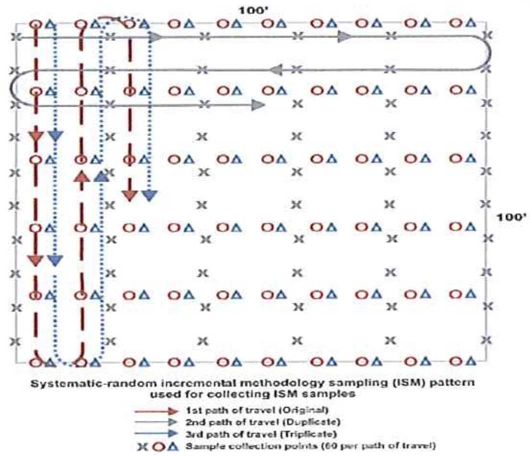
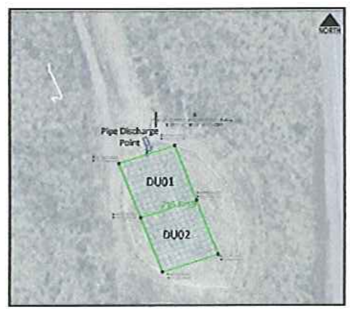
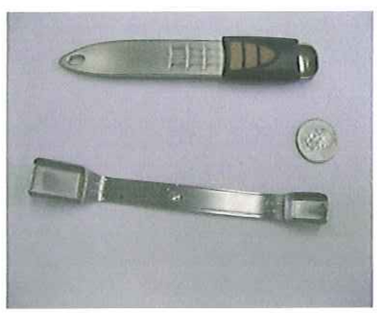
A Comparison Study of Soil Sampling Techniques for Radiation Levels in the Soil







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Statistics 146 Project

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Soil Sampling Techniques for Environmental Studies

Introduction:

Contamination is never a good thing when it comes to earth's wonders, such as soil that can get to underground water. This underground water can then transfer into rivers, such as the Columbia River, which many people rely on to get drinking water or by fishing to acquire food. However, when contamination does inevitably occur there needs to be tests to determine how much damage is being done. Such measures are very useful in determining whether the contamination is being damaging to the soil and whether it's doing so much damage that it's affecting the wildlife and human life around a community. Basically, the entire point to this report is to compare three different types of soil sampling; MIS, judgmental and systematic. Currently, Hanford is using the systematic sampling technique to collect different kinds of soil samples. As of now, the Department of Ecology would like Hanford to switch to the MIS sampling method because it's more cost effective. Through this report, it will show, statistically, whether or not there are differences within the results between systematic sampling and MIS sampling for soil. After all the analysis has been done, it can be used to identify "hot spots" where there is a lot of contamination and fix the problem at the source. The following are three different sampling methods that Hanford used for this comparison study:

Incremental Sampling Methodology (MIS) was developed to address some of the limitations mentioned above. MIS is a composite sampling approach where many (between 30 and 100) equal-mass increments are collected and combined in an unbiased manner from throughout the entire area of the soil/volume of interest. Once the combined increments are processed at the laboratory, a subsample is taken and analyzed.

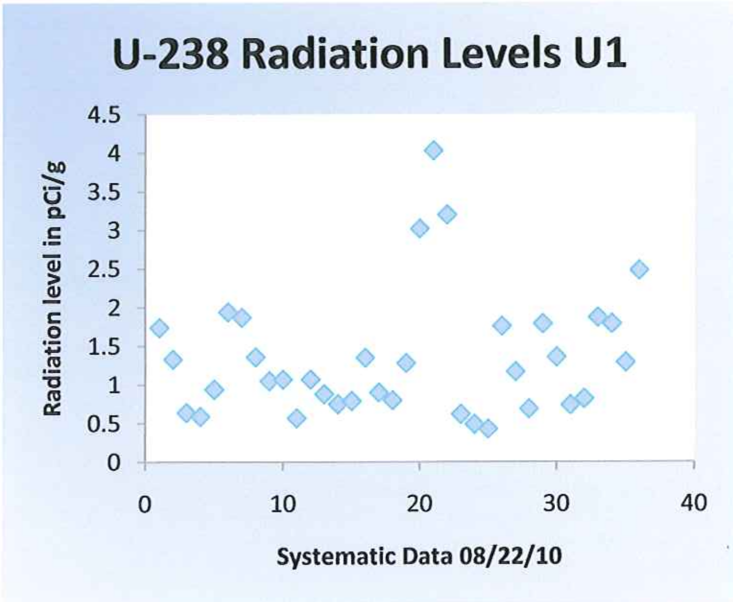
Judgmental Sampling is used when only a few discrete samples are collected. The number of samples collected is determined by negotiation, budget, professional judgment, or happenstance. The number of samples is often not based on statistical or other scientific rationale, and the location of the samples is often judgmental. Judgmental sampling plans are effective when source areas or migration pathways of high concentrations are being investigated.

Systematic Sampling requires that the area of interest be divided up into a number of grids and then a random sample(s) is taken from each and analyzed from within each of the grids. The combined results are used to represent the area of concern. The number of samples for this type of analysis may be quite large.

Graphing and Summarizing Data

1. Graphic Investigation of U-238

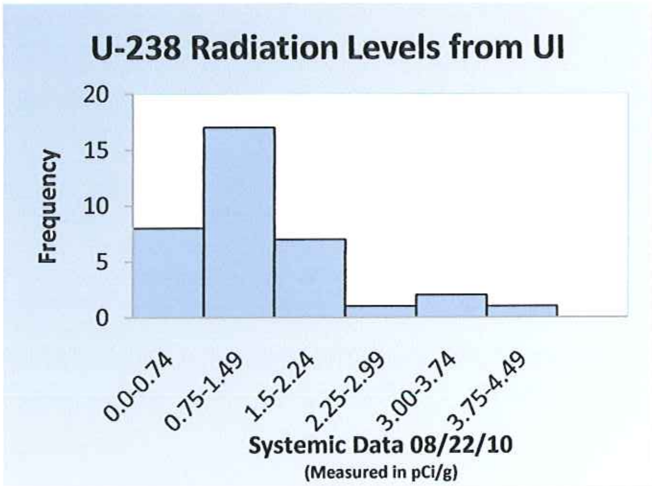
Initially the scatter plot below of the U-238 systematic data for area U1 collected August 22, 2010 was constructed to investigate the radiation levels of this element that were present at the time the sample was collected. This plot also demonstrates the heterogeneity (or homogeneity) of this radioactive element in area U1.



Further analysis of the isotope U-238 was conducted using the same systematic data from August 22, 2010. This analysis is summarized in the Frequency Table and Histogram presented below.

U-238 Area U1

Radiation Level (measured in pCi/g)	Frequency
0.00-0.74	8
0.75-1.49	17
1.50-2.24	7
2.25-2.99	1
3.00-3.74	8
3.75-4.49	1



This scatter plot could be interpreted as a heterogeneous or homogeneous. An argument for heterogeneous is supported by the four points around observation 20 and the point that is towards the end of the graph. Because of this it can make it seem that way. However, that is three observation points out of 36 observations. That makes it roughly only 11% that is not under the typical "homogeneous" mixture. Which means that 89% of the collected data are roughly in the same general homogenous area. For this reason, the mixture is considered to be a homogeneous mixture with consistent variation between observations.

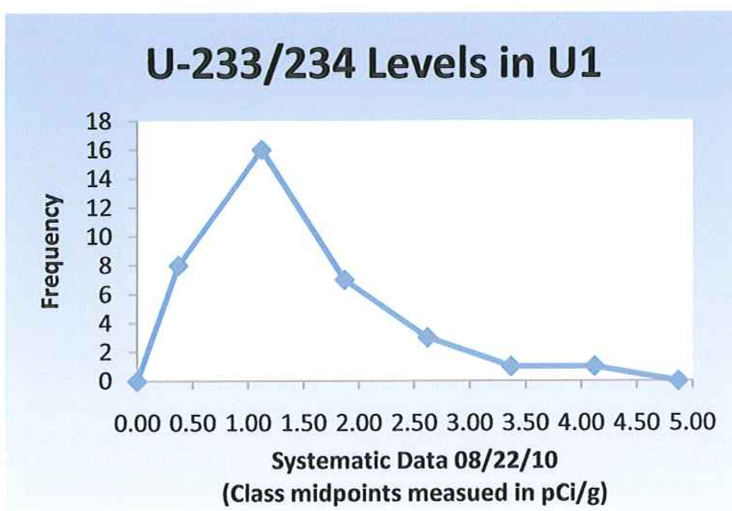
The histogram shows that this data has a distribution that is skewed to the right. Most of the radiation levels for this data set were between the 0 and 2.24 pCi/g. The only exception was the four other radiation levels that were between 2.25 and 4.49 pCi/g. Overall, this is a good thing that it is skewed to the right, because when it comes to radiation in the soil, it wouldn't be good to have high levels of U-238. The frequency table gives an even better view of how the higher frequencies are present at lower radiation levels and the higher levels of radiation have the lower frequencies. When looking at the frequency table, you're able to determine how many samples are in each interval of radiation levels.

2. Graphic Investigation of U-233/234

The Frequency Polygon pictured below was used to illustrate the radiation levels of the isotope U-233/234 from the systematic data for area U1 collected August 22, 2010. The graph was constructed using the class midpoints for the frequency distribution below. This graph also shows the nature of the distribution of this element in area U1 at the time it was collected.

Uranium 233-234 Area U1

Radiation Level (measured in pCi/g)	Frequency
0.00-0.74	8
0.75-1.49	16
1.50-2.24	7
2.25-2.99	3
3.00-3.74	1
3.75-4.49	1



The frequency distribution representing the systematic data for U-233/234 from UI shows that the frequencies are higher at the lower radiation levels like between the classes of 0.00-0.74 pCi/g and 0.75-1.49 pCi/g. This is a positive thing to attain. If the frequencies would have been larger at the higher radiation levels, then it would indicate that there may be cause for concern regarding this area.

The frequency polygon shows the same type of information as the frequency table does. It shows that the frequencies are higher at the lower radiation levels than at the higher ones. The frequency polygon shows that the data is skewed to the right.

3. Comparison of U-238 and U-233/234

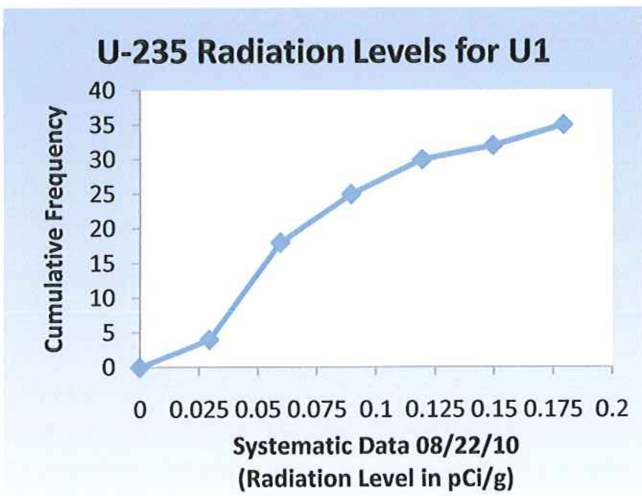
The histogram for Uranium 238 and the frequency polygon for Uranium 233/234 show the same kind of curve. Both distributions are skewed to the right. The frequency distributions of both U-238 and U-233/234 are, for the most part, are very similar in numbers. It seems to show that both isotopes have similar radiation levels within this given area and the frequencies for each given radiation level seems to be pretty similar. The conclusion that can be drawn by this information is that U-238 and U-233/234 are very similar when it comes to comparing radiation levels in the soil between them

4. Graphic Investigation of U-235

The radioactive isotope U-235 was analyzed using a Cumulative Frequency Distribution in conjunction with an Ogive (cumulative frequency graph). The systematic data for this isotope was collected from area U1 on August 22, 2010. The single sample, B242080, had a level of 1.34 pCi/g and was left out of this analysis. This value is considered an outlier and is assumed to be unrepresentative of this area.

