Tennessee Valley Authority
1101 Market Street
Chattanooga, Tennessee 37402

October 16, 2017

Statistical Methods Certification
for Compliance with the Final Coal Combustion Residuals Rule (40 CFR §257.93)

Cumberland Fossil Plant
Gypsum Storage Area
CCR Groundwater Monitoring Network

1.0 Introduction

The U.S. Environmental Protection Agency's (USEPA's) final Coal Combustion Residuals (CCR) Rule establishes a comprehensive set of requirements for the management and disposal of CCR (or coal ash) in landfills and surface impoundments by electric utilities. The Tennessee Valley Authority (TVA) Cumberland Fossil Plant (CUF), located in Cumberland City in Stewart County, Tennessee, has a CCR unit that is subject to the CCR Rule: the CUF Gypsum Storage Area.

This report includes a summary of the statistical methodology selected for evaluating groundwater monitoring data at the abovementioned CCR unit and supports compliance with requirements outlined in Sections 257.93(f) and 257.93(g) of the CCR Rule. As a means to develop the most appropriate methods to validate assumptions, evaluate the groundwater data, and develop background concentrations, the statistical methodology is generally based on the USEPA "Unified Guidance" [1] and ProUCL Technical Guide[2].

The statistical methods for evaluating groundwater monitoring data described in this document are consistent with method/paragraph (3) of Section 257.93(f), which includes a tolerance or predication interval procedure. As reference, **Table 1** includes the professional engineer's confirmation that the required performance standards of Section 257.93(g) of the CCR Rule

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[1] USEPA, Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance. Office of Resource Conservation and Recovery, Program Implementation and Information Division, USEPA, EPA 530/R-09-007, 2009.

[2] Singh, A. and Ashok Singh. ProUCL 5.1.002 Technical Guide Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations. EPA/600/R07/041, 2015.

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have been met, as appropriate, based on the proposed statistical test method, and indicates which sections of this report provide details that indicate compliance with the methodology performance standards.

Groundwater monitoring activities commenced in October 2016 and, at the time of this report, TVA contractors obtained the minimally prescribed number of samples (i.e., “eight independent samples for each background and downgradient well”) to comply with the initial timeframe requirements included in §257.90(b) of the CCR Rule. Results from the background wells will be pooled as part of interwell testing for the statistical methods. The groundwater monitoring dataset will continue to be refined as additional data becomes available throughout the life of the CCR Rule groundwater monitoring program.

As the chosen statistical methodology is applied to the groundwater quality data for determining background concentrations and evaluating downgradient sampling results, revisions to the statistical methods may be warranted to ensure the groundwater monitoring data is evaluated appropriately. TVA reserves the right to use any other statistical test(s) that, as allowed by the CCR Rule, would meet the performance standards established by §257.93(g) of the CCR Rule. If the statistical analysis method(s) described herein are subsequently revised, TVA will submit a Management of Change form into its Operating Record along with the revised copy of the backup documentation followed by its posting onto the corresponding TVA-managed CCR Rule web site. Pursuant to the CCR Rule requirements, the enclosed Professional Engineer’s certification record will also be revised to conform to the description of the updated statistical methods and data set modifications.

Table 1: 40 CFR §257.93(g) Statistical Methods Performance Standards (1) through (6)

Performance Standards	Compliance with Standard
(1) The statistical method used to evaluate groundwater monitoring data shall be appropriate for the distribution of constituents. Normal distributions of data values shall use parametric methods. Non-normal distributions shall use non-parametric methods. If the distribution of the constituents is shown by the owner or operator of the CCR unit to be inappropriate for a normal theory test, then the data must be transformed or a distribution-free (non-parametric) theory test must be used. If the distributions for the constituents differ, more than one statistical method may be needed.	**Yes.** See Sections 2 and 3. (Note that Gamma distribution is included in the methodology and will be used as appropriate.)
(2) If an individual well comparison procedure is used to compare an individual compliance well constituent concentration with background constituent concentrations or a groundwater protection standard, the test shall be done at a Type I error level no less than 0.01 for each testing period. If a multiple comparison procedure is used, the Type I experiment wise error rate for each testing period shall be no less than 0.05; however, the Type I error of no less than 0.01 for individual well comparisons must be maintained. This performance standard does not apply to tolerance intervals, prediction intervals, or control charts.	**Not Applicable.** This approach is not included in the chosen statistical test method.

