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Mr. K. Michael Thompson
Senior Project Manager
Groundwater Project
U. S. Department of Energy
Richland Operations Office
Richland, WA 99352

RE: Responses to comments on proposed revision to the RCRA 300 Area Process Trenches Groundwater Monitoring Plan to be sent to Ted Wooley of Ecology

Dear Mr. Thompson:

Attached are responses to comments on the proposed revision to the RCRA 300 Area Process Trenches groundwater monitoring plan. Also attached is the revised portion of the plan (WHC-SD-EN-AP-185.3 ROA) so that you can see how these comments were implemented. 44844

If you have any questions about the comment responses or resolutions please contact Jon Lindberg at 376-5005 or Charissa Chou at 372-3804.

Sincerely,

Ronald M. Smith

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Project Manager
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RMS/JWL:vaa

enclosure

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Comments on WHC-SD-EN-AP-185.3 ROA

General statistical questions

1) EPA document (530-R-93-003) points to the fact that available normality tests are relatively poor at rejecting non-parametric data (indicating a normal distribution when in fact it is not) when the sample number is less then 20. How was this anomaly addressed with regard to the historical ground water data used for the 300 Area Process Trenches?

Disposition: Yes, you are right. All of the available tests for normality do, at best, a fair job of rejecting non-normal data when the sample size is small (i.e., do not exhibit a high degree of statistical power). The assumption of normality of data was tested using Lilliefors test for normality and found reasonable. The number of baseline data used was small because the site conditions have changed over time. Data obtained after January 1995 was judged to be most representative of current site conditions (e.g., ERA conducted in June 1991, termination of all discharges to the trenches occurred in December 1994). To pool heterogeneous data (to obtain a larger sample size) was not appropriate because this would result in larger estimates of standard deviation and, therefore, higher control limits for the constituents of interest. As more data become available in the future, baseline data set will be updated and refined.

2) Was the data homogeneous; were causes of variability assignable or nonassignable? How is the sensitivity of the proposed CUSUM-Shewart model affected by this parameter?

Disposition: The homogeneity of baseline data, for each constituent of interest from each well, was obtained by carefully examining the historical data sets and included only those data points collected after January 1995 (see disposition #1). By excluding data that were heterogeneous, only nonassignable (chance) causes of variability were present in the baseline data sets. Thus the derived control limits for the 300 APT should be more sensitive to detect changes over time that may be due to assignable causes such as a new source of contamination, sampling or measurement biases, etc.

3) Gilbert's 1987 book "Statistical Methods for Environmental Pollution Monitoring" page 193 section 15.6, discusses that having control charts based both on the mean and standard deviations or ranges is required for completeness. How is this satisfied with the proposed model?

Disposition: The proposed statistical method is the combined Shewhart-CUSUM control chart for checking whether current data are consistent with past data. A lack of consistency over time (as shown by exceeding the control limits) may indicate shifts or trends in mean concentrations or in levels of variability (Gilbert 1987, page 193). Thus, the presence of shifts in process variability as well as mean concentrations will be revealed as data are plotted over time.

4) What control chart formulas (and numerical values for variables) were used for calculating values for: 1) the centerline; 2) control limits? Again were these based on a mean concentration or a standard deviation of (or from) the mean?

Disposition: The formulas are provided in Section 6.2.4 of the subject plan. The combined Shewhart-CUSUM chart differs from a traditional $\bar{x}$ chart. The centerline is the mean concentration (estimated by $\bar{x}$) or zero (if data are expressed in standardized unit). The control limits for the combined Shewart-CUSUM control chart were calculated based on estimates of the process mean and process standard deviation. Attachment (Table 1 for your information only) summarizes the requested information. The control limits were calculated using estimates of the mean concentration and standard deviation (from) the mean.

5) Description of Modification: cost savings of 50%-75% is presumably based on a drastic decrease in the number of samples. By sampling less, how is a greater ability to sense changes in trending and detection of releases achieved?