U-235 in Area U1

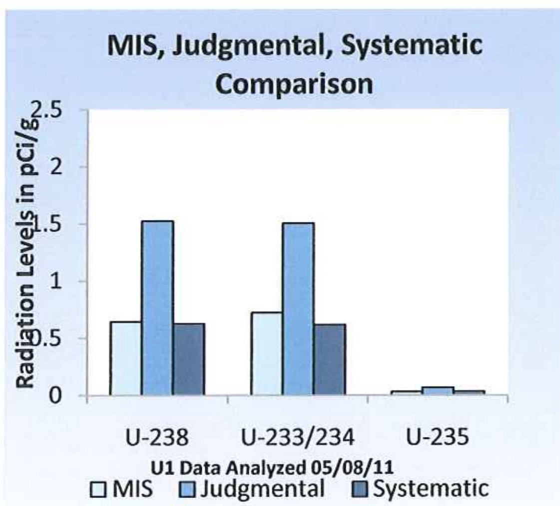
Radiation Level (measured in pCi/g)	Cumulative Frequency
Less than 0.03	4
Less than 0.06	18
Less than 0.09	25
Less than 0.12	30
Less than 0.15	32
Less than 0.18	35

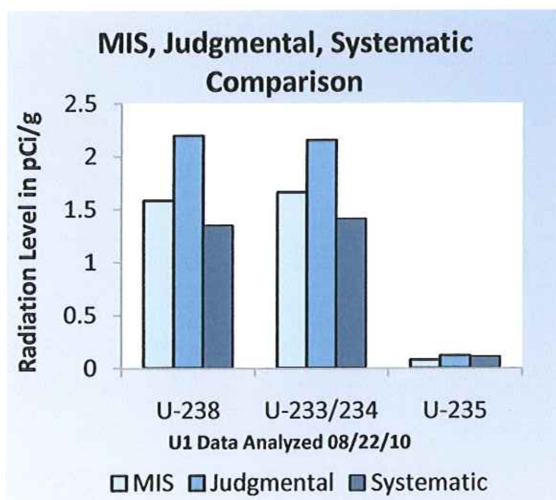


The U-235 radiation levels from area U1 in the cumulative frequency distribution demonstrates the number of frequencies that lie at or below that level. From this information it is easy to conclude the number of values that are located above a given radiation level. For example if you look at the upper class limit of less than 0.150 pCi/g that shows that there were 32 values below this value. The ogive graph shows this information in graphic form. This graph is very helpful because it shows the total accumulated frequencies at any given point in time. Also, one of the numbers was left out of this data, which had a radiation level of 1.34 pCi/g with the ID of B242080. This was excluded from the cumulative frequency table and ogive graph because it is considered an anomaly.

5. Graphic Comparison of Sampling Methods for U-238, U-233/234, and U-235

A comparison analysis was conducted on the levels of radiation in the MIS, Judgmental, and systematic data collected from area U1 for U-238, U-233/234, and U-235 on August 22, 2010 and on May 8, 2010. The Multiple Bar graphs below were used to analyze this information.





Both of these graphs from 05/08/10 and 08/22/10 show that MIS does work as a soil sampling technique. In the August 22, 2010 data for U1, it seems to show that the MIS sampling technique had a mean radiation level for the U-238 and U-233/234 between the lower levels of the systematic sampling and the higher levels of the judgmental sampling. With this, it can be concluded that more analysis should be done to help to see whether these specific differences are very significant of not. In the May 08, 2010 data for U1, it seems to show that the MIS sampling technique had roughly the exact same data as the systematic sampling technique. With this, it can be shown that there isn't much of a difference between the two different sampling methods and that they produce roughly the same type of information. In both August

8, 2010 and May 08, 2010 for U1 data of U-235, it demonstrates that they both have very low radiation levels, so it can be concluded that all the sampling methods work just fine for that specific element at low concentrations.

6. Graphic Investigation of Chromium

A Stem and Leaf Plot was used to investigate the levels of Chromium contained in the systematic data for area U1 collected on August 22, 2010. The plot was constructed with the stems representing the ones digit of the original data values and the leaves representing the tenths digit of the original data values. This plot not only shows the nature of the Chromium distribution in the area U1 at the time of collection but allows for the preservation of the original data values.

U1 Chromium in mg/kg

Stem (Ones digit)	Leaf (tenth digit)
4	9
5	5 5 6 6 7 8 8
6	1 2 4 4 4 7 8 9
7	0 2 4 4 5 5 6 8
8	0 5 5 5 7 8
9	0 2 2 5 9
10	0

This stem and leaf plot shows that the distribution is somewhat of a normal, bell-shaped, distribution. This stem and leaf plot, if rotated would show what a histogram of this data would look like. This particular plot is especially good because it shows all the original data values. So a positive point of using this stem and leaf plot is that it shows all of the data that was used, so none of it was lost, and also it can show what a distribution would look for this Chromium data that has been acquired.

Descriptive Statistics and Probability

1. Descriptive Statistics for U-238, U2344/234, and U-235

The first part of this report analyzed data collected primarily from area U1 on August 22, 2010. This section of the report will analyze data collected primarily from area U1 on May 8, 2010. Measures of central tendency and variation are extremely important when analyzing a data set. Thus, the following calculations were made and summarized in the table below for the isotopes U-238, U-233/234, and U-235 using the systematic data for U1 collected on May 8, 2020. Results were rounded to three decimal places.

Systematic Data from May 8, 2010 from area U1

pCi/g	Mean	Median	Standard Deviation	Range
U-238	0.624	0.56	0.239	1.18
U-233/234	0.617	0.555	0.206	1.02
U-235	0.0327	0.032	0.0164	0.08

The above information was used to calculate the minimum and maximum "usual" values for each isotope. Two techniques were used for these calculations, the Empirical Rule for 95% of data values and Chebyshev's Theorem for at least 93.75% of data values.

The Empirical Rule assumes that the population is normally distributed. It states that 95% of data values fall within 2 standard deviations of the mean. These calculations are presented below.

Equations for Empirical Data:
Minimum Value for Empirical Rule = $\bar{x} - 2s$
Maximum Value for Empirical Rule = $\bar{x} + 2s$

Systematic Data from May 8, 2010 from area U1 (in pCi/g)

U-238
$Minimum\ Value: (0.624) - 2(0.239) = 0.146 \text{ pCi/g}$
$Maximum\ Value: (0.624) + 2(0.239) = 1.102 \text{ pCi/g}$

U-233/234

$Minimum\ Value: (0.617) - 2(0.206) = 0.205\ \text{pCi/g}$

$Maximum\ Value: (0.617) + 2(0.206) = 1.029\ \text{pCi/g}$

U-235

$Minimum\ Value: (0.0327) - 2(0.0164) = -0.0001\ \text{pCi/g}$

$Maximum\ Value: (0.0327) + 2(0.0164) = 0.0655\ \text{pCi/g}$

Chebyshev's Theorem makes no assumptions about the distribution of the population from which the data was sampled. As a result, it provides a conservative estimate of the minimum and maximum "usual" values of a data set. This theorem states that at least 93.75% of data values fall within 4 standard deviations of the mean. To arrive at the assumption that there must be four standard deviations, it goes by these rules: take the number 4, which is the number of standard deviations it takes to make 93.75% of the data according to this given rule. Square the number 4, which gives 4^2= 16. Then to finish the equation out to show that 4 standard deviations is 93.75%, take 1 - $^1/_{16}$= .9375; multiply this number by 100 and it comes to 93.75%. These calculations are presented below.

Equations for Chebyshev's Theorem:

Minimum Value for Chebyshev's Theorem = $\bar{x} - 4s$

Maximum Value for Chebyshev's Theorem = $\bar{x} + 4s$

Systematic Data from May 8, 2010 from area U1 (in pCi/g)

U-238

$Minimum\ Value: (0.624) - 4(0.239) = -0.332\ \text{pCi/g}$

$Maximum\ Value: (0.624) + 4(0.239) = 1.58\ \text{pCi/g}$

U-233/234

$Minimum\ Value: (0.617) - 4(0.206) = -0.207\ \text{pCi/g}$

$Maximum\ Value: (0.617) + 4(0.206) = 1.441\ \text{pCi/g}$

U-235

$Minimum\ Value: (0.0327) - 4(0.0164) = -.0329\ \text{pCi/g}$

$Maximum\ Value: (0.0327) + 4(0.0164) = 0.0983\ \text{pCi/g}$

Using the minimum and maximum "usual" values, unusual data values can then be determined. It is plainly seen that the population can play a major role in the determination of which technique to use for a given data set. "Unusual" data values found by using Empirical Rule and Chebyshev's rule are presented below for U-238, U-233/234 and U-235. Each of these data values used is systematic and is collected from area U1 on May 8, 2010.

"Unusual" Radiation Levels for Systematic Data from May 8, 2010 from area U1 (Measured in pCi/g)

Type of Element	Empirical Rule	Chebyshev's Theorem
U-238	1.13 1.33 1.62	1.62
U-233/234	1.03 1.04 1.19 1.43	
U-235	0.066 0.086	

Comparing the differences between usual values when using each method, it is clear to see that the Empirical rule has a smaller range in minimum and maximum values than the Chebyshev's Theorem produces. Take for example the minimum value and maximum value for U-238. For the Empirical rule, the values are 0.146 pCi/g to 1.102 pCi/g, for Chebyshev's rule it is -0.332 pCi/g to 1.58 pCi/g. As it's clear to see, the Empirical rule has a range of 0.956 pCi/g and Chebyshev's rule has a range of 1.912 pCi/g. That is a difference in ranges of about 0.95 pCi/g. That means that Chebyshev's rule has more "usual" numbers than the Empirical rule, which would in turn give Chebyshev's rule less "unusual" data numbers. Looking at the chart of "unusual" numbers, it proves this point by showing that the Empirical rule has more "unusual" numbers than Chebyshev's theorem. Chebyshev's theorem only has one "unusual" number from the three types of elements, while the Empirical rule has nine "unusual" numbers. Also, given from the table, it is clear to see that the most "unusual" number is 1.62 since it's under both the Empirical rule and Chebyshev's theorem.

The most appropriate method for this data set would be Chebyshev's theorem. Chebyshev's theorem is the most appropriate because it can be used on any data set. Since this data, as shown by the boxplots, is not normally distributed it requires Chebyshev's theorem for use. The

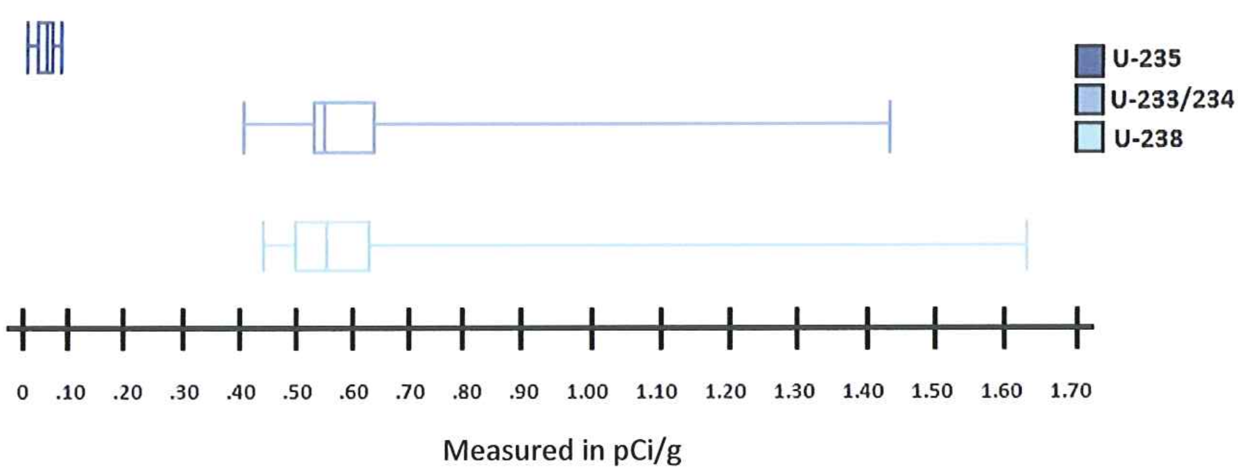
Empirical rule can only be used on normally distributed data, so this data cannot use this rule because all three data sets have data that is skewed to the right.

Descriptive statistical analysis also includes a 5-number consisting of the minimum value, the 25th percentile, the median, the 75th percentile, and the maximum value. These values are used to construct a boxplot representing the data set of interest. In this analysis 5-number summaries and stacked boxplots were calculated for the systematic data collected on May 8, 2010 from area U1 for U-238, U-233/234, and U-235. This information is presented below.

