Measured beta concentrations at ANVDEMO1 for Hydraulic Hammer

Sample Collection Date	AERMOD Predicted Concentration (μCi/ml)	Background Concentration (μCi/ml)	Total Predicted Concentration (μCi/ml)	Filter Measured Concentration (μCi/ml)
12/6/17	5.74E-13	2.22E-14	5.96E-13	2.48E-14
12/13/17	3.03E-13	1.50E-14	3.18E-13	1.83E-14
12/20/17	2.44E-13	1.50E-14	2.59E-13	1.80E-14
12/27/17 (a)	2.44E-13	1.65E-14	2.60E-13	1.54E-14
1/3/18 (a)	5.68E-13	1.65E-14	5.85E-13	1.89E-14
1/10/18	7.87E-13	1.77E-14	8.04E-13	2.54E-14
1/17/18	1.85E-12	1.77E-14	1.87E-12	1.84E-14
1/24/18	1.80E-12	2.17E-14	1.82E-12	2.61E-14
1/31/18 (a)	2.41E-12	2.17E-14	2.44E-12	2.00E-14
2/7/18 (a)	1.18E-12	1.85E-14	1.20E-12	1.67E-14
2/14/18 (a)	8.38E-13	1.85E-14	8.57E-13	2.76E-14
2/21/18 (a)	1.30E-13	1.61E-14	1.46E-13	2.04E-14
2/28/18 (a)	8.96E-14	1.61E-14	1.06E-13	1.43E-14
3/7/18 (a)	7.57E-14	1.51E-14	9.08E-14	2.21E-14
3/14/18 (a)	3.25E-14	1.51E-14	4.76E-14	8.43E-15
3/21/18 (a)	2.21E-14	1.46E-14	3.67E-14	2.12E-14
3/28/18	5.54E-13	1.46E-14	5.69E-13	1.40E-14
4/5/18	1.48E-12	1.31E-14	1.49E-12	1.89E-14
4/11/18	9.12E-13	1.31E-14	9.25E-13	1.90E-14
4/18/18	1.96E-13	1.46E-14	2.10E-13	1.39E-14
4/25/18	4.75E-13	1.46E-14	4.90E-13	2.51E-14
5/2/18	1.40E-13	1.59E-14	1.56E-13	1.64E-14
5/9/18	1.29E-12	1.59E-14	1.30E-12	2.07E-14
5/16/18	1.23E-12	1.25E-14	1.24E-12	1.53E-14
5/23/18	1.05E-12	1.25E-14	1.07E-12	1.38E-14
5/30/18	4.40E-13	1.54E-14	4.55E-13	2.78E-14
6/6/18	2.10E-13	1.54E-14	2.26E-13	1.02E-14
6/13/18	1.08E-12	1.12E-14	1.09E-12	1.59E-14
6/20/18	8.85E-14	1.12E-14	9.97E-14	1.65E-14
(a) Indicates weeks with pile only emissions.				

Table 16: Predicted vs. Measured alpha concentrations at ANVDEMO2 for Hydraulic Hammer

Sample Collection Date	AERMOD Predicted Concentration (μCi/ml)	Background Concentration (μCi/ml)	Total Predicted Concentration (μCi/ml)	Filter Measured Concentration (μCi/ml)
12/6/17	4.32E-16	9.71E-16	1.40E-15	8.56E-16
12/13/17	1.60E-15	7.26E-16	2.33E-15	7.76E-16
12/20/17	1.04E-15	7.26E-16	1.76E-15	5.32E-16
12/27/17 [(a)]	1.04E-15	8.39E-16	1.88E-15	6.91E-16
1/3/18 [(a)]	1.65E-15	8.39E-16	2.49E-15	8.64E-16
1/10/18	4.12E-15	1.10E-15	5.22E-15	9.08E-16
1/17/18	1.47E-15	1.10E-15	2.57E-15	7.45E-16
1/24/18	3.32E-15	8.66E-16	4.19E-15	6.58E-16
1/31/18 [(a)]	7.33E-15	8.66E-16	8.20E-15	7.25E-16
2/7/18 [(a)]	2.31E-15	7.19E-16	3.03E-15	1.46E-15
2/14/18 [(a)]	8.72E-16	7.19E-16	1.59E-15	7.22E-16
2/21/18 [(a)]	1.29E-16	6.39E-16	7.67E-16	8.24E-16
2/28/18 [(a)]	6.72E-17	6.39E-16	7.06E-16	5.15E-16
3/7/18 [(a)]	1.93E-16	9.76E-16	1.17E-15	1.02E-15
3/14/18 [(a)]	6.61E-17	9.76E-16	1.04E-15	2.85E-16
3/21/18 [(a)]	1.35E-16	1.02E-15	1.15E-15	9.76E-16
3/28/18	2.58E-16	1.02E-15	1.27E-15	8.20E-16
4/5/18	8.23E-16	7.09E-16	1.53E-15	7.44E-16
4/11/18	3.28E-15	7.09E-16	3.99E-15	1.26E-15
4/18/18	1.14E-15	7.82E-16	1.92E-15	5.38E-16
4/25/18	1.62E-16	7.82E-16	9.44E-16	1.14E-15
5/2/18	8.81E-17	1.10E-15	1.19E-15	7.01E-16
5/9/18	2.22E-15	1.10E-15	3.33E-15	6.48E-16
5/16/18	5.66E-15	6.11E-16	6.27E-15	7.38E-16
5/23/18	3.55E-15	6.11E-16	4.16E-15	6.81E-16
5/30/18	1.21E-15	6.83E-16	1.90E-15	1.74E-15
6/6/18	1.22E-15	6.83E-16	1.91E-15	1.38E-16
6/13/18	1.84E-15	5.24E-16	2.36E-15	7.77E-16
6/20/18	6.28E-16	5.24E-16	1.15E-15	5.18E-16
(a) Indicates weeks with pile only emissions.				

Table 17: Predicted vs. Measured beta concentrations at ANVDEMO2 for Hydraulic Hammer

Sample Collection Date	AERMOD Predicted Concentration (μCi/ml)	Background Concentration (μCi/ml)	Total Predicted Concentration (μCi/ml)	Filter Measured Concentration (μCi/ml)
12/6/17	5.35E-14	2.22E-14	7.58E-14	2.45E-14
12/13/17	1.99E-13	1.50E-14	2.14E-13	1.85E-14
12/20/17	1.29E-13	1.50E-14	1.44E-13	2.10E-14
12/27/17 [a]	1.29E-13	1.65E-14	1.45E-13	1.92E-14
1/3/18 [a]	2.04E-13	1.65E-14	2.21E-13	3.26E-14
1/10/18	5.11E-13	1.77E-14	5.28E-13	2.85E-14
1/17/18	1.82E-13	1.77E-14	2.00E-13	1.94E-14
1/24/18	4.12E-13	2.17E-14	4.34E-13	2.76E-14
1/31/18 [a]	9.09E-13	2.17E-14	9.31E-13	1.92E-14
2/7/18 [a]	2.87E-13	1.85E-14	3.05E-13	3.56E-14
2/14/18 [a]	1.08E-13	1.85E-14	1.27E-13	2.87E-14
2/21/18 [a]	1.60E-14	1.61E-14	3.20E-14	2.62E-14
2/28/18 [a]	8.33E-15	1.61E-14	2.44E-14	1.35E-14
3/7/18 [a]	2.40E-14	1.51E-14	3.91E-14	2.15E-14
3/14/18 [a]	8.19E-15	1.51E-14	2.33E-14	9.22E-15
3/21/18 [a]	1.68E-14	1.46E-14	3.14E-14	1.93E-14
3/28/18	3.20E-14	1.46E-14	4.66E-14	1.37E-14
4/5/18	1.02E-13	1.31E-14	1.15E-13	1.45E-14
4/11/18	4.07E-13	1.31E-14	4.20E-13	1.85E-14
4/18/18	1.42E-13	1.46E-14	1.56E-13	1.34E-14
4/25/18	2.01E-14	1.46E-14	3.47E-14	2.04E-14
5/2/18	1.09E-14	1.59E-14	2.68E-14	2.33E-14
5/9/18	2.76E-13	1.59E-14	2.92E-13	4.15E-14
5/16/18	7.02E-13	1.25E-14	7.14E-13	1.79E-14
5/23/18	4.40E-13	1.25E-14	4.52E-13	1.60E-14
5/30/18	1.50E-13	1.54E-14	1.66E-13	4.34E-14
6/6/18	1.52E-13	1.54E-14	1.67E-13	1.56E-14
6/13/18	2.28E-13	1.12E-14	2.40E-13	3.04E-14
6/20/18	7.78E-14	1.12E-14	8.91E-14	1.76E-14
(a) Indicates weeks with pile only emissions.				

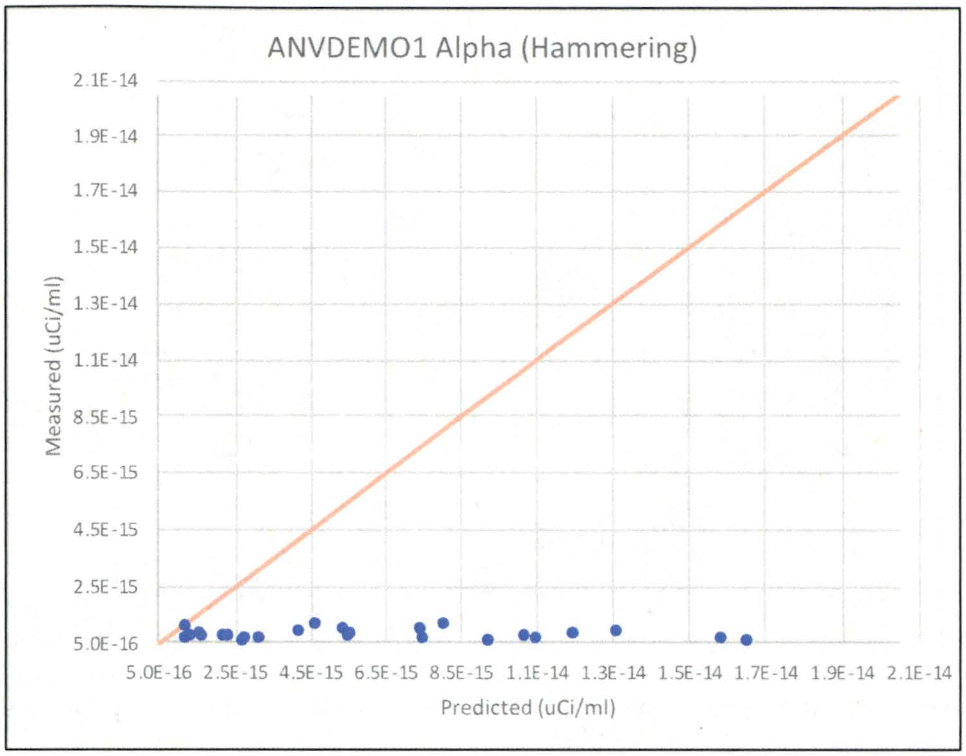


Figure 11: ANVDEMO1 alpha -comparison of Predicted to Measured values for Hydraulic Hammer

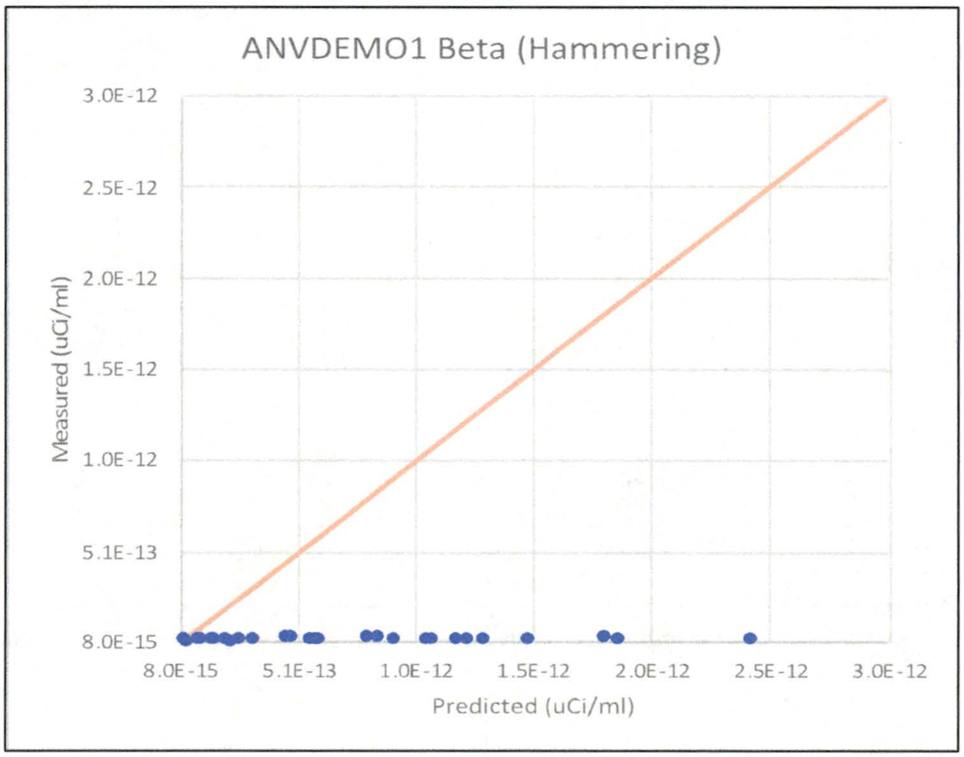


Figure 12: ANVDEMO1 beta -comparison of Predicted to Measured values for Hydraulic Hammer

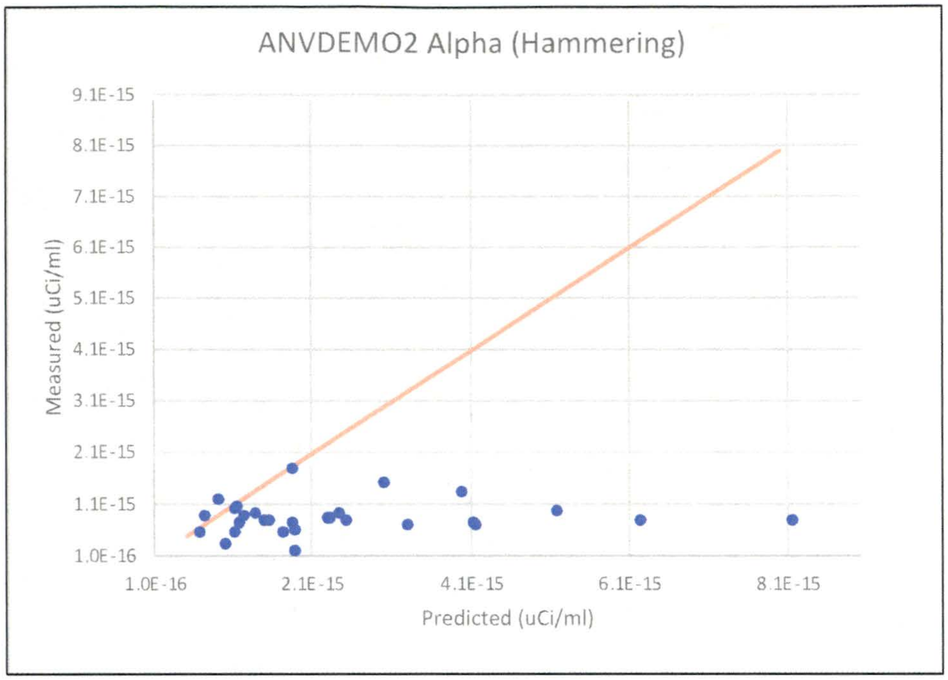


Figure 13: ANVDEMO2 alpha -comparison of Predicted to Measured values for Hydraulic Hammer

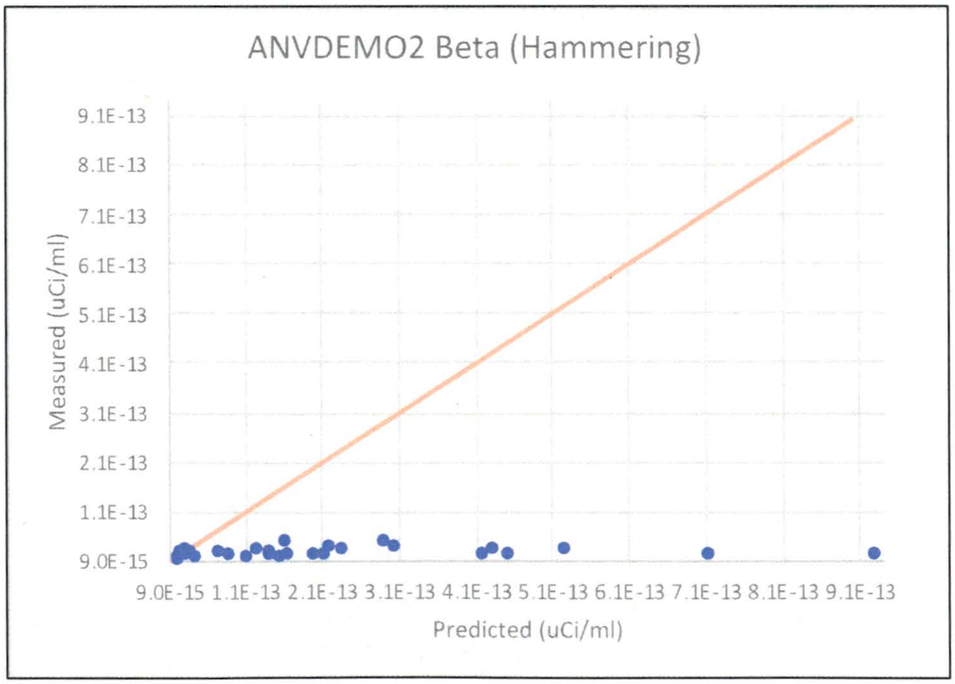


Figure 14: ANVDEMO2 beta -comparison of Predicted to Measured values for Hydraulic Hammer

5.2.3 Hot Cutting data sets

A very limited set of data was available for hot cutting. Hot cutting of the upper Crane Maintenance Room (CMR) shield door was performed with an oxylance. A total of 12.6 hours of cutting was performed during two of the one-week sample periods. During the first week some cutting of rebar around the door and minor hydraulic hammering occurred. During the second week the only demolition activities were positioning the door to continue cutting and physical cutting. For this analysis, only the hot cutting has been considered. The times and duration of the cutting is provided in Table 18.

During hot cutting, the exhaust gases were forced through a water curtain using fans. The water curtain was provided by water cannons previously used for misting of demolition operations. There was no data available on the exit temperature of the exhaust gas once it exited the water curtain. It is reported that the demolition crews did an excellent job in setting up the fans and making the best possible use of the water curtain. The exit velocity was set to 0.0001 m/s and the exit temperature was set to ambient. As a test of the dependence on concentration at each sampler vs temperature, the exit temperature was changed to 200 °C. Over 4 significant figures there was no difference in the predicted concentration between an ambient exit temperature and a 200 °C exit temperature.

Table 18: Hot cutting dates and times

Date	Start Cutting	Stop cutting	Total time (hr)
7/25/18	NA	NA	0.00
7/26/18	NA	NA	0.00
7/27/18	NA	NA	0.00
7/28/18	NA	NA	0.00
7/29/18	NA	NA	0.00
7/30/18	4:20	5:55	1.58
	23:45	0:00	0.25
7/31/18	0:01	2:00	1.98
	4:00	5:45	1.75
	23:00	0:00	1.00
8/1/18	0:01	1:45	1.73
	3:30	5:10	1.67
	23:00	0:00	1.00
8/2/18	0:01	0:45	0.73
	1:15	1:25	0.17
8/3/18	NA	NA	0.00
8/4/18	NA	NA	0.00
8/5/18	NA	NA	0.00
8/6/18	NA	NA	0.00
8/7/18	17:35	18:20	0.75
8/8/18	NA	NA	0.00

The isotopic "Contamination Levels" for this door was taken from the Vitrification Facility Exemption Calculation or a sensitivity analysis which are kept on file and is provided in Column "A" Table 19. For the oxylance, the cut width is taken as 3.8 cm with a heat effect zone of 7 cm on either side of the cut.

Seven cuts were made on the door. Five of the cuts were about 447.1 cm long and 2 of the cuts were about 115.8 cm long, for a total area 43920 cm^2. The MAR in units of Ci is calculated by multiplying the contamination level by the area heated and is presented as Column B in Table 19. A MAR in units of grams is determined by dividing the MAR in curies by the Specific Activity of the radionuclide; the results are presented in Table 19 as column C. The MAR that is released is found as the product of the MAR in grams and the 0.07[11] physical state factor, which is presented in Table 19 as column D. Dividing the sum of the MAR released in units of grams by the 12.6 hours yields an emission rate of 9.4067E-08 g/s. Although a water curtain was used to limit emissions, this type of control is not listed in 40 CFR 61 Appendix D and as such no credit was taken for this control. The cutting was performed in the open-air where this type of control device would provide limited emission reduction.

Table 19: Hot cutting MAR

Radionuclide	*[Column A]* Contamination Level (Ci/cm^2)	*[Column B]* MAR (Ci)	*[Column C]* MAR (g)	*[Column D]* MAR Released (g)
Am-241	1.873E-10	8.228E-06	2.399E-06	1.679E-07
Cm-243	2.495E-13	1.096E-08	2.119E-10	1.483E-11
Cm-244	6.278E-12	2.757E-07	3.310E-09	2.317E-10
Cs-137	3.306E-08	1.452E-03	1.669E-05	1.168E-06
Np-237	1.994E-14	8.756E-10	1.242E-06	8.694E-08
Pu-238	5.544E-11	2.435E-06	1.421E-07	9.949E-09
Pu-239	3.069E-11	1.348E-06	2.167E-05	1.517E-06
Pu-240	2.341E-11	1.028E-06	4.509E-06	3.157E-07
Pu-241	5.125E-10	2.251E-05	2.186E-07	1.530E-08
Sr-90	2.000E-09	8.785E-05	6.412E-07	4.489E-08
U-232	1.336E-12	5.867E-08	2.740E-09	1.918E-10
U-233	4.776E-13	2.097E-08	2.173E-06	1.521E-07
U-234	4.776E-13	2.097E-08	3.361E-06	2.353E-07
U-235	7.080E-14	3.109E-09	1.440E-03	1.008E-04
U-238	4.542E-13	1.995E-08	5.954E-02	4.168E-03
Total alpha	3.063E-10	1.345E-05	1.755E-05	4.271E-03
Total beta	3.557E-08	1.56E-03	6.104E-02	1.229E-06
Total				4.273E-03

[11] As discussed in the AM, the emission rate for Hot Cutting is determined with 40CFR61 Appendix D method, but with a new Physical State Factor. The Physical State factor in the original (revision 0) of the AM is 0.07 for hot cutting.

As with the other evaluations, an hourly emission rate file was produced based on the day and time that the cutting occurred. The hourly emission file was used as input into the AERMOD modeling software for the sampling period of each filter. The AERMOD results along with the measured values found on ANVDEMO1 and ANVDEMO2 are presented in Table 20, Table 21, Table 22, and Table 23.

In all but one case the Total Predicted alpha results are greater than the alpha values measured on the filters. For beta results are all non-conservative, with the ratio of measured to predicted ranging from 1.13 to 5.61. The majority of the beta source term is Cs-137, which has a very low boiling point. This may contribute to the difference in the alpha (typically high boiling points) and beta results. A visual representation of these results is presented below in Figure 15, Figure 16, Figure 17 and Figure 18.

Table 20: Predicted vs. Measured alpha concentrations at ANVDEMO1 for Hot Cutting

Sample Collection Date	AERMOD Predicted Concentration (μCi/ml)	Background Concentration (μCi/ml)	Total Predicted Concentration (μCi/ml)	Filter Measured Concentration (μCi/ml)
8/1/18	1.71E-15	7.43E-16	2.46E-15	9.44E-16
8/8/18	1.75E-16	9.46E-16	1.12E-15	9.36E-16

Table 21: Predicted vs. Measured beta concentrations at ANVDEMO1 for Hot Cutting

Sample Collection Date	AERMOD Predicted Concentration (μCi/ml)	Background Concentration (μCi/ml)	Total Predicted Concentration (μCi/ml)	Filter Measured Concentration (μCi/ml)
8/1/18	1.99E-13	1.34E-14	2.13E-13	2.40E-13
8/8/18	2.04E-14	2.38E-14	4.41E-14	6.51E-14

Table 22: Predicted vs. Measured alpha concentrations at ANVDEMO2 for Hot Cutting

Sample Collection Date	AERMOD Predicted Concentration (μCi/ml)	Background Concentration (μCi/ml)	Total Predicted Concentration (μCi/ml)	Filter Measured Concentration (μCi/ml)
8/1/18	3.45E-16	7.43E-16	1.09E-15	6.16E-16
8/8/18	1.04E-16	9.46E-16	1.05E-15	1.35E-15

Table 23: Predicted vs. Measured beta concentrations at ANVDEMO2 for Hot Cutting

Sample Collection Date	AERMOD Predicted Concentration (μCi/ml)	Background Concentration (μCi/ml)	Total Predicted Concentration (μCi/ml)	Filter Measured Concentration (μCi/ml)
8/1/18	4.00E-14	1.34E-14	5.34E-14	1.74E-13
8/8/18	1.20E-14	2.38E-14	3.58E-14	2.01E-13

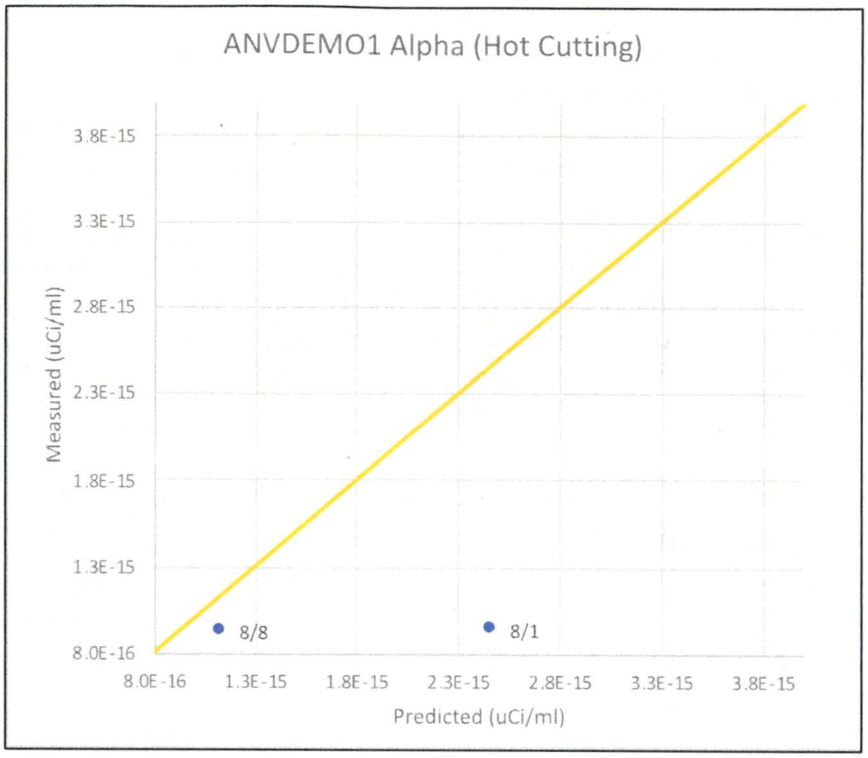


Figure 15: ANVDEMO1 alpha -comparison of Predicted to Measured values for Hot cutting

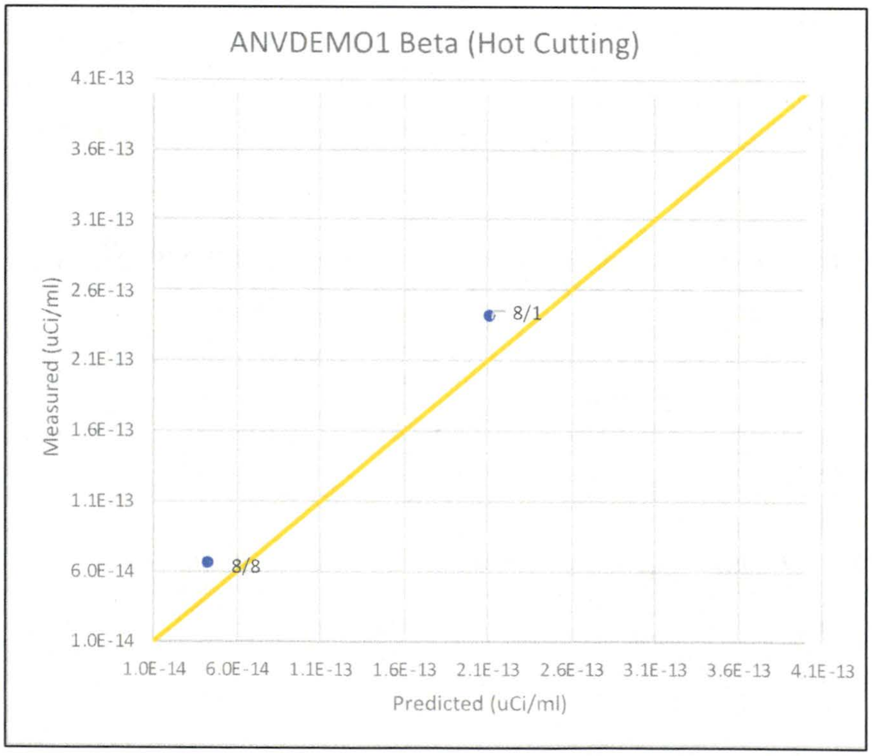


Figure 16: ANVDEMO1 beta -comparison of Predicted to Measured values for Hot cutting

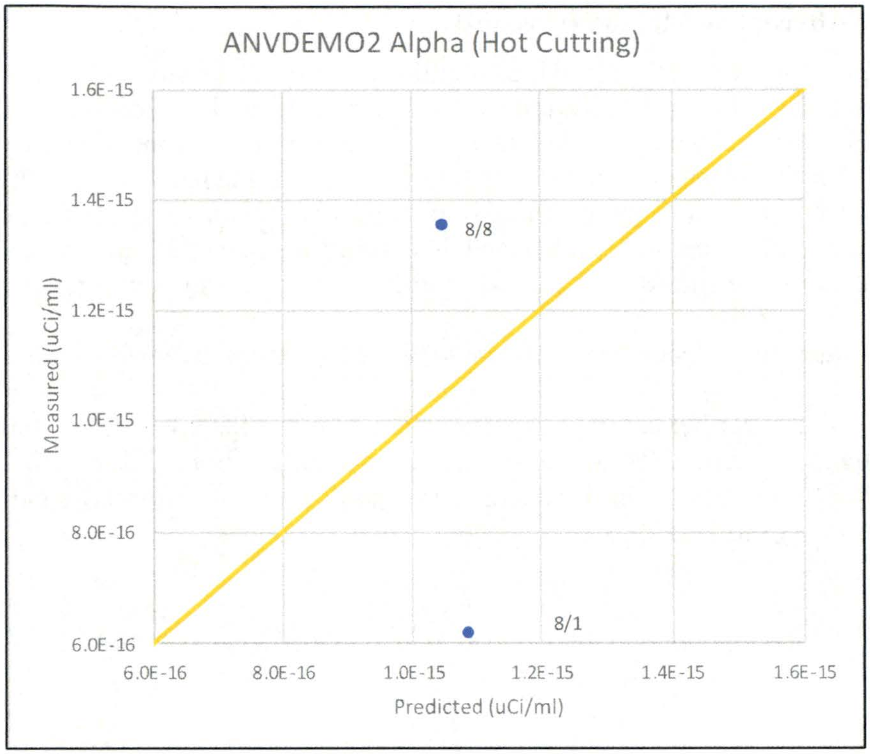


Figure 17: ANVDEMO2 alpha -comparison of Predicted to Measured values for Hot cutting

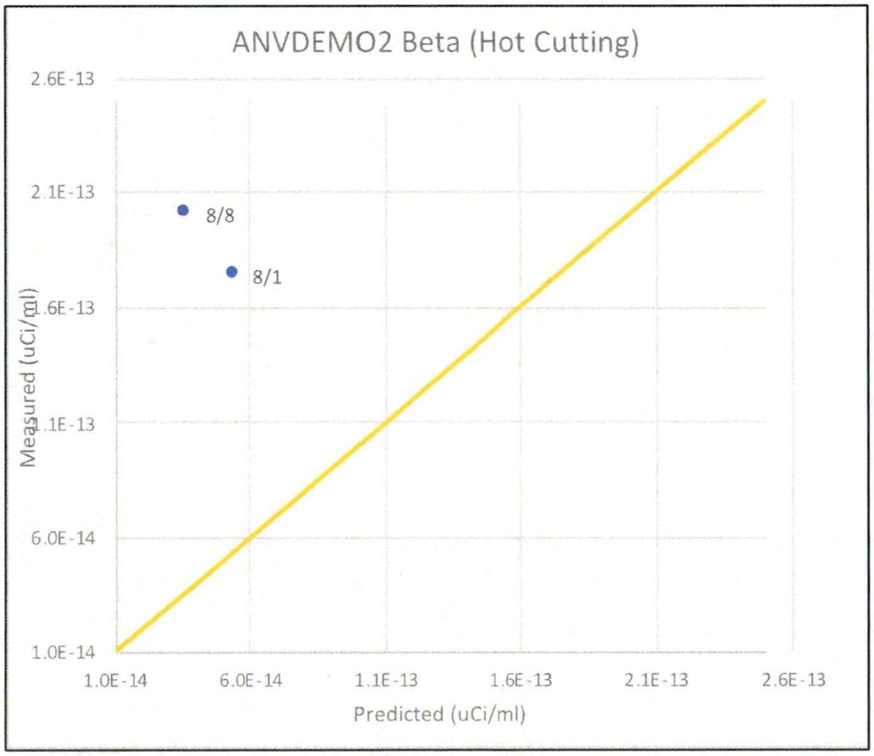


Figure 18: ANVDEMO2 beta -comparison of Predicted to Measured values for Hot cutting

5.3 Results for Alternative Method revision 0

Revision 0 of the Alternative Method provides slightly conservative results for Mechanical Shearing and Loading operations. The rubble pile equation works well with the moisture content used in the evaluation. It is recommended that for preplanning purposes a moisture content of a wetted pile resulting from mechanical shearing of metal structures be set to 2%. For a pile resulting from hydraulic hammering of concrete structures, 2% moisture is extremely conservative. However, for planning purposes and for estimating emissions of planned demolition, a value of 2% moisture should be used as a first approximation of pile emissions from hydraulic hammering of concrete structures.