Disposition: The advantages mentioned are attributable to both the proposed new sampling schedule, as well as to the new statistical method. Revisions to the sampling schedule and the statistical methods are needed to reflect changing monitoring objectives at the site (i.e., from comparing with compliance limits (MCLs) to corrective action monitoring. One advantage attributable to the new sampling plan is that the wells showing exceedances will be monitoring more frequently (quarterly versus semiannual monitoring). The gains in monitoring for trend and detecting new releases are mostly due to the revised statistical method. The CUSUM-Shewhart control chart method is particularly suited to monitor trends, and is sensitive to changes in groundwater concentrations that can be the basis for rapid notification to Ecology. In addition, lower limits (significantly lower than MCLs) will be used for comparison purposes for non-exceedance wells.

6) Section 6.2.1; 6.2.2 has a small discussion on establishing control limits for wells that have never exceeded MCLs. A similar discussion should be added to section 6.2.1. Revise document to describe how the control limits can get very large for wells that are known to have exceeded MCLs.

Disposition: A small discussion will be added to 6.2.1 to describe how the control limits can get large for wells that are known to have exceeded MCLs. The discussion will be simply stated in a similar fashion to the following: The control limits are calculated from the trend of the data during the baseline period. It should be noted that for wells that are known to have exceeded MCLs the calculated control limits can be very large. This is due to the fact that if the baseline data set shows a high mean concentration of a constituent of concern and the variability of the constituent trend is large, then the upper control limit (which is based on the mean and standard deviation of the data during the baseline period) will be larger than the MCL.

7) Section 6.2.3, first bullet: Please explain how this method meets WAC-173-303 requirements, for final status/compliance monitoring.

Disposition: The proposed method is one of the acceptable statistical methods given in WAC 173-303-645(8)(h)(iv) (i.e., a control chart approach that gives control limits for each constituent).

8) Section 6.2.4: This section explains that data that are not normally distributed can be handled lognormally. Why hasn't any non-parametric [sic] statistical methods been considered for analyzing data that is not normally distributed.

Disposition: All statistical methods were considered. The power of a statistical test based on normal (or log-normal) distribution is more powerful than non-parametric statistics. Therefore, the more powerful parametric (with normal or log-normal distributions) statistical methods are preferred if the data support the assumption of normal (or log-normal) distributions. All available statistical goodness-of-fit tests do not exhibit a high degree of power when sample size is small (say less than 20 or 30). However, the changing site conditions preclude the use of a larger baseline data set. As more data become available, baseline data set will be updated and refined (see Disposition #1).

9) Section 6.2.4, "procedural steps": Number 2 states that if the SCL is lowered to 2 from 4.5, the result is a single control limit. Assuming that a standard control chart has a upper and lower control limit, which one is lost and why? How does this effect the usability of the control chart?

Disposition: One can use a one-sided (upper in this case) or two-sided (upper and lower) control limits depending on the situation occurring at a site. "Testing" for only one trend (either up or down) does not in any way reduce the sensitivity of the analysis or make the control chart less usable. The concern, for those non-exceedance wells at the 300 APT, is that the trend might go up. Therefore, an upper control limit is appropriate for trending upward data that might occur in these wells sometime in the future. Concentrations going down in these wells are not a big concern. In fact, downward trending concentrations are desirable. For those exceedance wells, two-sided control limits were proposed (see December 4, 1997 handout), however, formula are not provided in the plan. Formula for two-sided control limits will be added in Section 6.2.4.

10) Section 6.2.4, number 6: What criteria was/is used for handling outliers. 1) How is it determined that a point is an outlier? 2) Is replacement sampling done to replace an outlier and if not how is that data gap addressed?

Disposition: The criteria to handle outliers will follow generally accepted statistical methods (e.g., the Grubbs' method as outlined in EPA 1989, pages 8-11 to 8-14 or the box-and-whisker plots). During the routine data review process, the project scientist or the hydrogeologist investigator who is knowledgeable about the site checks the data for consistency. If inconsistency is noted, further investigation (e.g., verification re-sampling or re-run the analysis) will follow. Outliers could be due to sampling, laboratory, transcription errors, or by chance alone. Outliers are not noted in the baseline data sets. The plan will be revised to reference statistical methods to handle outliers that may occur in the future.