5-Number Summary of Systematic Data from May 8, 2010 from Area U1

pCi/g	U-238	U-233/234	U-235
Minimum Value	0.44	0.41	0.006
25th percentile	0.50	0.53	0.021
Median	0.56	0.555	0.032
75th percentile	0.625	0.64	0.0415
Maximum Value	1.62	1.43	0.086

Comparison Box-Plots of Systematic Data from May 8, 2010 from Area U1



The boxplots show for each element its range, 25th percentile, 75th percentile, and median. These boxplots show that U-238 has the highest range of values, U-235 has the smallest range and U-233/234 is right in the middle. The radiation levels for both U-238 and U-233/234 appear to be quite similar as shown by their respective boxplots. Looking at U-235, it's clear to see that the all of the 5-number summary numbers are very close and are closer than the other two elements; U-233/234 and U-238. U-233/234 and U-238 have distributions that are both skewed to the right and U-235 is a more normal shaped distribution. Because of this, it shows that for U-233/234 and U-238, more of the data is at the lower numbers and that for U-235 it is also skewed to the right, just not as dramatically as U-233/234 and U-238.

2. Selecting Subsamples of U-238

Researchers observed several anomalies in the U-238 systematic data collect from area U1 on May 8, 2010. As a result of these observations, they were tasked with performing a more in depth analysis of this data. Due to budget constraints only 10 of the original samples will be selected for this extended analysis. The number of different subsamples of size 10 was determined using the following calculation:

$$
\begin{aligned}
{}_{n}C_{r} &= \frac{n!}{(n-r)!r!} \\
{}_{40}C_{10} &= \frac{40!}{(40-10)!\,10!} \\
&= 847{,}660{,}528
\end{aligned}
$$

There are 847,660,528 ways that the researcher is able to choose those 10 subsamples from a total of 40. These 10 subsamples will then be used for further analysis of the U-238 systematic data that is collected from area U1 on May 8, 2010.

Once the researchers selected their 10 subsamples for extended analysis they were instructed to initially test only 4 of these subsamples. The order in which these 4 subsamples are tested is critical to their in-depth analysis. The number of different orders that 4 of the 10 subsamples can be selected and tested was determined using the following calculation:

$$
\begin{aligned}
{}_{n}P_{r} &= \frac{n!}{(n-r)!} \\
{}_{10}P_{4} &= \frac{10!}{(10-4)!} \\
&= 5{,}040
\end{aligned}
$$

There are 5,040 different orders that the researcher is able to pick those 4 subsamples from the sample size of 10. These 4 subsamples will then be used for a more in depth analysis of the U-238 systematic data that is collected from area U1 on May 8, 2010.

3. Sample Probabilities for U-238, U-233/234, and U-235

Part of this soil sample research involves calculating different probabilities. The table below presents 120 different measurements taken of the radiation levels for U-238, U-233/234, and U-235 for the systematic data from U1 collected on May 8, 2010. The information in this table was used to calculate these probabilities.

Radiation Levels for the Systematic Data Collect on May 8, 2010 in Area U1

pCi/g	U-238	U-233/234	U-235	Total
0.00 -0.50	10	8	40	58
0.51-1.00	26	28	0	54
1.01-1.51	3	4	0	7
1.51-2.00	1	0	0	1
Totals	**40**	**40**	**40**	**120**

A single measurement was selected at random for analysis. The probability that the measurement had a radiation level of 0.50 pCi/g or less where the source of the radiation was unknown was calculated as follows:

$$P\left(0.50\frac{pCi}{g} \, or \, less\right) = \frac{\# \, of \, 0.50\frac{pCi}{g} \, or \, less}{Total \, \# \, of \, element \, levels}$$
$$= \frac{58}{120}$$
$$= 0.483$$

Two samples of size 4 each were selected at random and only their U-238 radiation level was analyzed. The probability that all 4 samples would have a radiation level of 0.50 pCi/g or less was evaluated. The first sample was selected with replacement. The second sample was selected without replacement. The detailed calculations of each of these probabilities are presented below.

With Replacement:

$$P\left(U238\ radiation\ levels\ of\ 0.50\frac{pCi}{g}\ or\ less\right) = \frac{\#\ of\ 0.50\frac{pCi}{g}or\ less\ in\ U238}{Total\ \#\ of\ U238}$$
$$= \frac{10}{40}\cdot\frac{10}{40}\cdot\frac{10}{40}\cdot\frac{10}{40}$$
$$= 0.00391$$

Without Replacement:

$$P\left(U238\ radiation\ levels\ of\ 0.50\frac{pCi}{g}\ or\ less\right) = \frac{\#\ of\ 0.50\frac{pCi}{g}or\ less\ in\ U238}{Total\ \#\ of\ U238}$$
$$= \frac{10}{40}\cdot\frac{9}{39}\cdot\frac{8}{38}\cdot\frac{7}{37}$$
$$= 0.002230$$

A sample of size 4 was selected at random with replacement in which only the U-233/234 radiation levels were evaluated. To determine the probability that at least 1 out of these 4 samples has a radiation level that is greater than 0.50 pCi/g the following calculations were done.

With Replacement:

$$P\left(1\ is\ greater\ than\ 0.50\frac{pCi}{g}\right) = 1 - P\left(less\ than\ 0.50\frac{pCi}{g}\right)$$
$$= 1 - \frac{32}{40}$$
$$= 0.20$$

$$P\left(at\ least\ 1\ of\ 4\ is\ greater\ than\ 0.50\frac{pCi}{g}\right) = 1 - P\left(All\ 4\ less\ than\ 0.50\frac{pCi}{g}\right)$$
$$= 1 - (0.20)^4$$
$$= 0.998$$

Two measurements were to be randomly selected, without replacement, from the 120 radiation level measurements. The probability that the first would have a radiation level greater than 1.00 pCi/g source unknown and second would have a radiation level of 0.50 pCi/g or less source unknown was calculated as shown below.

$$P\left(First\ selected\ is\ > 1.00\frac{pCi}{g}, second\ selected\ is\ 0.50\frac{pCi}{g}\ or\ less\right) =$$
$$\left(\frac{\#\ Greater\ than\ 1.00\frac{pCi}{g}}{Total\ \#\ of element\ levels}\right)\cdot\left(\frac{\#\ of\ 0.50\frac{pCi}{g}or\ less}{Total\ \#\ of\ element\ levels{-}1}\right)$$
$$= \frac{8}{120}\cdot\frac{58}{119}$$
$$= 0.0325$$

A sample was found in the lab after all the other samples had been properly stored. This sample had a radiation level between 0.00 and 0.50 pCi/g. The researchers decided to use probability to help them find the source of this radiation. The following probabilities were calculated to assist them in this determination.

$$P\left(U238 \,\middle|\, radiation\ level\ \leq 0.50\frac{pCi}{g}\right) = \frac{\#\ of\ 0.50\frac{pCi}{g} or\ less\ in\ U28}{Total\ \#\ of\ 0.50\frac{pCi}{g} in\ U28}$$
$$= \frac{10}{58}$$
$$= 0.172$$

$$P\left(U233/234 \,\middle|\, radiation\ level\ \leq 0.50\frac{pCi}{g}\right) = \frac{\#\ of\ 0.50\frac{pCi}{g} or\ less\ in\ U233/234}{Total\ \#\ of\ 0.50\frac{pCi}{g} in\ U233/234}$$
$$= \frac{8}{58}$$
$$= 0.138$$

$$P\left(U235 \,\middle|\, radiation\ level\ \leq 0.50\frac{pCi}{g}\right) = \frac{\#\ of\ 0.50\frac{pCi}{g} or\ less\ in\ U235}{Total\ \#\ of\ 0.50\frac{pCi}{g} in\ U235}$$
$$= \frac{40}{58}$$
$$= 0.690$$

U-235 is the likely source of the radiation because it has the highest probability of the three element types.

Analysis Samples and Probability Distributions

1. Ensuring Enough Samples for Analysis

The Hanford test planning team determined that the minimum number of samples required for analysis of their soil data would be 35. The test engineer is aware that samples can be excluded from the analysis for a variety of legitimate reasons. To ensure that at least 35 of the samples are fit for analysis, the test engineer proposes that they collect 40 samples. He uses the following Probability Distribution of usable data samples from a sample of size 40 to support his proposal.

Probability Distribution of Usable Samples from a Size of 40 Samples

X	P(x)	xP(x)	X^2P(x)
40	0.021	0.84	33.6
39	0.153	5.967	232.713
38	0.281	10.678	405.764
37	0.253	9.361	346.357
36	0.139	5.004	180.144
35	0.104	3.64	127.4
34	0.023	0.782	26.588
33	0.015	0.495	16.335
32	0.011	0.352	11.264
Totals	**1.000**	**37.119**	**1380.165**

According to this Probability Distribution of Usable Samples, the expected number (mean) of usable samples out of 40 samples, would be $\mu = \sum X_i P(X_i)$, which is 37.1 samples. In addition the standard deviation for this distribution was calculated using the following formula, $\sigma = \sqrt{\sum X_i^2 P(X_i) - [\sum X_i P(X_i)]^2}$. This calculation resulted in a standard deviation of 1.5 samples. The σ (mean) and μ (standard deviation) are used to calculate the minimum and maximum values for usable samples. These values represent 95% of the data values. The formulas and calculations are presented below:

Minimum Usual Value: $\mu - 2\sigma = 37.1 - 2(1.5) = 34.1\ samples$
Maximum Usual Value: $\mu + 2\sigma = 37.1 + 2(1.5) = 40.1\ samples$

The above values represent the samples that would be considered normal. The minimum usual number of samples out of the 40 is 34.1 samples. The maximum usual number of usable samples out of 40 is 40.1 samples. With these numbers, the test engineer can feel very comfortable with his choice of collecting 40 samples. Through this approach, he will have the correct amount of samples, at least 35, roughly 95% of the time.

2. Results Validation and Quality Control

Critical decisions about whether or not to cleanup areas U1 and U2 are to be made as a result of this analysis. To ensure the validity and quality of these results the test analysts require data from at least at 13 duplicate tests. The test engineer is aware of the fact that any given test may fail to meet the minimum usable sample requirement of at least 35 usable samples. To ensure that 13 usable duplicate tests are collected, he proposes that they conduct 15 duplicate tests. To support his proposal, initially the test engineer calculated the probability of a given sample having at least 35 usable samples out of 40 collected samples.

$$\begin{aligned} P(at\ least\ 35\ usable\ samples\ out\ of\ 40) &= 1 - P(34) - P(33) - P(32) \\ &= 1 - 0.023 - 0.015 - 0.011 \\ &= 0.951 \end{aligned}$$

He then proceeded to calculate the probability of at least 13 usable tests out of 15 tests conducted using two different techniques. The first technique that he used involved the Binomial Probability Formula and the second technique that he used was the Normal Approximation to the Binomial Formula. These calculations are presented below.

Binomial Probability Formula:

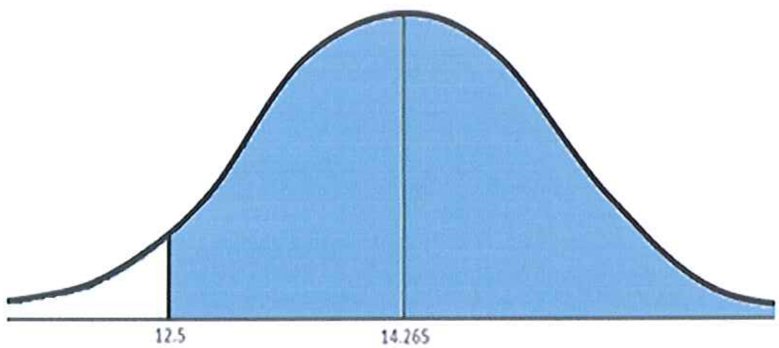
$$\begin{aligned} P(at\ least\ 13\ of\ 15\ samples) &= P(13) + P(14) + P(15) \\ &= {}_{15}C_{13}\,(0.951)^{13}(0.049)^{2} + {}_{15}C_{14}\,(0.951)^{14}(0.049)^{1} + {}_{15}C_{15} \\ &\quad (0.951)^{15}(0.049)^{0} \\ &= 0.966 \end{aligned}$$

Normal Approximation to the Binomial Formula:

N= 15
P=0.951
Q=0.049
X=13

$$\begin{aligned} \sigma &= \sqrt{npq} \\ &= \sqrt{15(0.951)(0.049)} \\ &= 0.836053228 \end{aligned}$$

$$\begin{aligned} \mu &= np \\ &= (15)(0.951) \\ &= 14.265 \end{aligned}$$



Duplicate Samples

$$P(at\ least\ 13\ of\ 15\ samples) = P(x \geq 13)$$
$$= P(x > 12.5)$$
$$= 1 - P(x < 12.5)$$
$$= 1 - P\left(z < \frac{12.5 - 14.265}{0.836053228}\right)$$
$$= 1 - P(z < -2.11)$$
$$= 1 - 0.0174$$
$$= 0.9826$$
$$= 0.983$$

The test engineer should feel quite comfortable with his choice of conducting 15 duplicate tests. According to his calculations, he will have the correct number of duplicate tests approximately 96.6% of the time. In this case, it is inappropriate to use the Normal Approximation to the Binomial Formula calculations above. This particular data set fails the requirement that $nq \geq 5$ since $nq = 15(0.049)$ which is 0.735.