The hydraulic hammering emission factor of 1.0E-03 is very conservative.

Based on the limited data for hot cutting, it appears that a Physical State Factor[12] of 0.07 is appropriate for the less volatile radionuclides. However, for the more volatile radionuclides, such as Cs-137, a physical state factor of 0.07 results in an underestimation of the emissions of those radionuclides by factors ranging from 1.13 to 5.61.

[12] As discussed in the AM, the emission rate for Hot Cutting is determined with 40CFR61 Appendix D method, but with a new Physical State Factor.

5.4 Predicted vs. Measured Test Discussion for the revision 1 of the Alternative Method

To better represent open-air demo emissions a revision to the alternative method has been prepared that removes some of the conservatism in the hydraulic hammering emission factors and adds conservatism for hot cutting. A copy of revision 1 of the alternative method is provided in Appendix F. No changes are made in revision 1 for Shearing, Loading and rubble pile emission factors.

5.4.1 Revised Hydraulic Hammer data sets

During the time that hydraulic hammering was being used as the demolition technique there was a 10-week period when no demolition occurred. Emissions during this 10-week period were primarily due to resuspension from the rubble pile. The weeks with rubble pile only emissions are noted in Table 24, Table 25, Table 26 and Table 27. It was observed by the loading crew that the wetted rubble pile often had water dripping from the loader buckets.

The first step in adjusting the hydraulic hammering emission factor is to increase the moisture content of the rubble pile as allowed by the rubble pile emission factor equation:

$$Emission\ Factor = (0.0016)\frac{\left({Wind\ Speed}/{2.2}\right)^{1.3}}{\left({Moisture\ content}/{2}\right)^{1.4}}$$

It was found that an adjustment of moisture content[13] from 2% to 9% produced predicted emissions that more closely matched the measured emissions during this time period when the only emission source was the rubble pile. The results of this change are presented in Figure 19, Figure 20, Figure 21, and Figure 22. In the majority (32 out of 40) of the weekly predicted values the comparisons are still conservative, but more closely match the measured values.

[13] The equation for rubble pile emissions in the AM is from Sections 4.1.1 and 4.1.4 of "*Methods for Estimating Fugitive Air Emissions of Radionuclides from Diffuse Sources at DOE Facilities*", published by EPA in 2004. This document allows for the moisture content to be varied from 0.44 to 10%.

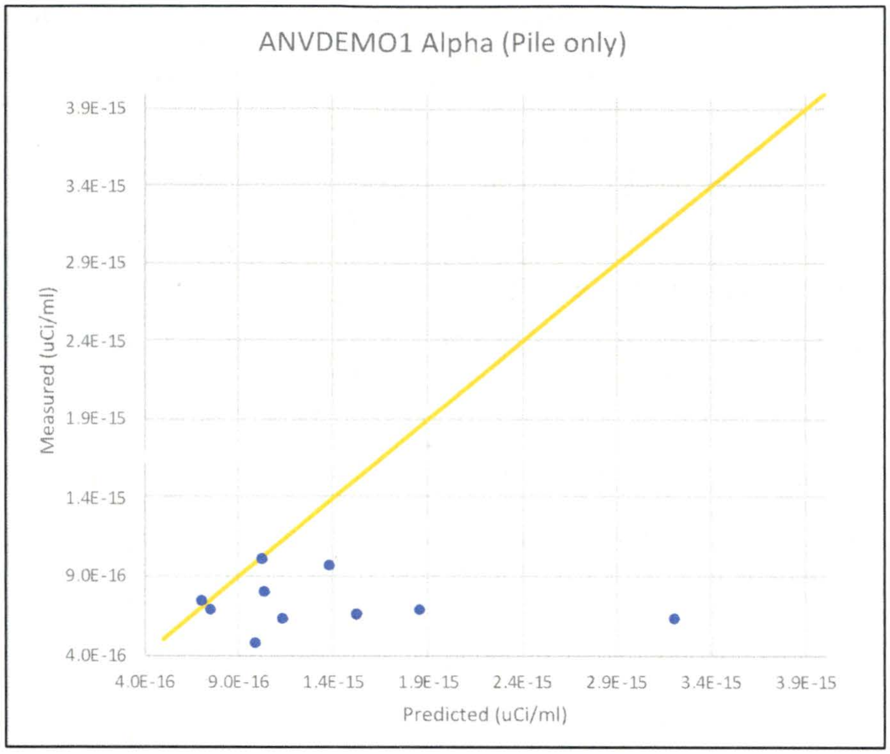


Figure 19: ANVDEMO1 alpha -comparison of Predicted to Measured values for Rubble Pile

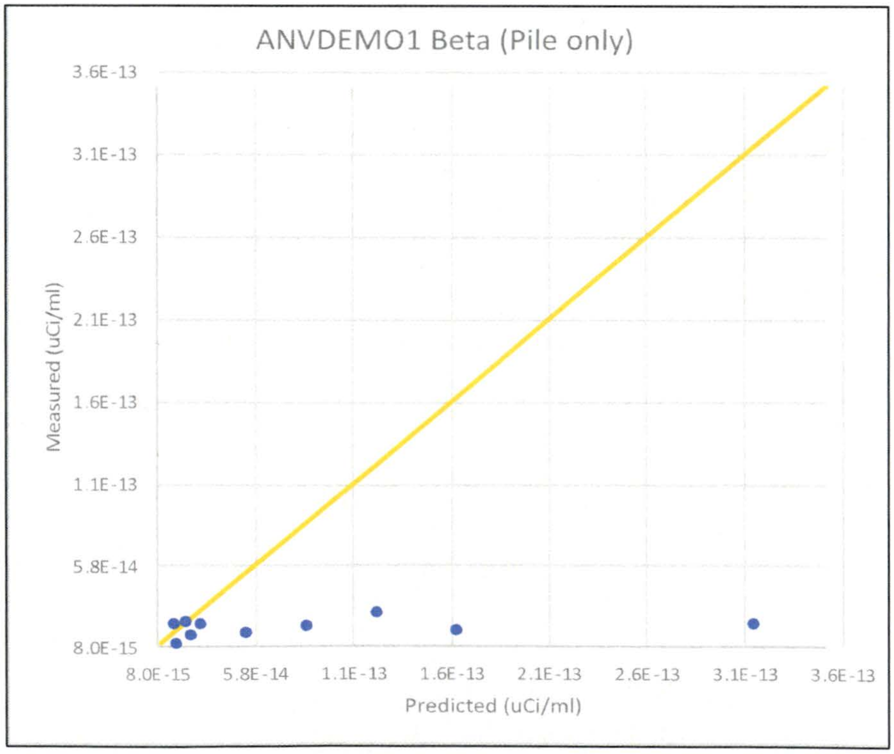


Figure 20: ANVDEMO1 beta -comparison of Predicted to Measured values for Rubble Pile

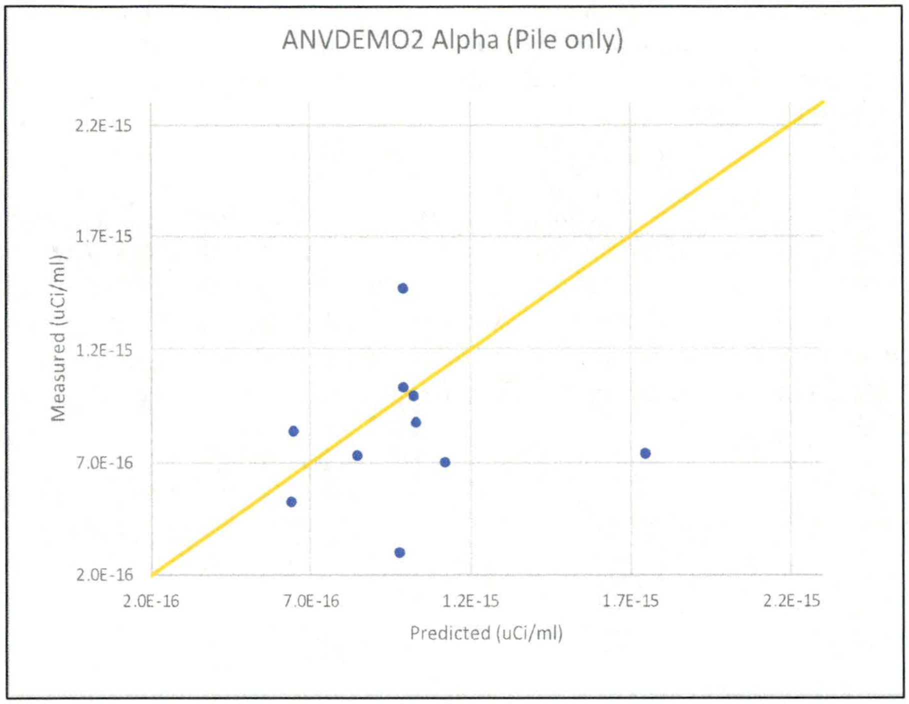


Figure 21: ANVDEMO2 alpha -comparison of Predicted to Measured values for Rubble Pile

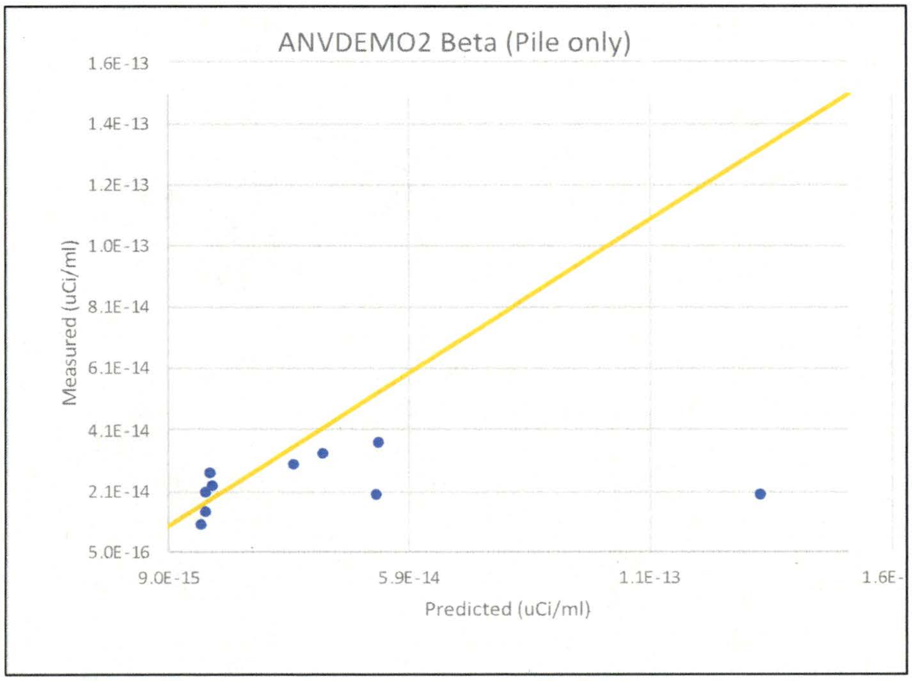


Figure 22: ANVDEMO2 beta -comparison of Predicted to Measured values for Rubble Pile

The next step was to change the hydraulic hammering emission factor from 1.0E-03 to 1.0E-05. The entire 29-week period when hydraulic hammering was used as the demolition technique was run in AERMOD and a new comparison made with the measured values. The results are presented in Table 24, Table 25, Table 26, and Table 27. A graphical presentation of the comparisons is presented in Figure 23, Figure 24, Figure 25, and Figure 26.

The change in moisture content and the emission factor for hydraulic hammering results in predicted data that are still conservative, but more closely represents the measured values. There is a total of 16 data points where the predicted value is above the measured value. However, 8 of the data points are accounted for in the rubble pile evaluation discussed previously. There are 8 data points out of a total of 40 where the new hydraulic hammering emission factor would result in a slightly non-conservative value. There are more than eight data points where the predicted value is very conservative compared to the measured value.

Table 24: Predicted vs. Measured alpha concentrations at ANVDEMO1 for New Hydraulic Hammer

Sample Collection Date	AERMOD Predicted Concentration (μCi/ml)	Background Concentration (μCi/ml)	Total Predicted Concentration (μCi/ml)	Filter Measured Concentration (μCi/ml)
12/6/17	5.59E-16	9.71E-16	1.53E-15	8.28E-16
12/13/17	2.93E-16	7.26E-16	1.02E-15	6.20E-16
12/20/17	2.38E-16	7.26E-16	9.63E-16	5.66E-16
12/27/17 [a]	3.10E-16	8.39E-16	1.15E-15	6.16E-16
1/3/18 [a]	5.57E-16	8.39E-16	1.40E-15	9.60E-16
1/10/18	7.73E-16	1.10E-15	1.88E-15	9.36E-16
1/17/18	1.82E-15	1.10E-15	2.92E-15	5.70E-16
1/24/18	1.76E-15	8.66E-16	2.63E-15	6.18E-16
1/31/18 [a]	2.36E-15	8.66E-16	3.22E-15	6.12E-16
2/7/18 [a]	1.15E-15	7.19E-16	1.87E-15	6.76E-16
2/14/18 [a]	8.23E-16	7.19E-16	1.54E-15	6.43E-16
2/21/18 [a]	1.27E-16	6.39E-16	7.66E-16	6.69E-16
2/28/18 [a]	8.81E-17	6.39E-16	7.27E-16	7.27E-16
3/7/18 [a]	7.42E-17	9.76E-16	1.05E-15	7.94E-16
3/14/18 [a]	3.19E-17	9.76E-16	1.01E-15	4.59E-16
3/21/18 [a]	2.17E-17	1.02E-15	1.04E-15	1.00E-15
3/28/18	5.22E-16	1.02E-15	1.54E-15	6.62E-16
4/5/18	1.40E-15	7.09E-16	2.11E-15	8.92E-16
4/11/18	8.85E-16	7.09E-16	1.59E-15	1.12E-15
4/18/18	1.83E-16	7.82E-16	9.64E-16	6.99E-16
4/25/18	4.47E-16	7.82E-16	1.23E-15	1.13E-15
5/2/18	1.36E-16	1.10E-15	1.24E-15	6.65E-16
5/9/18	1.26E-15	1.10E-15	2.37E-15	7.85E-16
5/16/18	1.20E-15	6.11E-16	1.81E-15	6.44E-16
5/23/18	1.04E-15	6.11E-16	1.65E-15	2.93E-16
5/30/18	4.29E-16	6.83E-16	1.11E-15	8.75E-16
6/6/18	2.03E-16	6.83E-16	8.86E-16	3.51E-16
6/13/18	1.05E-15	5.24E-16	1.58E-15	5.44E-16
6/20/18	8.50E-17	5.24E-16	6.08E-16	6.47E-16
(a) Indicates weeks with pile only emissions.				

Table 25: Predicted vs. Measured beta concentrations at ANVDEMO1 for New Hydraulic Hammer

Sample Collection Date	AERMOD Predicted Concentration (µCi/ml)	Background Concentration (µCi/ml)	Total Predicted Concentration (µCi/ml)	Filter Measured Concentration (µCi/ml)
12/6/17	6.94E-14	2.22E-14	9.16E-14	2.48E-14
12/13/17	3.63E-14	1.50E-14	5.13E-14	1.83E-14
12/20/17	2.95E-14	1.50E-14	4.45E-14	1.80E-14
12/27/17 (a)	3.85E-14	1.65E-14	5.50E-14	1.54E-14
1/3/18 (a)	6.91E-14	1.65E-14	8.56E-14	1.89E-14
1/10/18	9.59E-14	1.77E-14	1.14E-13	2.54E-14
1/17/18	2.26E-13	1.77E-14	2.44E-13	1.84E-14
1/24/18	2.18E-13	2.17E-14	2.40E-13	2.61E-14
1/31/18 (a)	2.92E-13	2.17E-14	3.14E-13	2.00E-14
2/7/18 (a)	1.43E-13	1.85E-14	1.61E-13	1.67E-14
2/14/18 (a)	1.02E-13	1.85E-14	1.21E-13	2.76E-14
2/21/18 (a)	1.58E-14	1.61E-14	3.19E-14	2.04E-14
2/28/18 (a)	1.09E-14	1.61E-14	2.70E-14	1.43E-14
3/7/18 (a)	9.20E-15	1.51E-14	2.43E-14	2.21E-14
3/14/18 (a)	3.96E-15	1.51E-14	1.91E-14	8.43E-15
3/21/18 (a)	2.69E-15	1.46E-14	1.73E-14	2.12E-14
3/28/18	6.47E-14	1.46E-14	7.93E-14	1.40E-14
4/5/18	1.73E-13	1.31E-14	1.86E-13	1.89E-14
4/11/18	1.10E-13	1.31E-14	1.23E-13	1.90E-14
4/18/18	2.26E-14	1.46E-14	3.73E-14	1.39E-14
4/25/18	5.54E-14	1.46E-14	7.01E-14	2.51E-14
5/2/18	1.69E-14	1.59E-14	3.28E-14	1.64E-14
5/9/18	1.56E-13	1.59E-14	1.72E-13	2.07E-14
5/16/18	1.49E-13	1.25E-14	1.61E-13	1.53E-14
5/23/18	1.29E-13	1.25E-14	1.42E-13	1.38E-14
5/30/18	5.33E-14	1.54E-14	6.86E-14	2.78E-14
6/6/18	2.52E-14	1.54E-14	4.06E-14	1.02E-14
6/13/18	1.31E-13	1.12E-14	1.42E-13	1.59E-14
6/20/18	1.05E-14	1.12E-14	2.18E-14	1.65E-14
(a) Indicates weeks with pile only emissions.				

Table 26: Predicted vs. Measured alpha concentrations at ANVDEMO2 for New Hydraulic Hammer

Sample Collection Date	AERMOD Predicted Concentration (μCi/ml)	Background Concentration (μCi/ml)	Total Predicted Concentration (μCi/ml)	Filter Measured Concentration (μCi/ml)
12/6/17	5.13E-17	9.71E-16	1.02E-15	8.56E-16
12/13/17	1.83E-16	7.26E-16	9.08E-16	7.76E-16
12/20/17	1.26E-16	7.26E-16	8.51E-16	5.32E-16
12/27/17 (a)	2.91E-16	8.39E-16	1.13E-15	6.91E-16
1/3/18 (a)	2.01E-16	8.39E-16	1.04E-15	8.64E-16
1/10/18	5.02E-16	1.10E-15	1.61E-15	9.08E-16
1/17/18	1.80E-16	1.10E-15	1.28E-15	7.45E-16
1/24/18	4.03E-16	8.66E-16	1.27E-15	6.58E-16
1/31/18 (a)	8.92E-16	8.66E-16	1.76E-15	7.25E-16
2/7/18 (a)	2.80E-16	7.19E-16	9.98E-16	1.46E-15
2/14/18 (a)	1.35E-16	7.19E-16	8.53E-16	7.22E-16
2/21/18 (a)	1.57E-17	6.39E-16	6.54E-16	8.24E-16
2/28/18 (a)	8.19E-18	6.39E-16	6.47E-16	5.15E-16
3/7/18 (a)	2.36E-17	9.76E-16	9.99E-16	1.02E-15
3/14/18 (a)	8.04E-18	9.76E-16	9.84E-16	2.85E-16
3/21/18 (a)	1.65E-17	1.02E-15	1.03E-15	9.76E-16
3/28/18	2.93E-17	1.02E-15	1.05E-15	8.20E-16
4/5/18	9.89E-17	7.09E-16	8.08E-16	7.44E-16
4/11/18	3.90E-16	7.09E-16	1.10E-15	1.26E-15
4/18/18	1.38E-16	7.82E-16	9.20E-16	5.38E-16
4/25/18	1.85E-17	7.82E-16	8.00E-16	1.14E-15
5/2/18	9.78E-18	1.10E-15	1.11E-15	7.01E-16
5/9/18	2.66E-16	1.10E-15	1.37E-15	6.48E-16
5/16/18	6.80E-16	6.11E-16	1.29E-15	7.38E-16
5/23/18	4.25E-16	6.11E-16	1.04E-15	6.81E-16
5/30/18	1.47E-16	6.83E-16	8.31E-16	1.74E-15
6/6/18	1.48E-16	6.83E-16	8.31E-16	1.38E-16
6/13/18	2.20E-16	5.24E-16	7.44E-16	7.77E-16
6/20/18	7.51E-17	5.24E-16	5.99E-16	5.18E-16
(a) Indicates weeks with pile only emissions.				

Table 27: Predicted vs. Measured beta concentrations at ANVDEMO2 for New Hydraulic Hammer

Sample Collection Date	AERMOD Predicted Concentration (µCi/ml)	Background Concentration (µCi/ml)	Total Predicted Concentration (µCi/ml)	Filter Measured Concentration (µCi/ml)
12/6/17	6.36E-15	2.22E-14	2.86E-14	2.45E-14
12/13/17	2.27E-14	1.50E-14	3.77E-14	1.85E-14
12/20/17	1.56E-14	1.50E-14	3.06E-14	2.10E-14
12/27/17 (a)	3.60E-14	1.65E-14	5.26E-14	1.92E-14
1/3/18 (a)	2.49E-14	1.65E-14	4.14E-14	3.26E-14
1/10/18	6.23E-14	1.77E-14	8.00E-14	2.85E-14
1/17/18	2.23E-14	1.77E-14	4.00E-14	1.94E-14
1/24/18	5.00E-14	2.17E-14	7.17E-14	2.76E-14
1/31/18 (a)	1.11E-13	2.17E-14	1.32E-13	1.92E-14
2/7/18 (a)	3.47E-14	1.85E-14	5.31E-14	3.56E-14
2/14/18 (a)	1.67E-14	1.85E-14	3.52E-14	2.87E-14
2/21/18 (a)	1.95E-15	1.61E-14	1.80E-14	2.62E-14
2/28/18	1.02E-15	1.61E-14	1.71E-14	1.35E-14
3/7/18	2.92E-15	1.51E-14	1.80E-14	2.15E-14
3/14/18	9.97E-16	1.51E-14	1.61E-14	9.22E-15
3/21/18	2.05E-15	1.46E-14	1.67E-14	1.93E-14
3/28/18	3.63E-15	1.46E-14	1.82E-14	1.37E-14
4/5/18	1.23E-14	1.31E-14	2.54E-14	1.45E-14
4/11/18	4.83E-14	1.31E-14	6.14E-14	1.85E-14
4/18/18	1.72E-14	1.46E-14	3.18E-14	1.34E-14
4/25/18	2.30E-15	1.46E-14	1.69E-14	2.04E-14
5/2/18	1.21E-15	1.59E-14	1.71E-14	2.33E-14
5/9/18	3.30E-14	1.59E-14	4.90E-14	4.15E-14
5/16/18	8.44E-14	1.25E-14	9.69E-14	1.79E-14
5/23/18	5.27E-14	1.25E-14	6.52E-14	1.60E-14
5/30/18	1.83E-14	1.54E-14	3.36E-14	4.34E-14
6/6/18	1.83E-14	1.54E-14	3.37E-14	1.56E-14
6/13/18	2.73E-14	1.12E-14	3.86E-14	3.04E-14
6/20/18	9.31E-15	1.12E-14	2.06E-14	1.76E-14
(a) Indicates weeks with pile only emissions.				

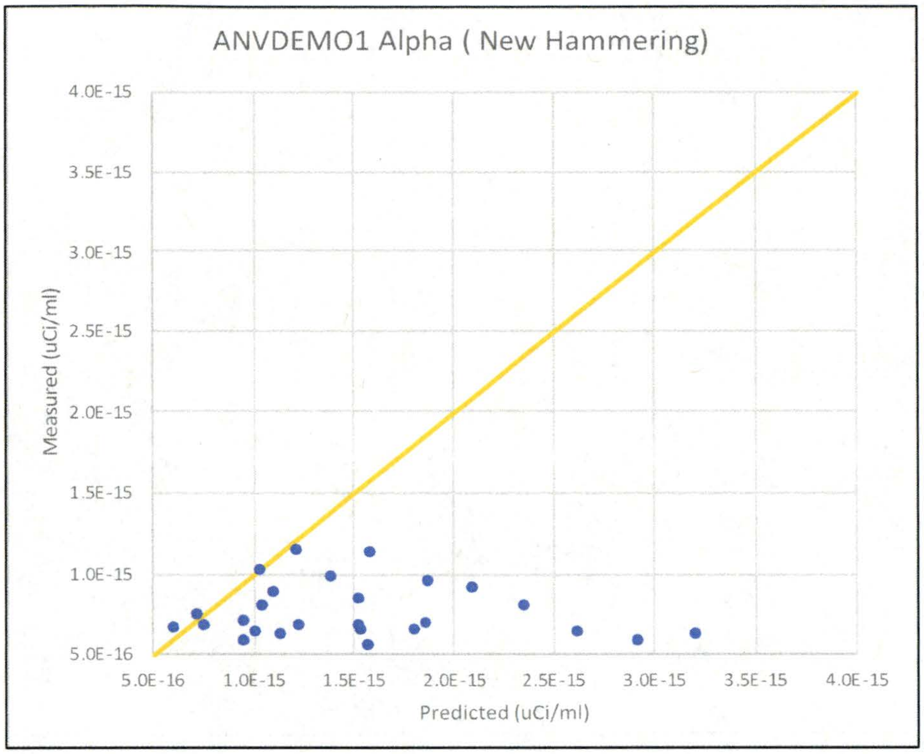


Figure 23: ANVDEMO1 alpha -comparison of Predicted to Measured values for Hydraulic Hammer

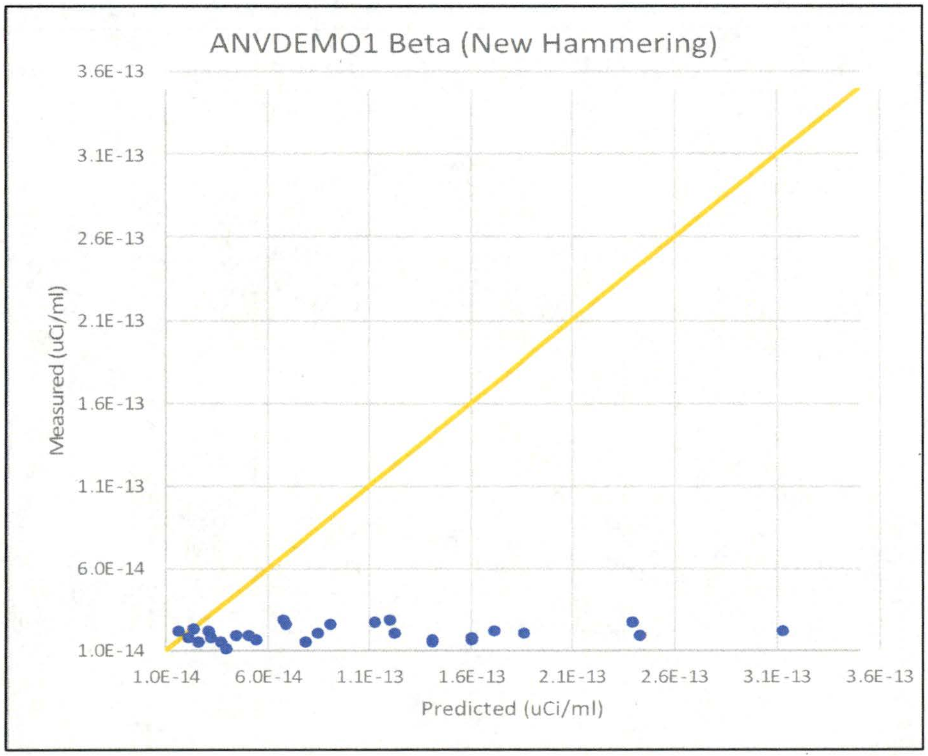


Figure 24: ANVDEMO1 beta -comparison of Predicted to Measured values for Hydraulic Hammer

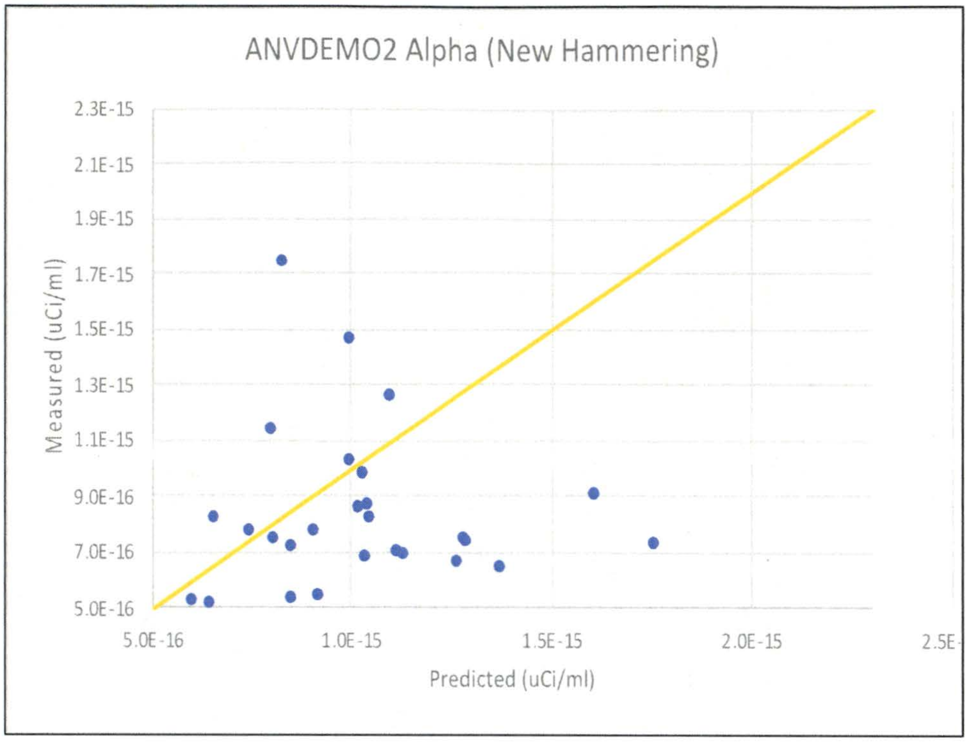


Figure 25: ANVDEMO2 alpha -comparison of Predicted to Measured values for Hydraulic Hammer

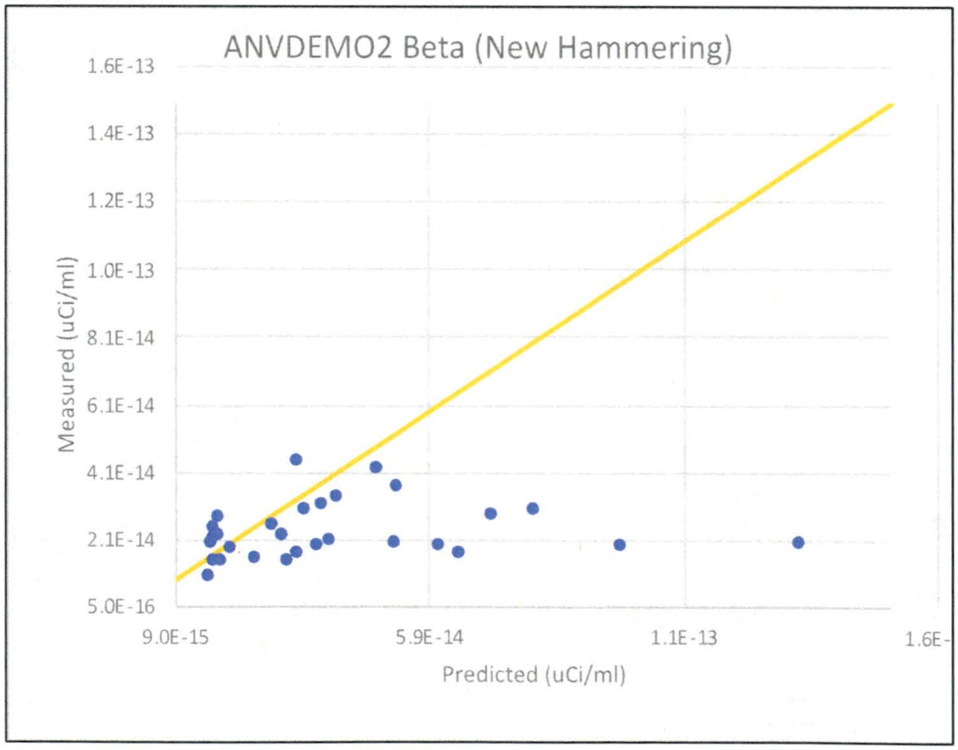


Figure 26: ANVDEMO2 beta -comparison of Predicted to Measured values for Hydraulic Hammer

5.4.2 Revised Hot Cutting data sets

Based on the limited data in the study for hot cutting, it appears that material with a lower volatility is emitted at a greater rate than 0.07, the rate proposed in revision 0 of the AM. The oxylance used for the cutting can reach temperatures of 7500°F, which will vaporize most metals. However, for metals with higher boiling points, such a PuO_2 (Boiling point = 5072°F) the volatile material would cool rapidly and change physical state back to a solid, while material such as one of the various CsOxides, which either decompose at a low temperature or boils at around 1700°F, would remain vapors much longer before changing physical state back to a solid. However, with the limited data available from this study, the only demarcation is either alpha or beta emitter. Therefore, the Physical State factor was changed to 0.7 for the beta material. Although this change did not make a large change in the mass emission rate, it did change the isotopic mixture of the source term significantly. The new emission rate is 9.43E-08 g/s. An hourly emission file with this new emission rate was prepared and processed with AERMOD. The comparison of predicted versus measured is provided in Table 28, Table 29, Table 30, and Table 31. A graphical presentation is provided in Figure 27, Figure 28, Figure 29, and Figure 30.