Table 1. Summary Statistics and Calculated Control Limits for Selected Wells for the 300 APT.

Summary Statistics	CisDCE		TCE		Uranium	
	3-1-16A	3-1-16B[a]	3-1-16A	3-1-16B[a]	3-1-17A[a]	3-1-17B
N	9	9	9	9	15	10
Average ($\bar{x}$)	0.213	150.8	0.64	3.91	198.0	0.059
Std Dev. (s)	0.131	24.8	0.24	2.95	67.5	0.136
Minimum	ND	100	0.3	0.26	108	ND
Maximum	0.3	190	1.0	10	313	1.33
Control Limit: ($\bar{x} \pm 4.5s$)	0.803 < 1	[39, 262]	1.72 < 2	[0, 17.2]	[0, 468]	0.67 <1
Control Limit: ($\bar{x} \pm 3s$)	0.606 < 1	[76, 225]	1.36 < 2	[0, 12.8]	[0, 400]	0.47 < 1
Control Limit: ($\bar{x} \pm 2s$)	0.475 < 1	[101, 200]	1.12 < 2	[0, 9.8]	[63, 333]	0.33 < 1

[a] Shaded areas denote compliance point wells where MCLs have been and still are exceeded. Two-sided control limits are calculated.

6.0 Corrective Action Program

6.1 Introduction

Concentration limits for the constituents of interest (TCE, cis-DCE, and uranium) have been, and still are, exceeded in some compliance wells at the 300 Area Process Trenches (300 APT). Therefore, a plan for a corrective action groundwater-monitoring program needs to be developed. An alternative sampling procedure and statistical method are hereby proposed that will improve the ability of the monitoring program to monitor for trends and to detect impacts to groundwater quality and achieves significant cost savings by reducing the number of routine groundwater samples required for statistical testing purposes. This alternative sampling procedure and statistical method will meet the intent of a final status compliance groundwater-monitoring program.

The objective of a compliance groundwater monitoring program is to determine statistically whether concentration limits (i.e., MCLs) are exceeded (Sections 1.0 – 5.0 of this groundwater-monitoring plan). The statistical method specified in Section 4.6 (i.e., compare maximum concentrations from downgradient compliance wells to MCLs) has demonstrated the exceedances of MCLs in some compliance wells. The proposed corrective action groundwater-monitoring program should be consistent with the interim Record of Decision for the 300-FF-5 Operable Unit because the 300 APT lies with the boundaries of that operable unit. The interim Record of Decision calls for no additional corrective measures for groundwater (e.g., natural attenuation). To continue the statistical evaluation method specified in Section 4.6 of this plan, four independent groundwater samples must be collected semiannually to conform exceedances already known, a very costly proposal. However, the objective of a corrective action program is to demonstrate the effectiveness of the corrective program through trend monitoring where one groundwater sample collected semiannual will be adequate. Therefore, a corrective action program that will demonstrate the following is proposed:

meet the needs of final status compliance monitoring, as well as

provide for an efficient sampling plan that relies on only one groundwater sample per compliance well per sampling period.

6.2 Alternate Statistical Method

The alternate statistical method uses the combined CUSUM-Shewhart control chart (EPA 1992, section 7; ASTM 1996, section 6.3; and Gibbons 1994, chapter 8). It combines the advantages of Shewhart control chart (which is sensitive to large and abrupt shifts) with the CUSUM control chart (which is sensitive to small and gradual changes). For instance, if the observed concentration of a particular groundwater constituent does not change significantly in a given well, then deviations between observed values and the expected values and their cumulative sums of the deviations should fluctuate randomly around zero (this situation is then "in control" statistically speaking). On the other hand, if a large difference and/or cumulative sum is observed (and confirmed by verification sampling) then the concentration of the groundwater constituent is changing significantly from the baseline conditions. The process is then considered to be "out of control" (statistically speaking). Of course, if the process is out of control and the concentration of the groundwater constituent is decreasing significantly, one could conclude that the selected corrective action is successful. However, the converse situation where the out of control process is due to the concentration increasing significantly is of particular concern (see next section). For wells that have not shown exceedances of concentrations limits, groundwater monitoring should provide confidence that there are no new releases of the contaminants of concern (see Section 6.2.2).