3. Probabilities Involving Uranium Radiation Levels

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) require the cleanup of surface soil having a radiation level of 5 pCi/g or more. The table below lists the samples that exceed that level.

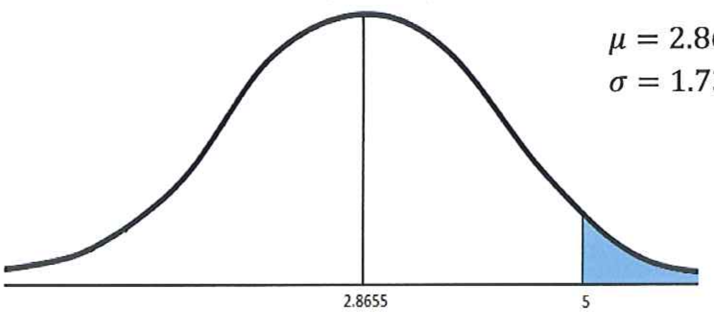
Radiation levels of 5 pCi/g or more

Uranium U1 05/08/10	Uranium U1 08/22/10	Uranium U2 05/08/11	Uranium U2 08/22/10
None	B24208	None	B24260
	B24209		B24268
	B24210		
	B24226		

Out of 40 samples that were collected from area U1 on May 8, 2010, there weren't any that were above the radiation level of 5 pCi/g. On the other hand, out of the 36 samples that were collected from the same area on August 22, 2010 there were four samples that had radiation levels over 5 pCi/g. Through this, it indicates that roughly 11 percent of the August samples collected from area U1 exceeded the CERCLA radiation cleanup level of 5 pCi/g. More analysis should be presented to check the area before it can truly be considered clean. Out of the 40 samples that were collected from area U2 on May 8, 2010, there weren't any that were above the radiation level of 5 pCi/g. On the other hand, out of the 39 samples that were collected from the same area on August 22, 2010 there were two samples that had radiation levels over 5 pCi/g. This shows that roughly 5 percent of the August samples collected from area U2 exceeded the CERCLA radiation cleanup level of 5 pCi/g. This isn't as dramatic as the 11 percent that area U1 from August, but it still brings up concern and should have further analysis done before it can truly be considered clean.

As a follow up to the reporting of sample radiation it has been determined that the August 22, 2010 sample data needs to be analyzed in greater detail. Due to budget constraints not all these samples can be analyzed again. Therefore the following probabilities were calculated to determine the probability of selecting one sample with a radiation level that may result in cleanup of the area U1. The probability was also calculated of selecting four samples with a mean radiation level that may result in the cleanup of area U1.

Single Sample

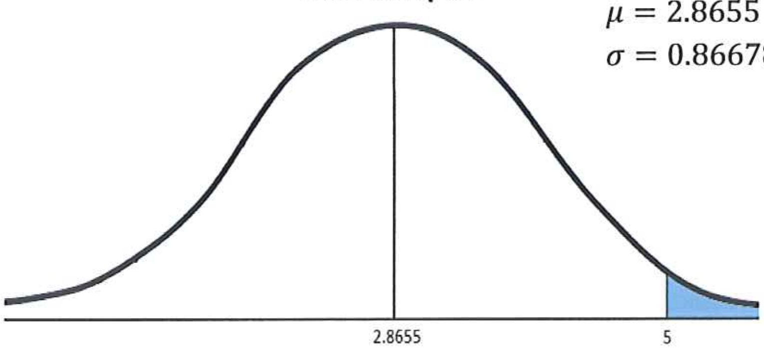


U1 Single sample normal Distribution

$$\mu = 2.8655$$
$$\sigma = 1.73357$$

$$P(x > 5) = 1 - P(x < 5)$$
$$= 1 - P\left(z < \frac{5 - 2.8655}{1.73357}\right)$$
$$= 1 - P(z < 1.23)$$
$$= 1 - 0.8907$$
$$= 0.109$$

Four Samples



U1 four samples sample normal Distribution

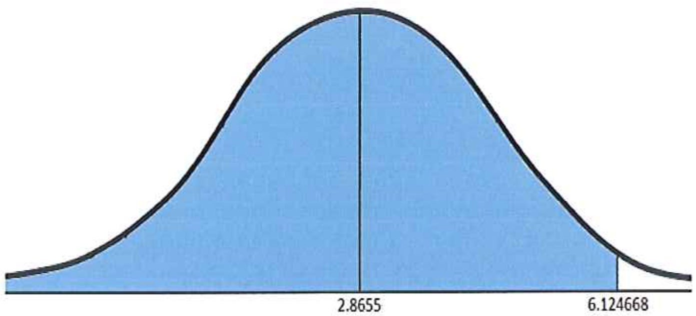
$$\mu = 2.8655$$
$$\sigma = 0.866784$$

$$P(\bar{x} > 5) = 1 - P(\bar{x} < 5)$$
$$= 1 - P\left(z < \frac{5 - 2.8655}{0.866784}\right)$$
$$= 1 - P(z < 2.46)$$
$$= 1 - 0.9931$$
$$= 0.0069$$
$$= 0.007$$

4. Percentiles Involving Uranium Radiation Levels

The assumption of normality was made with respect to the radiation levels of Uranium in areas U1 and U2 collected on August 22, 2010 in order to calculate the ninety-seventh percentile. This value represents the radiation level that separates the bottom 97% of radiation levels from the top 3%. A decision to declare an area clean will be made if at least 97% of the data values fall below 5 pCi/g. Otherwise, further testing will be conducted to determine if cleanup is required.

U1 97th percentile

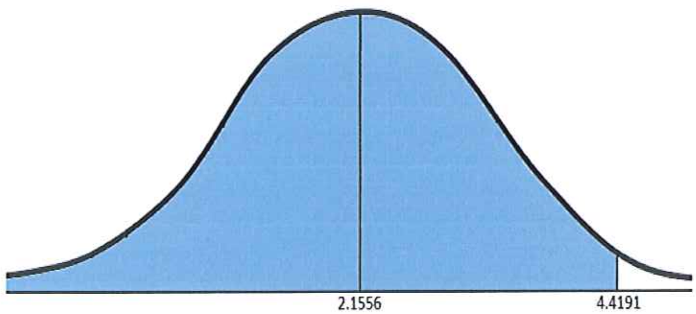


U1 collected on 08/22/10

$$\bar{x} = 2.8655$$
$$S = 1.73357$$

$$\begin{aligned} x &= \bar{x} + 1.88s \\ &= 2.8655 + 1.88(1.73357) \\ &= 6.124668\ pCi/g \end{aligned}$$

U2 97th percentile



U2 collected on 08/22/10

$$\bar{x} = 2.1556$$
$$S = 1.204$$

$$\begin{aligned} x &= \bar{x} + 1.88s \\ &= 2.1556 + 1.88(1.204) \\ &= 4.4191\ pCi/g \end{aligned}$$

Area U1 would require further cleaning and testing, while U2 is considered clean. Area U1 would need further analysis and cleaning because it exceeds CERCLA's limit. Since area U1 is over the required 5 pCi/g at 6.124668 pCi/g, it requires further analysis and cleaning. Generally, this means that at least 97% of the data values failed to fall below 5 pCi/g. Area U2 is clean and does not need further cleaning because it is under 5 pCi/g; U2 has radiation levels for 97 percent of their data at 4.4191 pCi/g.

Confidence Intervals and Hypothesis Tests

In 2008, the Washington State Department of Ecology in cooperation with the Department of Energy (DOE) and the CH2M HILL Plateau Remediation Company (CHPRC) collected two samples from a single location immediately adjacent to the pipe discharge point for the pond designated 216-S-19. These samples were designated as "screening" samples in order to determine if the site would be a suitable location to conduct a comparison of three sampling designs (Judgmental, MIS, and Systematic). Based on the results of this screening effort, contaminants of potential concern (COPCs) were identified. The contaminants were Nitrate, Copper, Chromium, Zinc, Uranium-233/234, Uranium-238, Uranium-235, Plutonium-239/240, Plutonium-238, and Americium-241. This section of the report will be looking at the total radiation levels of Uranium and Nitrate.

1. Confidence Intervals on the Proportion of the Pond with High Radiation Levels of Uranium

DOE is concerned about the proportion of this pond that contains Uranium radiation levels above the CERCLA standard of 5 pCi/g. The Systematic sample data collected on August 22, 2010 from both areas U1 and U2 was used to address this concern. For the proportion of the contaminant in each area, a 90% confidence interval was constructed. It was assumed that all requirements for constructing this type of confidence interval were satisfied.

Area U1 from August 22, 2010

Best estimate point: the proportion of the 216-S-19 pond with a Uranium radiation level that is greater than 5 pCi/g

$$\hat{p} = \frac{number\ of\ samples\ with\ a\ Uranium\ radiation\ level\ at\ exceed\ 5\frac{pCi}{g} sample}{Total\ number\ of\ samples\ from\ Uranium\ radiation\ levels}$$

$$\hat{p} = \frac{4}{36}$$

$$\hat{p} = \frac{1}{9}\ (\hat{p} \approx 0.111)$$

Margin of error: before constructing the 90% confidence interval, the margin of error must be calculated; calculations are below

$$E = Z_{\alpha/2}\sqrt{\frac{\hat{p}\hat{q}}{n}}$$

n = 36 $\hat{p}$ = 1/9 $\hat{q}$ = 8/9 $Z_{0.10/2} = Z_{0.05} = 1.645$

$$E = 1.645\sqrt{\frac{\left(\frac{1}{9}\right)\left(\frac{8}{9}\right)}{36}}$$
$$E = 0.0861245611$$
$$E = 0.086$$

The 90% confidence interval

$$\hat{p} - E < p < \hat{p} + E$$
$$\frac{1}{9} - 0.086 < p < \frac{8}{9} + 0.086$$
$$0.0251 < p < 0.197$$

Area U2 from August 22, 2010

Best point estimate: the proportion of the 216-S-19 pond with a Uranium radiation level that is greater than 5 pCi/g

$$\hat{p} = \frac{\textit{number of samples at area U2 that exceed the CERCLA } 5\frac{pCi}{g} \textit{ sample}}{\textit{Total number of samples from area U1}}$$

$$\hat{p} = \frac{2}{39}\ (\hat{p} \approx 0.0513)$$

Margin of error: before constructing the 90% confidence interval, the margin of error must be calculated; calculations are below

n = 39
$\hat{q}$ = 37/39
$\hat{p}$ = 2/39

$Z_{0.10/2} = Z_{0.05}$
= 1.645

$$E = Z_{\alpha/2}\sqrt{\frac{\hat{p}\hat{q}}{n}}$$

$$E = 1.645\sqrt{\frac{\left(\frac{2}{39}\right)\left(\frac{37}{39}\right)}{39}}$$
$$E = 0.0581011665$$
$$E = 0.058$$

The 90% confidence interval

$$\hat{p} - E < p < \hat{p} + E$$
$$\frac{2}{39} - 0.058 < p < \frac{37}{39} + 0.058$$
$$-0.007 < p < 0.109$$

EPA guidance states that "because of the uncertainty associated with estimating the true proportion of a contaminant at a site, the 95% upper confidence limit (UCL) of the proportion should be used". The lower bound of a confidence interval for the proportion of COPCs is not that significant. However, the upper bound of a confidence interval for the proportion of COPCs is significant. Analysis presented the following results for U1 and U2. For area U1, we are 95% confident that the proportion this area contains Uranium radiation levels of 5 pCi/g and less than 0.197. For area U2, we are 95% confident that the proportion this area contains Uranium radiation levels of 5 pCi/g and less than 0.109.