After making the Physical State factor changes, only one gross beta predicted value is less than the measured value. The gross beta values range for 32% to 356% conservative and one value at 60% non-conservative. This approach is presented in revision 1 of the alternative method.

Table 28: Predicted vs. Measured alpha concentrations at ANVDEMO1 for New Hot Cutting

Sample Collection Date	AERMOD Predicted Concentration (μCi/ml)	Background Concentration (μCi/ml)	Total Predicted Concentration (μCi/ml)	Filter Measured Concentration (μCi/ml)
8/1/18	1.71E-15	7.43E-16	2.46E-15	9.44E-16
8/8/18	1.75E-16	9.46E-16	1.12E-15	9.36E-16

Table 29: Predicted vs. Measured beta concentrations at ANVDEMO1 for New Hot Cutting

Sample Collection Date	AERMOD Predicted Concentration (μCi/ml)	Background Concentration (μCi/ml)	Total Predicted Concentration (μCi/ml)	Filter Measured Concentration (μCi/ml)
8/1/18	1.99E-12	1.34E-14	2.00E-12	2.40E-13
8/8/18	2.04E-13	2.38E-14	2.27E-13	6.51E-14

Table 30: Predicted vs. Measured alpha concentrations at ANVDEMO2 for New Hot Cutting

Sample Collection Date	AERMOD Predicted Concentration (μCi/ml)	Background Concentration (μCi/ml)	Total Predicted Concentration (μCi/ml)	Filter Measured Concentration (μCi/ml)
8/1/18	3.45E-16	7.43E-16	1.09E-15	6.16E-16
8/8/18	1.04E-16	9.46E-16	1.05E-15	1.35E-15

Table 31: Predicted vs. Measured beta concentrations at ANVDEMO2 for New Hot Cutting

Sample Collection Date	AERMOD Predicted Concentration (μCi/ml)	Background Concentration (μCi/ml)	Total Predicted Concentration (μCi/ml)	Filter Measured Concentration (μCi/ml)
8/1/18	4.00E-13	1.34E-14	4.14E-13	1.74E-13
8/8/18	1.20E-13	2.38E-14	1.44E-13	2.01E-13

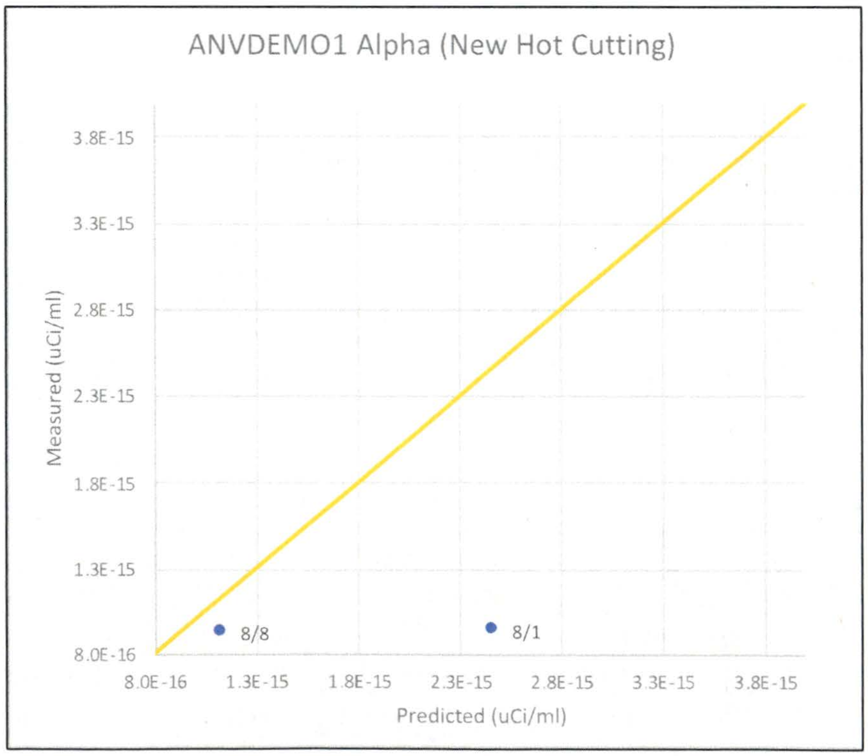


Figure 27: ANVDEMO1 alpha -comparison of Predicted to Measured values for New Hot cutting

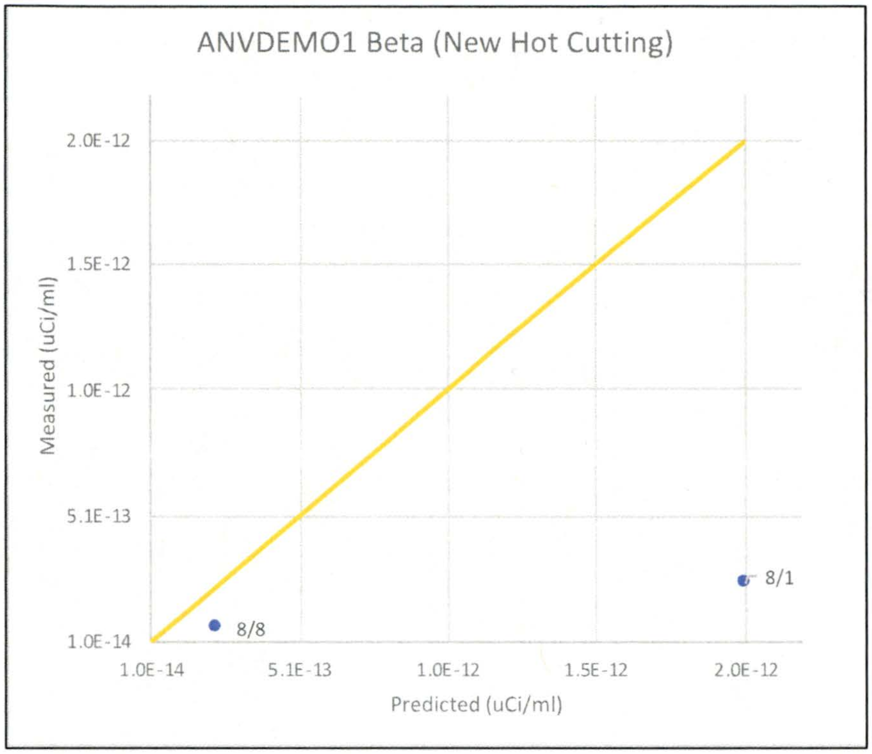


Figure 28: ANVDEMO1 beta -comparison of Predicted to Measured values for New Hot cutting

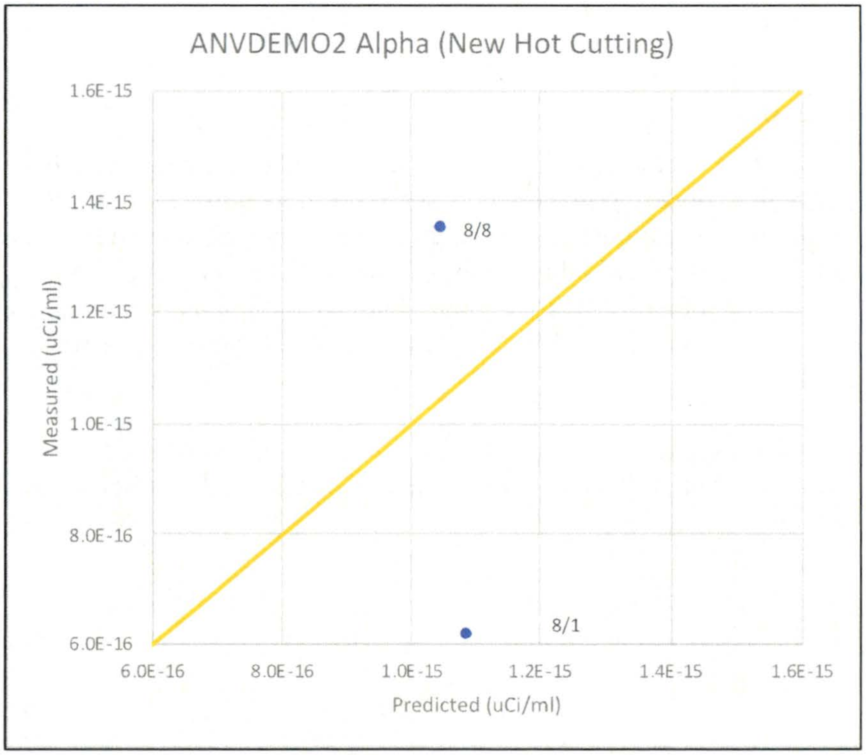


Figure 29: ANVDEMO2 alpha -comparison of Predicted to Measured values for New Hot cutting

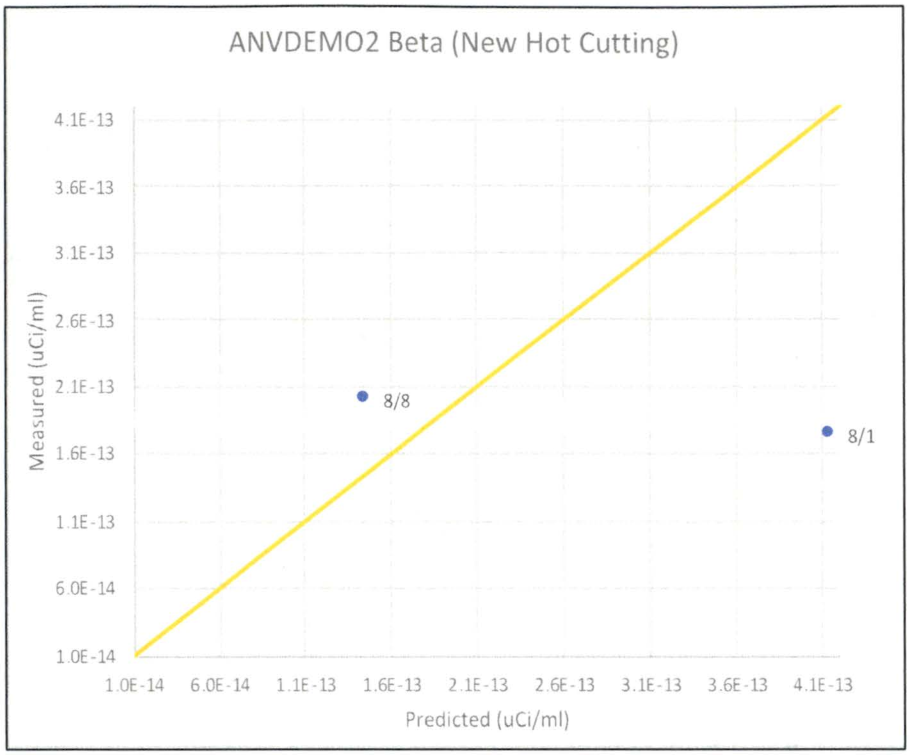


Figure 30: ANVDEMO2 beta -comparison of Predicted to Measured values for New Hot cutting

6 Summary of Results

Revision 0 of the Alternative Method produced predicted values that are realistic, but slightly conservative for Mechanical Shearing, load operations and rubble pile emissions. Predicted emissions from Hydraulic Hammering operations are extremely conservative and have been revised. Hot cutting has a limited data set, but the physical state factor proposed in revision 0 of the AM appears to be conservative for radionuclides that have higher boiling points and non-conservative for radionuclides with lower boiling points. A revised set of Physical State factors for hot cutting are provided in revision 1 of the Alternative Method.

Based on the validation study, the emission factors in revision 1 of the Alternative Method are representative of emissions, but still conservative. The revision 1 emission factors are presented in Table 32.

Table 32: Emission Factors for Demolition Methods (Changed values are bolded for emphasis)

Method	Emission Factor
Shearing	5.0E-05
Hydraulic Hammer	**1.0E-05**
Diamond Wire Saw	$(5.0E-05)\frac{(Length\ of\ cuts)(width\ of\ kerf)}{Area\ Slab}$
Wall Saw	$(5.0E-03)\frac{(Length\ of\ cuts)(width\ of\ kerf)}{Area\ Slab}$
Rubble Pile Emissions a)	$(0.0016)\frac{\left(\frac{Wind\ Speed}{2.2}\right)^{1.3}}{\left(\frac{Moisture\ content}{2}\right)^{1.4}}$
Load Out Emissions	2.9E-05
Hot Cutting (alpha) b)	Physical State Factor = 0.07
Hot Cutting (beta) b)	**Physical State Factor = 0.7**

a) Wind Speed units are m/s
Moisture content units are %
b) Note that as discussed in the AM, the emission rate for Hot Cutting is determined with 40CFR61 Appendix D method, but with a new Physical State Factor.

7 References

Blunt 2016a Blunt BC. *Methodology for Radionuclide Source Term Calculations for Air Emissions from Demolition Activities. Rev. 0.* Blunt Consulting LLC. January 2016

Blunt 2016b Blunt BC. *Test Plan for Study of Air Emissions from the Demolition of the Vitrification Facility at West Valley Demonstration Project Compared to Emissions Estimates using Methodology for Radionuclide Source Term Calculations for Air Emissions from Demolition Activities. Rev. D.* Blunt Consulting LLC. December 2016

EPA 2017 *40 CFR Appendix W to part 51, Guideline on Air Quality models.* US EPA. January 2017

EPA 2018a *User's Guide for the AMS/EPA Regulatory Model (AERMOD)*, EPA-454/B-18-001, EPA, April 2018

EPA 2018b *AERMOD Implementation Guide*, EPA-454/B-18-003, EPA, April 2018

Strom 2012 Strom DJ, K Joyce, J MacLellan, DJ Watson, T Lynch, C Antonio, A Birchall, K Anderson and P Zharov, 2012. *Disaggregating Measurement Uncertainty from Population Variability and Bayesian Treatment of Uncensored Results.* Radiation Protection Dosimetry, 149(3):251-267

Appendix A

Siting of Ambient Samplers

The results from the AERMOD calculations were used to help plan demolition activities which are expected to last close to a year. Therefore, annual average concentration profiles were used to site ambient air samplers. Annualized isopleths of hypothetical plume concentrations based on site-specific meteorological data for 2008 through 2012 and the average using all 5 years are presented in Figure 31. It is apparent that the hypothetical plume pathway is very similar for all 5 years analyzed and would not be expected to change during demolition. To confirm that assumption, the wind roses for the 10-meter level for 2008 through 2015 are presented in Figure 32. Note that the patterns of all the wind roses are similar, confirming the assumption that the wind pattern in near term future years would remain the same. The locations of the on-site ambient air samplers are in the projected demolition plume path based on individual year meteorological data, a five-year average meteorological file and eight years of annual wind rose plots.

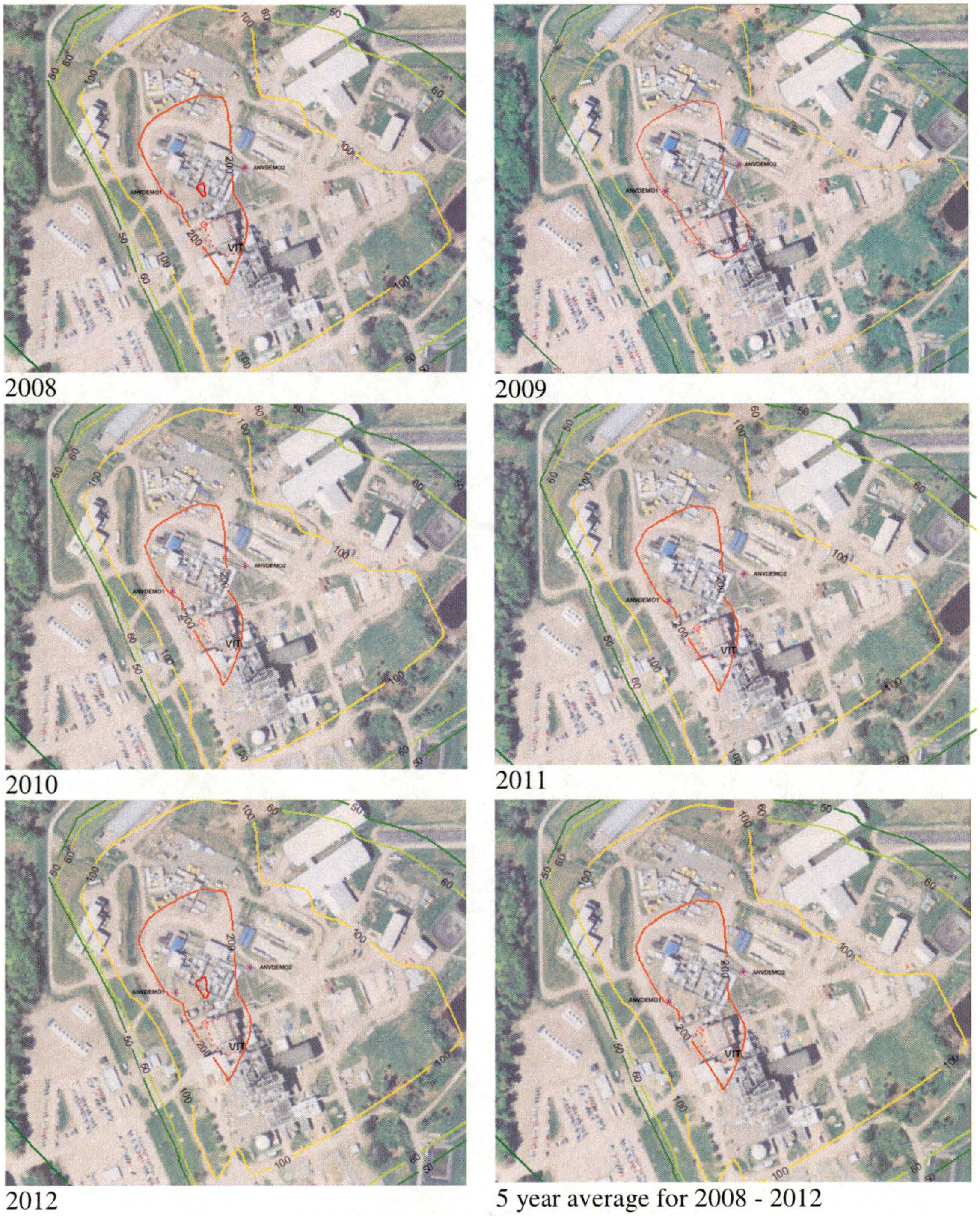


Figure 31: Annualized hypothetical plume isopleths based on site-specific meteorology

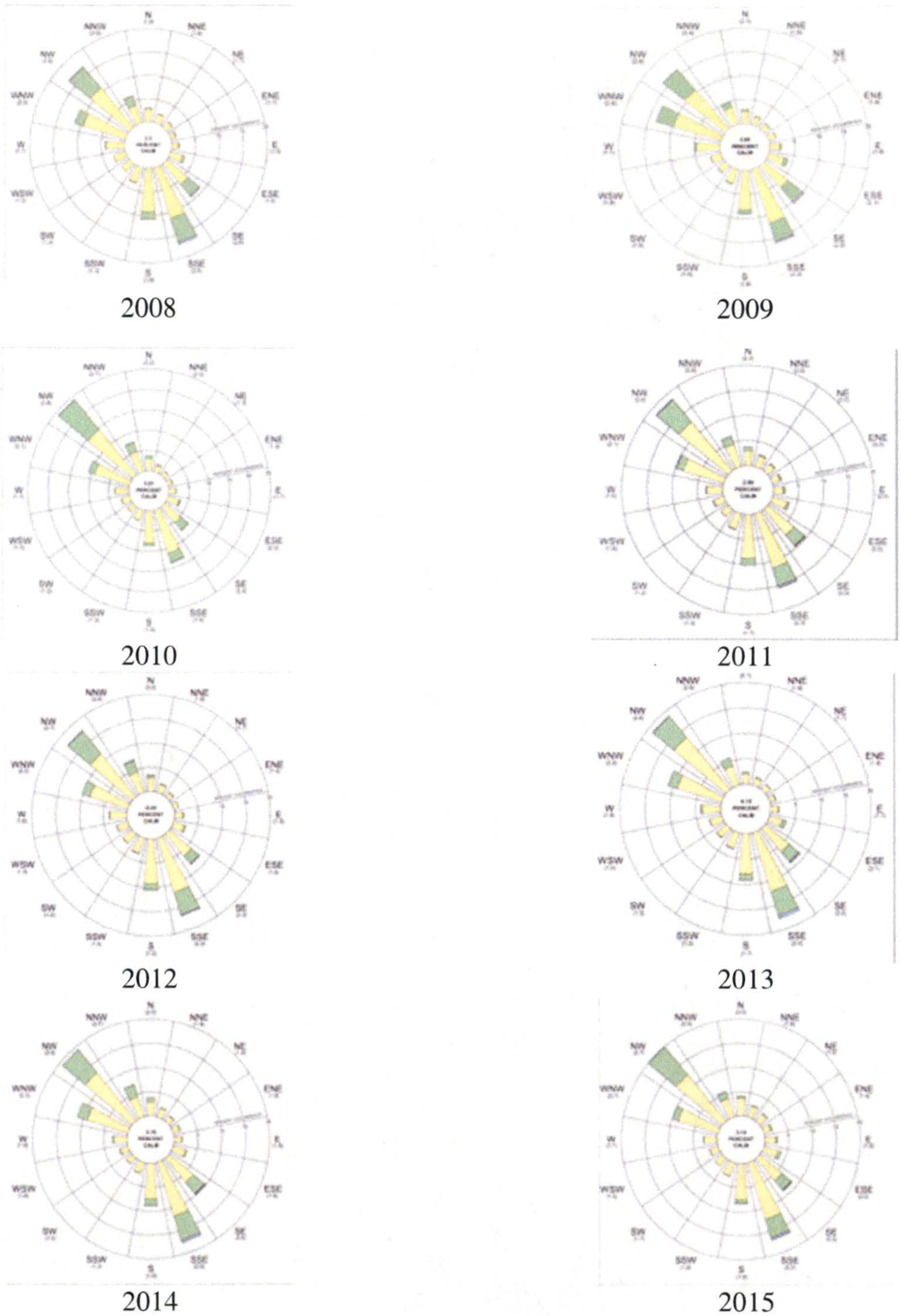


Figure 32: 10-meter annual wind rose plots

Appendix B

Baseline Sampler Data

Table 33: ANVDEMO1 Baseline data

Date	Gross Alpha		Gross Beta	
	Filter Result (µCi/ml)	Uncertainty (µCi/ml)	Filter Result (µCi/ml)	Uncertainty (µCi/ml)
19-Oct-16	7.96E-16	2.44E-16	2.40E-14	1.09E-15
26-Oct-16	2.35E-16	1.82E-16	1.09E-14	7.79E-16
02-Nov-16	6.87E-16	2.16E-16	1.97E-14	9.74E-16
09-Nov-16	6.69E-16	2.35E-16	2.05E-14	1.02E-15
16-Nov-16	5.47E-16	2.37E-16	1.99E-14	9.81E-16
22-Nov-16	9.45E-16	2.76E-16	2.09E-14	1.11E-15
30-Nov-16	4.83E-16	2.00E-16	1.66E-14	8.55E-16
07-Dec-16	2.54E-16	1.68E-16	1.16E-14	8.16E-16
14-Dec-16	5.35E-16	2.25E-16	1.92E-14	9.63E-16
21-Dec-16	9.46E-16	2.57E-16	1.86E-14	9.67E-16
28-Dec-16	5.72E-16	2.17E-16	2.11E-14	1.02E-15
04-Jan-17	3.63E-16	2.03E-16	1.36E-14	8.55E-16
11-Jan-17	4.02E-16	1.99E-16	1.64E-14	9.12E-16
18-Jan-17	7.02E-16	2.30E-16	1.77E-14	9.60E-16
25-Jan-17	3.21E-16	1.81E-16	1.07E-14	8.03E-16
01-Feb-17	2.63E-16	1.90E-16	1.22E-14	8.38E-16
08-Feb-17	5.27E-16	2.11E-16	1.75E-14	9.58E-16
15-Feb-17	7.47E-16	2.31E-16	1.73E-14	9.78E-16
22-Feb-17	7.93E-16	2.48E-16	1.94E-14	1.01E-15
01-Mar-17	6.38E-16	2.38E-16	1.74E-14	9.56E-16
08-Mar-17	7.26E-16	2.41E-16	1.78E-14	9.86E-16
15-Mar-17 [a]	2.86E-17	1.48E-16	2.84E-15	5.48E-16
22-Mar-17	6.70E-16	2.36E-16	1.83E-14	9.88E-16
29-Mar-17	6.03E-16	2.47E-16	1.47E-14	9.13E-16
05-Apr-17	5.52E-16	2.21E-16	9.34E-15	8.15E-16
12-Apr-17	5.65E-16	2.22E-16	1.25E-14	8.52E-16
19-Apr-17	4.66E-16	2.14E-16	1.48E-14	8.96E-16
26-Apr-17	3.52E-16	1.97E-16	8.74E-15	7.69E-16
03-May-17	4.30E-16	2.09E-16	1.11E-14	8.32E-16
10-May-17	5.61E-16	2.09E-16	9.77E-15	7.81E-16
17-May-17	4.38E-16	2.28E-16	1.06E-14	8.13E-16
24-May-17	6.49E-16	2.27E-16	1.48E-14	9.21E-16
31-May-17	3.54E-16	1.88E-16	1.06E-14	8.18E-16
07-Jun-17	6.05E-16	2.34E-16	1.36E-14	9.03E-16
14-Jun-17	6.06E-16	2.27E-16	1.90E-14	1.01E-15
21-Jun-17	3.77E-16	1.90E-16	1.51E-14	9.28E-16
28-Jun-17	5.81E-16	1.96E-16	1.17E-14	8.24E-16
05-Jul-17	5.45E-16	2.09E-16	1.60E-14	9.67E-16
12-Jul-17	6.69E-16	2.43E-16	1.88E-14	1.03E-15
19-Jul-17	6.12E-16	2.21E-16	1.77E-14	9.76E-16
26-Jul-17	5.23E-16	2.30E-16	1.81E-14	1.00E-15
02-Aug-17	6.92E-16	2.55E-16	1.62E-14	9.98E-16
09-Aug-17	4.72E-16	2.55E-16	1.88E-14	1.00E-15
16-Aug-17	1.14E-15	2.80E-16	2.63E-14	1.17E-15
23-Aug-17	1.08E-15	2.82E-16	2.10E-14	1.07E-15
30-Aug-17	5.70E-16	2.33E-16	1.44E-14	9.30E-16
06-Sep-17	7.72E-16	2.35E-16	1.65E-14	9.66E-16
13-Sep-17	3.47E-16	2.11E-16	1.16E-14	8.24E-16
(a) Filter rejected. Filter was found off-set in sample holder				

Table 34: ANVDEMO2 Baseline data

Date	Gross Alpha		Gross Beta	
	Filter Result (µCi/ml)	Uncertainty (µCi/ml)	Filter Result (µCi/ml)	Uncertainty (µCi/ml)
19-Oct-16	7.78E-16	2.80E-16	2.28E-14	1.24E-15
26-Oct-16	1.56E-16	1.78E-16	9.62E-15	7.78E-16
02-Nov-16	7.77E-16	3.92E-16	1.31E-14	1.55E-15
09-Nov-16	7.22E-16	2.54E-16	2.22E-14	1.10E-15
16-Nov-16	6.90E-16	2.69E-16	1.97E-14	1.03E-15
22-Nov-16	7.49E-16	2.65E-16	2.25E-14	1.20E-15
30-Nov-16	2.70E-16	1.83E-16	1.78E-14	9.20E-16
07-Dec-16	1.63E-16	1.62E-16	1.16E-14	8.60E-16
14-Dec-16	5.66E-16	2.43E-16	1.98E-14	1.03E-15
21-Dec-16	6.81E-16	2.38E-16	1.83E-14	1.01E-15
28-Dec-16	6.71E-16	2.42E-16	2.09E-14	1.07E-15
04-Jan-17	5.05E-16	2.36E-16	1.41E-14	9.17E-16
11-Jan-17	6.55E-16	2.45E-16	1.63E-14	9.63E-16
18-Jan-17	6.92E-16	2.43E-16	1.76E-14	1.01E-15
25-Jan-17	2.42E-16	1.82E-16	1.05E-14	8.53E-16
01-Feb-17	2.96E-16	2.14E-16	1.19E-14	8.98E-16
08-Feb-17	7.41E-16	2.53E-16	1.82E-14	1.03E-15
15-Feb-17	5.23E-16	2.13E-16	1.81E-14	1.05E-15
22-Feb-17	8.17E-16	2.65E-16	1.93E-14	1.06E-15
01-Mar-17	6.65E-16	2.56E-16	1.76E-14	1.01E-15
08-Mar-17	9.66E-16	2.83E-16	1.68E-14	1.02E-15
15-Mar-17	7.16E-16	2.59E-16	1.59E-14	9.57E-16
22-Mar-17	8.57E-16	2.71E-16	1.85E-14	1.05E-15
29-Mar-17	5.12E-16	2.51E-16	1.57E-14	9.83E-16
05-Apr-17	4.12E-16	2.13E-16	9.04E-15	8.52E-16
12-Apr-17	5.54E-16	2.35E-16	1.26E-14	9.05E-16
19-Apr-17	6.32E-16	2.48E-16	1.47E-14	9.46E-16
26-Apr-17	5.00E-16	2.31E-16	8.91E-15	8.26E-16
03-May-17	7.17E-16	2.60E-16	1.15E-14	8.97E-16
10-May-17	8.91E-16	2.65E-16	1.04E-14	8.58E-16
17-May-17	4.77E-16	2.48E-16	1.17E-14	8.87E-16
24-May-17	7.11E-16	2.49E-16	1.72E-14	1.03E-15
31-May-17	4.71E-16	2.19E-16	1.14E-14	8.90E-16
07-Jun-17	5.11E-16	2.37E-16	1.40E-14	9.66E-16
14-Jun-17	5.22E-16	2.31E-16	2.18E-14	1.13E-15
21-Jun-17	6.30E-16	2.43E-16	1.54E-14	1.01E-15
28-Jun-17	4.94E-16	1.94E-16	1.26E-14	8.99E-16
05-Jul-17	1.47E-15	6.80E-16	2.18E-14	2.59E-15
12-Jul-17	8.06E-16	2.76E-16	1.86E-14	1.09E-15
19-Jul-17	5.54E-16	2.26E-16	1.91E-14	1.06E-15
26-Jul-17	8.28E-16	2.84E-16	1.94E-14	1.10E-15
02-Aug-17	5.92E-16	2.57E-16	1.71E-14	1.07E-15
09-Aug-17	7.94E-16	3.08E-16	1.97E-14	1.08E-15
16-Aug-17	1.14E-15	2.95E-16	2.67E-14	1.24E-15
23-Aug-17	1.06E-15	2.95E-16	2.25E-14	1.15E-15
30-Aug-17	6.59E-16	2.59E-16	1.59E-14	1.02E-15
06-Sep-17	9.58E-16	2.71E-16	1.66E-14	1.03E-15
13-Sep-17	3.91E-16	2.31E-16	1.15E-14	8.66E-16

Appendix C

Phase 1 Demolition Activities

Date	Hours of Demolition	Hours of Demolition	Method	Hours of Loading	Intermodal Containers Loaded	Packaged Waste (lb)
9/13/17	6.50	West side Roof	Shear	6.50	1	1,800
9/14/17	7.17	Westside Roof	Shear	7.17	1	4,500
9/15/17	3.50	West Aisle	Shear	0	0	0
9/16/17	0	None	NA	0	0	0
9/17/17	0	None	NA	0	0	0
9/18/17	3.92	West Aisle	Shear	3.92	2	17,050
9/19/17	3.75	West Aisle	Shear	3.75	6	79,930
9/20/17	1.00	West Aisle	Shear	1.00	2	32,910
9/21/17	6.30	West and East Aisles	Shear	6.30	4	51,250
9/22/17	5.00	West and East Aisles	Shear	5.00	5	90,890
9/23/17	0	None	NA	0	0	0
9/24/17	0	None	NA	0	0	0
9/25/17	5.13	West and East Aisles	Shear	5.57	4	75,720
9/26/17	5.77	West and East Aisles	Shear	5.77	8	163,320
9/27/17	4.50	West and East Aisles	Shear	0	0	0
9/28/17	3.92	West and East Aisles	Shear	0	0	0
9/29/17	0	None	NA	0	0	0
9/30/17	0	None	NA	0	0	0
10/1/17	0	None	NA	0	0	0
10/2/17	2.25	East Aisle	Shear	5.88	2	34,220
10/3/17	2.67	East Aisles	Shear	5.25	2	39,970
10/4/17	6.08	North and East Aisle	Shear	6.08	2	20,130
10/5/17	5.67	North and East Aisle	Shear	5.67	3	30,360
10/6/17	0	None	NA	3.33	4	89,380
10/7/17	0	None	NA	0	0	0
10/8/17	0	None	NA	0	0	0
10/9/17	0	None	NA	0.00	0	0
10/10/17	4.42	North Aisle	Shear	4.42	1	11,440
10/11/17	5.67	North Aisle	Shear	5.67	2	20,780
10/12/17	3.83	North Aisle	Shear	4.75	4	49,650
10/13/17	7.17	East Aisle	NA	7.17	5	138,130
10/14/17	0	None	NA	0	0	0
10/15/17	0	None	NA	0	0	0
10/16/17	5.42	East Aisle Roof	Shear	5.42	1	21,860
10/17/17	3.42	East Aisle Roof	Shear	5.00	6	145,070
10/18/17	1.50	East Aisle Roof	Shear	3.33	4	83,530