6.2.1 Approach for Wells Where MCLs Have Been Exceeded

The first step is to identify a representative baseline period. Care must be taken to select a representative baseline where conditions are similar to the current period to avoid comparing unrelated factors. For instance, at the 300 APT it would be inappropriate to choose as the representative baseline period any time when wastewater was being discharged to the 300 APT. By introducing large amounts of wastewater to the aquifer underlying the 300 APT, the aquifer conditions were artificially induced to be different than they are now that discharges have ceased. Prior to the expedited response action in 1991, the wastewater was bringing higher concentrations of the contaminants of concern to the aquifer. After 1991, the large volumes of wastewater were relatively clean which caused the groundwater samples from wells near the 300 APT to be relatively clean. Therefore, the representative time period must be after December 1994 when the wastewater discharges were terminated at the 300 APT.

The second step is to establish appropriate control limits. These can be established by reference to EPA (1992), ASTM (1996), and Gibbons (1994) or as directed by governmental regulators.

The wells will be sampled quarterly. In essence, these (exceedance) wells are monitored for trend(s) under a corrective action mode. If future observations are within the established upper and lower control limits, the process behaves as expected (is in control). The quarterly sampling will be continued until reduced monitoring is warranted [e.g., concentrations are below the MCLs for 3 consecutive years, see WAC 173-303-645(11)(f)]. If future observations exceed the established upper control limits, the process is out of control and results will be communicated to the DOE, BHI, and Ecology for appropriate future action(s).

6.2.2 Approach for Wells Where MCLs Have Not Been Exceeded

For wells where MCLs have not been exceeded, the representative baseline period and appropriate control limits will be established as in the previous section. The wells will be sampled semiannually. In essence, these non-exceedance wells are monitored to provide confidence (on a timely basis) that concentrations of constituents of concern do not increase with potentially new release(s) from the 300 APT. The calculated upper control limits are much lower than the MCLs. For example, uranium MCL is 20 μg/L and the control limit established for well 399-1-17B is significantly lower (i.e., $< 1 \mu g/L$). The use of upper control limits as comparison values is more sensitive to detect additional release(s) of constituents of concern, if any, than the use of MCLs. Hence, it is judged to be more protective of human health and the environment. If future observations are within the established upper control limits, the process is in control. The sampling will continue on a semiannual frequency until exceedance of control limit is observed and confirmed. If confirmed, a "mini-assessment" on that well will be conducted to identify possible causes and to assess the likelihood of exceeding MCL. The sampling frequency will then be adjusted accordingly (e.g., as outlined in previous section).

6.2.3 Benefits of Alternate Statistical Method

The following are benefits of the alternate statistical method:

Meets the intent of final status compliance monitoring because the proposed method is one of the acceptable statistical methods given in WAC 173-303-645 (8)(h)(iv) (i.e., a control chart approach that gives control limits for each constituent).

Allows statistical testing of each new groundwater sample as it is collected analyzed thereby providing a more timely detection of a new release and/or confirmation of impacts.

Is more protective of human health and the environment. That is, it is more sensitive to detect new release(s) than the use of MCLs as comparison values for non-exceedance wells.

Is flexible and incorporates enhanced monitoring (more frequent sampling) when needed.

Achieves significant cost savings. It does not require four independent samples for each testing period. Only one sample is needed.

6.2.4 Procedure for Using Combined CUSUM-Shewhart Control Chart

As with most statistical procedures, the data are assumed to be independent and normally distributed with a fixed mean (μ) and variance (σ^2). Data that are not normally distributed can be handled by transformations (e.g., log transformations). The assumption of normality of data was tested using Lilliefors test for normality and found reasonable. All available statistical goodness-of-fit tests do not exhibit a high degree of power when sample size is small (say less than 20 or 30). However, the changing site conditions (post-discharge termination) preclude the use of a larger baseline data set. As more data become available, baseline data set will be updated and refined in the future. To ensure independence of data, samples should not be sampled more frequently than monthly.