2. Confidence Intervals for the Nitrate Level in the 216-S-19 Pond

During the "screening" process of the 216-S-19 pond, Nitrate was identified as one of the COPCs. Prior to the excavation of this pond, data was collected in both areas U1 and U2 on May 8, 2010. Three different sampling techniques were used; Systematic, MIS, and Judgmental. Separate 90% confidence intervals for the mean Nitrate levels contained in each area were calculated for the Systematic data and again for the MIS data. These confidence intervals were used to address the different sampling techniques as well as the mean levels of Nitrate in the soil in areas U1 and U2. All confidence intervals were constructed using a Student's-t distribution. The key underlying assumptions necessary to use this distribution were validated. The calculations are presented below.

Area U1 Nitrate levels from systematic data on August 22, 2010

Best estimate point: for the Nitrate levels

$$\bar{x} = \frac{\sum x}{n}$$

$$\bar{x} = 21.255\frac{mg}{kg}$$

Margin of error: before constructing the 90% confidence interval, the margin of error must be calculated; calculations are below

$$E = t_{\frac{\alpha}{2}}\frac{s}{\sqrt{n}}\ where, E = t_{\frac{\alpha}{2}}(n-1) = t_{\frac{0.10}{2}}(39) = 1.685, n = 40, s = 13.399\ mg/kg$$

$$E = (1.685)\frac{17.399}{\sqrt{40}}$$

$$E = 4.635\frac{mg}{kg}$$

The 90% confidence interval

$$\bar{x} - E < \mu < \bar{x} + E$$
$$21.255 - 4.635 < \mu < 21.255 + 4.635$$
$$16.62\frac{mg}{kg} < \mu < 25.89\frac{mg}{kg}$$

Area U1 Nitrate levels from MIS data on August 22, 2010

Best point estimate: for the Nitrate levels

$$\bar{x} = \frac{\sum x}{n}$$
$$\bar{x} = 10.1\frac{mg}{kg}$$

Margin of error: before constructing the 90% confidence interval, the margin of error must be calculated; calculations are below

$$E = t_{\frac{\alpha}{2}}\frac{S}{\sqrt{n}}\ where, E = t_{\frac{\alpha}{2}}(n-1) = t_{\frac{0.10}{2}}(4) = 2.132\ n = 5, s = 0.85732141\ mg/kg$$
$$E = (2.132)\frac{0.85732141}{\sqrt{5}}$$
$$E = 0.817\frac{mg}{kg}$$

The 90% confidence interval

$$\bar{x} - E < \mu < \bar{x} + E$$
$$10.1 - 0.817 < \mu < 10.1 + 0.817$$
$$9.283\frac{mg}{kg} < \mu < 10.917\frac{mg}{kg}$$

Area U2 Nitrate levels from systematic data on August 22, 2010

Best point estimate: for the Nitrate levels

$$\bar{x} = \frac{\sum x}{n}$$
$$\bar{x} = 13.315\frac{mg}{kg}$$

Margin of error: before constructing the 90% confidence interval, the margin of error must be calculated; calculations are below

$$E = t_{\frac{\alpha}{2}} \frac{S}{\sqrt{n}} \ where, E = t_{\frac{\alpha}{2}}(n-1) = \ t_{\frac{0.10}{2}}(39) = 1.685 \ n = 40, s = 13.173 \ mg/kg$$

$$E = (1.685)\frac{13.173}{\sqrt{40}}$$

$$E = 3.510\frac{mg}{kg}$$

The 90% confidence interval

$$\bar{x} - E < \mu < \bar{x} + E$$

$$13.315 - 3.510 < \mu < 13.315 + 3.510$$

$$9.805\frac{mg}{kg} < \mu < 16.825\frac{mg}{kg}$$

Area U2 Nitrate levels from MIS data on August 22, 2010

Best point estimate: for the Nitrate levels

$$\bar{x} = \frac{\sum x}{n}$$

$$\bar{x} = 11.82\frac{mg}{kg}$$

Margin of error

$$E = t_{\frac{\alpha}{2}} \frac{S}{\sqrt{n}} \ where, E = t_{\frac{\alpha}{2}}(n-1) = \ t_{\frac{0.10}{2}}(4) = 2.132 \ n = 5, s = 3.076036411 \ mg/kg$$

$$E = (2.132)\frac{3.076036411}{\sqrt{5}}$$

$$E = 2.933\frac{mg}{kg}$$

The 90% confidence interval

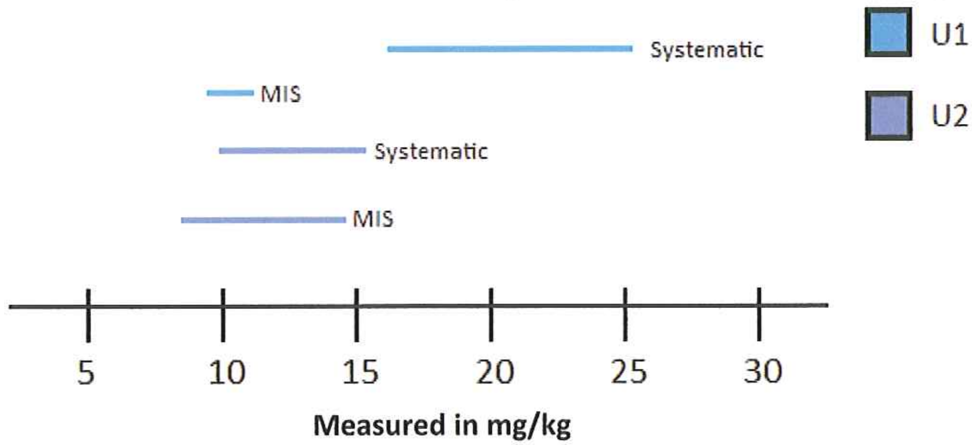
$$\bar{x} - E < \mu < \bar{x} + E$$

$$11.82 - 2.933 < \mu < 11.82 + 2.933$$

$$8.887\frac{mg}{kg} < \mu < 14.753\frac{mg}{kg}$$

Presented below is a confidence interval comparison of systematic and MIS data for areas U1 and U2. This confidence interval comparison compares how the two different areas compare in two different sampling techniques.

Confidence Intervals for U1 AND U2 with systematic and MIS data from May 2010



For area U1, confidence interval overlapping is not present, so it does appear that each sampling technique produces different mean Nitrate levels. For area U2, confidence interval overlapping is present, so there does not appear to be any differences in the mean Nitrate levels for the given sampling technique.

Again, the EPA guidance with respect to the mean level of a contaminant in a designated area states that "because of the uncertainty associated with estimating the true average concentration of a contaminant at a site, the 95% upper confidence limit (UCL) of the arithmetic mean should be used." We are 95% confident that the mean Nitrate level for area U1 using the systematic sampling technique is less than 25.89 mg/kg. We are 95% confident that the mean Nitrate level for area U1 using the MIS sampling technique is less than 10.917 mg/kg. We are 95% confident that the mean Nitrate level for area U2 using the systematic sampling technique is less than 16.825 mg/kg. We are 95% confident that the mean Nitrate level for area U2 using the MIS sampling technique is less than 14.753 mg/kg.

3. Hypothesis Tests for Nitrate Levels in the 216-S-19 Pond

According to Hanford Contamination Levels, Nitrate levels of 40 mg/kg or more are a cause for concern that could lead to area cleanup. The there were no MIS samples collected on May 8, 2010 in either area U1 or U2 that exceeded this level. However, during the same time period there were 6 Systematic samples out of 40 in area U1 and 3 Systematic samples out of 40 in area U2 that exceeded this contamination level. These samples are identified in the chart below.

Systematic Nitrate exceeding radiation levels from May 8, 2010

U1		U2	
ID number	Reported Nitrate	ID number	Reported Nitrate level
B241K4	44 mg/kg	B241R3	49 mg/kg
B241K8	42 mg/kg	B241R4	61 mg/kg
B241L0	47 mg/kg	B241W1	43 mg/kg
B241L9	71 mg/kg		
B241M0	60 mg/kg		
B241P0	48 mg/kg		
B241P2	48 mg/kg		

Hypothesis tests were conducted to formally test the claim that the mean Nitrate levels for the May 8, 2010 Systematic data in areas U1 and U2 are below the Hanford Contamination Level. These two tests are presented below.

Area U1 Nitrate level for May 8, 2010 Systematic data

H_0: $\mu = 40$
H_1: $\mu < 40$ (claim)

n=40
$\bar{x}$=21.255 mg/kg
S=17.399 mg/kg
μ=40

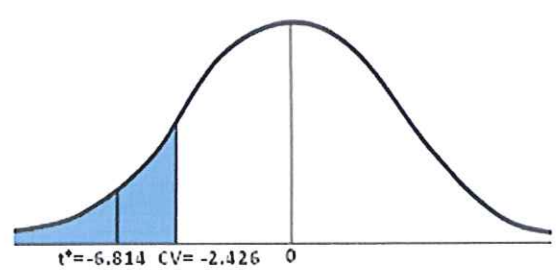
$$t^* = \frac{X-\mu}{s/\sqrt{n}}$$

$$t^* = \frac{21.255-40}{17.399/\sqrt{40}}$$

$$t^* = -6.814$$

$t_{.01}(39)=-2.426$
CV=-2.426

Since the test statistic of -6.81 is less than the critical value of -2.426, reject H_0. There is sufficient evidence to support the claim that the mean Nitrate level for the given area on May 8, 2010 is less than the action level of 40 mg/kg.



Student's t distribution, Nitrate levels area U1 collected May 8, 2010

Area U2 Nitrate level for May 8, 2010 Systematic data

H_0: μ = 40
H_1: μ < 40 (claim)

n=40
x̄=13.315mg/kg
S=13.173mg/kg
μ=40

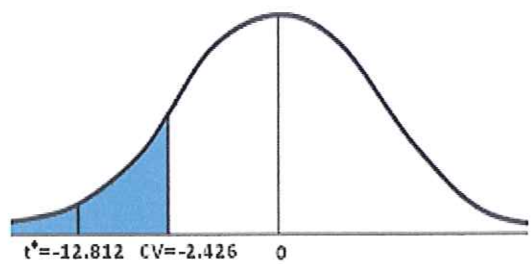
$$t^* = \frac{X-\mu}{s/\sqrt{n}}$$

$$t^* = \frac{13.315-40}{13.173/\sqrt{40}}$$

$$t^* = -12.812$$

$t_{.01}(39)$=-2.426
CV=-2.426

Since the test statistic of -12.81 is less than the critical value of -2.426, reject H_0. There is sufficient evidence to support the claim that the mean Nitrate level for the given area on May 8, 2010 is less than the action level of 40 mg/kg.



Student's t distribution, Nitrate levels area U2 collected May 8, 2010

4. Calculating Sample Size

In order to meet EPA standards, the Hanford test designers determined that they want the estimates of the mean Nitrate level in areas U1 and U2 to be within 5 mg/kg of the true population mean Nitrate level. The number of usable systematic samples that need to be randomly collected from each of the areas U1 and U2 were calculated using a 95% confidence level. The population standard deviation is assumed to be 15.0 mg/kg.

$\sigma = 15.0\ mg/kg$ $\alpha = 0.05$ $Z = 1.96$ $E = 5\ mg/kg$

$$n = \left[\frac{Z_{\frac{\alpha}{2}}\sigma}{E}\right]^2$$

$$n = \left[\frac{(1.96)(15)}{5}\right]^2$$

$$n = [5.88]^2$$

$$n = 34.5744$$

$$n = 35\ samples$$

$$n = 35\ samples$$

After finding *n*, it is clear to the test designer that 35 samples are what should be used to have a 95% confidence level sample.

Hypothesis Tests Comparing MIS, Systematic, and Judgmental Sampling

In 2008, Washington Department of Ecology in cooperation with DOE (Department of Energy) and CHPRC (CH2M Hill Plateau Remediation Company) collected two soil samples from a single location immediately adjacent to the Point of Discharge of the 216-S-19 Pond, a waste site of the 200-MG-1 Operable Unit. These samples were designed as "screening" in order to determine if the site would be a suitable location to conduct a comparison of three (Judgmental, Systematic Random, and Multi-Incremental) sampling designs. Based on the results of the Washington State Department of Ecology screening effort, COPCs (Chemical of Potential Concern) were selected and are the following: Chromium, Copper, Zinc, Mercury, Uranium-238, Uranium-233/234, Uranium-235, Plutonium-238, Plutonium-239/240, Americium-241, and Nitrate.