Date	Hours of Demolition	Hours of Demolition	Method	Hours of Loading	Intermodal Containers Loaded	Packaged Waste (lb)
10/19/17	4.50	East Aisle	Shear	0.00	0	0
10/20/17	0	None	NA	0	0	0
10/21/17	0	None	NA	0	0	0
10/22/17	0	None	NA	0	0	0
10/23/17	3.75	East Aisle	Shear	4.21	2	22,800
10/24/17	6.50	East Aisle	Shear	6.92	6	100,580
10/25/17	0.00	None	NA	2.33	3	71,670
10/26/17	0.00	None	NA	3.50	3	63,530
10/27/17	0	None	NA	0	0	0
10/28/17	0	None	NA	0	0	0
10/29/17	0	None	NA	0	0	0
10/30/17	0	None	NA	5.00	3	54,000
10/31/17	0	None	NA	12.00	4	105,070
11/1/17	0.67	Northwest Corner Vit Cell	Hammer	0.67	0	0
11/2/17	5.00	Northwest Corner Vit Cell	Hammer	5.00	2	52,190
11/3/17	2.00	Northwest Corner Vit Cell	Hammer	2.00	1	30,590
11/4/17	0	None	NA	0	0	0
11/5/17	0	None	NA	0	0	0
11/6/17	0.00	Sample Transfer Cell	NA	2.00	1	12,900
11/7/17	5.00	Sample Transfer Cell	Hammer	0.00	0	0
11/8/17	1.08	Sample Transfer Cell	Hammer	0.00	0	0
11/9/17	0	None	NA	0	0	0
11/10/17	0	None	NA	0	0	0
11/11/17	0	None	NA	0	0	0
11/12/17	0	None	NA	0	0	0
11/13/17	0	None	NA	2.00	0	0
11/14/17	2.50	Vit Cell Roof	Shear	2.50	0	0
11/15/17	0	None	NA	2.83	1	10,890
11/16/17	0	None	NA	3.50	0	0
11/17/17	0	None	NA	0	0	0
11/18/17	0	None	NA	0	0	0
11/19/17	0	None	NA	0	0	0
11/20/17	0	None	NA	0	0	0
11/21/17	0	None	NA	0	0	0
11/22/17	0	None	NA	0	0	0
11/23/17	0	None	NA	0	0	0
11/24/17	0	None	NA	0	0	0

Date	Hours of Demolition	Hours of Demolition	Method	Hours of Loading	Intermodal Containers Loaded	Packaged Waste (lb)
11/25/17	0	None	NA	0	0	0
11/26/17	0	None	NA	0	0	0
11/27/17	0	None	NA	0	0	0
11/28/17	0	None	NA	0	0	0
11/29/17	0.67	NE Corner of VIT	Hammer	1.25	0	0
11/30/17	0	NE Corner of VIT	Hammer	0.58	0	0
12/1/17	0	None	NA	0	0	0
12/2/17	0	None	NA	0	0	0
12/3/17	0	None	NA	0	0	0
12/4/17	1.67	NE Corner of VIT	Hammer	0	0	0
12/5/17	0	None	NA	0	0	0
12/6/17	0	None	NA	0	0	0
12/7/17	1.50	NW Corner of VIT	Hammer	4.75	1	25,730
12/8/17	0	None	NA	0	0	0
12/9/17	0	None	NA	0	0	0
12/10/17	0	None	NA	0	0	0
12/11/17	2.08	NW Corner of VIT	Hammer	1.00	1	31,570
12/12/17	2.50	NW Corner of VIT	Hammer	2.50	1	27,620
12/13/17	0	None	NA	4	1	30,900
12/14/17	3.00	North Wall VIT	Hammer	1.17	1	31,020
12/15/17	0	None	NA	0	0	0
12/16/17	0	None	NA	0	0	0
12/17/17	0	None	NA	0	0	0
12/18/17	4.50	North Wall VIT	Hammer	2.75	1	30,950
12/19/17	3.00	North Wall VIT	Hammer	4	1	32,080
12/20/17	2.00	North Wall VIT	Hammer	4	0	0
12/21/17	0	None	NA	4.00	2	62,440
12/22/17	0	None	NA	0	0	0
12/23/17	0	None	NA	0	0	0
12/24/17	0	None	NA	0	0	0
12/25/17	0	None	NA	0	0	0
12/26/17	0	None	NA	0	0	0
12/27/17	0	None	NA	0	0	0
12/28/17	0	None	NA	0	0	0
12/29/17	0	None	NA	0	0	0
12/30/17	0	None	NA	0	0	0
12/31/17	0	None	NA	0	0	0

Date	Hours of Demolition	Hours of Demolition	Method	Hours of Loading	Intermodal Containers Loaded	Packaged Waste (lb)
1/1/18	0	None	NA	0	0	0
1/2/18	0	None	NA	0	0	0
1/3/18	1.42	North Wall VIT	Hammer	4	1	40,300
1/4/18	0	None	NA	0	0	0
1/5/18	0	None	NA	0	0	0
1/6/18	0	None	NA	0	0	0
1/7/18	0	None	NA	0	0	0
1/8/18	0.92	North Wall VIT	Hammer	0	0	0
1/9/18	0	None	NA	0	0	0
1/10/18	0	None	NA	0	0	0
1/11/18	1.42	North Wall VIT	Hammer	0	0	0
1/12/18	3.27	North Wall VIT	Hammer	0	0	0
1/13/18	0	None	NA	0	0	0
1/14/18	0	None	NA	0	0	0
1/15/18	0.92	North Wall VIT	Hammer	0.92	2	33,150
1/16/18	1.08	North Wall VIT	Hammer	2.25	2	60,580
1/17/18	1.92	North Wall VIT	Hammer	1.92	1	26760
1/18/18	4.25	North Wall VIT	Hammer	0	0	0
1/19/18	2.75	North Wall VIT	Hammer	0	0	0
1/20/18	0	None	NA	0	0	0
1/21/18	0	None	NA	0	0	0
1/22/18	3.00	North Wall VIT	Hammer	0	0	0
1/23/18	0	Cleanup	NA	0	0	0
1/24/18	0	Cleanup	NA	0	0	0
1/25/18	0	Cleanup	NA	0	0	0
1/26/18	0	None	NA	0	0	0
1/27/18	0	None	NA	0	0	0
1/28/18	0	None	NA	0	0	0
1/29/18	0	None	NA	3.42	4	108020
1/30/18	0.25	Vit Liner in Cell	Shear	2.25	2	59950
1/31/18	2.00	Vit Liner in Cell	Shear	0	0	0
2/1/18	3.25	Vit Liner in Cell	Shear	0	0	0
2/2/18	0	None	NA	0	0	0
2/3/18	0	None	NA	0	0	0
2/4/18	0	None	NA	0	0	0
2/5/18	0	None	NA	5.03	4	113790
2/6/18	0	None	NA	0	0	0

Date	Hours of Demolition	Hours of Demolition	Method	Hours of Loading	Intermodal Containers Loaded	Packaged Waste (lb)
2/7/18	0	None	NA	0.00	0	0
2/8/18	0	None	NA	0.00	0	0
2/9/18	0	None	NA	0	0	0
2/10/18	0	None	NA	0	0	0
2/11/18	0	None	NA	0	0	0
2/12/18	0	None	NA	0.00	0	0
2/13/18	0	None	NA	6.03	2	60090
2/14/18	0	None	NA	5.27	2	44090
2/15/18	0	None	NA	3.73	1	16400
2/16/18	0	None	NA	0	0	0
2/17/18	0	None	NA	0	0	0
2/18/18	0	None	NA	0	0	0
2/19/18	0	None	NA	0	0	0
2/20/18	0	None	NA	0	0	0
2/21/18	0	None	NA	0	0	0
2/22/18	0	None	NA	0	0	0
2/23/18	0	None	NA	0	0	0
2/24/18	0	None	NA	0	0	0
2/25/18	0	None	NA	0	0	0
2/26/18	0	None	NA	0	0	0
2/27/18	0	None	NA	0	0	0
2/28/18	0	None	NA	0	0	0
3/1/18	0	None	NA	0	0	0
3/2/18	0	None	NA	0	0	0
3/3/18	0	NW Cooler	NA	0	0	0
3/4/18	0	None	NA	0	0	0
3/5/18	0	pkg cooler	NA	0	0	0
3/6/18	0	None	NA	0	0	0
3/7/18	0	None	NA	0	0	0
3/8/18	0	None	NA	0	0	0
3/9/18	0	NE, SE and SW coolers lowered	NA	0	0	0
3/10/18	0	None	NA	0	0	0
3/11/18	0	None	NA	0	0	0
3/12/18	0	Pkg NE cooler	NA	0	0	0
3/13/18	0	Pkg SE cooler	NA	0	0	0
3/14/18	0	None	NA	0	0	0
3/15/18	0	Pkg SW cooler	NA	0	0	0

Date	Hours of Demolition	Hours of Demolition	Method	Hours of Loading	Intermodal Containers Loaded	Packaged Waste (lb)
3/16/18	0	None	NA	0	0	0
3/17/18	0	None	NA	0	0	0
3/18/18	0	None	NA	0	0	0
3/19/18	0	None	NA	0	0	0
3/20/18	0	Size reduce Bathroom Anchors	NA	0	0	0
3/21/18	0	East/West Crane Rail (25ft)	NA	0	0	0
3/22/18	0	None	NA	0	0	0
3/23/18	0	None	NA	0	0	0
3/24/18	0	None	NA	0	0	0
3/25/18	0	None	NA	0	0	0
3/26/18	3.67	West Wall	Hammer	0	0	0
3/27/18	0	None	NA	0	0	0
3/28/18	5.42	VIT Ceiling	Hammer	0	0	0
3/29/18	0	None	NA	0	0	0
3/30/18	0	None	NA	0	0	0
3/31/18	0	None	NA	0	0	0
4/1/18	0	None	NA	0	0	0
4/2/18	0	None	NA	5.58	4	114740
4/3/18	3.67	West Wall and Ceiling	Hammer	3.67	2	60100
4/4/18	0	None	NA	0	0	0
4/5/18	2.42	Ceiling	Hammer	1.18	2	61030
4/6/18	0	None	NA	0	0	0
4/7/18	0	None	NA	0	0	0
4/8/18	0	None	NA	0	0	0
4/9/18	3.80	West wall	Hammer	0	0	0
4/10/18	0	None	NA	4.33	3	93860
4/11/18	4.83	East Wall / ceiling	Hammer	3.53	3	88500
4/12/18	0.40	west wall	Hammer	5.50	3	89340
4/13/18	0	None	NA	6.75	7	202500
4/14/18	0	None	NA	0	0	0
4/15/18	0	None	NA	0	0	0
4/16/18	5.67	ceiling	Hammer	0	0	0
4/17/18	1.42	west wall and Ceiling	Hammer	3.67	4	116520
4/18/18	4.42	West Wall and Ceiling	Hammer	2.50	2	58030
4/19/18	0	None	NA	3.83	4	115870
4/20/18	0	None	NA	0	0	0
4/21/18	0	None	NA	0	0	0

Date	Hours of Demolition	Hours of Demolition	Method	Hours of Loading	Intermodal Containers Loaded	Packaged Waste (lb)
4/22/18	0	None	NA	0	0	0
4/23/18	4.95	ceiling	Hammer	3.00	4	111680
4/24/18	5.05	West Wall and Ceiling	Hammer	2.22	4	121530
4/25/18	2.00	West Wall	Hammer	3.08	4	125800
4/26/18	2.75	west wall	Hammer	2.33	4	116230
4/27/18	0	None	NA	0	0	0
4/28/18	0	None	NA	0	0	0
4/29/18	0	None	NA	0	0	0
4/30/18	6.45	west wall	Hammer	3.33	4	117110
5/1/18	0.42	crane area	Hammer	0	1	31100
5/1/18	3.17	crane rail	Shear	0	0	0
5/2/18	2.58	crane rail	Shear	2.42	2	58200
5/3/18	1.75	east Wall / ceiling	Hammer	2.50	1	43223
5/4/18	0	None	NA	0	0	0
5/5/18	0	None	NA	0	0	0
5/6/18	0	None	NA	0	0	0
5/7/18	2.67	ceiling	Hammer	0.58	2	57200
5/8/18	5.58	east wall	Hammer	2.83	4	118840
5/9/18	5.75	east wall	Hammer	2.83	4	133520
5/10/18	2.58	ceiling	Hammer	2.58	5	153800
5/11/18	0	None	NA	0	0	0
5/12/18	0	None	NA	0	0	0
5/13/18	0	None	NA	0	0	0
5/14/18	5.08	ceiling	Hammer	0	0	0
5/15/18	5.83	ceiling	Hammer	0	0	0
5/16/18	0	None	NA	5.50	4	107910
5/17/18	0	None	NA	5.25	8	263490
5/18/18	0	None	NA	0	0	0
5/19/18	0	None	NA	0	0	0
5/20/18	0	None	NA	0	0	0
5/21/18	5.00	east and west walls	Hammer	0	0	0
5/22/18	2.50	east and west walls	Hammer	5.42	6	203650
5/23/18	3.17	ceiling	Hammer	3.42	4	138780
5/24/18	2.08	west wall	Hammer	2.08	0	42506.3
5/25/18	0	None	NA	0	0	0
5/26/18	0	None	NA	0	0	0
5/27/18	0	None	NA	0	0	0

Date	Hours of Demolition	Hours of Demolition	Method	Hours of Loading	Intermodal Containers Loaded	Packaged Waste (lb)
5/28/18	0	None	NA	0	0	0
5/29/18	0	None	NA	4.58	4	93513.8
5/30/18	1.50	Size reduce crane	Shear	0	0	0
5/31/18	0.50	west wall	Hammer	0	0	0
6/1/18	0	None	NA	0	0	0
6/2/18	0	None	NA	0	0	0
6/3/18	0	None	NA	0	0	0
6/4/18	5.33	east and west walls	Hammer	0	0	0
6/5/18	4.50	west wall	Hammer	4.50	0	70174.3
6/6/18	2.25	east wall	Hammer	6.00	5	93565.7
6/7/18	5.92	east wall	Hammer	0	0	0
6/8/18	0	None	NA	0	0	0
6/9/18	0	None	NA	0	0	0
6/10/18	0	None	NA	0	0	0
6/11/18	5.67	east and west walls	Hammer	2.00	0	69958.3
6/12/18	0.25	east wall	Hammer	3.75	6	131171.7
6/13/18	1.25	east wall	Hammer	3.25	0	44856.8
6/14/18	0.42	demo	Hammer	2.58	0	35655.4
6/15/18	0	None	NA	0	0	0
6/16/18	0	None	NA	0	0	0
6/17/18	0	None	NA	0	0	0
6/18/18	5.75	demo	Hammer	2.25	0	31054.7
6/19/18	0	None	NA	6.23	6	86033.1
6/20/18	0	None	NA	0	0	0