In general, a representative baseline period that covers at least eight independent samples is needed to provide reliable estimates of process mean and standard deviation. Care must be taken when selecting the representative baseline period as discussed in Section 6.2.1.

Three parameters must be specified. They are as follows:

k = a parameter selected to be about one-half of the shift we are interested in detecting. For instance, when k = 1, a shift of two standard deviations will be quickly detected.
h = the decision value (expressed in units of standard deviations) to be compared with the cumulative sum in the CUSUM control chart.
SCL = the upper Shewhart control limit which is expressed in units of standard deviations.

For groundwater applications, k = 1, h = 5, and SCL = 4. 5 are most appropriate (Lucas 1982, Starks 1988, and ASTM 1996). The EPA (1989) in their interim final guidance document echoes this sentiment. For the 300 Area Process Trenches, Ecology prefers h = 2 and SCL = 2. A two-sided control chart will be established for wells which have known to exceed the MCLs, and a one-sided control chart will be established for wells which have exceeded the MCLs.

The procedural steps based on Ecology directed h and SCL values are as follows:
Obtain estimates of process mean ($\bar{x}_b$) and standard deviation (s_b) using baseline data.

Select the three Shewhart-CUSUM parameters, k, h, and SCL. For ease of application k = 1, h = 4.5, and SCL = 4.5 are suggested. Thus, standardized future observation (see 3 below) will be compared to the Shewhart decision value (e.g., SCL = 4.5) and their cumulative sums (as obtained in 4 below) will be compared to the CUSUM decision value (e.g., h = 4.5). This will result in a single control limit with no compromise in leak detection capabilities (see ASTM 1996, page 12).

Denote the new measurement at time-point t_i as x_i and compute the standardized value z_i where
$z_i = (x_i - \bar{x}_b) / s_b$.

For a one-sided upper control limit, at each time period, t_i, compute the cumulative sum S_i, as $S_i = \max[0, (z_i - k) + S_{i-1}]$ where max [a,b] is the maximum of a and b, and $S_0 = 0$. For a two-sided control chart, at each time period, t_i, compute the pair of cumulative sum S_{Hi}, as $S_{Hi} = \max[0, (z_i - k) + S_{Hi-1}]$ and S_{Li}, as $S_{Li} = \max[0, (-z_i - k) + S_{Li-1}$ where the first (S_{Hi}) is for detecting positive mean shifts and the second (S_{Li}) is for detecting negative mean shifts and max [a,b] is the maximum of a and b, and $S_0 = 0$.

Plot the values of S_i and z_i (y-axis) versus t_i (x-axis) on a time chart (Note: For a two-sided control chart, plot the values of S_{Hi}, S_{Li}, and z_i (y-axis) versus t_i (x-axis). For a one-sided control chart, declare an "out-of-control" situation if $S_i \geq h = 2$ or $z_i \geq SCL = 2$. For a two-sided control chart, declare an "out-of-control" situation if either S_{Hi} or S_{Li} becomes larger than the decision value $h = 2$. Note: Any such designation must be verified through verification sampling before further investigation is indicated. Note when baseline data points $n \geq 12$, use $k = 0.75$, $h = SCL = 4$ (see ASTM 1996, page 12).

Baseline data need to be updated periodically (every one to two years).

Outlier(s), if existed in the historical database, need to be removed. The criteria to handle outliers will follow generally accepted statistical methods (e.g., the Grubbs' methods as described in EPA, 1989 pages 8-11 to 8-14 or the box-and-whisker plot). In addition, when large baseline data are available (e.g., 2 years of monthly or quarterly data), obvious cyclic or trend patterns can be removed from both the baseline data and from the future data to be plotted on the chart.

6.2.5 References

ASTM June 1996, *Provisional Standard Guide for Developing Appropriate Statistical Approaches for Ground-Water Detection Monitoring Programs*, PS 64-96, In : Annual Book of ASTM Standards, American Society for Testing and Materials, West Conshohocken, Pennsylvania.

EPA 1989, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities - Interim Final Guidance*, PB89-151047, U.S. Environmental Protection Agency, Washington.

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