MIS sample points were selected by dividing each Decision Unit into grids with 100 units. One sample increment was collected from each grid unit for a total of 100 increments to comprise a single, multi-incremental "parent" sample. Four field replicate samples were also collected from each of the 100 grid-units in each Decision Unit.

Systematic Random sample points were selected using the 100-grid locations established in the MIS scheme above. Discrete sampling locations were proportioned out evenly within each Decision Unit using a random start point. In order to achieve a uniform distribution over each Decision Unit, 42 sample locations were identified rather than 40 as specified in the SAP.

Judgmental sample points were selected primarily based on field observations, professional judgment, and radiological field screening measurements. One location of highest expected (encountered) concentration will be selected, with the remaining four locations fanning out from that position. A total of five locations within each of the two Decision Units were identified and sampled.

Comparison testing of the mean concentration level of each of the elements listed above was done for these three different sampling techniques. Due to the nature of MIS sampling, the Central Limit Theorem applies, and this data can be assumed to be normally distributed as can the Systematic sampling data. The same assumption was made for the Judgmental sample data. However, any results involving Judgmental sampling should be viewed with caution as the assumption of normality is questionable. Due to time constraints, only the data collected on August 22, 2010 from area U1 were used in this analysis.

All comparison tests were conducted using a Student's t Distribution. The results for each test are summarized by element in various tables presented on the following pages. All 33 hypothesis tests used the following general format, test statistic, significance level, and critical value.

General Approach: Testing a Claim about Two Independent Population Means

Claim: There is no difference, when sampling the same area, between the mean element levels obtained from MIS sampling, Systematic sampling, and Judgmental sampling.

Hypothesis Test:

$$H_o : \mu_1 - \mu_2 = 0 \quad (Claim)$$

$$H_1 : \mu_1 - \mu_2 \neq 0$$

Test Statistic:

$$t^* = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Significance Level: $\alpha = 0.05$ Critical Value: $t_{0.05/2} = \pm 2.776$

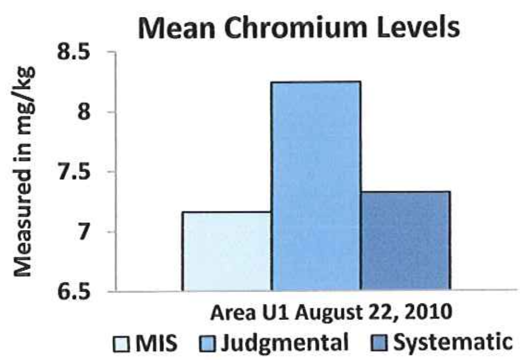
Degrees of Freedom: 4

Each element section is also accompanied by a bar graph which provides a visual comparison of the three sampling techniques and a table displaying the sample statistics used each hypothesis test. The results of these hypothesis tests are presented in a table along with the outcomes and written conclusions for each set of comparisons.

1. Comparison Tests Involving Chromium

Chromium Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	7.16	0.384707
Judgmental	8.24	0.559464
Systematic	7.3194444	1.4089144



Chromium Hypothesis Test Results

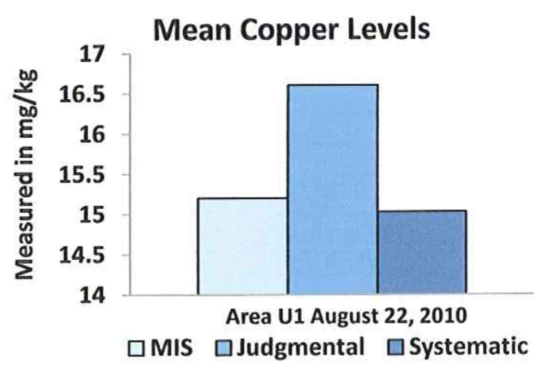
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-0.548	Fail to Reject H_0
MIS vs Judgmental	-3.557	Reject H_0
Systematic vs Judgmental	-2.683	Fail to Reject H_0

Conclusion: Since the test statistics for both the comparison of MIS and Systematic sampling as well as Systematic and Judgmental sampling (-0.548 and -2.683 respectively) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject H_0. There is insufficient evidence to reject the claim that there is no difference between mean Chromium levels obtained from MIS and Systematic sampling as well as Systematic and Judgmental sampling. However, the test statistic for the comparison of MIS and Judgmental sampling (-3.557) is less than the critical value of -2.766, reject H_0. There is sufficient evidence to reject the claim that there is no difference between Chromium levels obtained from MIS and Judgmental sampling.

2. Comparison Tests Involving Copper

Copper Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	15.2	1.6432
Judgmental	16.6	2.6077
Systematic	15.028	1.7966



Copper Hypothesis Test Results

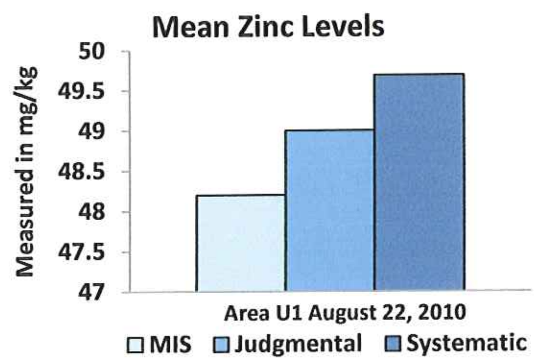
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	0.217	Fail to reject H_0
MIS vs Judgmental	-1.016	Fail to reject H_0
Systematic vs Judgmental	-1.306	Fail to reject H_0

Conclusion: Since the test statistics in all three comparisons (0.217, -1.016, and -1.306) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject H_0. There is insufficient evidence to reject the claim that there is no difference between mean Copper levels obtained from MIS, Systematic, and Judgmental sampling.

3. Comparison Tests Involving Zinc

Zinc Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	48.2	1.095445
Judgmental	49	2.345208
Systematic	49.69	2.955087



Zinc Hypothesis Test Results

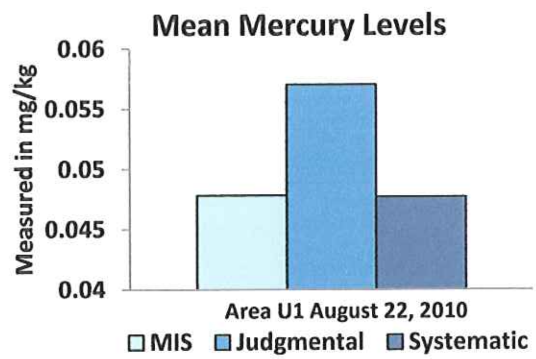
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-2.145	Fail to reject H_0
MIS vs Judgmental	-0.691	Fail to reject H_0
Systematic vs Judgmental	0.596	Fail to reject H_0

Conclusion: Since the test statistics in all three comparisons (-2.145, -0.691, and 0.596) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject H_0. There is insufficient evidence to reject the claim that there is no difference between mean Zinc levels obtained from MIS, Systematic, and Judgmental sampling.

4. Comparison Tests Involving Mercury

Mercury Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	0.0478	0.00602
Judgmental	0.057	0.01739
Systematic	0.04767	0.03079



Mercury Hypothesis Test Results

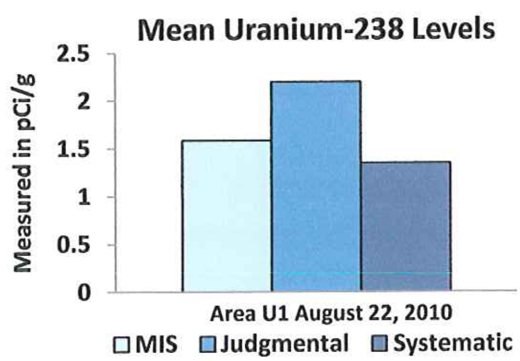
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	0.0224	Fail to reject H_0
MIS vs Judgmental	-1.118	Fail to reject H_0
Systematic vs Judgmental	-1.001	Fail to reject H_0

Conclusion: Since the test statistics in all three comparisons (0.0224, -1.118, and -1.001) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject H_0. There is insufficient evidence to reject the claim that there is no difference between mean Mercury levels obtained from MIS, Systematic, and Judgmental sampling.

5. Comparison Tests Involving Uranium-238

U-238 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	1.584	0.08532
Judgmental	2.196	1.52677
Systematic	1.34639	0.811



Uranium-238 Hypothesis Test Results

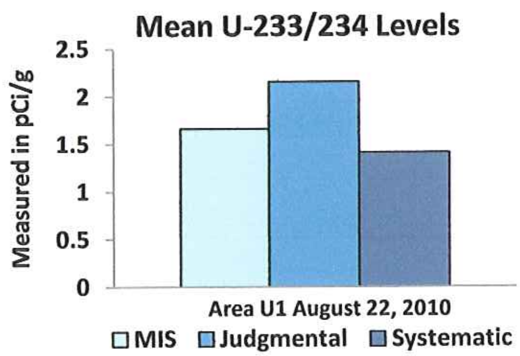
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	1.692	Fail to reject H_0
MIS vs Judgmental	-0.895	Fail to reject H_0
Systematic vs Judgmental	-1.221	Fail to reject H_0

Conclusion: Since the test statistics in all three comparisons (1.692, -0.895, and -1.221) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject H_0. There is insufficient evidence to reject the claim that there is no difference between mean Uranium-238 levels obtained from MIS, Systematic, and Judgmental sampling.

6. Comparison Tests Involving Uranium-233/234

U-233/234 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	1.662	0.09471
Judgmental	2.154	1.32022
Systematic	1.41055	0.815535



Uranium-233/234 Hypothesis Test Results

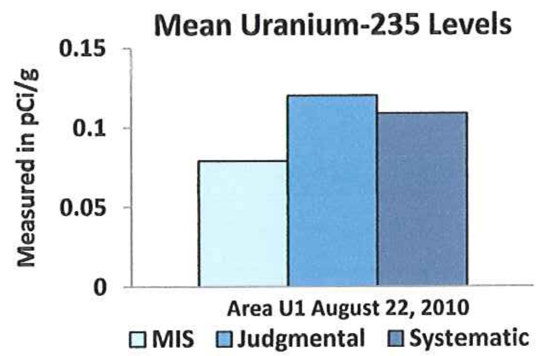
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	1.766	Fail to reject H_0
MIS vs Judgmental	-0.831	Fail to reject H_0
Systematic vs Judgmental	-1.227	Fail to reject H_0

Conclusion: Since the test statistics in all three comparisons (1.766, -0.831, and -1.227) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject H_0. There is insufficient evidence to reject the claim that there is no difference between mean Uranium-233/234 levels obtained from MIS, Systematic, and Judgmental sampling.

7. Comparison Tests Involving Uranium-235

Uranium-235 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.079	0.0157
Judgmental	0.1198	0.06423
Systematic	0.10856	0.21524



Uranium-235 Hypothesis Test Results

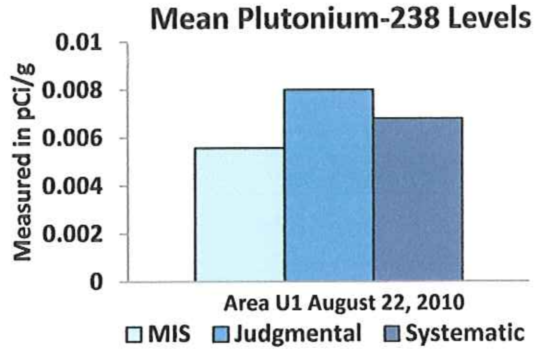
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-0.809	Fail to reject H_0
MIS vs Judgmental	-1.380	Fail to reject H_0
Systematic vs Judgmental	-0.245	Fail to reject H_0

Conclusion: Since the test statistics in all three comparisons (-0.809, -1.380, and -0.245) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject H_0. There is insufficient evidence to reject the claim that there is no difference between mean Uranium-235 levels obtained from MIS, Systematic, and Judgmental sampling.