Appendix D

Probability Density Function Plots

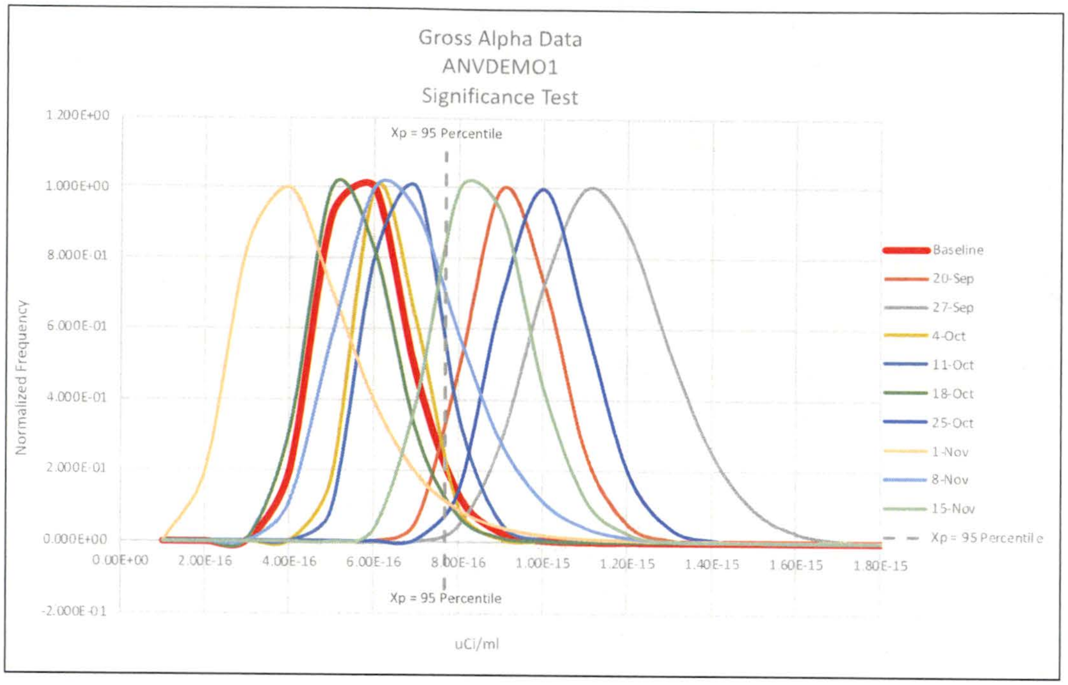


Figure 33: ANVDEMO1 alpha PDF

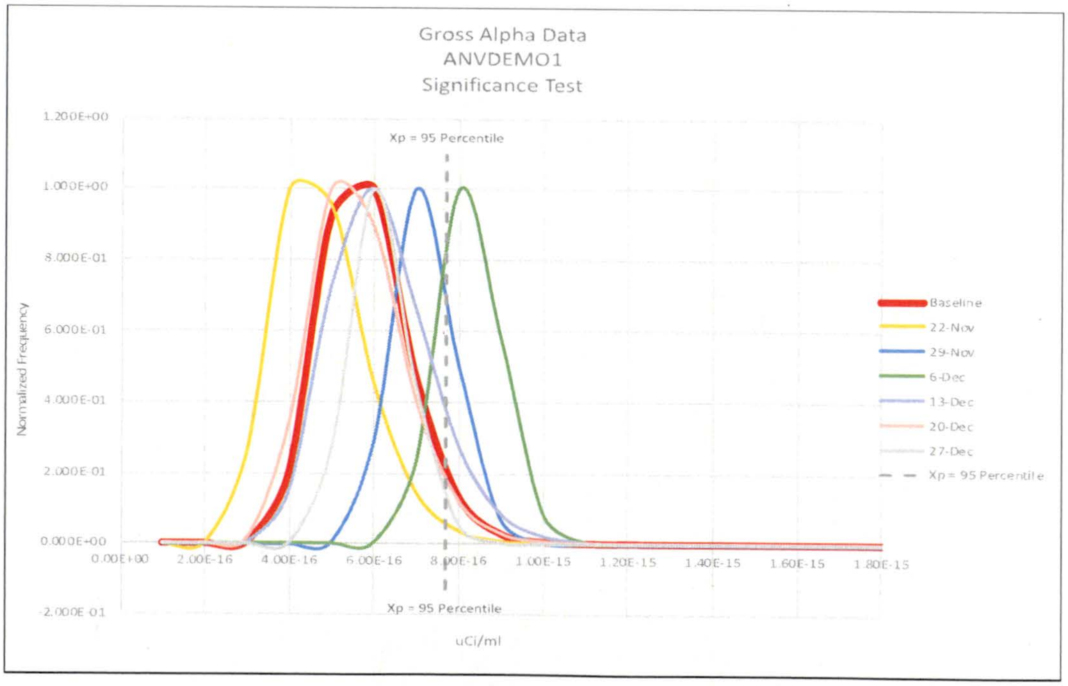


Figure 34: ANVDEMO1 alpha PDF

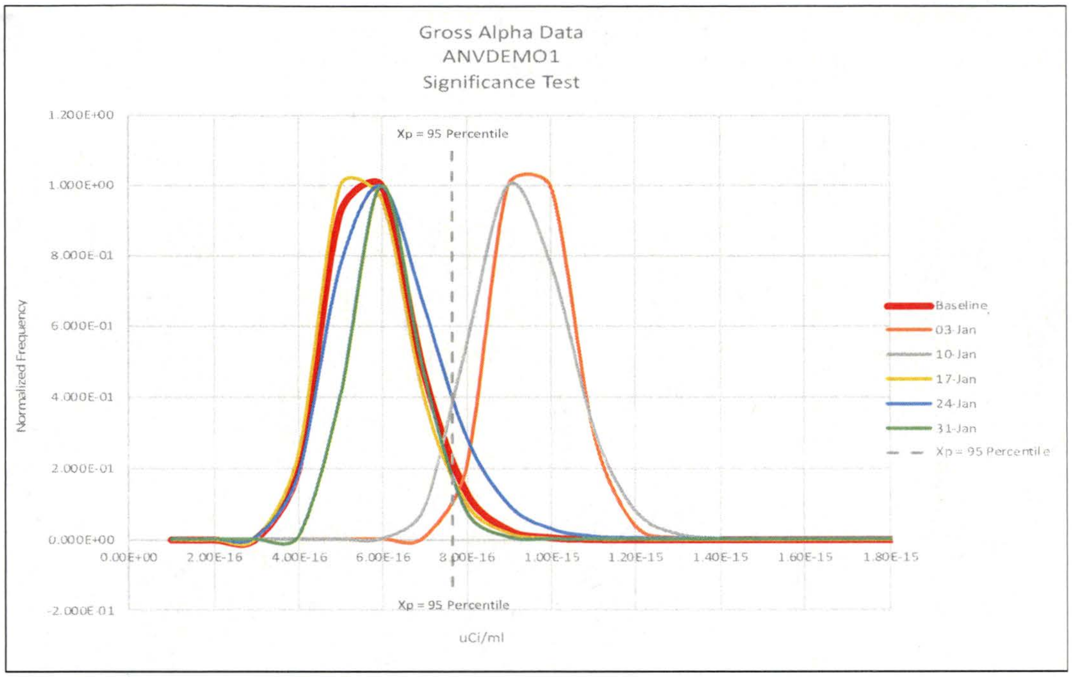


Figure 35: ANVDEMO1 alpha PDF

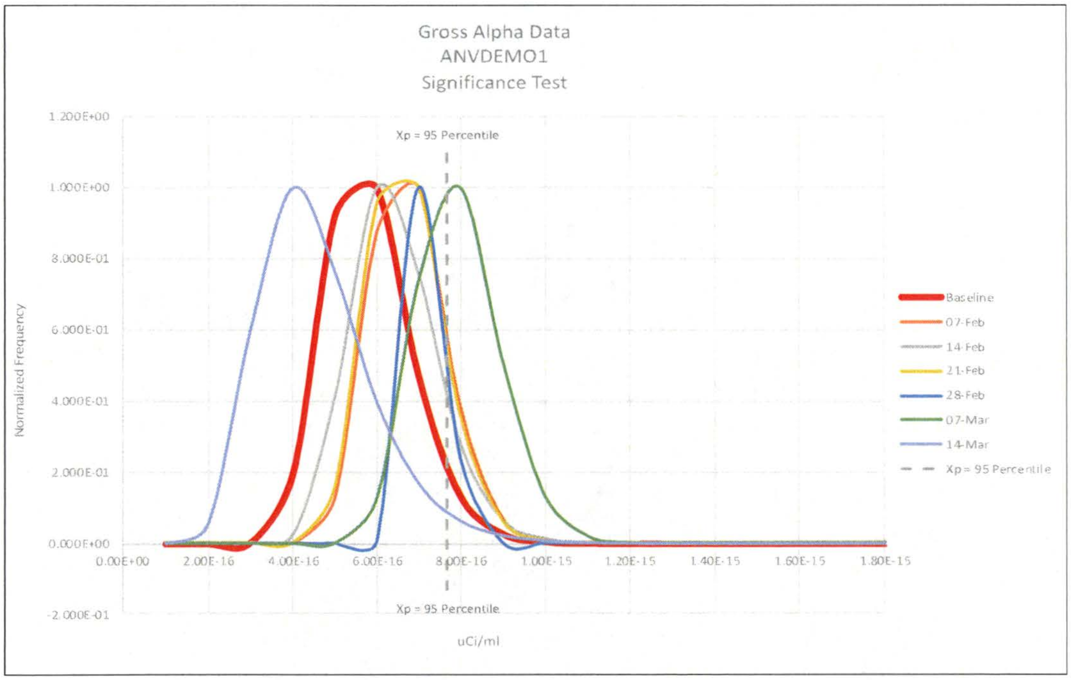


Figure 36: ANVDEMO1 alpha PDF

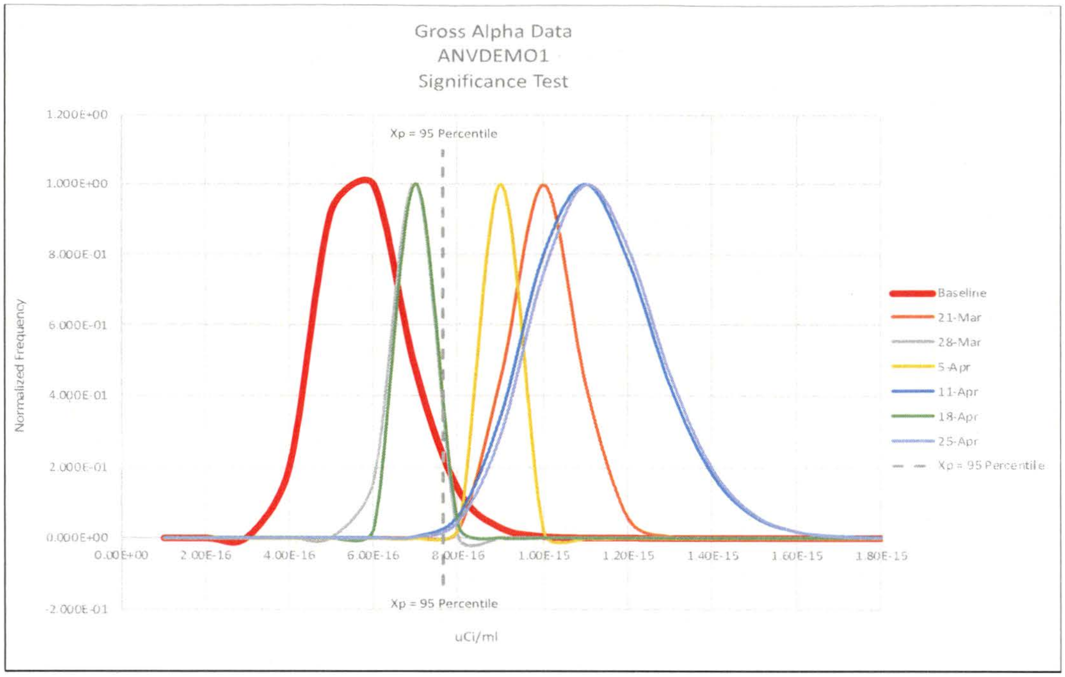


Figure 37: ANVDEMO1 alpha PDF

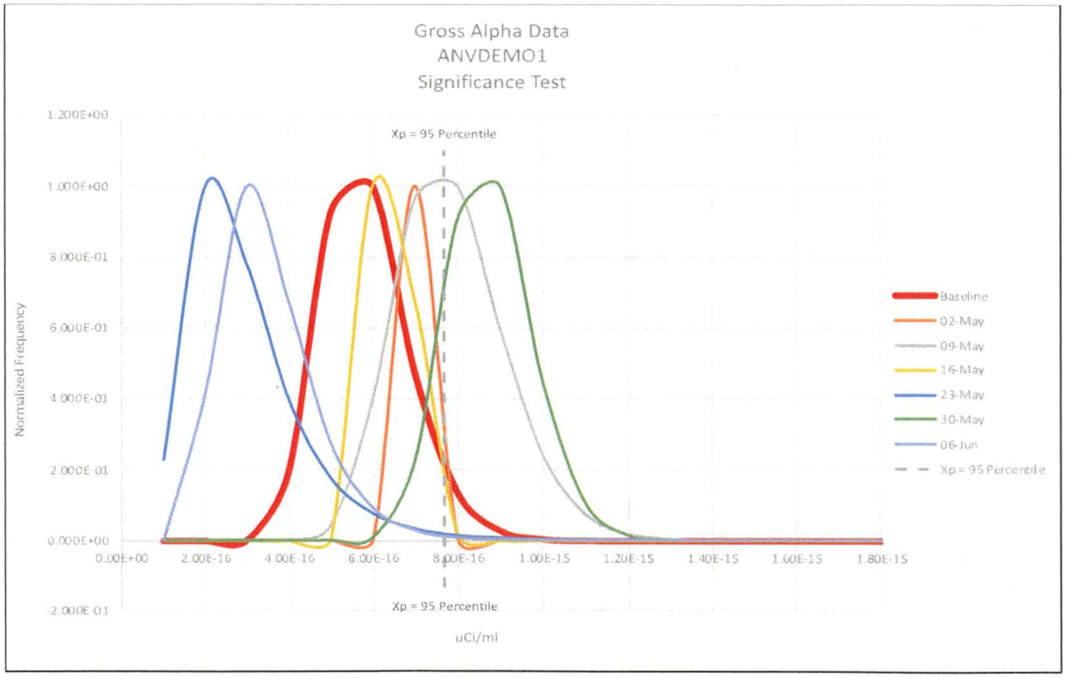


Figure 38: ANVDEMO1 alpha PDF

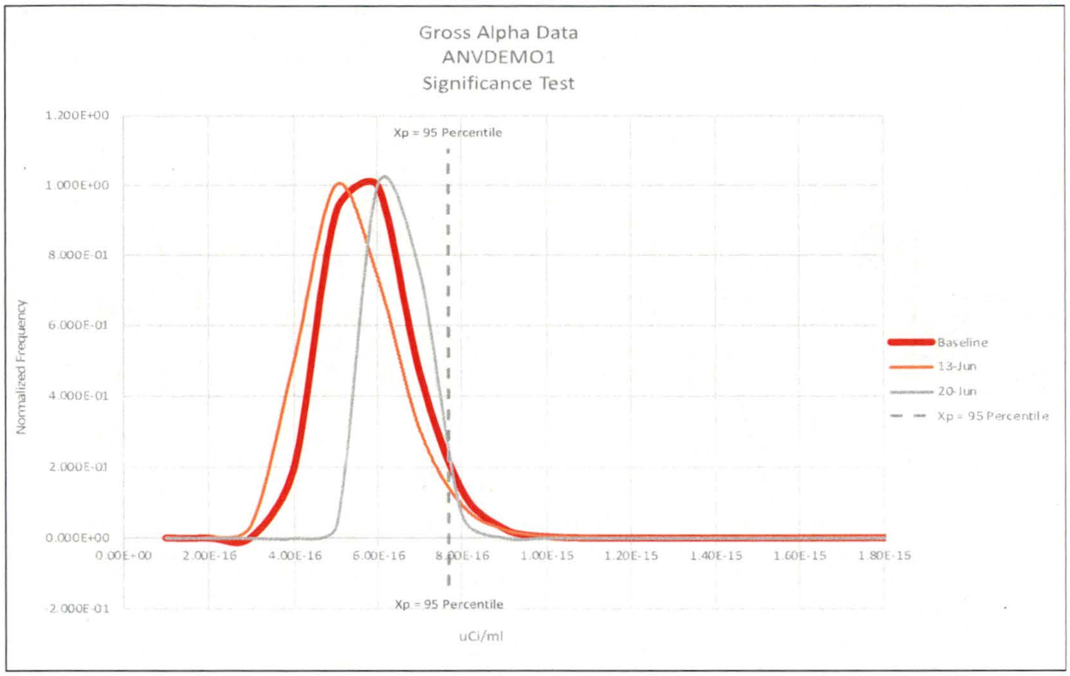


Figure 39: ANVDEMO1 alpha PDF

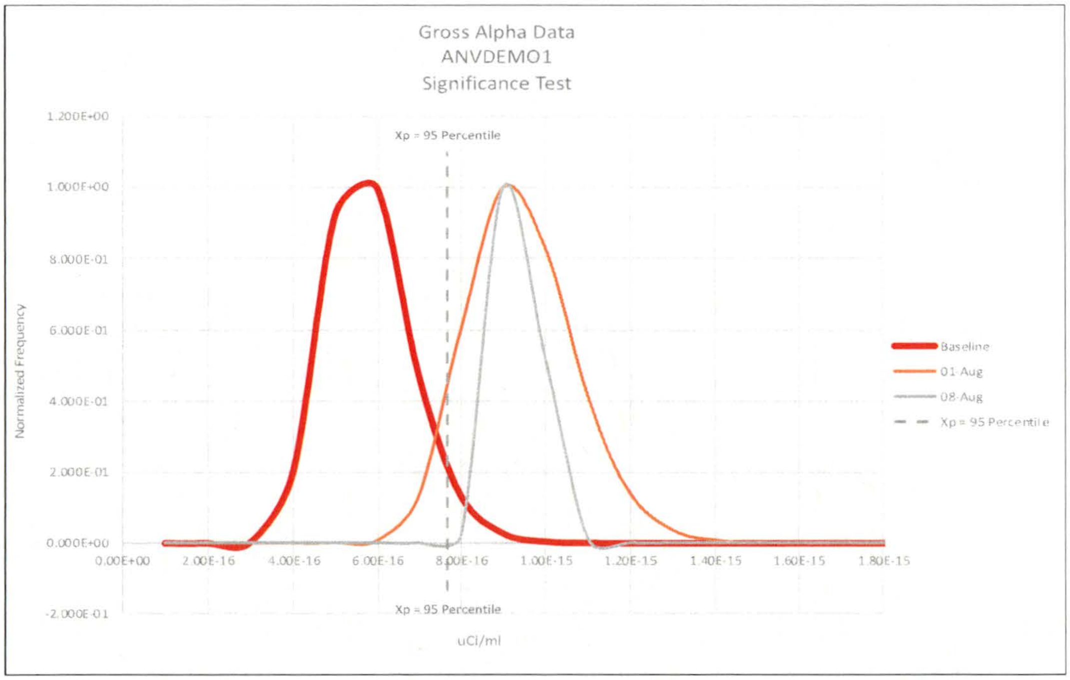


Figure 40: ANVDEMO1 alpha PDF

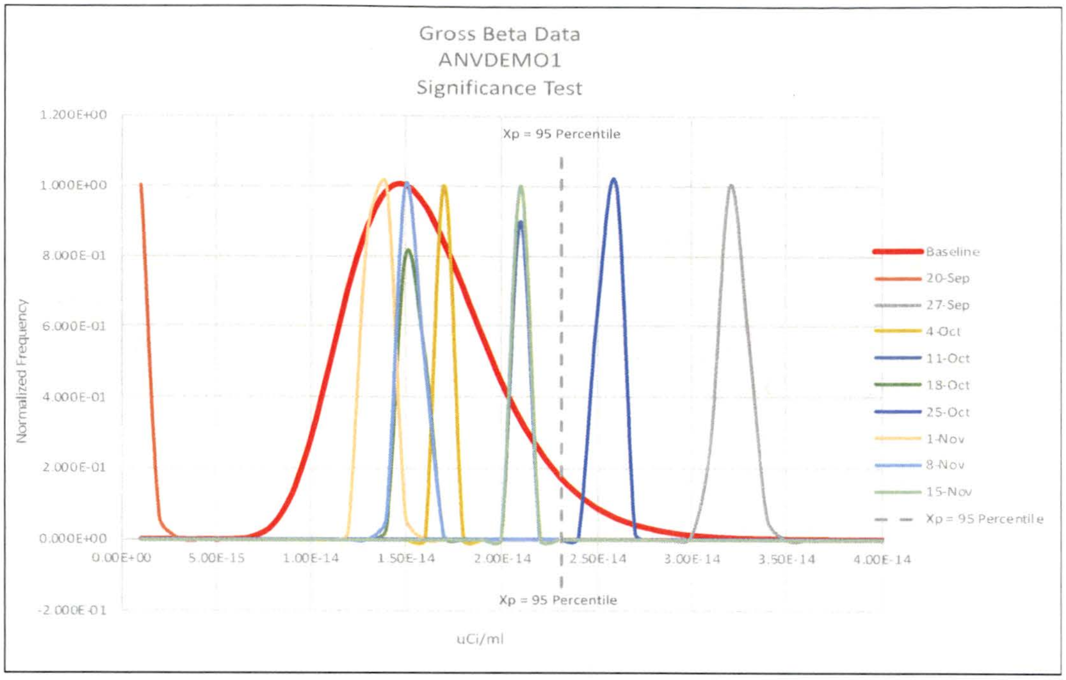


Figure 41: ANVDEMO1 beta PDF

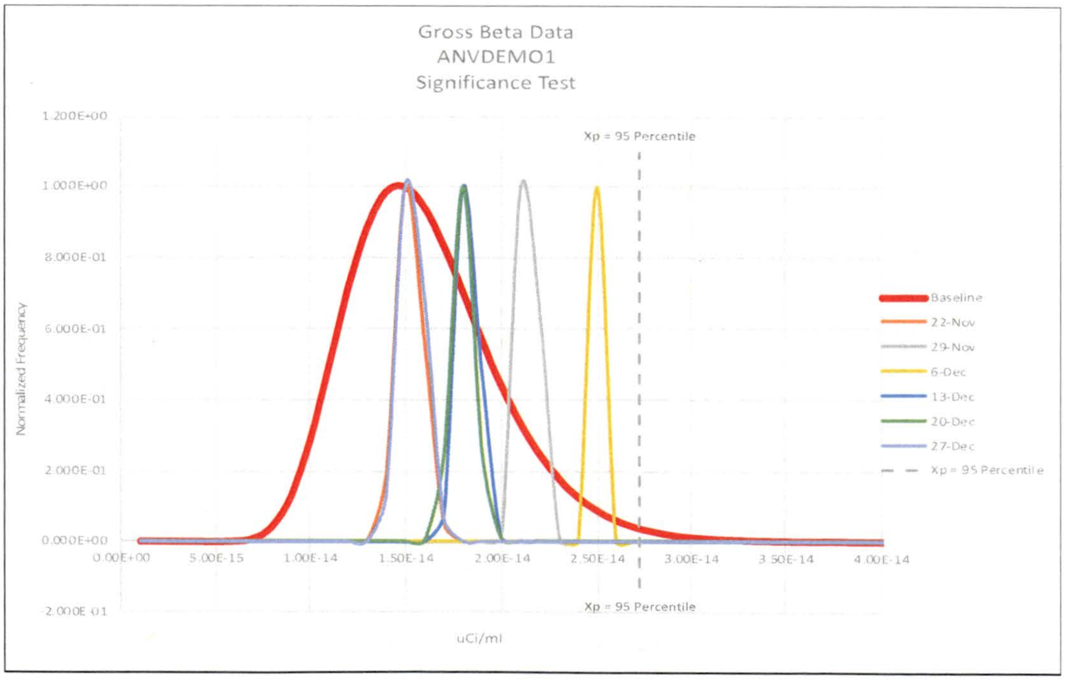


Figure 42: ANVDEMO1 beta PDF

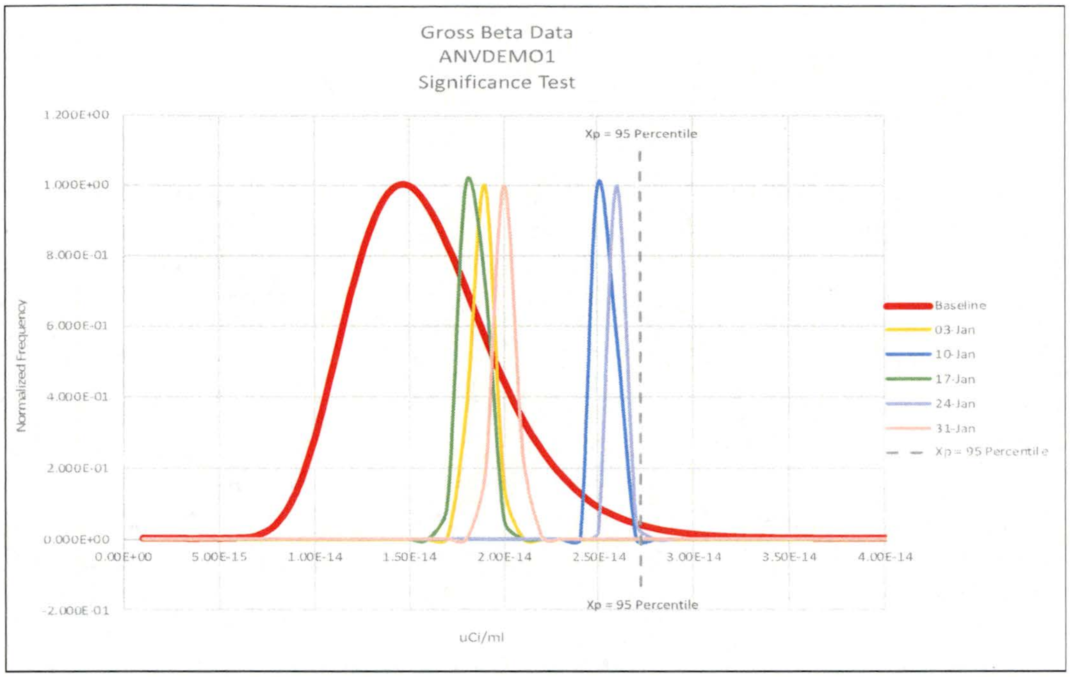


Figure 43: ANVDEMO1 beta PDF

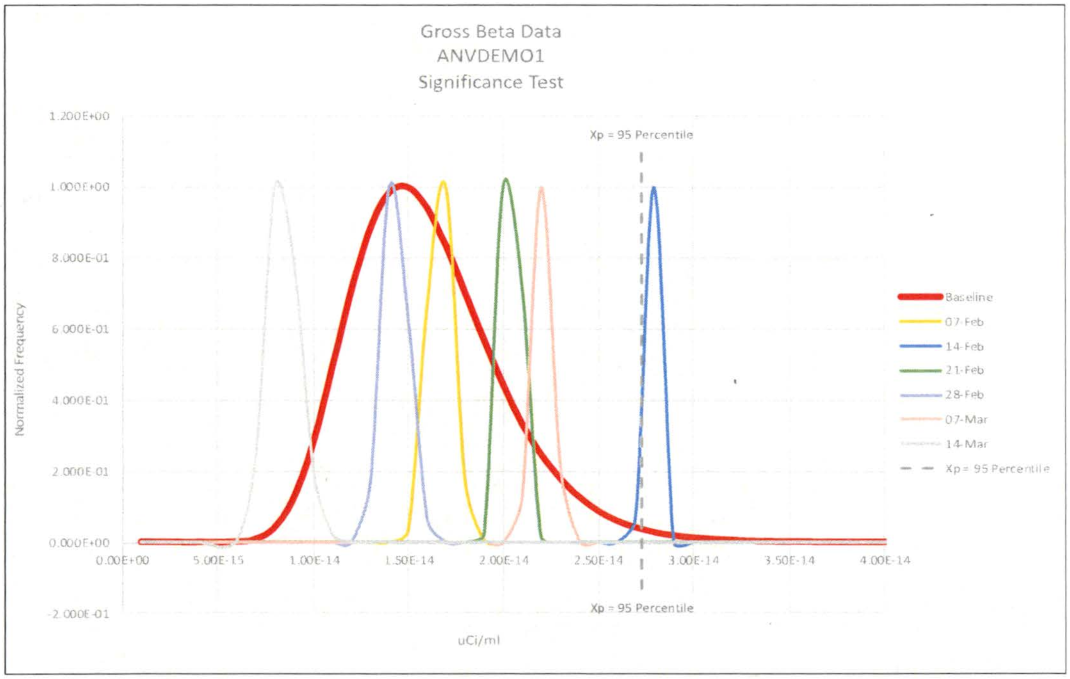


Figure 44: ANVDEMO1 beta PDF

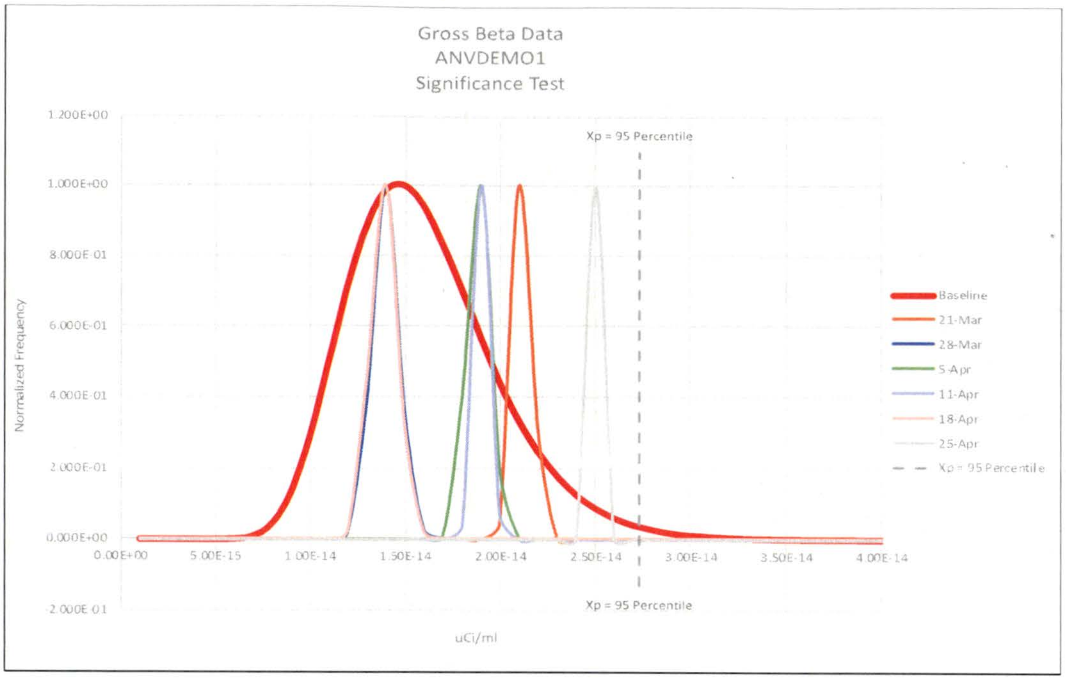


Figure 45: ANVDEMO1 beta PDF

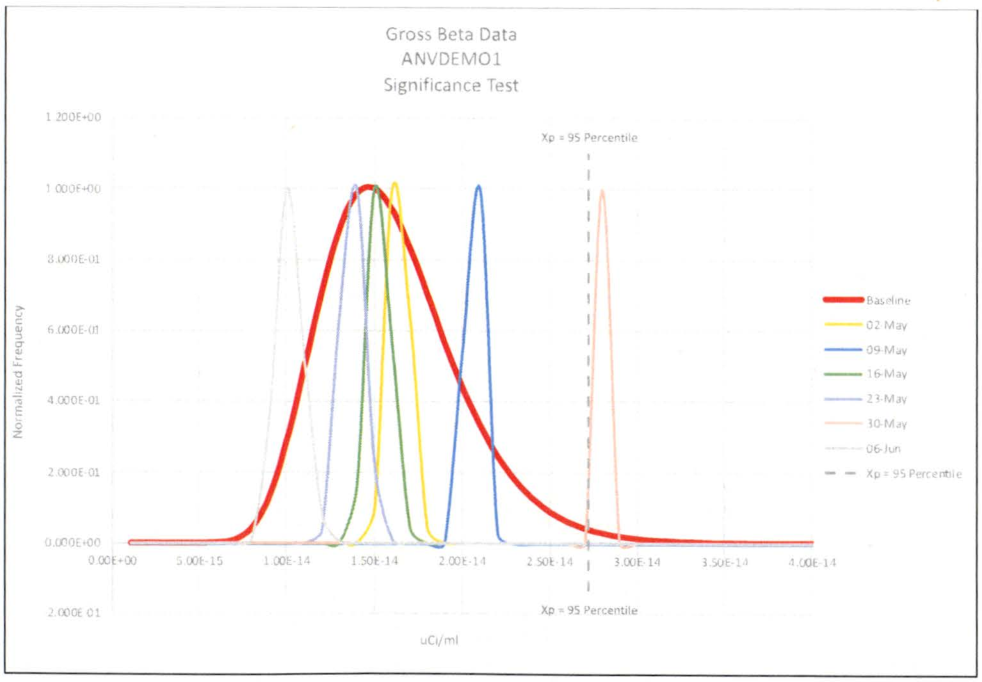


Figure 46: ANVDEMO1 beta PDF

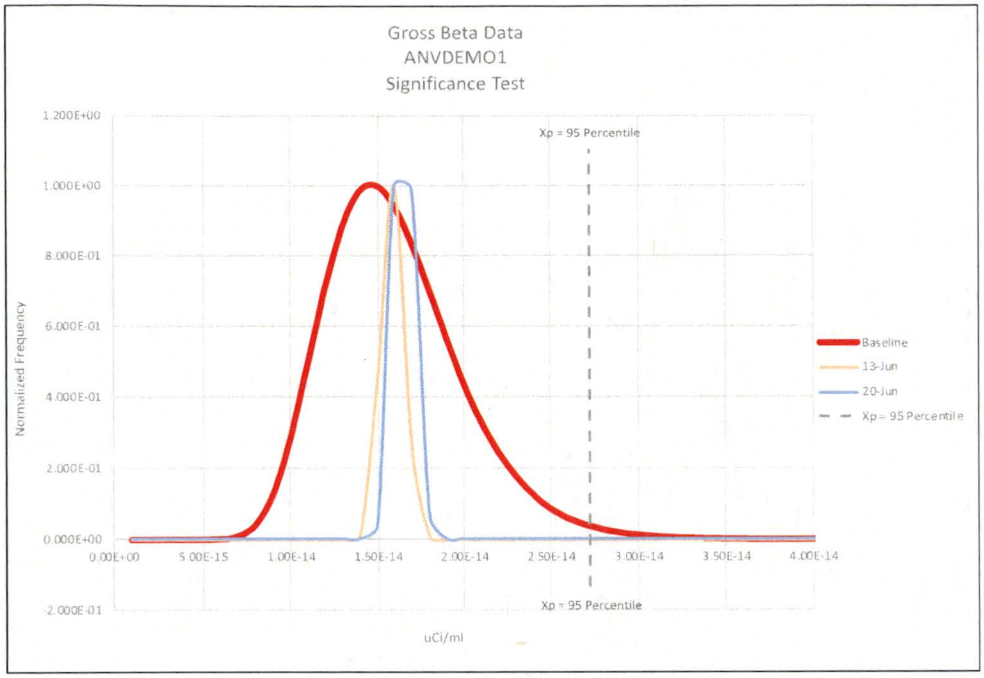


Figure 47: ANVDEMO1 beta PDF

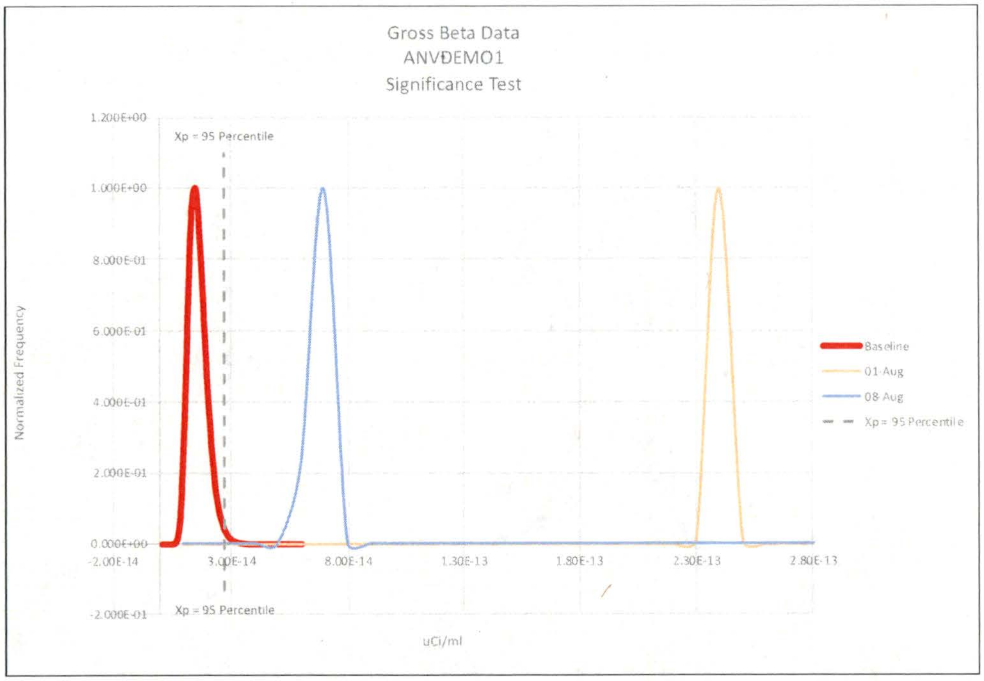


Figure 48: ANVDEMO1 beta PDF

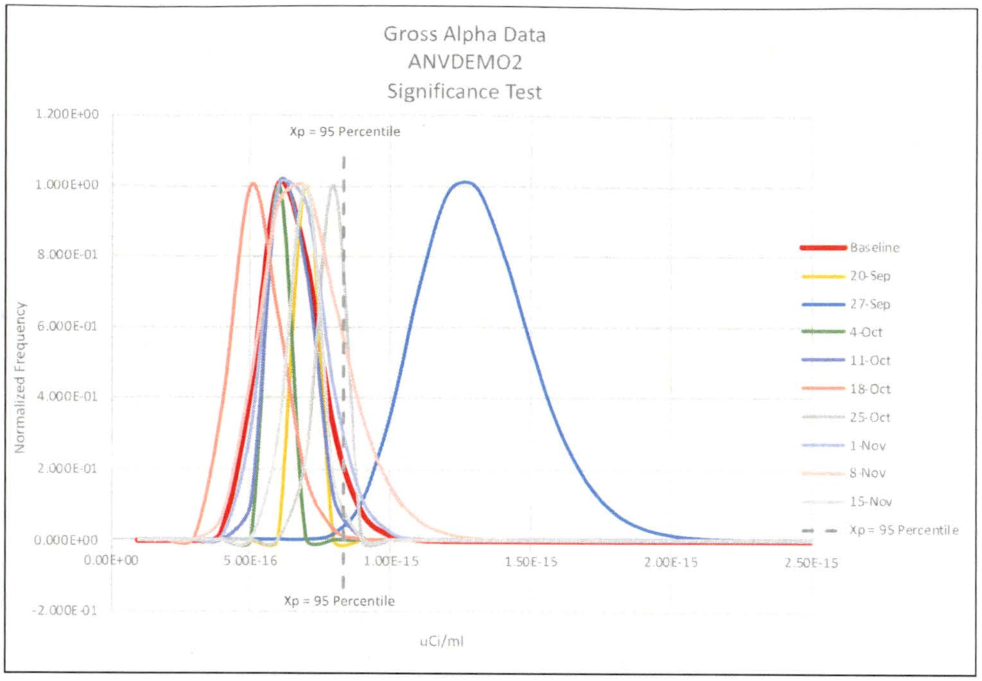


Figure 49: ANVDEMO2 alpha PDF

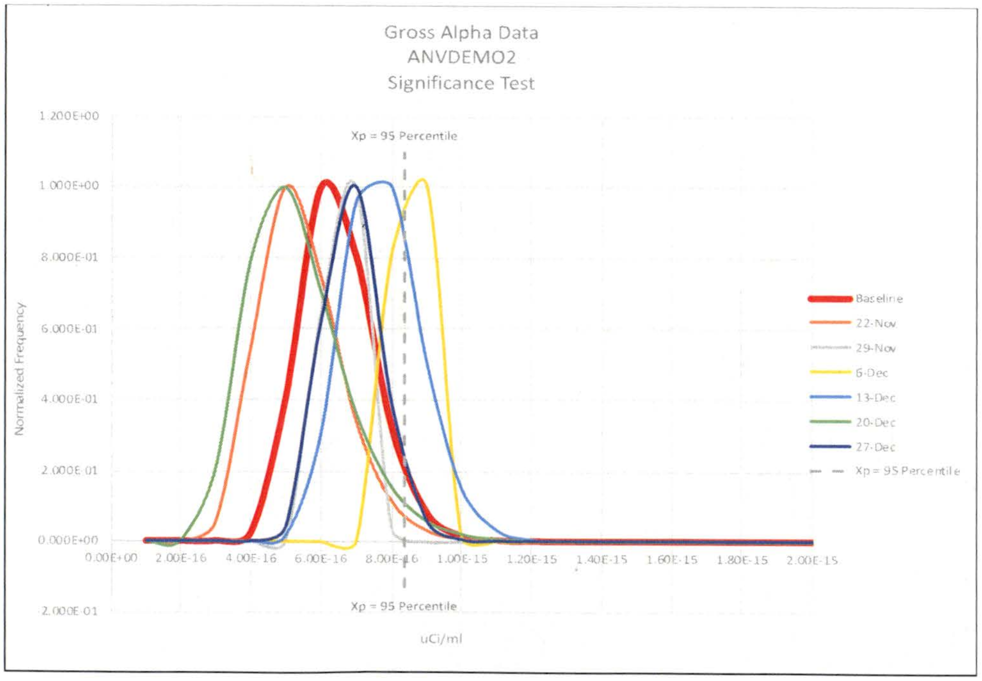


Figure 50: ANVDEMO2 alpha PDF

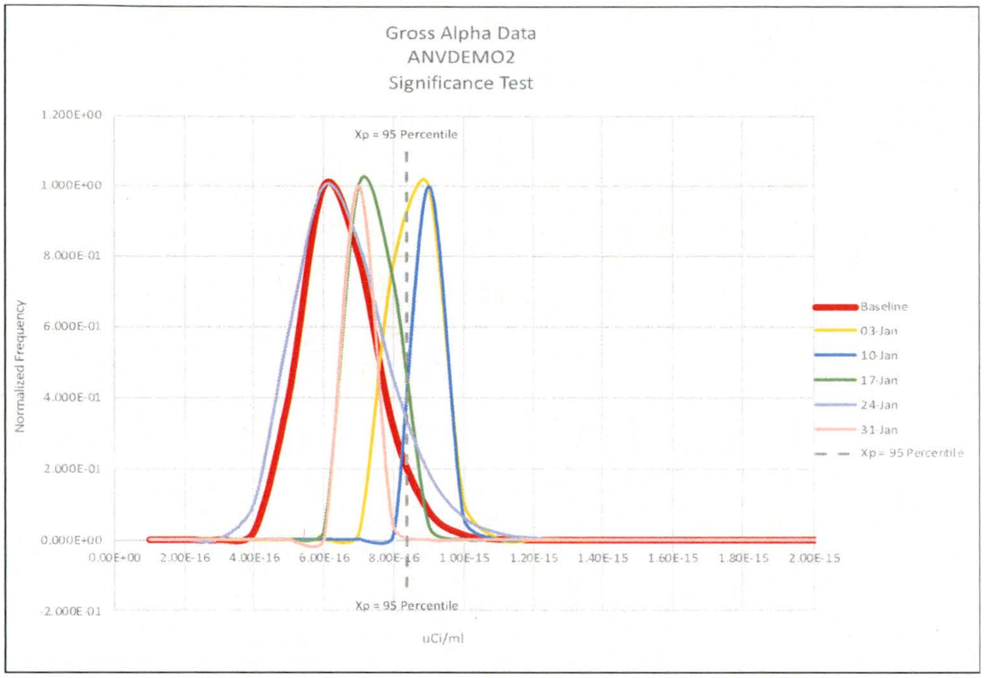


Figure 51: ANVDEMO2 alpha PDF

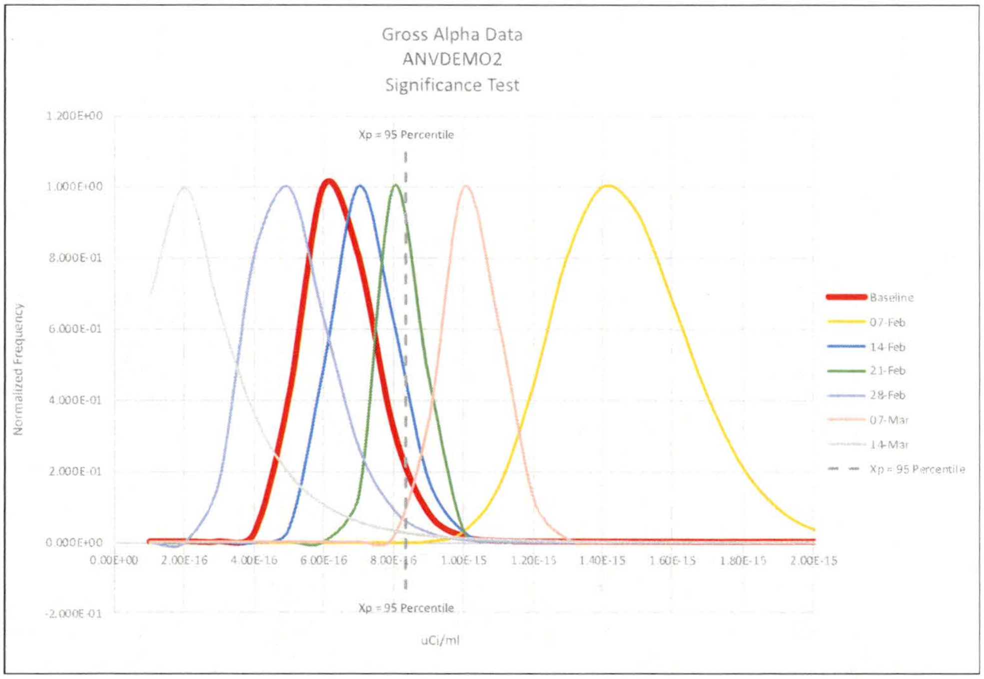


Figure 52: ANVDEMO2 alpha PDF

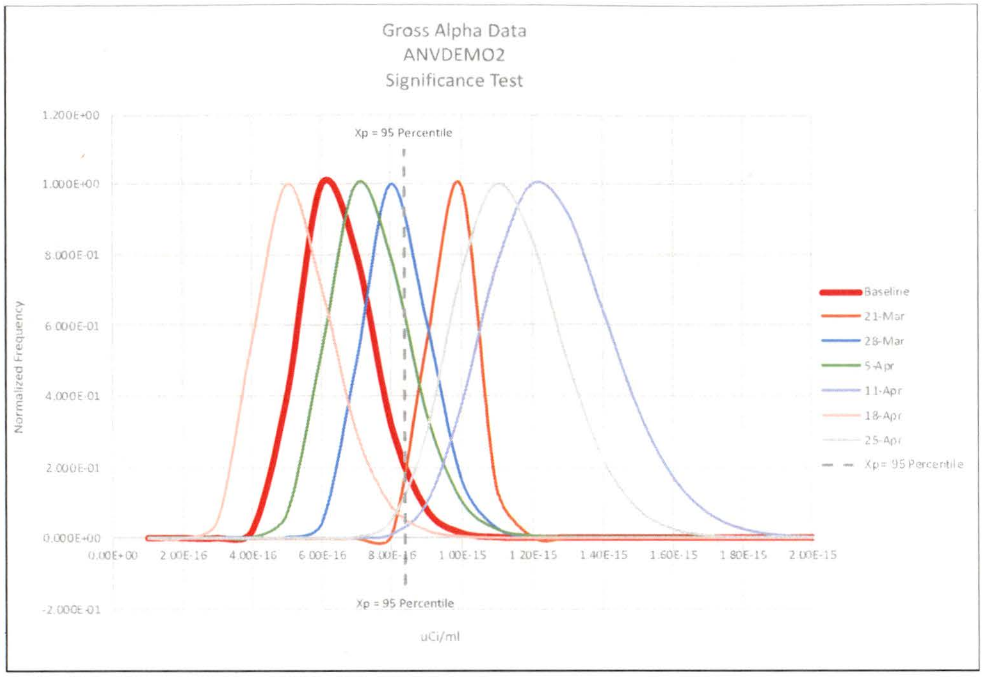


Figure 53: ANVDEMO2 alpha PDF

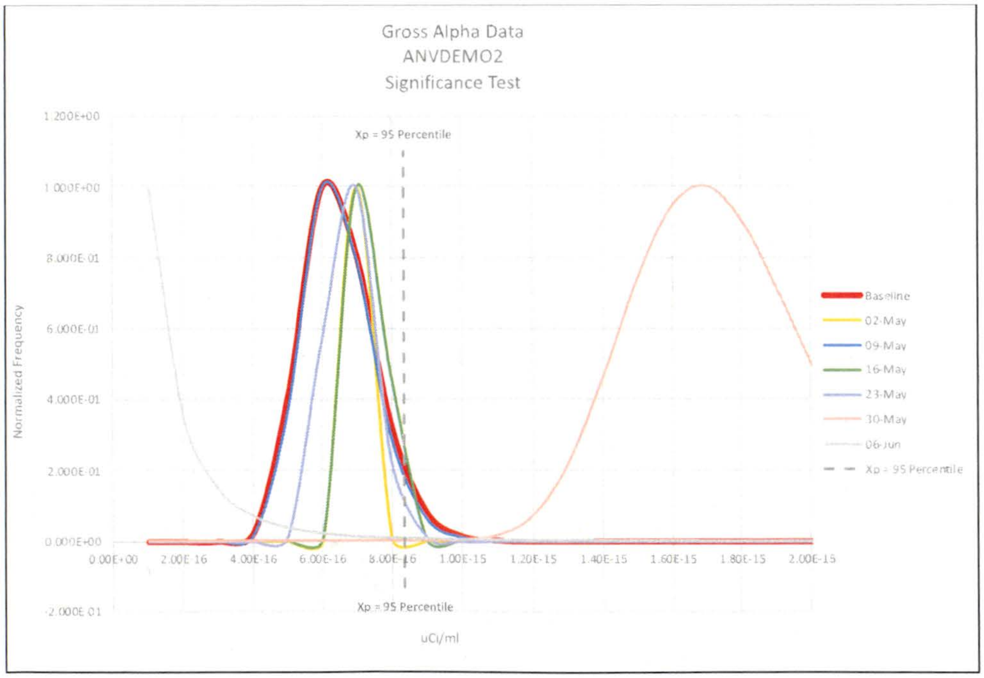


Figure 54: ANVDEMO2 alpha PDF

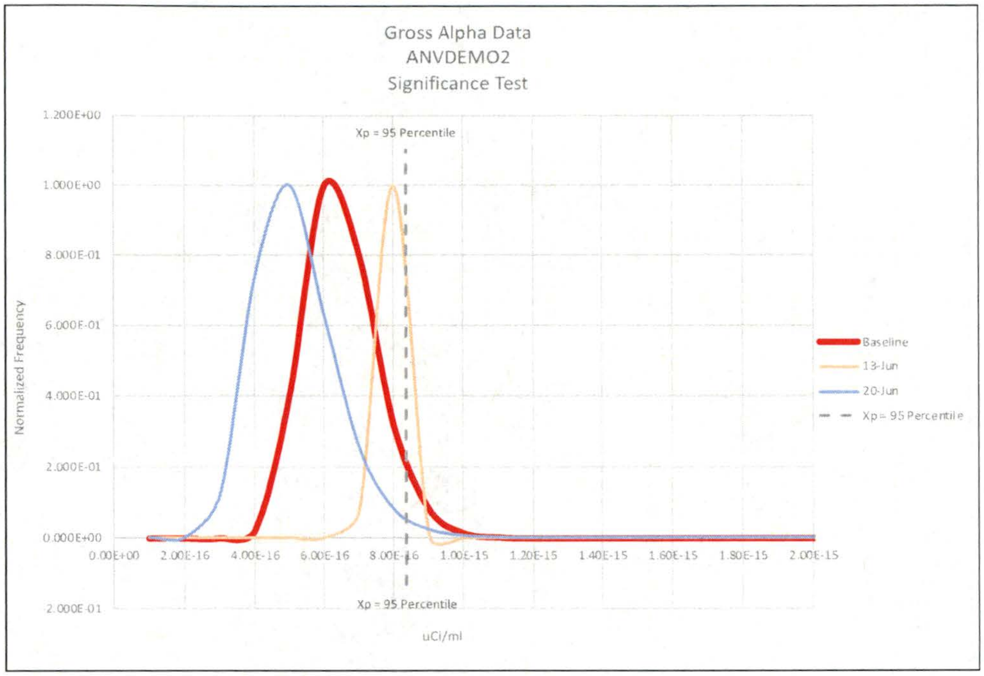


Figure 55: ANVDEMO2 alpha PDF

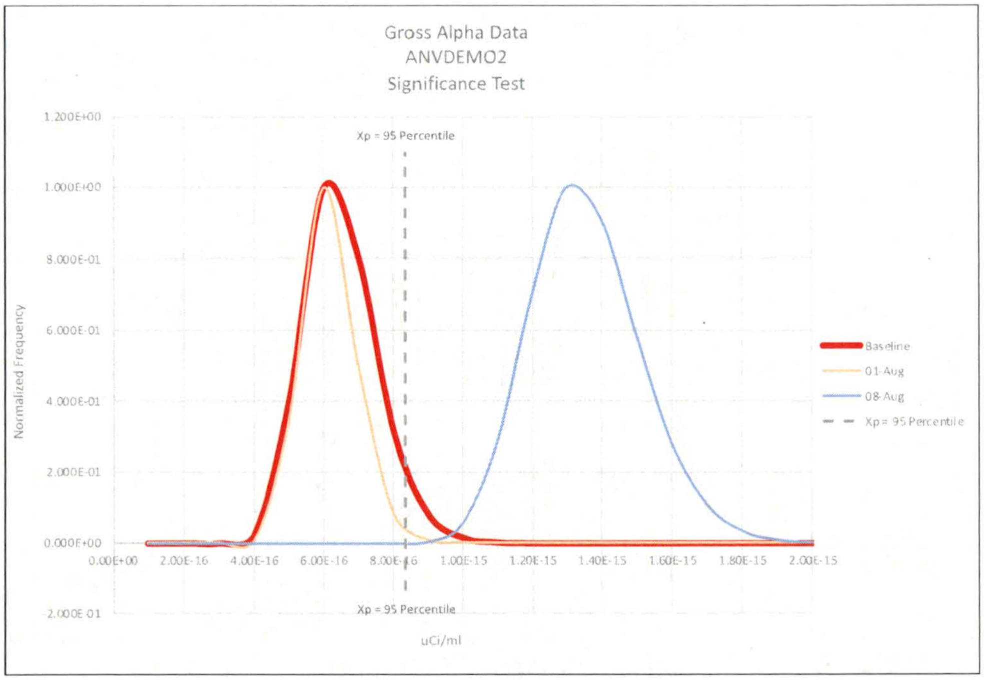


Figure 56: ANVDEMO2 alpha PDF

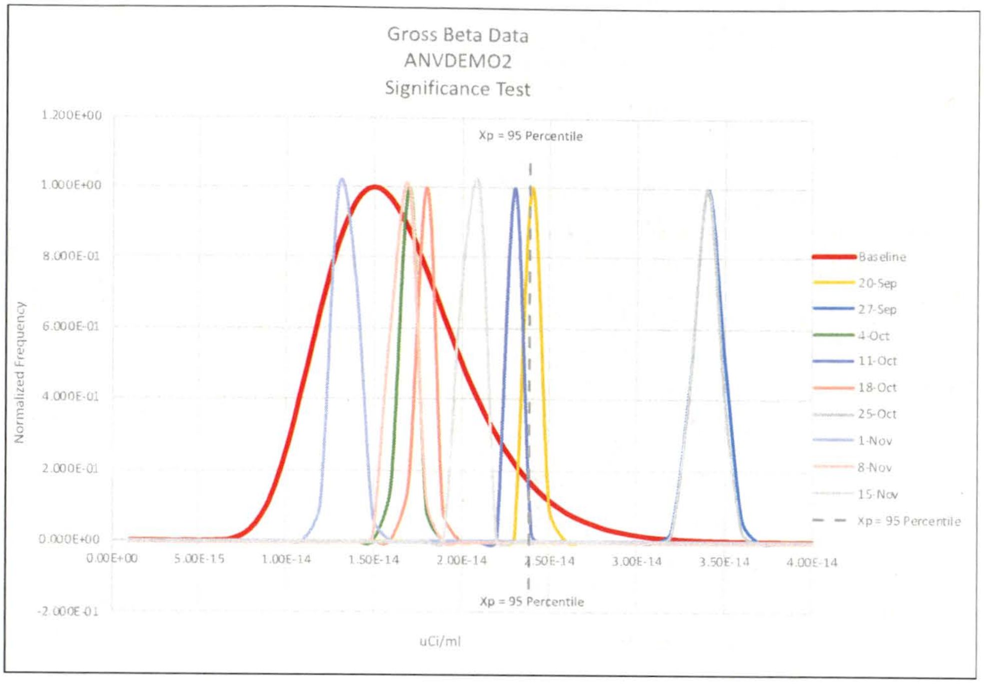


Figure 57: ANVDEMO2 beta PDF

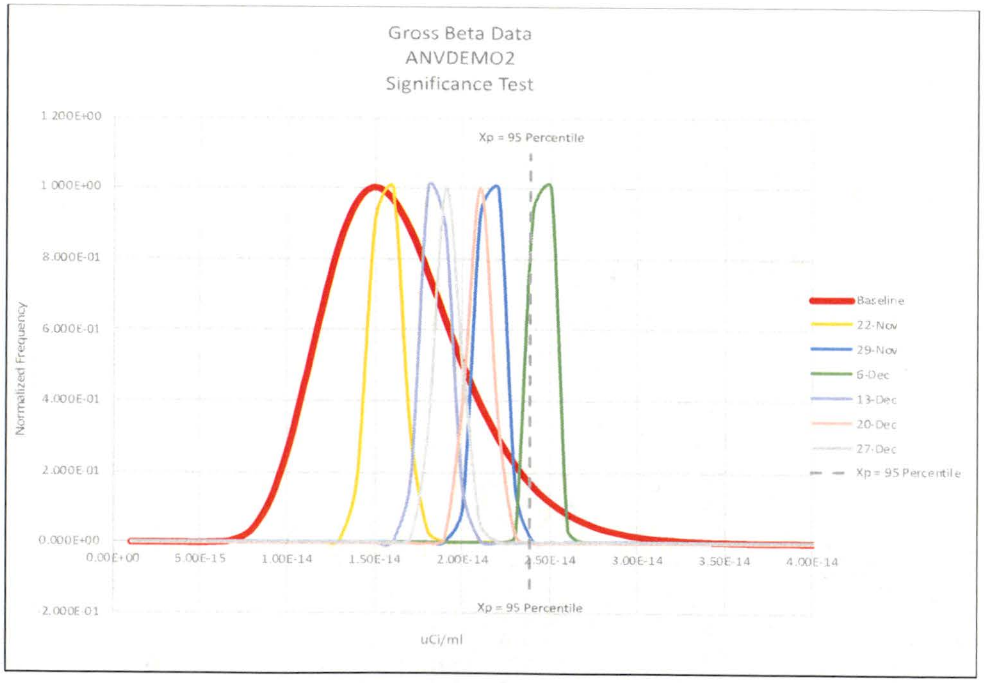


Figure 58: ANVDEMO2 beta PDF

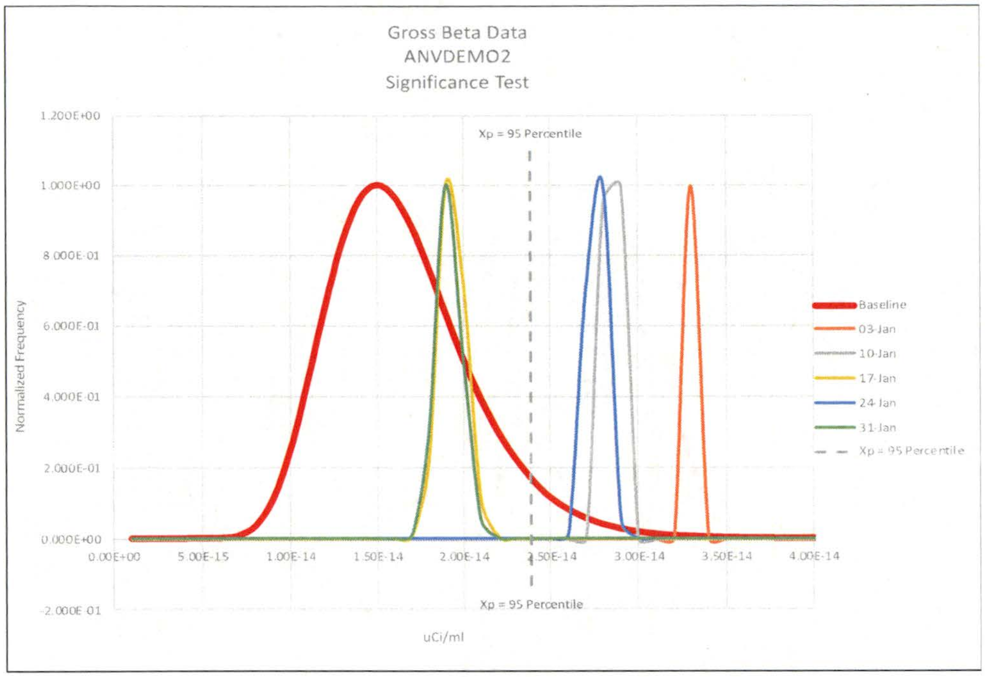


Figure 59: ANVDEMO2 beta PDF

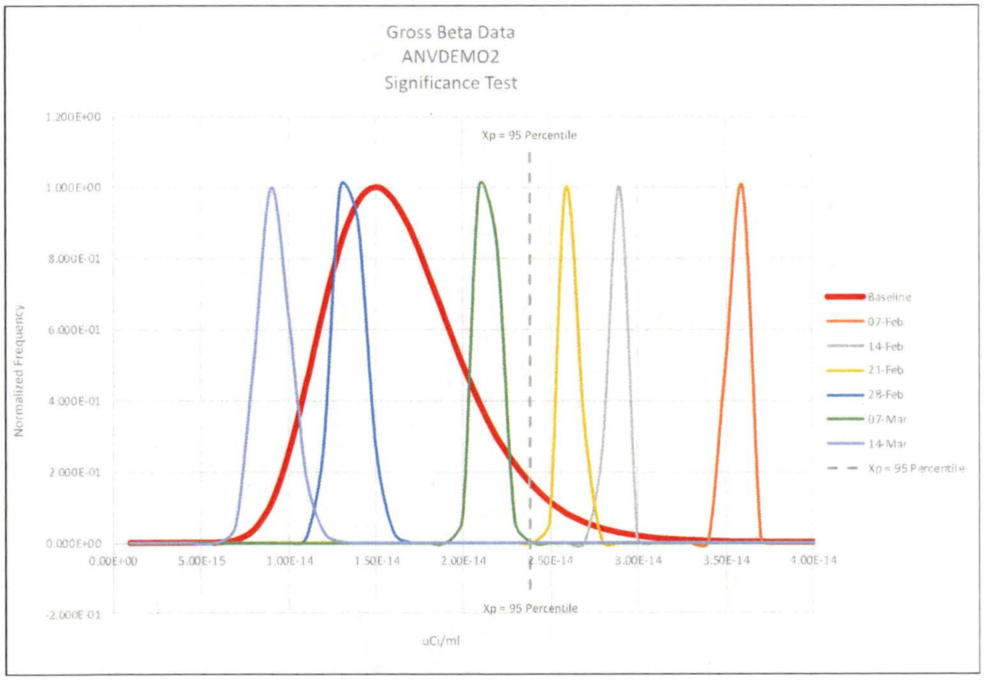


Figure 60: ANVDEMO2 beta PDF

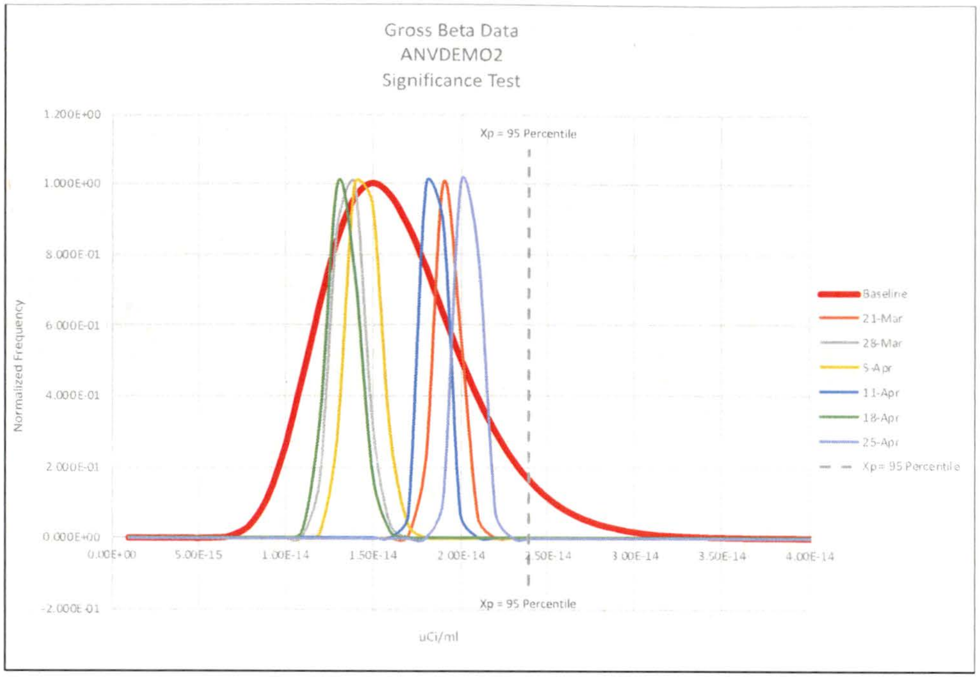


Figure 61: ANVDEMO2 beta PDF

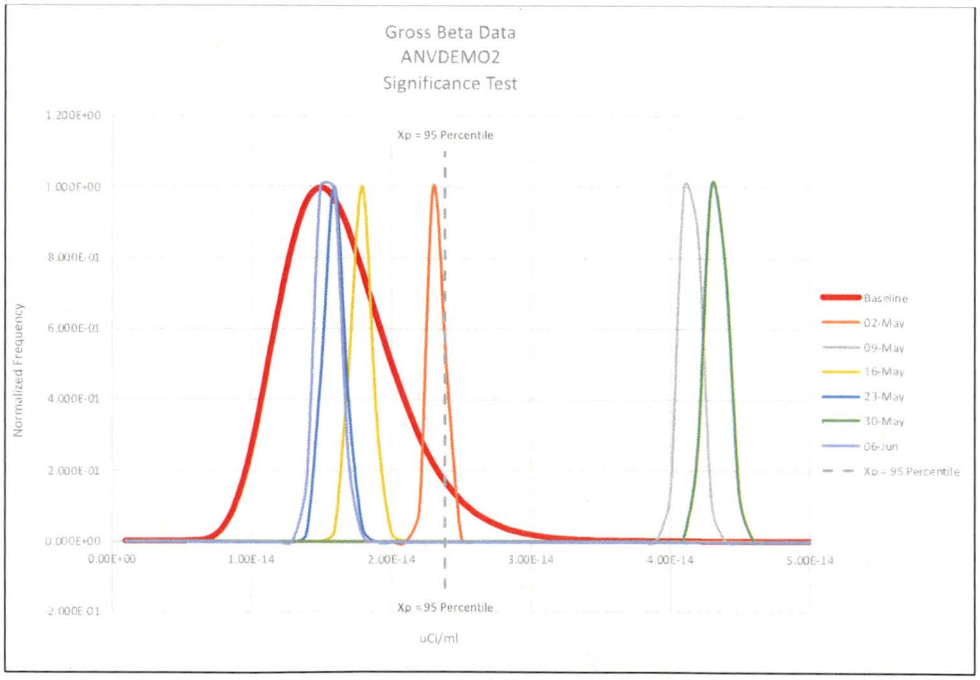


Figure 62: ANVDEMO2 beta PDF

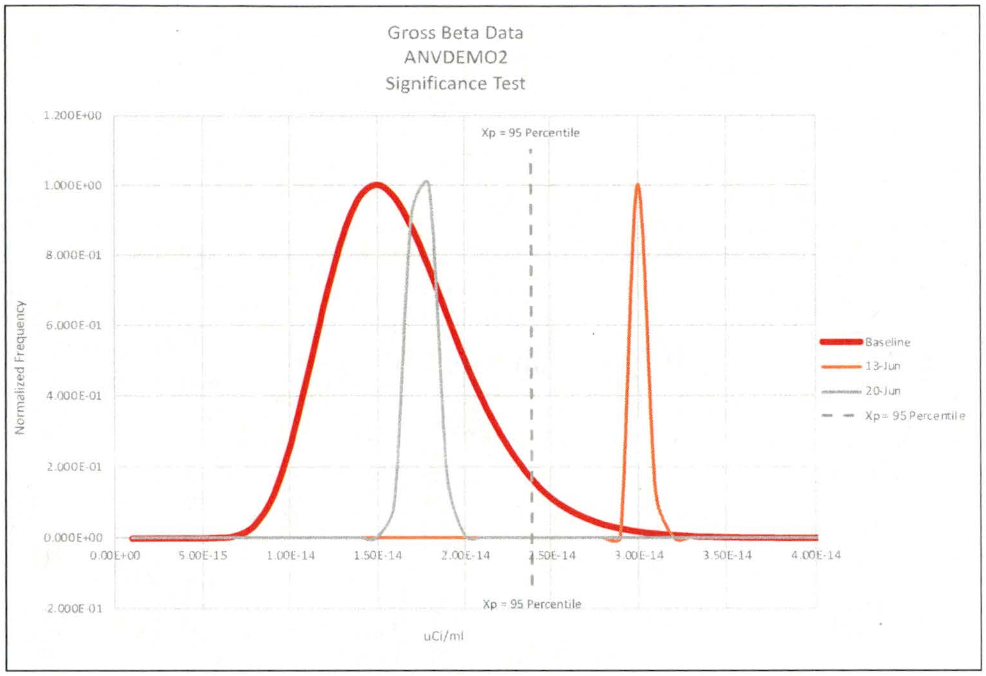


Figure 63: ANVDEMO2 beta PDF

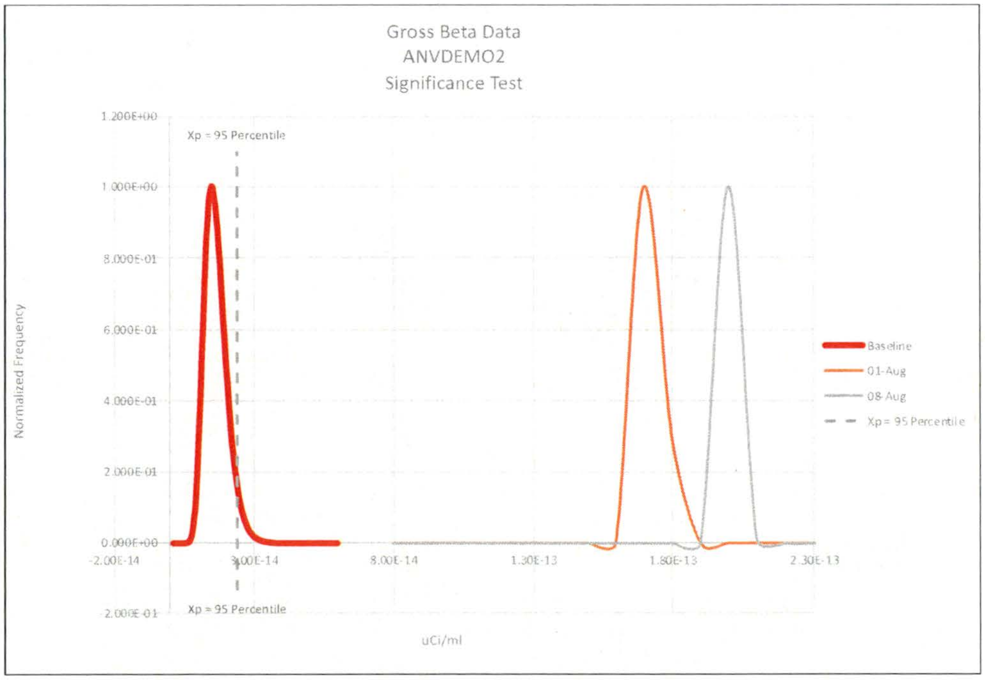


Figure 64: ANVDEMO2 beta PDF

Appendix E

Test Plan for Study of Air Emissions, Rev D

BLUNT CONSULTING LLC

Doc. ID Number	BC-RP-0112
Revision Number	D

Test Plan for Study of Air Emissions
from the
Demolition of the Vitrification Facility
at
West Valley Demonstration Project
Compared to
Emissions Estimates using
Methodology for Radionuclide Source Term Calculations
for Air Emissions from Demolition Activities

Submitted to: West Valley Demonstration Project

Submitted by: Blunt Consulting, LLC
283 Heritage Rd
Williston, SC 29853

Revision History

Revision	Changes	Date
A	Issued for review	10/06/2016
B	Incorporate review comments	11/01/2016
C	Incorporate review comments	11/25/2016
D	Incorporate review comments	12/4/2016

Scope

The US Environmental Protection Agency (EPA) granted the West Valley Demonstration Project (WVDP) approval to use *"Methodology for Radionuclide Source Term Calculations for Air Emissions from Demolition Activities, Rev. 0", authored by B. C. Blunt and submitted to EPA on January 25, 2016,* as an alternative method for calculating emissions from the demolition of the Vitrification facility. The approved method can be used in lieu of 40 CFR 61 Appendix D, however, before the alternative calculation method can be used for other demolition actions, a study must be conducted to validate that the method does not significantly underestimate emissions[1]. This document provides an outline of the actions to be taken and/or considered for completion of this study.