8. Comparison Tests Involving Plutonium-238

Pu-238 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.00556	0.00433
Judgmental	0.008	0.0051
Systematic	0.00679	0.00474



Plutonium-238 Hypothesis Test Results

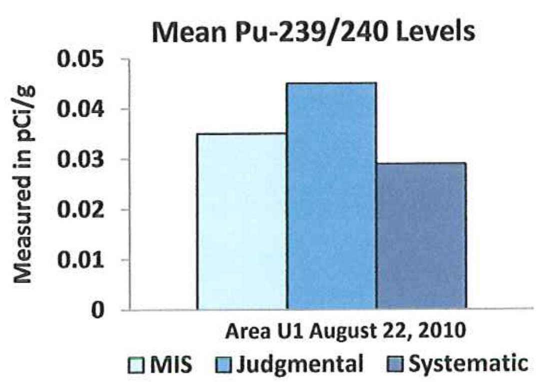
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-0.588	Fail to reject H_0
MIS vs Judgmental	-0.816	Fail to reject H_0
Systematic vs Judgmental	-0.501	Fail to reject H_0

Conclusion: Since the test statistics in all three comparisons (-0.588, -0.816, and -0.501) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject H_0. There is insufficient evidence to reject the claim that there is no difference between mean Plutonium-238 levels obtained from MIS, Systematic, and Judgmental sampling.

9. Comparison Tests Involving Plutonium-239/240

Pu-239/240 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.035	0.0081558
Judgmental	0.045	0.0310242
Systematic	0.028889	0.0330414



Plutonium-239/240 Hypothesis Test Results

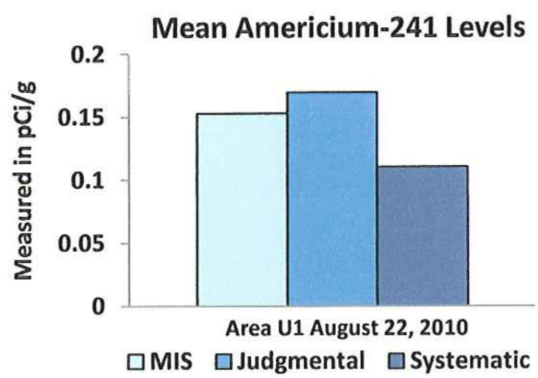
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	0.925	Fail to reject H_0
MIS vs Judgmental	-0.697	Fail to reject H_0
Systematic vs Judgmental	-1.079	Fail to reject H_0

Conclusion: Since the test statistics in all three comparisons (0.925, -0.697, -1.079) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject H_0. There is insufficient evidence to reject the claim that there is no difference between mean Plutonium-239/240 levels obtained from MIS, Systematic, and Judgmental sampling.

10. Comparison Tests Involving Americium-241

Am-241 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.1528	0.02381
Judgmental	0.1696	0.11122
Systematic	0.11039	0.18687



Americium-241 Hypothesis Test Results

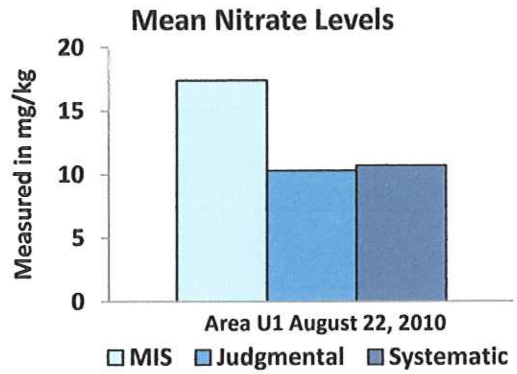
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	1.288	Fail to reject H_0
MIS vs Judgmental	-0.330	Fail to reject H_0
Systematic vs Judgmental	-1.009	Fail to reject H_0

Conclusion: Since the test statistics in all three comparisons (1.288, -0.330, and -1.009) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject H_0. There is insufficient evidence to reject the claim that there is no difference between mean Americium-241 levels obtained from MIS, Systematic, and Judgmental sampling.

11. Comparison Tests Involving Nitrate

Nitrate Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	17.4	1.81659
Judgmental	10.28	11.4305
Systematic	10.69167	8.94943



Nitrate Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	3.950	Reject H_0
MIS vs Judgmental	1.376	Fail to reject H_0
Systematic vs Judgmental	0.077	Fail to reject H_0

Conclusion: Since the test statistics for both the comparison of MIS and Judgmental sampling as well as Systematic and Judgmental sampling (1.376 and 0.077 respectively) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject H_0. There is insufficient evidence to reject the claim that there is no difference between mean Nitrate levels obtained from MIS and Systematic sampling as well as Systematic and Judgmental sampling. However, the test statistic for the comparison of MIS and Systematic sampling (3.950) is greater than the critical value of 2.766, reject H_0. There is sufficient evidence to reject the claim that there is no difference between Nitrate levels obtained from MIS and Systematic sampling.

Comparison Summary: From area U1 data on August 22, 2010, there were two incidences where there was a statistical difference between sampling methods. One of these incidences involved Judgmental samples for Chromium. Given how Judgmental samples are done, this shouldn't be taken seriously. Judgmental sampling, in general, is biased and the assumption of normality is questionable. The other incidence that had a statistical difference in sampling methods was for the element Nitrate; the sampling methods were between MIS and Systematic. Given how hypothesis testing is done, it shouldn't be that unexpected, when doing multiple hypothesis tests, to reject H_0, when it is in fact true. In other words, the significance level of 0.05 defines the probability of making a mistake. In these particular tests, there were 11 hypothesis tests comparing MIS and Systematic sampling means for a variety of elements. So, there was really only one test that had a statistical difference. This represents approximately 9% of the 11 tests. The significance level states that this mistake can happen around 5% of the time. Further analysis should be done to determine whether in fact a statistical difference exists.

Location	Date	ID	Chromium	Copper	Zinc	Mercury	U 238	U233/234	U235	Pu238	Pu239/240	Am 241	Nitrate	
U1	8/22/2010	B23NF3	7	14	48	0.047	1.62	1.73	0.085	0.0007	0.036	0.149	18	
		B23NH6	7	15	47	0.058	1.71	1.68	0.07	0.01	0.027	0.152	17	
		B23NH7	7.2	14	48	0.046	1.57	1.55	0.093	0.009	0.039	0.188	15	MIS closeout
	MIS closeout	B23NH8	7.8	15	50	0.042	1.49	1.58	0.091	0.0068	0.027	0.154	20	
		B23NH9	6.8	18	48	0.046	1.53	1.77	0.056	0.0013	0.046	0.121	17	
U1		B23NP4	8.4	20	51	0.059	1.92	2.06	0.112	0.004	0.036	0.281	9.3	
		B23NP5	8.2	17	50	0.055	4.6	4.18	0.194	0.002	0.023	0.094	0.8	Judgemental
	Judgemental	B23NP6	7.3	14	46	0.056	1.29	1.42	0.118	0.014	0.094	0.147	5.5	closeout
		B23NP7	8.6	18	51	0.082	2.56	2.45	0.154	0.008	0.055	0.287	30	
		B23NP8	8.7	14	47	0.033	0.61	0.66	0.021	0.012	0.017	0.039	5.8	
U1	Systematic	B241X6	7	15	46	0.051	1.74	2.05	0.089	0.003	0.018	0.072	6.1	Systematic
		B241X7	9.9	20	55	0.044	1.33	1.5	0.11	0.003	0.035	0.047	16	closeout
		B241X8	7.4	14	47	0.036	0.64	0.74	0.06	0.008	0.034	0.113	2.5	
		B241X9	7.6	13	49	0.05	0.59	0.55	0.038	0.01	0.15	1.09	2.7	
		B241Y0	6.4	13	47	0.034	0.94	1.15	0.069	0.0072	0.028	0.111	15	
		B241Y1	8.8	16	52	0.035	1.94	2.04	0.098	0.013	0.0008	0.009	34	
		B241Y2	8.5	15	52	0.041	1.87	1.73	0.086	0.0053	0.019	0.063	35	
		B241Y3	6.4	14	48	0.033	1.36	1.31	0.092	0	0.027	0.059	18	
		B241Y4	9.5	19	54	0.036	1.05	1.15	0.049	0.015	0.024	0.035	34	
		B241Y5	7.5	15	51	0.048	1.07	1.13	0.043	0.0028	0.068	0.164	16	
		B241Y6	9.2	17	52	0.034	0.57	0.68	0.02	0.0051	0.0053	0.003	2.8	
		B241Y7	6.9	14	50	0.034	1.07	1.22	0.032	0.009	0.021	0.143	14	
		B241Y8	8	16	52	0.034	0.88	0.96	0.058	0.012	0.029	0.085	12	
		B24200	10	17	56	0.035	0.75	0.71	0.025	0.009	0.012	0.066	19	
		B24201	7.4	16	52	0.034	0.79	0.8	0.032	0	0.007	0.037	18	
		B24202	6.4	13	48	0.033	1.35	1.42	0.143	0.017	0	0.042	7.2	
		B24203	8.7	17	55	0.035	0.9	0.92	0.057	0.0007	0.0061	0.053	15	
		B24204	8.5	16	52	0.092	0.8	0.8	0.037	0.011	0.084	0.307	12	
		B24207	8.5	16	49	0.041	1.28	1.34	0.093	0.0067	0.03	0.09	4.4	
		B24208	9.2	17	52	0.2	3.02	2.8	1.34	0.009	0.059	0.241	5.5	
		B24209	9	18	52	0.035	4.03	4.24	0.171	0.003	0.009	0.032	4.3	

B24234	6.9	14	47	0.035	0.58	0.72	0.044	0.012	0.035	0.044	6.8
B24235	6.1	14	46	0.034	1.21	1.08	0.066	0.02	0.029	0.096	5.5
B24236	7.9	14	48	0.035	1.09	1.08	0.05	0.01	0.008	0.053	5.6
B24237	5.3	14	46	0.033	0.86	0.9	0.047	0.003	0.038	0.038	5.6
B24238	6.8	13	45	0.034	0.86	0.92	0.052	0.011	0.012	0.022	5.9
B24239	7.1	14	47	0.047	1.15	1.07	0.072	-0.0002	0.033	0.116	4.3
B24240	6.2	14	46	0.034	0.88	0.92	0.076	0.019	0.013	0.057	5.4
B24241	6.6	14	46	0.035	0.55	0.52	0.044	0.01	0.041	0.047	12
B24243	6.8	14	46	0.034	1.08	1.02	0.068	0.011	0.019	0.151	18
B24244	7	14	47	0.035	1.34	1.38	0.07	0.0067	0.012	0.138	12
B24245	6.8	14	49	0.035	1	1.02	0.054	0.0052	0.035	0.119	15
B24246	7.4	14	50	0.035	1.38	1.31	0.05	0.008	0.026	0.121	8.7
B24247	7.5	14	50	0.035	1.42	1.59	0.071	-0.001	0.028	0.08	24
B24248	5.9	12	43	0.034	0.55	0.56	0.014	0.017	0.007	0.002	2
B24249	5.8	15	49	0.034	0.56	0.67	0.042	0.009	0.063	0.059	6.1
B24250	7.2	15	49	0.048	1.14	1.18	0.143	0.012	0.09	0.197	12
B24252	7.4	13	50	0.035	0.66	0.62	0.029	0.012	0.031	0.053	15
B24253	8.6	16	49	0.036	0.84	0.88	0.055	0.01	0.026	0.103	6.6
B24254	7.7	15	49	0.035	0.79	0.75	0.037	0.0007	0.018	0.038	9.9
B24255	9	16	53	0.041	1.62	1.7	0.023	0.0042	0.055	0.249	14
B24256	9.6	14	49	0.035	0.79	0.78	0.027	0.0017	0.008	0.021	5.5
B24257	5	18	49	0.033	0.46	0.412	0.015	-0.0009	0.004	0.009	4.2
B24258	7.6	16	50	0.083	1.66	1.83	0.115	0.006	0.159	0.252	15
B24259	6.9	14	48	0.072	1.99	1.9	0.097	0.0074	0.108	0.191	17
B24260	8.3	16	49	0.14	2.82	2.72	0.154	0.008	0.179	0.403	6.6
B24261	6.2	13	48	0.034	0.8	0.73	0.043	0.008	0.048	0.031	4.3
B24262	7.3	14	47	0.046	1.01	0.89	0.074	0.013	0.032	0.132	7.1
B24263	6.5	14	47	0.034	0.72	0.62	0.045	0.011	0.039	0.114	11
B24264	5.9	13	47	0.034	0.65	0.71	0.05	0.019	0.096	0.089	2.7
B24265	7	16	48	0.051	0.96	0.96	0.059	0.008	0.225	0.303	10
B24267	5.7	13	49	0.038	1.79	1.92	0.152	0.002	0.013	0.014	12
B24268	7.2	16	50	0.16	2.6	2.66	0.129	0.005	0.064	0.118	15
B24269	9.3	16	50	0.1	1.97	2.04	0.143	0.007	0.028	0.041	3