The study will compare results of ambient monitoring conducted during demolition of the Vitrification Facility (VF) to predicted values using a source term derived with the approved alternative method. The Material at Risk (MAR), based on actual measured radiological conditions at the time of demolition, will be used as the input to the approved alternative method to establish a source term. A modeling analysis will compare atmospheric concentration sampling results measured during demolition with modeling results based on this source term and the actual meteorological conditions measured during demolition. EPA's AERMOD software will be used for the modeling analysis. Baseline sampling is being conducted prior to the start of demolition. A statistical approach will be used to determine if sampling results are significant; i.e. are the results at the sample locations for that sample due to demolition activities or are they near baseline values.

This test plan has been prepared to meet the intent of the EPA document EPA/240/B-06/001 (EPA QA/G-4) with regard to the use of the Data Quality Objectives (DQO) process.

[1] 40CFR61.93(d) Allows for emissions to be estimated by approved alternative methods that do not significantly underestimate emissions.

Introduction

The WVDP, shown in Figure 1, has several large structures that will influence the local atmospheric dispersion. These structures have the potential to affect dispersion and deposition patterns through various meteorological phenomena, including building wake effects.

Figure 1: WVDP Plant

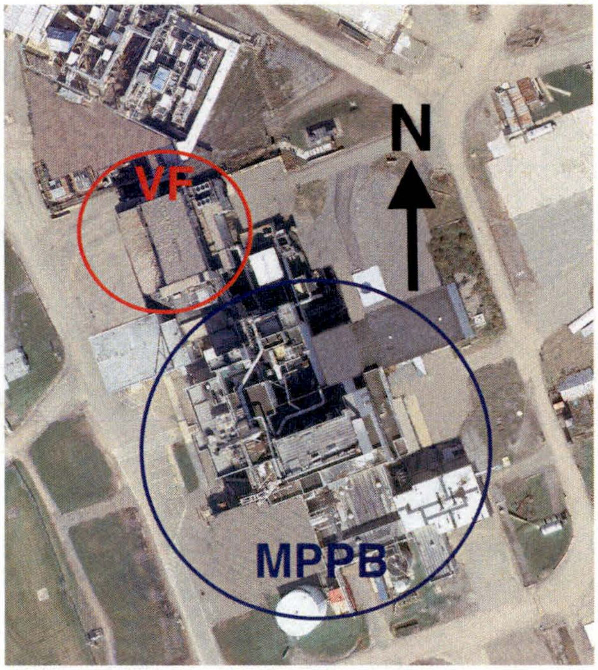


Figure 2:VF location relative to the MPPB

In the case of the VF, located on the north end of the Main Plant Processing Buildings (MPPB) (see Figure 2), wake affects will be primarily due to the main plant buildings. By using the EPA Building Profile Input Program (BPIP) along with AERMOD, the building wake affects can be predicted and accounted for in estimating the plume location of the ambient concentration at receptor locations.

A post-demolition modeling analysis will be conducted to compare during-demolition atmospheric concentration monitoring results with modeling results based on the actual radiological conditions in the spaces being demolished and meteorological conditions during the demolition activities. In order to make this comparison ambient monitors must be sited and operated both before and during demolition activities.

Location of Ambient Samplers

For this project, atmospheric dispersion calculations have been made using the AERMOD dispersion model developed by the EPA. AERMOD is the EPA's recommended dispersion model for regulatory applications; the model incorporates the latest understanding of atmospheric dispersion, and it explicitly accounts for building wake effects. The results from the AERMOD calculations are used to help plan demolition activities and can be used to predict the plume path. The demolition activities are expected to last close to a year, therefore annual average concentration profiles can be used to site ambient air samplers. Annualized isopleths of hypothetical plume concentrations based on site-specific meteorological data for 2008 through 2012 and the average using all 5 years are presented in Figure 3. It is apparent that the hypothetical plume pathway is very similar for all 5 years analyzed and would not be expected to change during demolition. To confirm that assumption, the wind

roses for the 10-meter level for 2008 through 2015 are presented in Figure 4. Note that the patterns of all the wind roses are similar, confirming the assumption that the wind pattern in near term future years will remain the same. The proposed locations of the on-site ambient air samplers are in the projected demolition plume path based on individual year meteorological data, a five-year average meteorological file and eight years of annual wind rose plots.

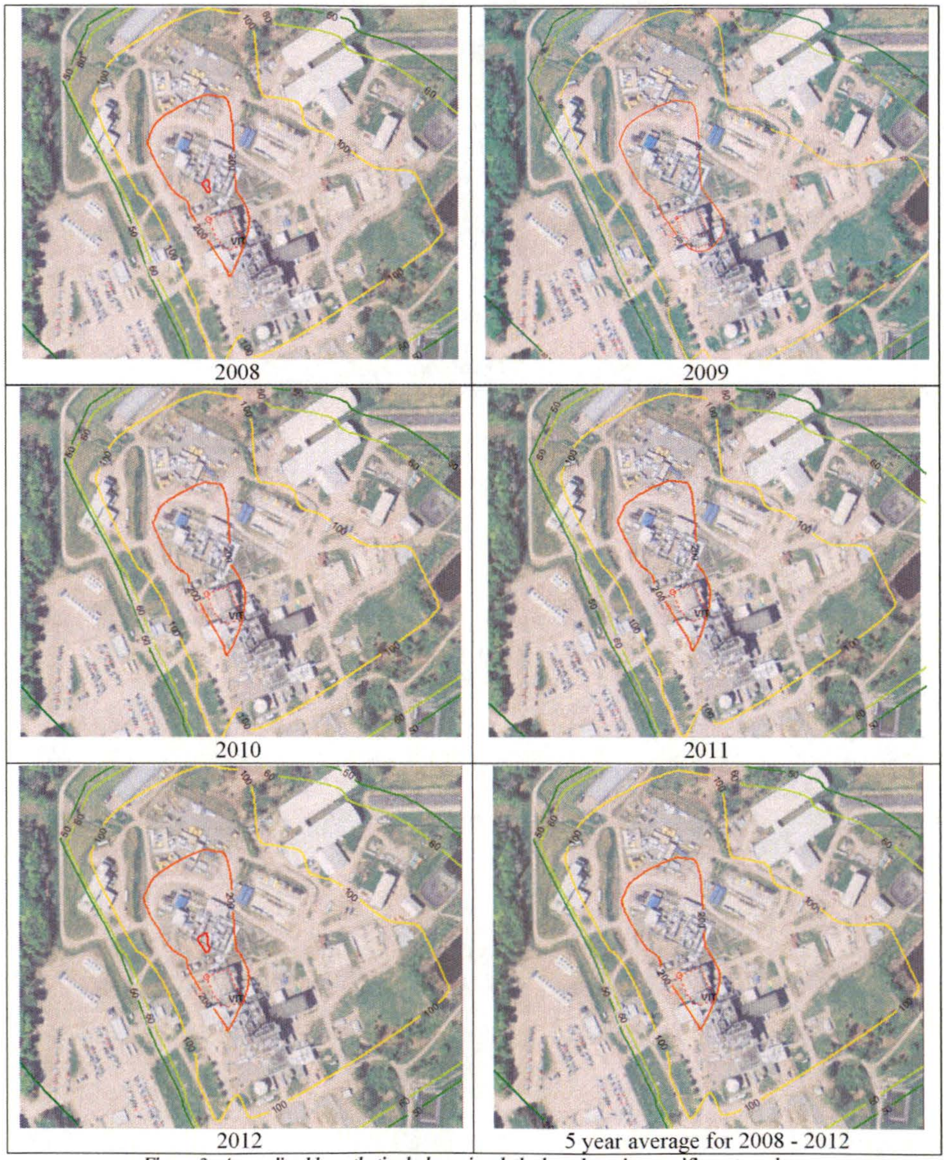


Figure 3: Annualized hypothetical plume isopleths based on site-specific meteorology

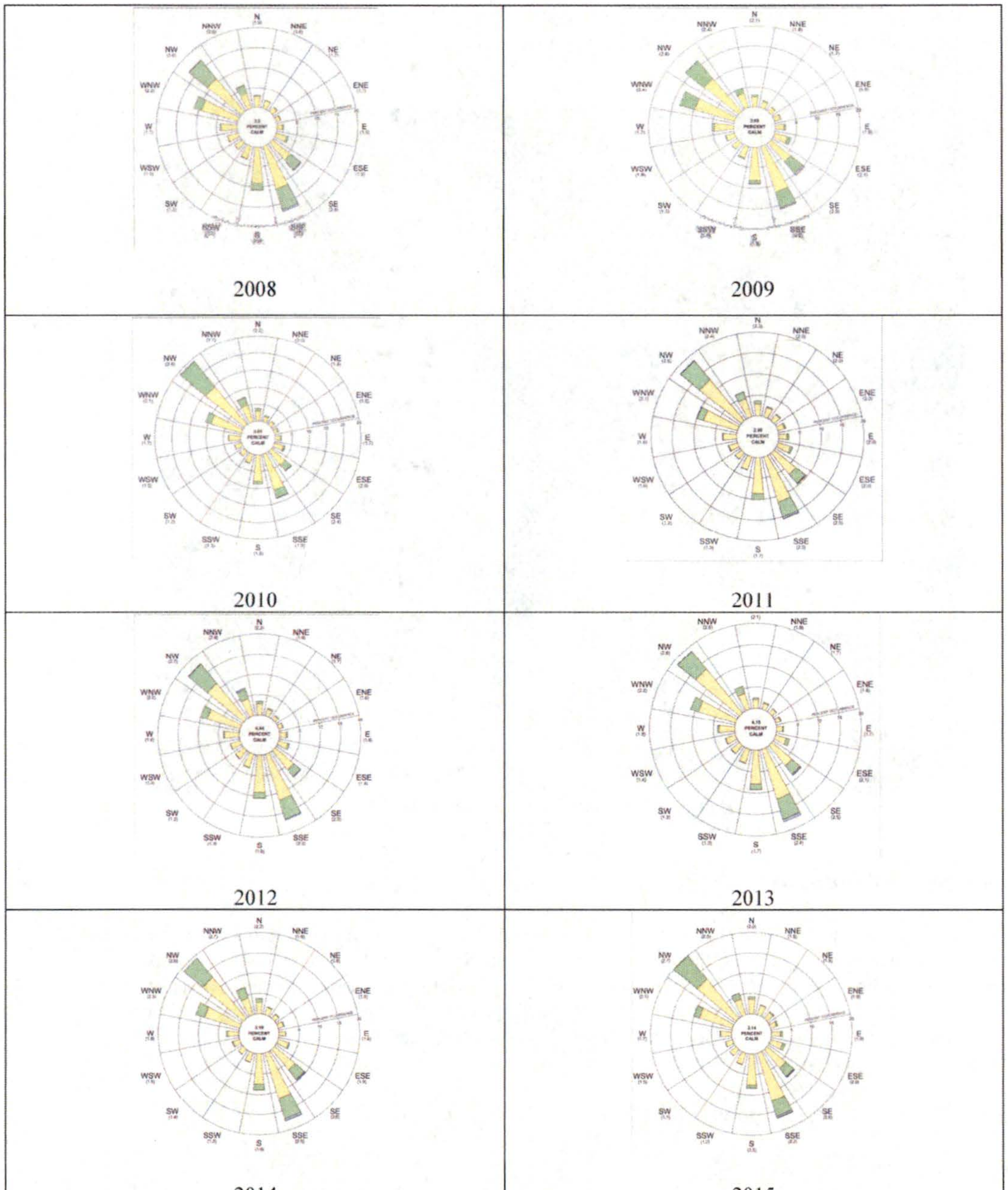


Figure 4: 10-meter annual wind rose plots

Based on the isopleths for a hypothetical plume for calendar years 2008-2012, proposed ambient air sampler locations are presented below in Figure 5. Two low-volume air samplers have been placed on both sides of the annualized plume pathway.