Location	Date	ID	Chromium	Copper	Zinc	Mercury	U 238	U233/234	U235	Pu238	Pu239/240	Am 241	Nitrate	
U1	5/8/2010	B23NF2	11	13	45	0.056	0.55	0.71	0.031	0	0.081	0.119	11	
		B23NF7	6	7.2	27	0.08	0.77	0.98	0.03	0.028	1.19	0.331	9.7	
	MIS	B23NF8	15	15	52	0.15	0.62	0.67	0.055	0.004	0.305	0.46	9.7	MIS
		B23NF9	17	21	51	0.23	0.73	0.72	0.021	0.023	0.297	0.36	9.1	
		B23NH0	9.9	14	49	0.053	0.55	0.53	0.012	-0.011	0.083	0.099	11	
U1		B23NN2	11	19	39	0.15	0.85	0.64	0.037	0.026	1.04	0.5	6	
		B23NN3	7.7	12	36	0.086	0.64	0.63	0.027	0.017	0.74	0.319	5.3	
	Judgmental	B23NN4	77	150	60	37	6.3	6.3	0.246	2.41	57.1	123	23	Judgmental
		B23NN5	6.3	12	37	0.035	0.55	0.54	0.017	-0.006	0.007	0.007	38	
		B23NN6	6.3	12	36	0.035	0.4	0.45	0.036	-0.002	0.016	0.042	30	
		B23NN7	6.4	11	35	0.037	0.4	0.47	0.026	-0.003	0.052	0.052	12	
	Systematic	B241J9	7.7	11	49	0.043	0.56	0.64	0.032	-0.0013	0.018	0.01	15	
		B241K1	7.6	10	46	0.036	0.62	0.55	0.024	-0.0011	0.0019	0.018	14	
		B241K2	7.6	9.6	46	0.035	0.59	0.55	0.017	0.0023	0.015	0.018	22	
		B241K3	7.5	8.9	45	0.039	0.47	0.54	0.011	0	0.01	0.021	19	
		B241K4	23	14	50	0.14	0.6	0.65	0.017	0.0082	0.208	0.063	44	Systematic
		B241K5	7.4	12	47	0.035	0.57	0.53	0.036	0.0006	0.0102	0.007	11	
		B241K6	7.5	11	47	0.037	0.6	0.48	0.032	0.001	0.0121	0.01	26	
		B241K7	7	9.9	47	0.036	0.56	0.46	0.027	-0.0022	0.016	0.003	3.3	
		B241K8	7.7	10	46	0.044	0.63	0.64	0.042	0.008	0.198	0.125	42	
		B241K9	7	8.3	45	0.036	0.53	0.57	0.048	0	0.0058	0.019	3.5	
		B241L0	8.6	8.9	47	0.035	0.44	0.53	0.017	0	0.01	0.042	47	
		B241L1	16	12	48	0.053	0.55	0.63	0.022	-0.0004	0.037	0.047	8.6	
		B241L3	16	13	52	0.072	0.64	0.65	0.043	-0.0013	0.103	0.015	3.1	
		B241L4	7.8	9.4	49	0.043	0.49	0.56	0.035	0.0062	0.014	0.008	11	
		B241L5	19	19	50	0.073	0.63	0.53	0.031	0.045	0.394	0.407	11	
		B241L6	7.7	8.9	47	0.034	0.47	0.47	0.007	-0.002	0.053	0.064	32	
		B241L7	9	10	47	0.037	0.61	0.56	0.034	-0.0004	0.026	0.04	34	
		B241L8	7.9	8.2	46	0.035	0.51	0.58	0.041	-0.002	0.0034	0.002	23	
		B241L9	13	12	49	0.084	0.52	0.53	0.006	-0.003	0.12	0.036	71	

		B241M0	17	12	48	0.076	0.57	0.55	0.024	0.01	0.159	0.054	60	
		B241M1	14	18	55	2.3	1.62	1.43	0.086	0.029	0.91	0.18	7.7	
		B241M2	7.7	10	48	0.037	0.64	0.67	0.058	-0.0013	0.069	0.026	5.1	
		B241M3	8.4	9.1	47	0.036	0.56	0.51	0.025	0.003	0.034	0.038	5	
		B241M4	8.1	9.7	49	0.044	0.61	0.53	0.031	-0.0023	0.029	0.014	36	
		B241M5	8	8.3	47	0.035	0.56	0.65	0.036	-0.0021	0.017	0.011	4	
		B241M6	7.6	8.6	48	0.034	0.49	0.57	0.015	-0.0036	0.03	0.013	29	
		B241M7	25	56	63	4.8	1.01	1.04	0.058	0.57	4.75	15.9	9.6	
		B241M9	7.8	9.9	47	0.037	0.55	0.5	0.03	0.0007	0.038	0.031	4.2	
		B241N0	7.8	11	52	0.036	0.44	0.43	0.035	0.009	0.049	0.044	4.2	
		B241N1	8.1	9.2	47	0.037	0.68	0.6	0.043	-0.005	0.078	0.098	8.1	
		B241N2	9.7	36	51	0.1	1.13	1.19	0.043	0.225	2.53	5.27	15	
		B241N3	7.3	7.6	45	0.035	0.52	0.53	0.032	0.0009	0.0091	0.002	14	
		B241N4	6.9	8.7	46	0.035	0.49	0.5	0.036	-0.0023	0.041	0.24	6.8	
		B241N5	76	16	57	0.29	0.65	0.73	0.02	0.0111	0.428	0.062	39	
		B241N6	8	9.9	48	0.036	0.52	0.6	0.011	-0.0011	0.057	0.045	11	
		B241N8	8	9.8	48	0.037	0.49	0.58	0.052	0.004	0.039	0.044	18	
		B241N9	12	21	51	0.51	1.33	1.03	0.066	0.14	4.17	5.6	22	
		B241P0	8.3	13	51	0.036	0.44	0.45	0.026	0.008	0.035	0.098	48	
		B241P1	8.2	12	51	0.042	0.48	0.41	0.019	0	0.007	0.009	15	
		B241P2	8.3	12	50	0.036	0.58	0.53	0.038	0.01	0.021	0.018	48	
Location	Date	ID	Chromium	Copper	Zinc	Mercury	U 238	U233/234	U235	Pu238	Pu239/240	Am 241	Nitrate	
U2	5/21/2011	B23NH1	6.4	12	44	0.031	0.63	0.58	0.027	0.0096	0.115	0.068	7.1	
		B23NH2	7.7	13	47	0.046	0.56	0.58	0.023	0.0063	0.22	0.171	12	MIS
	MIS	B23NH3	7.2	13	49	0.027	0.54	0.64	0.025	0.0035	0.105	0.062	14	
		B23NH4	11	20	57	0.25	1.22	1.21	0.057	0.028	1.58	0.384	15	
		B23NH5	7.9	16	51	0.047	0.69	0.67	0.033	0.012	0.239	0.096	11	
U2		B23NN8	7.5	13	50	0.036	0.49	0.59	0.004	0	0.004	0.019	3.7	
		B23NP0	23	72	73	1.1	2.78	2.9	0.132	0.157	6.7	1.48	2.3	Judgmental
	Judgmental	B23NP1	71	360	190	5.6	5.71	5.92	0.31	1.36	22.3	12.3	4.5	
		B23NP2	7.1	9.9	50	0.037	0.41	0.58	0.028	0	0.045	0.015	7.5	
		B23NP3	7.3	12	50	0.037	0.53	0.56	0.024	0.009	0.096	0.046	2.7	

U2	Systematic	B241P3	7.9	12	51	0.037	0.45	0.47	0.033	0.0018	0.038	0.036	4.8	
		B241P4	7.5	9.4	51	0.036	0.53	0.46	0.075	0	0.012	0.013	4.3	
		B241P5	7.5	13	51	0.037	0.54	0.53	0.016	0.0019	0.022	0.028	4.1	
		B241P6	7	9.6	51	0.035	0.5	0.44	0.05	-0.002	0.037	0.12	14	Systematic
		B241P7	7.2	11	50	0.036	0.49	0.49	0.028	0.002	0.024	0.03	29	
		B241P8	7.2	14	51	0.041	0.58	0.6	0.045	0.002	-0.004	0.018	23	
		B241P9	7.4	18	50	0.042	0.48	0.48	0.01	-0.002	0.04	0.035	17	
		B241R1	7.2	9.7	51	0.039	0.5	0.57	0.017	0.004	0.002	0.02	4.3	
		B241R2	8.4	11	54	0.037	0.68	0.6	0.033	0.0058	0.042	0.048	8.2	
		B241R3	7.7	12	52	0.037	0.52	0.56	0.076	0.003	0.02	0.026	49	
		B241R4	7	13	57	0.039	0.49	0.58	0.016	0.0057	0.027	0.085	61	
		B241R5	7.2	13	52	0.037	0.38	0.49	0.025	0.0038	0	0.019	4.9	
		B241R6	7.3	14	52	0.04	0.57	0.6	0.03	-0.0055	0.013	0.015	16	
		B241R7	7.3	11	53	0.038	0.57	0.56	0.021	0	0.011	0.028	2.2	
		B241R8	7.3	9.9	51	0.039	0.5	0.67	0.051	0.006	0.082	0.051	3.5	
		B241R9	10	20	55	0.45	1.42	1.31	0.091	0.055	1.95	0.77	4.9	
		B241T0	7	13	51	0.04	0.52	0.6	0.002	-0.0057	0.081	0.035	21	
		B241T1	8.2	13	52	0.036	0.58	0.71	0.042	0.0018	-0.0018	0.0132	17	
		B241T3	15	30	57	0.77	1.72	1.72	0.105	0.058	1.57	0.76	5.9	
		B241T4	7.2	14	51	0.16	0.85	0.96	0.1	0.028	2.45	0.486	6.9	
		B241T5	7.4	11	51	0.038	0.62	0.51	0.016	0.0089	0.126	0.066	4	
		B241T6	7.4	14	55	0.093	0.63	0.61	0.03	0.005	0.074	0.133	2.4	
		B241T7	7.5	11	53	0.037	0.48	0.55	0.043	0	0.019	0.021	2.5	
		B241T8	7.7	11	52	0.036	0.54	0.62	0.028	0.0039	0.062	0.06	7.3	
		B241T9	8.6	14	52	0.037	0.64	0.59	0.032	0.0058	0.075	0.075	7.6	
		B241V0	7.6	11	51	0.037	0.56	0.5	0.031	-0.0018	0.0035	0.013	16	
		B241V1	8.4	13	53	0.045	1.6	1.7	0.089	0.024	1.46	0.299	13	
		B241V2	7.8	11	53	0.037	0.45	0.56	0.056	0.002	0.011	0.024	2.2	
		B241V3	8.1	12	53	0.037	0.48	0.54	0.057	0.0052	0.014	0.044	7.5	
		B241V5	7.6	11	53	0.037	0.46	0.53	0.014	0.016	0.067	0.072	4.7	
		B241V6	8.4	11	53	0.037	0.46	0.5	0.031	0.004	0.002	0.026	4.5	
		B241V7	7.4	13	52	0.036	0.57	0.51	0.006	0.0039	0.006	0.022	22	
		B241V8	9.4	13	53	0.036	0.48	0.57	0.04	0	-0.0016	0.014	8.2	
		B241V9	7.4	11	52	0.036	0.46	0.49	0.026	-0.0019	0.017	0.008	12	
		B241W0	7.2	10	51	0.037	0.6	0.66	0.037	0.003	0.047	0.032	3.7	

B241W1	8.5	13	54	0.13	0.83	0.89	0.05	0.006	0.275	0.295	43
B241W3	10	12	51	0.037	0.5	0.59	0.041	0.0087	0.087	0.083	13
B241W4	7.6	10	51	0.036	0.54	0.64	0.045	-0.0019	0.0037	0.025	12
B241W5	7.4	9.2	52	0.036	0.6	0.51	0.006	-0.002	0.025	0.022	25
B241W6	7.6	11	51	0.037	0.5	0.46	0.038	-0.0037	0.017	0.025	21