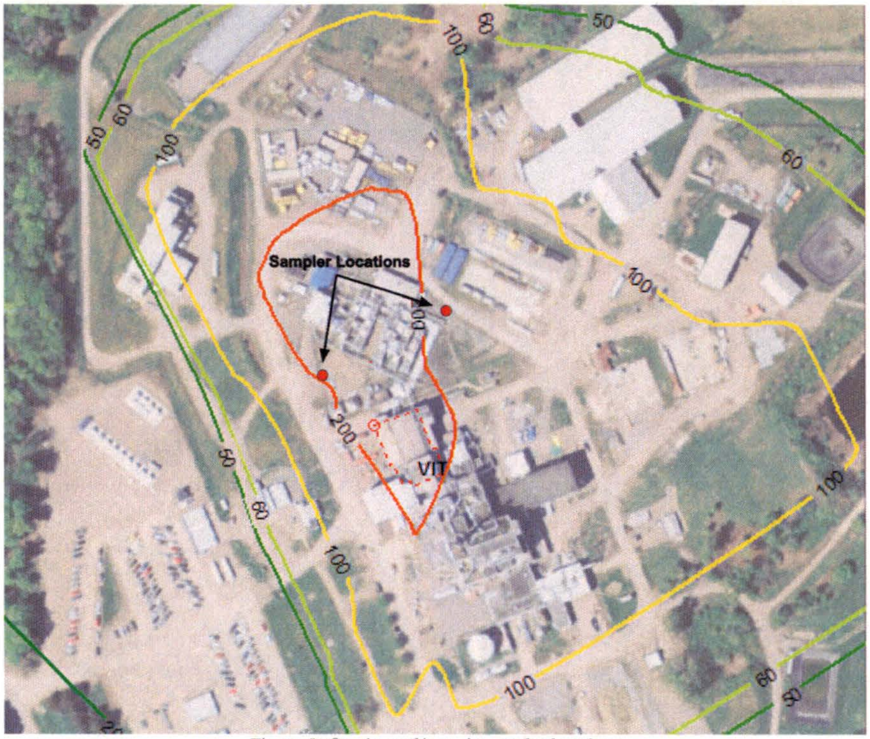


Figure 5: On-site ambient air sampler locations

Sampling and Testing Protocols

Two low-volume ambient air samplers operating at approximately 80 liters per minute are being used to collect weekly baseline samples before demolition activities begin. Samples will continue to be collected at these same locations during VF demolition, for at least 6-months. As previously discussed, the samplers have been located based on the projected plume pathways expected during demolition. Meteorological data will need to be collected both during demolition and baseline sample collection. Data from the on-site meteorological tower will be used for both phases of the study.

Analytical data will be collected on a per filter basis for the following analytes:

- Total particulate matter
- Gross alpha concentration
- Gross beta concentration
- Cs-137 concentration

Analysis will be performed at an on-site laboratory using established procedures. For Cs-137, a high-resolution gamma-spec system will be used, which would allow discrimination between radionuclides that are naturally occurring and contribute to positive alpha/beta activity, and those only of site origin (i.e., Cs-137). It is anticipated that the Cs-137 detection limit would be approximately 5 E-15 µCi/ml. Using an estimated demolition release of 5E-3 Ci over the entire demolition period and a demolition period of 2000 hours, the estimated average air concentration using AERMOD at the sampler location is approximately 1E-13 µCi/ml.

For gross alpha/beta determinations, a low-background counter will be used. In all cases, radiological analysis will be carried out using calibrated instruments verified periodically to be in control. Total particulate matter determinations will be carried out on the same filter used for the radionuclide determinations. Quality control practices such as filter observation, proper handling, equilibration prior to weighing, and using a calibrated analytical balance will follow EPA methodology. An appropriate number and type of quality control samples will be analyzed.

Evaluation Methodology

The objective of the post-demolition modeling is to validate that the alternative method does not significantly under estimate emissions. This will be accomplished by observing how well plume concentration in the sampling data are replicated by air dispersion modeling using the actual meteorological conditions. It is currently planned for the air dispersion modeling to be performed assuming a constant unit release rate spread out spatially over the assumed emission areas and temporally over each of the 1-week sampling periods.

After accounting for background, the results due to demolition can be deemed statistically significant using a method similar to that presented by Strom, et.al.[2] to produce a probability distribution function (PDF) of possibly true results. Statistical variances observed in environmental sampling results arise from a combination of measurement uncertainty and population variability. The method presented by Strom provides a technique to disaggregate measurement uncertainty from population variability. This technique makes the following assumptions:

- The measurements are unbiased. They are used as reported by the analytical laboratory.
- The measurement uncertainties are normally distributed
- The measurements are independent
- The measurements are lognormally distributed.

In this case the population is the group or set of sampler filters, and the measured value can be represented as

$$x_i = t_i + e_i$$

where

x_i = measured or reported value
t_i = true value
e_i = measured or observable error.

Assuming that all values are independent, then using traditional methods the variance of the measured values is

[2] Strom DJ, K Joyce, J MacLellan, DJ Watson, T Lynch, C Antonio, A Birchall, and P Zhaov, 2012. "Disaggregating Measurement Uncertainty from Population Variability and Bayesian Treatment of Uncensored Results." Radiation Protection Dosimetry, 149(3):251-267

found as

$$S_m^2 = \frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2$$

where

S_m^2	=	variance of the set or group of measured values
N	=	number of measurements
$\bar{x}$	=	sample mean, which is defined as:

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i$$

where

x_i	=	an individual measurement or sample result

For this study, the variance of the set or group of measured values is comprised of two components:

- the variability among the population, and
- the variability due to measurement uncertainty.

The expected value of the sample variance, $E(S_m^2)$, is represented by

$$E(S_m^2) = \sigma^2 + \frac{1}{N}\sum_{i=1}^{N} u_i^2$$

where

σ^2	=	variance within the population
u_i^2	=	standard uncertainty (measurement variance squared)

The variance within the population can be found by rearrangement,

$$\sigma^2 = S_m^2 - \frac{1}{N}\sum_{i=1}^{N} u_i^2$$

The mean and the standard deviation of the lognormal distribution can be calculated as follows:

$$\mu_{ln} = ln(\bar{x}_{ln}) - \left(\sigma_{ln}^2/_2\right)$$

and

$$\sigma_{ln} = \sqrt{ln\left(1 + \sigma^2/_{\bar{x}^2}\right)}$$

Once the data are disaggregated, a plot of the lognormal probability density function (PDF) for a sample compared to the lognormal PDF of the baseline will provide the tool needed to establish if a sample is significant; i.e. does it represent demolition emissions. The lognormal PDF, *P(x),* is given by

$$P(x) = \frac{1}{x\sigma_{ln}\sqrt{2\pi}} \, exp\left[-0.5\left(\frac{ln(x) - \mu_{ln}}{\sigma_{ln}}\right)^2\right]$$

and can be calculated using the excel® function "LOGNORMAL.DIST".

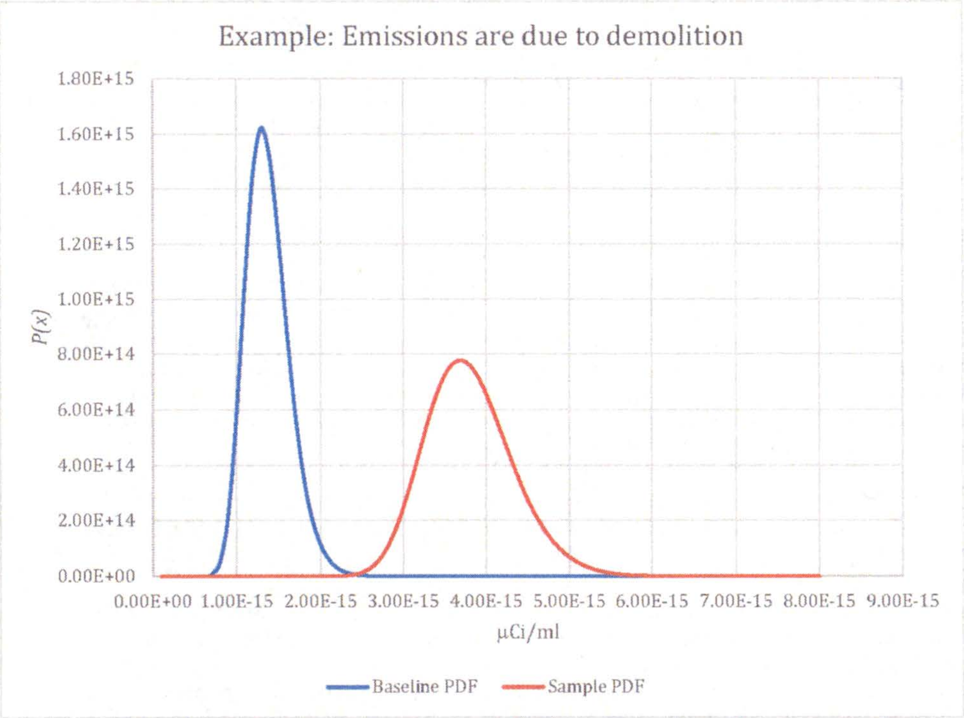


Figure 6:Example showing a case where sample PDF is separate and distinct from the baseline PDF

To demonstrate the technique, Figure 6 presents a PDF plot of example baseline emissions prior to demolition activities and an example sample that was collected during demolition activities. The mean value of the baseline data is 1.4E-15 µCi/ml and the sample result is 3.8E-15 µCi/ml, which is not much greater than the baseline values. The standard deviations are 2.6E-16 µCi/ml and 5.3E-16 µCi/ml for the baseline and sample, respectively. The PDF for the sample is clearly outside the baseline PDF. The results for the sample would be due to demolition activities.

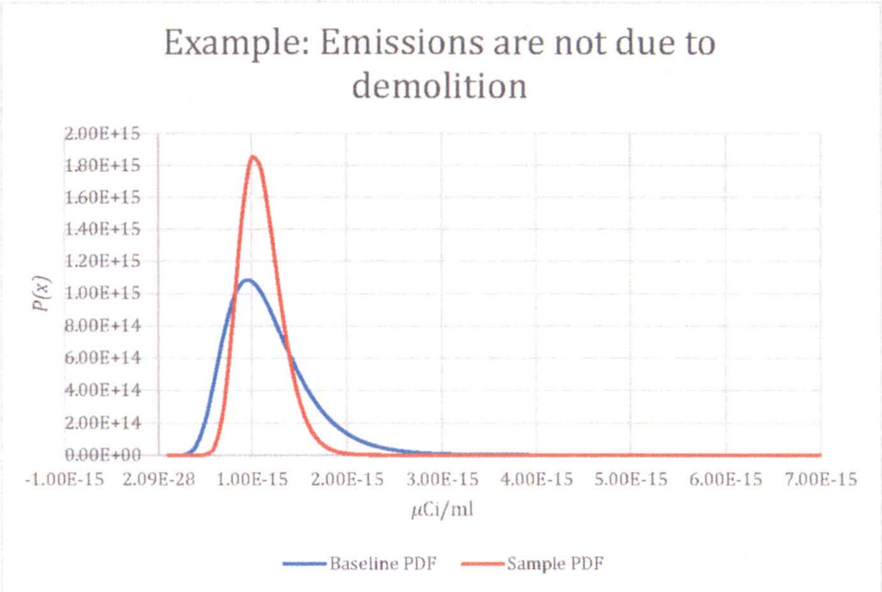


Figure 7: Sample PDF overlaps the baseline PDF

In contrast, Figure 7 presents a sample PDF that clearly overlaps and is within the baseline PDF. The mean value of the baseline data is 1.2E-15 μCi/ml and the sample result is 1.1E-15 μCi/ml. The standard deviations are 4.3E-16 μCi/ml and 2.2E-16 μCi/ml for the baseline and sample, respectively. In this case, the probability is that this sample is representative of the baseline data and not of demolition activities. Such a result might indicate that the emissions from the demolition activities are not contributing to the baseline concentrations. In this case, should the alternative method indicate that emissions at the sample location would be statistically significant, then the alternative method is overestimating emissions.

The predicted results from air dispersion modelling using a source term calculated with the alternative method as input to the AERMOD software, can then be compared to the measured results from the on-site ambient air samplers. There are three potential results for this comparison:

1) The results from the on-site samplers are consistently below the predicted results from AERMOD. In this case the alternative method over estimates emissions, is conservative, is validated, and can be used for future demolition actions.
2) The results from the on-site samplers are statistically significant and track well with the predicted results from AERMOD. In this case the alternative method is validated, and can be used for future demolition actions.
3) The results from the on-site samplers are statistically significant and are greater than the predicted result from AERMOD. In this case the alternative method requires modification and will require that EPA provide additional approvals before use with other demolition actions.

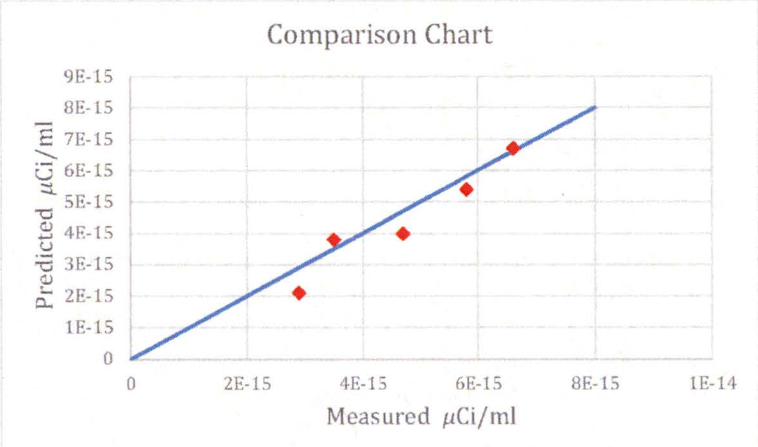


Figure 8: Comparison of measured to AERMOD predicted concentrations

A chart similar to Figure 8 will be used to compare the results of the on-site ambient air samples with the predicted values using AERMOD. The example given in Figure 8 shows that the measured values are slightly less than the predicted values for three of the five points, the point at the highest value is nearly perfect and one point slightly under estimated measured emissions. Radiological conditions from the areas processed in the demolition actions will be used to develop a source term with the alternative method. This source term and the local actual meteorological conditions will be input into AERMOD to predict ambient air concentrations per each filter collected.

Evaluation of the data will begin with each filter collected. Adjustments in the study will be made as needed to produce the best possible comparison data. Adjustments might include, but are not limited to:

- Moving the sampler to another location
- Changing the length of sample time
- Changing the sampler flow rate
- Changing the analytical parameters

Collection of Demolition Data

Since the source term for the AERMOD runs will be based on the estimated Material at Risk (MAR) that was affected by the demolition activity, a log of demolition activities will be required. The following information shall be documented on a weekly basis that corresponds with the collection of the sampler filters. Maintenance of a daily log will allow any anomalous results to be more accurately evaluated.

- Demolition activities
    - Section of building demolished
        - Method used for the demolition
        - Date and times of demolition
        - Estimated mass demolished

- Any emission controls used (e.g. wetting, hutting, wind screens, etc)
- Rubble Pile handling
  - Quantity of material processed per day
  - Any emission control methods deployed by day
- Load Out
  - Quantity of material loaded into containers.

Quality Assurance

The structuring of this study utilized the guidance contained in "Guidance on Systematic Planning Using the Data Quality Objectives Process," EPA/240/B-06/001 (EPA QA/G-4), February 2006. The elements in Table 1 of this document have all been incorporated in the Study effort. Each is briefly discussed below.

Organization: This document has been reviewed and approved by the management team at WVDP. As such, they have dedicated the organization and resources needed to conduct the Study.

Project Goal: The goal of the study is contained in the Scope section of this document.

Schedule: Baseline sampling began in early October 2016. The sampler locations will remain throughout the demolition of the VF as needed to complete scope of the Study. The schedule for the study is as follows:

a. 10/16 – Begin baseline sampling
b. Begin VF Demolition – Samplers continue to sample and filters are collected weekly
c. Approximately 6-months after beginning demolition of VF – Prepare a draft report that documents the data and provides recommendations for the alternative method
d. 3-months after completing draft report, issue final report and a revised alternative method if needed.

Data needs: The data needs are contained in this Test Plan.

Criteria: Samples will be collected based on established procedures. Analysis of samples will be per established WVDP procedures.

Data Collection: Samples will be collected weekly at the two designated on-site ambient air sampling locations. To develop a baseline concentration, samples are being collected prior to demolitions. Sampling will continue at the same locations and with the same sampling methods as is currently being done for the baseline data.

Quality Assurance: The established WVDP Quality Assurance Program will be applied to the Study.

Analysis: Data evaluation methods have been provided in this Test Plan.

This study will be conducted using the Quality Assurance program in place at the WVDP. The basic program, as it applies to this study is contained in existing, well documented and tested procedures, which are

- WVDP-098, *Environmental Monitoring Program Plan*
- WVDP-117, *CHBWV Policies and Procedure Manual*
- WVDP-130, *Quality Procedures Manual*
- WVDP-209 and 214, *Environmental Monitoring Procedures Manuals*
- WVDP-504, *Quality Assurance Project Plan (QAPP) for Environmental Measurements*

Appendix F

Alternative Method, Revision 1

BC-RP-0124, Rev 1
09/10/18

Methodology for Radionuclide Source Term Calculations for Air Emissions from Demolition Activities

Prepared by: ____________ **Date:** 09/10/18

B.C. Blunt

Reviewed by: ____________ **Date:** 09/10/18

J.R. Fox

Table of Contents

Glossary

AED	aerodynamic equivalent diameter
ARF	airborne release fraction
CF	Control Factor
Ci	Curie
cm	centimeter
DOE	Department of Energy
DR	Damage ratio
EF	Emission factor
EPA	Environmental Protection Agency
ER	Emission Reduction
I	Inventory
Kg	kilogram
lb	pounds
LPF	Leak path factor
m	meter
m/s	meters per second
MAR	Material-at-risk
PS	Physical State
RF	Respirable fraction
ST	Source Term
UDCF	Unit dose conversion factors
WVDP	West Valley Demonstration Project
μm	Micrometer

Purpose

This calculation estimates the emissions of radionuclides from the Demolition activities. The calculation includes emissions due to physical demolition by various methods, moving debris to process piles, processing the piles and loading the rubble from the piles into sealed packages (containers).

Background

Demolition of facilities can involve several activities such as

- the demolition of the main building,
- moving debris and rubble from the demolition area to a processing area,
- sorting and processing of the debris and rubble, and
- loading the debris and rubble into containers for storage.

Each of these activities is analyzed in this document.

Methodology Description

When demolition of the main building is undertaken, the physical demolition can involve equipment such as mechanical shears, saws, hydraulic hammers, and other means that are appropriate for the type of structure. This document analyzes those physical demolition activities that might be used at the West Valley Demonstration Project (WVDP).

Once the building or portions of the building are demolished, the debris or rubble is often moved to a processing area where the debris or rubble is size reduced and sorted. Finally the sorted debris or rubble is loaded into containers that are generally sealed. Radionuclides contained in a sealed container or package are not included in the building inventory for purposes of estimating emissions.

In general, misting, watering, and fixatives are used throughout the demolition and load-out processes to minimize airborne contamination spread. Other methods that minimize emissions, and which are implemented on a case-by-case basis, are the use of windscreens or limiting demolition and load-out activities to times when the wind speed is below an acceptable limit. For example, at the Hanford Site, the air operating permit [Hanford 2013] limits soil excavation activities to times when sustainable wind speed are less than 20 mph (8.8 m/s). At the WVDP, such limitations will be specified in work documents per industry practices.

Each step in the process will be evaluated separately in the following discussions.

Demolition Methods

DOE facilities typically estimate airborne source terms using the following five-component linear equation [DOE 1994]:

$$ST = MAR \times DR \times ARF \times RF \times LPF \qquad \textit{Equation 1}$$

where: ST = Source Term	=	the total quantity of respirable material released to the atmosphere during the demolition
MAR = Material-at-risk	=	the total quantity of radionuclide - in pounds (lb.) or curies (Ci) of activity for each radionuclide - available to be acted on by a given physical stress
DR = Damage ratio	=	the fraction of the MAR actually impacted by the demolition conditions
ARF = Airborne release fraction	=	the fraction of a radioactive material suspended in air as an aerosol and thus available for transport due to a physical stress from a specific activity
RF = Respirable fraction	=	the fraction of airborne radionuclides as particles that can be transported through air and inhaled into the human respiratory system and is commonly assumed to include particles 10-μm aerodynamic equivalent diameter (AED) and less. When RF = 1, all the particulate material is included in the calculation, and not just the respirable portion.
LPF = Leak path factor	=	the fraction of the radionuclides in the aerosol transported through some confinement deposition system.

In AP-42, *Compilation of Air Pollutant Emission Factors* [EPA 1995], airborne emissions or the source term is determined with Equation 2.

$$E = A \times EF \times \left(1 - {ER}/{100}\right) \qquad \textit{Equation 2}$$

where: E = Estimated emissions	=	the total quantity of material released to the atmosphere during the demolition
A = Activity Rate	=	the total quantity of radionuclides (in grams or curies of activity for each radionuclide) available to be acted on by a given physical stress
EF = Emission factor	=	relates the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant, in this case radionuclide.
ER = Emission Reduction	=	the percent reduction of the pollutant due to some type of effluent control device or process.

Equation 2 is a form of Equation 1 where

E = ST

A = MAR

EF = DR x ARF x RF

(1-ER/100) = LPF

A similar comparison can be made between Equation 1 and the emissions estimation method described in Appendix D to 40 CFR Part 61 [EPA 1989b], here after called the Appendix D method. The Appendix D method can be described mathematically as Equation 3

$$E_D = I \times PS \times CF \qquad \textit{Equation 3}$$

where:

E_D = Estimated emissions	=	the total quantity of material released to the atmosphere during the demolition
I = Inventory	=	the total quantity of radionuclides (in grams or curies of activity for each radionuclide) available to be acted on by a given physical stress.
PS = Physical State Factor	=	relates the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant, in this case radionuclide.
CF = Control Factor	=	the fraction of the radionuclides in the aerosol transported through some confinement deposition system.

Equation 3 is a form of Equation 1 where

E_D = ST

I = MAR

PS = DR x ARF x RF

CF = LPF

The Appendix D method was developed by the US Environmental Protection Agency (EPA) based on emission estimates from various processes typical of that time [EPA 1989a]. However, none of these processes involved demolition activities. The primary factor that is often missing when performing the Appendix D method is a control factor for the effluent controls used at Department of Energy (DOE) facilities. This is the case for demolition processes, i.e., there are no control methods listed in Appendix D that are used in demolition operations. In addition, the demolition techniques used can have varying degrees of impact on the facility, resulting in varying sizes of debris and rubble and varying degrees of aerosol creation. By using the more detailed Equation 1 the estimated emissions from the various demolition techniques can be

refined and described mathematically. This calculation method is a mechanistic approach, much like AP-42, to calculation of radionuclide emissions from demolition activities.

Emission factors for several demolition techniques are derived in the following sections.

Demolition with Mechanical Shears

Shears are two-bladed cutters acting as scissors. They are generally pneumatically or hydraulically operated. Mechanical shears are often used during demolition to perform "Cut; Shear; Break; Drop" operations. The "Cut; Shear; Break; Drop" approach can generally be described as cutting or shearing, breaking and dropping the building pieces to the ground within the controlled/regulated work area (drop zone). "Drop" would generally be "to lower carefully" based on strict procedural controls and conduct of operations.

Emissions using this demolition technique are estimated using an emission factor developed for similar activities by the Pacific Northwest National Laboratory (PNNL). PNNL has been involved in estimating and verifying the emissions from demolition of several building at the Hanford site. One such demolition was the 224-U and 224-UA Buildings on the Hanford site [Napier 2009]. PNNL used an emission factor of 5.00E-05 lb. released per lb. of material demolished or in terms of radioactive contamination the units would be Ci released per Ci processed in the demolition. This emission factor accounts for the fugitive emissions resulting from demolition using mechanical shears when water misting is used as a control mechanism. After completion of the demolition, PNNL evaluated the emission estimates for this project against ambient monitoring conducted during the demolition and found that the calculated predicted emissions were similar to that measured on the ambient systems. Of note is the fact that most measured ambient emissions were at or below detection limits during demolition. [Napier 2010]. The following discussion describes how PNNL developed each term, with the exception of the MAR, in Equation 1.

Damage Ratio (DR)

When mechanical shears are used to demolish the buildings, it is assumed that the MAR is evenly distributed over the entire contaminated area being worked on (wall segment, floor area, etc.). The DR is that portion or percentage of the contaminated area acted on by the shear force. Jaws are assumed to fracture, crush, spall, or otherwise impact the surface being sheared. For a concrete block and reinforced concrete construction, the equipment is assumed to reduce essentially the entire portion of wall or floor being worked on to small pieces. For metal structures, including pipes and ventilation ducts, large portions of the metal remain intact and not converted to particle sizes that could be airborne easily. For this analysis, half of the surfaces are assumed to be rubblized and will remain too large to become airborne during demolition operations. Napier [Napier 2009] uses a DR of 0.5 for the demolition of the 224-U and 224-UA buildings at the Hanford site. As noted by Napier, this value is greater than that used for the Hanford Site 232-Z Building which was based on pulling down a block wall, and slightly smaller than that used for the analysis of the reinforced concrete walls of the Hanford Site 233-S Building.

Airborne Release Fraction (ARF)

For demolition of walls and floors, DOE's factors for impaction stress due to vibration shock were selected as the most representative release fractions for the crushing processes; the factor selected was 0.001 for removable contaminants [DOE 1994[1]]. EPA's [EPA 1995] compilation of airborne release fractions includes a range of uncontrolled release fractions for crushing of ores and rocks that range from 0.012 to 6 pounds per ton of ore, which relates to an ARF of 6E-06 to 3E-03 lbs. released per lb. of ores or rocks processed (in radiological terms, Ci released per Ci processed). As these ranges overlap, thus supporting the selection of the DOE values.

Respirable Fraction (RF)

The RF is the fraction of airborne radionuclides as particles that can be transported through air and inhaled into the human respiratory system and is commonly assumed to include particles 10-micrometer (μm) Aerodynamic Equivalent Diameter (AED) and less. For this analysis, more than the respirable fraction is involved. Therefore, as a conservative measure, the RF is set to 1 in all cases. This practice effectively assumes all particulate mater is released with no reduction based on size.

Leak Path Factor (LPF)

The LPF is the fraction of the radionuclides in the aerosol transported through some confinement deposition or filtration mechanism. For the purpose of this calculation method, the LPF is used to address any controls applied during and after the demolition process. This includes the effects of water mists, sprays, and fixatives applied to surfaces and rubble after demolition. The application of a water mist to contaminated surfaces during demolition serves to reduce the percentage of airborne particulates in the respirable size range. The efficiency of the mist varies with each application and depends on, among other variables, mist particle size, water flow rate, and the size of potential airborne particles. OSHA [OSHA 2009] cites several case studies where misting during grinding and while using vehicle-mounted rock drilling rigs resulted in a 90% decrease in dust generation. EPA [1995[2] and 2004[3]] also lists watering as an effective dust control measure. Both references stated that up to a 90% reduction in emissions can be achieved by wetting of rubble piles.

For the purpose of this calculation, the water-mist application is assumed to reduce the quantity of airborne particulates by 90%, which results in a LPF of 0.1. The efficiency of the water-mist process must be weighed in light of the generated waste stream and the need to confine and capture runoff from the misting process. Thus, the LPF for concrete crushing is assumed to be 0.1. As noted by Napier [Napier 2009] this value is slightly lower than that used for the Hanford Site 233-S Building (0.3), based on observations of the effectiveness of the misting on that facility and during demolition of the Hanford Site 232-Z building. As previously discussed, the emissions when using this factor and the other factors discussed above for demolition with mechanical shears has been validated with ambient air sampling [Napier 2010].

[1] Section 4.4.3.3.1
[2] Section 13.2.4
[3] Section 4.3

Emission Estimation Equation

By substituting the above factors into Equation 1 the emissions when using mechanical shears for "Cut; Shear; Break; Drop" demolition operations are found. The final equation is presented below:

$$ST = MAR \times DR \times ARF \times RF \times LPF$$

$$ST = MAR \times 0.5 \times 0.001 \times 1 \times 0.1$$

$$ST = MAR \times 5.00\text{E-}05 \qquad \textit{Equation 4}$$

Demolition with a Hydraulic Hammer

A hydraulic hammer may be used to demolish structures constructed of non-reinforced or lightly reinforced concrete. The equipment generally consists of a hydraulically or pneumatically driven chisel or hammer.

The following discussion describes the development of each term, with the exception of the MAR, in Equation 1 for this demolition operation. Based on the validation study [Blunt 2018], the emissions from hydraulic hammering are less than originally expected. Changes to the Damage Ratio and the Airborne Release Fraction are based on the validation data.

Damage Ratio (DR)

When a hydraulic hammer is used to demolish buildings, it is assumed that the MAR is evenly distributed over the entire contaminated area being worked on (wall segment, floor area, etc.). The DR is that portion or percentage of the contaminated area acted on by the hammer or chisel force. In the case of the hydraulic hammer, the momentum, resulting energy imparted on the structure, and impact and vibration forces act on the entire structure being worked. Originally, the DR for this operation was set to 1.0. However, not all of the material volume is actually affected by the hammering. For this analysis and based on the validation data [Blunt 2018] a DR of 0.1 will be assigned to hydraulic hammering.

Airborne Release Fraction (ARF)

The hydraulic hammer can be used on both vertical and horizontal surfaces. Emission factors for both operations are evaluated separately and then the most conservative factor is used. This approach allows the equipment operator the flexibility to operate as needed and still be bounded by the emissions calculations.

The DOE's factors for large falling object impact were selected for this operation on horizontal surfaces [DOE 1994[4]]. The highest measured ARF was 1E-03, while the "median" value for all experimental configurations is 4E-04. Although DOE states that the data may not be bounding

[4] Section 4.4.3.3.2

and suggests as a conservative measure that a bounding value of 1E-02 be used for the ARF, based on the validation study [Blunt 2018], the ARF is set to 1E-03 for this operation.

When operating on a vertical surface the emissions from this action are due to Impact Stress. DOE's factors for Impact Stress on surface contamination were selected for this operation [DOE 1994[5]]. The bounding ARF is given as 1E-03.

Based on the validation study [Blunt 2018] the bounding ARF of 1E-03 is appropriate for this operation.

Respirable Fraction (RF)

The RF is the fraction of airborne radionuclides as particles that can be transported through air and inhaled into the human respiratory system and is commonly assumed to include particles 10-μm Aerodynamic Equivalent Diameter (AED) and less. For this analysis, more than the respirable fraction is involved. Therefore, as a conservative measure, the RF is set to 1 in all cases. This practice effectively assumes all particulate matter is released with no reduction based on size.

Leak Path Factor (LPF)

The LPF is the fraction of the radionuclides in the aerosol transported through some confinement deposition or filtration mechanism. For the purpose of this calculation method, the LPF is used to address any controls applied during and after the demolition process. This includes the effects of water mists, sprays, and fixatives applied to surfaces and rubble after demolition. The application of a water mist to contaminated surfaces during demolition serves to reduce the percentage of airborne particulates in the respirable size range. The efficiency of the mist varies with each application and depends on, among other variables, mist particle size, water flow rate, and the size of potential airborne particles. OSHA [OSHA 2009] cites several case studies where misting during grinding and while using vehicle-mounted rock drilling rigs resulted in a 90% decrease in dust generation. EPA [1995[6] and 2004[7]] also lists watering as an effective dust control measure. Both references stated that up to a 90% reduction in emissions can be achieved by wetting of rubble piles.

For the purpose of this calculation, the water-mist application is assumed to reduce the quantity of airborne particulates by 90%. The LPF is then 0.1.

[5] Section 5.1 provides a summary of ARFs
[6] Section 13.2.4
[7] Section 4.3

Emission Estimation Equation

By substituting the above factors into Equation 1 the emissions when using a hydraulic hammer for demolition operations are found. The final equation is presented below:

$$ST = MAR \times DR \times ARF \times RF \times LPF$$

$$ST = MAR \times 0.1 \times 0.001 \times 1 \times 0.1$$

$$ST = MAR \times 1.0\text{E-}05 \qquad \textit{Equation 5}$$

Demolition with a Diamond Wire Saw

A diamond wire saw typically involves the pulling of a multi-strand wire threaded with diamonds through the material to be cut. The diamond wire is threaded through a hole drilled at the top and bottom of the structure and guided through it via a series of pulleys. The process itself eliminates vibrations, does not weaken surrounding structures, and produces very little dust or flying debris.

The following discussion describes the development of each term, with the exception of the MAR, in Equation 1 for this demolition operation.

Damage Ratio (DR)

The DR is that portion or percentage of the contaminated area acted on by the wire saw. The wire saw removes a kerf of material the length of the cut. The material removed is then found as "width of kerf" times the "length of cuts". Typically, a maximum of four cuts are required to produce a slab of material. The "length of cuts" would include all cuts needed to produce the slab. The damage ratio is then found by dividing the material removed by the area of the slab produced or

$$DR = \frac{(Length\ of\ cuts)(width\ of\ kerf)}{Area\ of\ slab}$$

For example:
Assume the kerf is 1.0 centimeter (cm) wide and the slab produced is 91.40 cm by 91.40 cm (3 feet by 3 feet). Also assume 4 cuts are required, and all of the same length. Then the DR is

$$DR = \frac{4(91.4\ cm)(1\ cm)}{(91.4\ cm)(91.4\ cm)} = 0.044$$

Airborne Release Fraction (ARF)

The wire saw airborne release fraction results from the suspension of the contaminated material in an aqueous solution, which becomes a slurry. DOE's factors for free falling spill of slurries was selected for this operation [DOE 1994[8]]. The bounding value of the ARF is 5E-05.

Respirable Fraction (RF)

The RF is the fraction of airborne radionuclides as particles that can be transported through air and inhaled into the human respiratory system and is commonly assumed to include particles 10-μm Aerodynamic Equivalent Diameter (AED) and less. For this analysis, more than the respirable fraction is involved. Therefore, as a conservative measure, the RF is set to 1 in all cases. This practice effectively assumes all particulate matter is released with no reduction based on size.

Leak Path Factor (LPF)

The LPF is the fraction of the radionuclides in the aerosol transported through some confinement deposition or filtration mechanism. There are generally no controls associated with this process. An LPF of 1.0 will be used for this calculation method.

Emission Estimation Equation

By substituting the above factors into Equation 1, and then rearranging, the emissions when using a diamond wire saw for demolition operations are found. The final equation is presented below:

$$ST = MAR \times DR \times ARF \times RF \times LPF$$

$$ST = MAR \times \frac{(Length\ of\ cuts)(width\ of\ kerf)}{Area\ of\ slab} \times 0.00005 \times 1 \times 1$$

$$ST = 5.0\text{E-}05 \times MAR \times \frac{(Length\ of\ cuts)(width\ of\ kerf)}{Area\ of\ slab} \qquad \textit{Equation 6}$$

Demolition with a Wall Saw

Wall and floor saws use circular diamond or carbide blades to cut a kerf in the material being cut. The blade is rotated by air or hydraulic motors. Floor saws, also called slab saws feature a blade that is mounted on a walk-behind machine. Wall saws, also called track saws, use a blade on a track-mounted machine. The dust produced by the cutting action is controlled using a water spray.

The following discussion describes the development of each term, with the exception of the MAR, in Equation 1 for this demolition operation.

[8] Section 3.2.3.2

Damage Ratio (DR)

The DR is that portion or percentage of the contaminated area acted on by the wall saw. The wall saw removes a kerf of material the length of the cut. The material removed is then found as "width of kerf" times the "length of cuts". Typically, a maximum of four cuts are required to produce a slab of material. The "length of cuts" would include all cuts needed to produce the slab. The damage ratio is then found by dividing the material removed by the area of the slab produced or

$$DR = \frac{(Length\ of\ cuts)(width\ of\ kerf)}{Area\ of\ slab}$$

For example:
Assume the kerf is 1.0 centimeter (cm) wide and the slab produced is 91.40 cm by 91.40 cm (3 feet by 3 feet). Also assume 4 cuts are required, and all of the same length. Then the DR is

$$DR = \frac{4(91.4\ cm)(1\ cm)}{(91.4\ cm)(91.4\ cm)} = 0.044$$

Airborne Release Fraction (ARF)

The wall saw airborne release fraction results from the suspension of both fixed and removable contaminate into air. DOE's factors for venting of pressurized gases over a solid were selected for this operation [DOE 1994[9]]. The bounding value of the ARF is 5E-03.

Respirable Fraction (RF)

The RF is the fraction of airborne radionuclides as particles that can be transported through air and inhaled into the human respiratory system and is commonly assumed to include particles 10-μm Aerodynamic Equivalent Diameter (AED) and less. For this analysis, more than the respirable fraction is involved. Therefore, as a conservative measure, the RF is set to 1 in all cases. This practice effectively assumes all particulate matter is released with no reduction based on size.

Leak Path Factor (LPF)

Although the dust produced by the saw is controlled with a water spray, the degree of control is unknown. Therefore, as a conservative measure, the LPF will be set to 1.0 for the technique.

Emission Estimation Equation

By substituting the above factors into Equation 1, and then rearranging, the emissions when using a wall saw for demolition operations are found. The final equation is presented below:

$$ST = MAR \times DR \times ARF \times RF \times LPF$$

[9] Section 5.3.2.3

$$ST = MAR \times \frac{(Length\ of\ cuts)(width\ of\ kerf)}{Area\ of\ slab} \times 0.005 \times 1 \times 1$$

$$ST = 5.0\text{E-}03 \times MAR \times \frac{(Length\ of\ cuts)(width\ of\ kerf)}{Area\ of\ slab} \qquad \textit{Equation 7}$$

Equipment with Internal Loose Contamination (Segmenting)

Facilities destined for demolition often contain large pieces of equipment that are too large to remove as a single item and have loose internal contamination. This equipment is decontaminated and de-inventoried to remove the majority of the internal contamination prior to demolition, however some contamination will be very difficult to remove and will remain after the decontamination process is complete.

The following discussion describes the development of each term, with the exception of the MAR, in Equation 1 for this demolition operation.

Damage Ratio (DR)

The demolition process for this type of equipment can fall into two categories, which are discussed below. A DR of 0.10 is selected for both cases.

1. The equipment is too large to handle with another process and requires that it be broken into smaller pieces, but not completely size reduced. Assuming that the equipment is decontaminated and de-inventoried prior to beginning the demolition, the material that remains will be the most difficult to remove. It is assumed that the process of breaking the equipment into smaller pieces will impact 10% of the remaining internal contamination.

2. A mechanical shear, or similar type equipment can be used to break up the equipment. This will result in tears and holes in the piece of equipment. Assuming that the equipment is decontaminated and de-inventoried prior to beginning the demolition, the material that remains will be the most difficult to remove. It is assumed that the tears and holes will impact 10% of the remaining internal contamination.

Airborne Release Fraction (ARF)

Internal contamination released due to tears, holes or segmenting of the equipment will be released to the air and then fall to the work area. The DOE handbook [DOE 1994] discusses several sets of experimental observations directly related to airborne releases from falling powders. Based on work done by Sutter et al., the DOE handbook[10] selected a bounding ARF of

[10] Section 3.4.3.1.2

2E-03 for the spill of UO_3 and TiO_2 powders freely falling into moving air from a height of 3 meters.

Another method of estimating powder releases due to falling in moving air presented in the DOE handbook[11] is that of Ballinger, which is presented below as Equation 8:

$$ARF = 0.1064(M^{0.125})(H^{2.37})/\rho^{1.02} \qquad \textit{Equation 8}$$

where: M = mass spilled, kilograms (kg)
H = height of spill, meter (m)
ρ = density of material, kg/m^3

For a 1-kg release of UO3 powder, of density 7.29 g/mL (7290 kg/m3), from a height of 3 meters, the estimated ARF using Equation 8 is 1.65E-04. Similarly, for PuO2 with a density of 11.50 g/mL (11500 kg/m3) dropped from a height of 3 meters, the estimated ARF is 1.04E-04.

Once the powders fall to the ground, the ongoing demolition activities will result in rubble falling onto it. The DOE Handbook[12] indicates an ARF of about 1E-03 for suspension caused by objects falling into powder. Some data suggest that the release fractions could be as high as 1E-02, but as noted in the DOE handbook, when these ARF values are corrected for burial by fallen rubble, the ARF is bounded by 1E-03. Based on these observations, an airborne release fraction of 0.001 is selected for these demolition operations.

Respirable Fraction (RF)

The RF is the fraction of airborne radionuclides as particles that can be transported through air and inhaled into the human respiratory system and is commonly assumed to include particles 10-µm Aerodynamic Equivalent Diameter (AED) and less. For this analysis, more than the respirable fraction is involved. Therefore, as a conservative measure, the RF is set to 1 in all cases. This practice effectively assumes all particulate matter is released with no reduction based on size.

Leak Path Factor (LPF)

The LPF is the fraction of the radionuclides in the aerosol transported through some confinement deposition or filtration mechanism. For the purpose of this calculation method, the LPF is used to address any controls applied during and after the demolition process. This includes the effects of water mists, sprays, and fixatives applied to surfaces and rubble after demolition. The application of a water mist to contaminated surfaces during demolition serves to reduce the percentage of airborne particulates in the respirable size range. The efficiency of the mist varies with each application and depends on, among other variables, mist particle size, water flow rate, and the size of potential airborne particles. OSHA [OSHA 2009] cites several case studies where misting

[11] Section 4.4.3.1.3
[12] Section 4.4.3.3.2

during grinding and while using vehicle-mounted rock drilling rigs resulted in a 90% decrease in dust generation.

For the purpose of this calculation, the water-mist application is assumed to reduce the quantity of airborne particulates by 90% resulting in an LPF = 0.1.

Emission Estimation Equation

By substituting the above factors into Equation 1 the emissions from demolition (segmenting) of larger equipment with internal contamination operations are found. The final equation is presented below:

$$ST = MAR \times DR \times ARF \times RF \times LPF$$

$$ST = MAR \times 0.1 \times 0.001 \times 1 \times 0.1$$

$$ST = MAR \times 1.00\text{E-}05$$ *Equation 9*

Rubble Pile Emissions

Demolition of a building or structure will result in the formation of rubble and debris piles. EPA [EPA 2004][13] recommends the use of the aggregate handling and storage pile formulas for AP-42 [EPA 1995][14] to estimate emissions from operations on open waste piles. The AP-42 formula is reproduced below as Equation 10.

$$EF = 0.0016\, k \frac{\left(U/_{2.2}\right)^{1.3}}{\left(M/_{2}\right)^{1.4}}$$ *Equation 10*

Where: EF = Emission factor, mCi released per Ci in the pile[15]
k = particle size multiplier, dimensionless
U = Mean wind speed, m/s
M = Material moisture content, percent

[13] Section 4.1.1

[14] Section 13.2.4

[15] The AP-42 units are kg released per Mg material processed. If the units for contaminated material is Ci/Mg, the units then become mCi released per Ci processed

The particle multiplier varies with the aerodynamic particle size range. AP-42 lists a value of 0.74 for particles < 30 μm in size. For demolition, there can be particles with the potential to become airborne that are larger than 30 μm. To account for this, a value of 1.0 will be used for k.

The piles will be wet, due to the misting, when they are produced. The piles will be maintained in a wet condition with water spray and misting. Allowable moisture levels as given by EPA [EPA 2004] are 0.44 to 10%. In addition, fixative may be applied to the rubble piles. A 1% increase in moisture content will be assumed when fixative is applied.

Setting k = 1 in Equation 10 results in the following equation for estimating emissions from rubble piles.

$$EF = 0.0016 \frac{\left(U/_{2.2}\right)^{1.3}}{\left(M/_{2}\right)^{1.4}}$$

This emission factor can then be substituted into Equation 2 to determine the source term. Since the spraying and wetting of the pile is accounted for in the EF equation the ER term is set to 0. Keeping in mind that A = MAR and E = ST, the resulting equation is

$$E = A \times EF \times \left(1 - ER/_{100}\right)$$

$$ST = MAR \times 0.0016 \frac{\left(U/_{2.2}\right)^{1.3}}{\left(M/_{2}\right)^{1.4}} \times \left(1 - 0/_{100}\right)$$

$$ST = MAR \times 0.0016 \frac{\left(U/_{2.2}\right)^{1.3}}{\left(M/_{2}\right)^{1.4}} \qquad \textit{Equation 11}$$

Load Out Emissions

Load-out activities include picking up rubble with a front-end loader, a thumb and bucket on the excavator or similar equipment and dumping of rubble and larger pieces into transfer containers. The EPA [EPA 2004][16] suggests an emission factor of 0.029 kg released per Mg processed. Using a conversion factor of 1000 kg/Mg, the factor becomes 2.9E-05 Mg released per Mg processed. For radionuclide operation, the average radionuclide content of the waste material (Ci/Mg) will convert the emission factor to a Curie based factor. This mathematical operation results in an emission factor 2.9E-05 Ci released per Ci processed.

[16] Section 4.1.4 Equation 4-4

This emission factor can then be substituted into Equation 2 to determine the source term. As a conservative measure no credit is taken for emissions reduction or controls, therefore ER = 0. Keeping in mind that A = MAR and E = ST, the resulting equation presented below is

$$E = A \times EF \times \left(1 - {ER}/{100}\right)$$

$$ST = MAR \times 2.9\text{E-}05 \times \left(1 - {0}/{100}\right)$$

$$ST = MAR \times 2.9\text{E-}05 \qquad \textit{Equation 12}$$

Miscellaneous Source Emissions

During the demolition, it is possible that other processes could be used. For those processes not addressed in this calculation method emission estimates will be handled by the U.S. EPA approved method presented in 40 CFR 61 Appendix D [EPA 1989] or with a revision to this method, followed by EPA approval prior to using any newly proposed calculation methods. The Appendix D method has previously been presented as Equation 3, which is reproduced below.

$$E_D = I \times PS \times CF$$

where: E_D = Estimated emissions	=	the total quantity of material released to the atmosphere during the demolition
I = Inventory	=	the total quantity of radionuclides (in grams or curies of activity for each radionuclide) available to be acted on by a given physical stress.
PS = Physical State Factor	=	relates the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant, in this case radionuclide.
CF = Control Factor	=	the fraction of the radionuclides in the aerosol transported through some confinement deposition system.

Some cutting of metal may be required during demolition activities. At the end of chapter 12 of AP-42 [EPA 1995], EPA provides information on emissions from cutting operations. The document provided, "Emissions of Fumes, Nitrogen Oxides and Noise in Plasma Cutting of Stainless and Mild Steel", contains a table that provides emissions based on the material removed in the cut. For example, with dry cutting of a 35 mm thick steel plate, 1% of the material removed is vaporized and emitted. The remaining 99% remains on the cutting table. The PS factor for dry cutting of 35 mm thick steel plate is 0.01 for the material removed. The highest emission rate is 7% of the material removed. Based on limited data from the validation study [Blunt 2018], a PS factor of 0.07 is appropriate for radionuclides that are alpha emitters (generally material with low volatility). For beta emitters the Physical State factor was found to be more appropriately set at 0.7 (generally material with a higher volatility).

Metal fumes from welding operations are similar to cutting emissions. Chapter 12.19.2.2 of AP-42 discusses controls for welding fumes. Typical controls listed in this chapter include high efficiency filters, electrostatic precipitators, carbon filters and particulate scrubbers. Therefore, when control devices are used to capture cutting fumes, the Appendix D control factor should be applied.

Should contaminated haul roads be used for the demolition project, the methods described by EPA [1995[17] and 2004[18]] for unpaved roads will be used to estimate emissions from such uses.

[17] Section 13.2.2
[18] Section 4.2

Example Calculation

The following example illustrates how the above methodology would be used to calculate the demolition activities. The input data are hypothetical, and the results are not assumed to represent any activities currently in progress.

Based on characterization of a facility the following inventory has been established at the time that demolition will occur. Note that the inventory is presented based on the demolition means and methods that are planned for various portions of the hypothetical facility. As stated above, this is a hypothetical example and is only presented to demonstrate the use of the alternative methods presented for approval.

Table 1:Inventory or MAR[1]

Radionuclide	Mechanical Shearing Inventory (Ci)	Diamond Wire Saw Inventory (Ci)	Wall Saw Inventory (Ci)	Segmenting Large Equipment Inventory (Ci)	Hydraulic Hammer Inventory (Ci)	Facility Total Activity (Ci)
Am-241	2.35E-03	5.04E-04	1.68E-04	1.68E-04	1.68E-04	3.36E-03
Cm-243	3.13E-06	6.72E-07	2.24E-07	2.24E-07	2.24E-07	4.48E-06
Cm-244	7.89E-05	1.69E-05	5.63E-06	5.63E-06	5.63E-06	1.13E-04
Cs-137	4.20E-01	8.99E-02	3.00E-02	3.00E-02	3.00E-02	5.99E-01
Ba-137m	4.20E-01	8.99E-02	3.00E-02	3.00E-02	3.00E-02	5.99E-01
I-129	6.94E-11	1.49E-11	4.96E-12	4.96E-12	4.96E-12	9.91E-11
Np-237	2.50E-07	5.37E-08	1.79E-08	1.79E-08	1.79E-08	3.58E-07
Pu-238	6.96E-04	1.49E-04	4.97E-05	4.97E-05	4.97E-05	9.95E-04
Pu-239	3.86E-04	8.26E-05	2.75E-05	2.75E-05	2.75E-05	5.51E-04
Pu-240	2.94E-04	6.30E-05	2.10E-05	2.10E-05	2.10E-05	4.20E-04
Pu-241	6.50E-03	1.39E-03	4.65E-04	4.65E-04	4.65E-04	9.29E-03
Sr-90	5.08E-02	1.09E-02	3.63E-03	3.63E-03	3.63E-03	7.25E-02
Y-90	5.08E-02	1.09E-02	3.63E-03	3.63E-03	3.63E-03	7.25E-02
Tc-99	1.50E-05	3.21E-06	1.07E-06	1.07E-06	1.07E-06	2.14E-05
U-232	1.68E-05	3.60E-06	1.20E-06	1.20E-06	1.20E-06	2.40E-05
U-233	6.00E-06	1.29E-06	4.29E-07	4.29E-07	4.29E-07	8.57E-06
U-234	2.84E-06	6.10E-07	2.03E-07	2.03E-07	2.03E-07	4.06E-06
U-235	8.89E-07	1.91E-07	6.35E-08	6.35E-08	6.35E-08	1.27E-06
U-238	5.71E-06	1.22E-06	4.08E-07	4.08E-07	4.08E-07	8.15E-06

1) Material at Risk

In this example, most of the structure can be demolished using the mechanical shearing method, but some walls will require both types of sawing, and there is large contaminated equipment to be removed. It is also anticipated that some structures will require processing with a hydraulic hammer. The rubble produced by the demolition will be moved from the demolition area to a processing area where the rubble will be sorted. Finally, the sorted rubble will be loaded into containers, sealed and shipped to final storage. The methods described previously will be used to determine the demolition emissions.

For a mechanical shearing operation with water misting, the source term for that part of the demolition operation is found with Equation 4. The following example is presented for the Am-241 inventory given in Table 1.

$$ST_{Mech\,Shear} = MAR \times 5.00\text{E-}05$$

$$ST_{Mech\,Shear,\ \text{Am-241}} = 2.35\text{E-}03\ Ci \times 5.00\text{E-}05$$

$$ST_{Mech\,Shear,\ \text{Am-241}} = 1.18\text{E-}07\ Ci$$

When using a diamond wire saw, the source term for that part of the demolition operation is found with Equation 6. Assume the kerf is 1.0 centimeter (cm) wide and the slab produced is 91.40 cm by 91.40 cm (3 feet by 3 feet). Also assume 4 cuts are required, and all of the same length. The following example is presented for the Am-241 inventory given in Table 1.

$$ST_{Diamond\,wire} = 5.0\text{E-}05 \times MAR \times \frac{(Length\ of\ cuts)(width\ of\ kerf)}{Area\ of\ slab}$$

$$ST_{Diamond\,wire,\ \text{Am-241}} = 5.0\text{E-}05 \times 5.04\text{E-}04 \times \frac{4(91.4\ cm)(1\ cm)}{(91.4\ cm)(91.4\ cm)}$$

$$ST_{Diamond\,wire,\ \text{Am-241}} = 1.11\text{E-}09\ Ci$$

When using a wall saw, the source term for that part of the demolition operation is found with Equation 7. Assume the kerf is 1.0 centimeter (cm) wide and the slab produced is 91.40 cm by 91.40 cm (3 feet by 3 feet). Also assume 4 cuts are required, and all of the same length. The following example is presented for the Am-241 inventory given in Table 1.

$$ST_{Wall\ saw} = 5.0\text{E-}03 \times MAR \times \frac{(Length\ of\ cuts)(width\ of\ kerf)}{Area\ of\ slab}$$

$$ST_{Wall\ saw,\ \text{Am-241}} = 5.0\text{E-}03 \times 1.68\text{E-}04 \times \frac{4(91.4\ cm)(1\ cm)}{(91.4\ cm)(91.4\ cm)}$$

$$ST_{Wall\ saw,\ \text{Am-241}} = 3.70\text{E-}08\ Ci$$

For the segmentation of large equipment operation, the source term for that part of the demolition operation is found with Equation 9. The following example is presented for the Am-241 inventory given in Table 1.

$$ST_{Segmenting} = MAR \times 1.00\text{E-}05$$

$$ST_{Segmenting,\ \text{Am-241}} = 1.68\text{E-}04\ Ci \times 1.00\text{E-}05$$

$$ST_{Segmenting,\ \text{Am-241}} = 1.68\text{E-}09\ Ci$$

When using a hydraulic hammer, the source term for that part of the demolition operation is found with Equation 5. The following example is presented for the Am-241 inventory given in Table 1.

$$ST_{Hydraulic\ hammer} = MAR \times 1.00\text{E-}05$$

$$ST_{Hydraulic\ hammer,\ \text{Am-241}} = 1.68\text{E-}04\ Ci \times 1.00\text{E-}05$$

$$ST_{Hydraulic\ hammer,\ \text{Am-241}} = 1.68\text{E-}09\ Ci$$

The results of these calculations for each radionuclide in the facility inventory and for each demolition technique are presented in Table 2.

Table 2: Demolition operations emissions

Radionuclide	Releases due to Mechanical Shearing (Ci)	Releases due to Diamond Wire Saw Operations (Ci)	Releases due to Wall Saw Operations (Ci)	Releases due to Segmenting Large Equipment (Ci)	Releases due to Hydraulic Hammer Operations (Ci)	Demolition Total Release (Ci)
Am-241	1.18E-07	1.11E-09	3.70E-08	1.68E-09	1.68E-09	1.59E-07
Cm-243	1.57E-10	1.48E-12	4.93E-11	2.24E-12	2.24E-12	2.12E-10
Cm-244	3.94E-09	3.72E-11	1.24E-09	5.63E-11	5.63E-11	5.33E-09
Cs-137	2.10E-05	1.98E-07	6.59E-06	3.00E-07	3.00E-07	2.84E-05
Ba-137m	2.10E-05	1.98E-07	6.59E-06	3.00E-07	3.00E-07	2.84E-05
I-129	3.47E-15	3.27E-17	1.09E-15	4.96E-17	4.96E-17	4.69E-15
Np-237	1.25E-11	1.18E-13	3.94E-12	1.79E-13	1.79E-13	1.69E-11
Pu-238	3.48E-08	3.28E-10	1.09E-08	4.97E-10	4.97E-10	4.71E-08
Pu-239	1.93E-08	1.82E-10	6.06E-09	2.75E-10	2.75E-10	2.61E-08
Pu-240	1.47E-08	1.39E-10	4.62E-09	2.10E-10	2.10E-10	1.99E-08
Pu-241	3.25E-07	3.07E-09	1.02E-07	4.65E-09	4.65E-09	4.40E-07
Sr-90	2.54E-06	2.39E-08	7.98E-07	3.63E-08	3.63E-08	3.43E-06
Y-90	2.54E-06	2.39E-08	7.98E-07	3.63E-08	3.63E-08	3.43E-06
Tc-99	7.48E-10	7.05E-12	2.35E-10	1.07E-11	1.07E-11	1.01E-09
U-232	8.39E-10	7.91E-12	2.64E-10	1.20E-11	1.20E-11	1.13E-09
U-233	3.00E-10	2.83E-12	9.43E-11	4.29E-12	4.29E-12	4.06E-10
U-234	1.42E-10	1.34E-12	4.47E-11	2.03E-12	2.03E-12	1.92E-10
U-235	4.45E-11	4.19E-13	1.40E-11	6.35E-13	6.35E-13	6.01E-11
U-238	2.85E-10	2.69E-12	8.97E-11	4.08E-12	4.08E-12	3.86E-10

The next step in the process is to move the rubble pile to a sorting area. This process is considered rubble handling. Emissions from rubble handling are determined with Equation 11. The following example is presented for the total Am-241 inventory given in Table 1.

Typically, rubble piles will be processed when the winds are low, however as a bounding condition for this example assume a wind speed of 20 miles per hour (8.8 m/s). Also assume that the rubble piles are maintained wet at about 2% moisture and that fixative is applied. Therefore, the moisture factor is set to 3%.

$$ST = MAR \times 0.0016 \frac{\left(U/_{2.2}\right)^{1.3}}{\left(M/_{2}\right)^{1.4}}$$

$$ST_{Am\text{-}241} = 3.36\text{E-}03\ Ci \times \left(0.0016 \frac{\left(8.8/_{2.2}\right)^{1.3}}{\left(3/_{2}\right)^{1.4}} mCi/_{Ci} \right)$$

$$ST_{Am\text{-}241} = 3.36\text{E-}03\ Ci \times \left(5.50\text{E-}03\ mCi/_{Ci} \right)$$

$$ST_{Am\text{-}241} = (1.85\text{E-}05\ mCi)(1\text{E-}03\ Ci/_{mCi}) = 1.85\text{E-}08\ Ci$$

The results of this calculation for each radionuclide in the facility inventory are presented in Table 3.

Table 3: Rubble handling and sorting emissions

Radionuclide	Rubble Handling Emissions (Ci)
Am-241	1.85E-08
Cm-243	2.46E-11
Cm-244	6.20E-10
Cs-137	3.30E-06
Ba-137m	3.30E-06
I-129	5.45E-16
Np-237	1.97E-12
Pu-238	5.47E-09
Pu-239	3.03E-09
Pu-240	2.31E-09
Pu-241	5.11E-08
Sr-90	3.99E-07
Y-90	3.99E-07
Tc-99	1.18E-10
U-232	1.32E-10
U-233	4.71E-11
U-234	2.23E-11
U-235	6.99E-12
U-238	4.48E-11

The next step is to process the rubble by sorting into piles of similar waste category. Again, this process is a rubble handling operation. The emission would be calculated with Equation 11, as described above for moving the pile. Emissions resulting from this process would be the same as that presented in Table 3.

The final step is loading the rubble in containers for shipment. Emissions from load out are determined with Equation 12. The following example is presented with the Am-241 inventory given in Table 1.

$$ST = MAR \times 2.9\text{E-}05$$

$$ST_{Am\text{-}241} = 3.36\text{E-}03\ Ci \times 2.9\text{E-}05$$

$$ST_{Am\text{-}241} = 9.75\text{E-}08\ Ci$$

The results of this calculation for each radionuclide in the facility inventory are presented in Table 4

Table 4: Load out emissions

Radionuclide	Load Out Emissions (Ci)
Am-241	9.75E-08
Cm-243	1.30E-10
Cm-244	3.27E-09
Cs-137	1.74E-05
Ba-137m	1.74E-05
I-129	2.87E-15
Np-237	1.04E-11
Pu-238	2.89E-08
Pu-239	1.60E-08
Pu-240	1.22E-08
Pu-241	2.69E-07
Sr-90	2.10E-06
Y-90	2.10E-06
Tc-99	6.20E-10
U-232	6.95E-10
U-233	2.49E-10
U-234	1.18E-10
U-235	3.68E-11
U-238	2.36E-10

The total emissions from this demolition project are found as the sum of each process and are presented in Table 5.

Table 5: Emissions by process and as a total for the demolition project

Radionuclide	Demolition Emissions (Ci) [See Table 2]	Moving Debris Emissions (Ci) [See Table 3]	Rubble Sorting Emissions (Ci) [See Table 3]	Load Out Emissions (Ci) [See Table 4]	Total Demolition Project Emissions (Ci)
Am-241	1.59E-07	1.85E-08	1.85E-08	9.75E-08	2.94E-07
Cm-243	2.12E-10	2.46E-11	2.46E-11	1.30E-10	3.91E-10
Cm-244	5.33E-09	6.20E-10	6.20E-10	3.27E-09	9.84E-09
Cs-137	2.84E-05	3.30E-06	3.30E-06	1.74E-05	5.23E-05
Ba-137m	2.84E-05	3.30E-06	3.30E-06	1.74E-05	5.23E-05
I-129	4.69E-15	5.45E-16	5.45E-16	2.87E-15	8.66E-15
Np-237	1.69E-11	1.97E-12	1.97E-12	1.04E-11	3.12E-11
Pu-238	4.71E-08	5.47E-09	5.47E-09	2.89E-08	8.69E-08
Pu-239	2.61E-08	3.03E-09	3.03E-09	1.60E-08	4.81E-08
Pu-240	1.99E-08	2.31E-09	2.31E-09	1.22E-08	3.67E-08
Pu-241	4.40E-07	5.11E-08	5.11E-08	2.69E-07	8.11E-07
Sr-90	3.43E-06	3.99E-07	3.99E-07	2.10E-06	6.33E-06
Y-90	3.43E-06	3.99E-07	3.99E-07	2.10E-06	6.33E-06
Tc-99	1.01E-09	1.18E-10	1.18E-10	6.20E-10	1.87E-09
U-232	1.13E-09	1.32E-10	1.32E-10	6.95E-10	2.09E-09
U-233	4.06E-10	4.71E-11	4.71E-11	2.49E-10	7.48E-10
U-234	1.92E-10	2.23E-11	2.23E-11	1.18E-10	3.55E-10
U-235	6.01E-11	6.99E-12	6.99E-12	3.68E-11	1.11E-10
U-238	3.86E-10	4.48E-11	4.48E-11	2.36E-10	7.12E-10

The emissions determined by this method can now be modeled with CAP-88, or other approved dose calculation method, to determine the dose to the public or worker. Although not part of this method, this step is performed below using unit dose conversion factors (UDCF). UDCFs are determined by modeling 1 curie of a radionuclide with a dose model. The resulting dose is of the form mrem/Ci and can be used in calculation of doses in spreadsheets. Table 6 presents the results of applying UDCF values to the total emissions from Table 5.

Table 6: Dose estimation for demolition project

Radionuclide	Total Demolition Project Emissions (Ci)	UDCF (mrem/Ci)	Total Demolition Project Dose (mrem)
Am-241	2.94E-07	1.96E+02	5.76E-05
Cm-243	3.91E-10	1.48E+02	5.79E-08
Cm-244	9.84E-09	1.25E+02	1.23E-06
Cs-137	5.23E-05	6.26E+00	3.28E-04
Ba-137m	5.23E-05	1.44E-01	7.54E-06
I-129	8.66E-15	1.31E+01	1.13E-13
Np-237	3.12E-11	1.09E+02	3.41E-09
Pu-238	8.69E-08	2.17E+02	1.89E-05
Pu-239	4.81E-08	2.36E+02	1.14E-05
Pu-240	3.67E-08	2.36E+02	8.66E-06
Pu-241	8.11E-07	4.25E+00	3.45E-06
Sr-90	6.33E-06	1.06E+01	6.71E-05
Y-90	6.33E-06	3.57E-02	2.26E-07
Tc-99	1.87E-09	3.81E+00	7.11E-09
U-232	2.09E-09	4.73E+01	9.90E-08
U-233	7.48E-10	1.80E+01	1.35E-08
U-234	3.55E-10	1.76E+01	6.25E-09
U-235	1.11E-10	1.58E+01	1.75E-09
U-238	7.12E-10	1.46E+01	1.04E-08
		Total	5.04E-04

Summary

Since demolition activities were not considered when 40 CFR 61, Appendix D was promulgated, the use of the alternative calculation method described above is preferred, as it more accurately estimates emissions from demolition activities.

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WVDP RECORD OF REVISION

Rev. No.	Description of Changes	Revision On Page(s)	Dated
0	Original Issue. This document contains an EPA approved "alternative method" for the performance of rad-NESHAP evaluations of WVDP demolition activities in accordance with 40 CFR 61, subpart H. Also included is information used to validate the "alternative method." This document affects the Regulatory Strategy and Facility Disposition Departments directly and all WVDP departments indirectly.	All	09/05/19