Performance Standards	Compliance with Standard
(3) If a control chart approach is used to evaluate groundwater monitoring data, the specific type of control chart and its associated parameter values shall be such that this approach is at least as effective as any other approach in this section for evaluating groundwater data. The parameter values shall be determined after considering the number of samples in the background data base, the data distribution, and the range of the concentration values for each constituent of concern.	**Not Applicable.** This approach is not included in the chosen statistical test method.
(4) If a tolerance interval or a prediction interval is used to evaluate groundwater monitoring data, the levels of confidence and, for tolerance intervals, the percentage of the population that the interval must contain, shall be such that this approach is at least as effective as any other approach in this section for evaluating groundwater data. These parameters shall be determined after considering the number of samples in the background data base, the data distribution, and the range of the concentration values for each constituent of concern.	**Yes.** See Sections 3 and 4.
(5) The statistical method must account for data below the limit of detection with one or more statistical procedure that shall be at least as effective as any other approach in this section for evaluating groundwater data. Any practical quantitation limit that is used in the statistical method shall be the lowest concentration level that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions that are available to the facility.	**Yes.** See Sections 2 and 3.
(6) If necessary, the statistical method must include procedures to control or correct for seasonal and spatial variability as well as temporal correlation in the data.	**Yes.** See Sections 2 and 3.

2.0 Preliminary Data Analysis

Preliminary data analysis (PDA) includes multiple steps used to assess and transform data (where necessary) for use in producing background concentrations The PDA includes producing descriptive statistics such as sample size, number and percentage of detects and non-detects (NDs), location (mean, median) and spread statistics (standard deviation, skewness). Rosner’s and Dixson’s tests will be used to flag potential outliers. Side-by-side box-plots will be used to understand the level of spatial variability for sites with more than one background well. Graphical analysis will be used to aid in visualizing outliers (box-plots, Q-Q plots), distributions (scatter plots), and seasonality (side-by-side box-plots) depending on the quantity and quality of the data. If seasonality is observed (and there is sufficient data per season), deseasonalization of the data will be done prior to testing for trends over time. The parametric maximum likelihood regression method can test for statistically significant trends even with the presence of NDs under parametric distribution assumptions. The Mann-Kendall test is appropriate for testing for statistically significant trends for non-parametric distributions. Various goodness-of-fit tests will be used to discern if a constituent’s distribution is best explained by a parametric distribution such as the normal, lognormal or gamma or by a non-parametric distribution.

3.0 Compute Background Concentrations

To identify statistically significant increases (SSIs) in downgradient monitoring wells, the Unified Guidance recommends computing background concentrations for constituents being evaluated using upper prediction limits (UPLs) during detection monitoring. UPLs are suitable for detection monitoring primarily due to the potential and likely need for retesting. Using the data from the selected period of record, UPLs will be computed for each constituent in Appendix III of the CCR Rule. The only constituent/parameter that may require both upper and lower prediction limits (LPL) is pH. A minimum of eight valid background samples should be obtained prior to producing UPLs.

The EPA's software package ProUCL has incorporated algorithms to produce UPLs under varying distribution assumptions such as normal, lognormal, gamma and non-parametric with and without NDs. For background samples with NDs, ProUCL incorporates the regression on order statistic (ROS) and Kaplan-Meier (KM) techniques to impute values for the NDs under parametric distributional assumptions prior to estimating the appropriate UPL test statistics.

The formulation of the prediction limit may vary with the particulars of the test to be made and the characteristics of the data involved such as the type of distribution, the sample size, presence of NDs, and level of skewness, but for illustration, under normal distribution assumptions with no NDs, the formula for the prediction limit for 1 future or independent observation is:

$$UPL = \bar{x} + t_{1-\propto,n-1} S \sqrt{1 + \frac{1}{n}}$$

Where

$\bar{x}$	=	background sample mean
S	=	background standard deviation
t	=	Student's t with $1-\propto$ degrees of freedom
$\propto$	=	false positive rate (test significance level)
n	=	number of observations in the background dataset

The UPL offers the advantage of controlling false positive rates when testing an exact number of multiple independent or future observations. A false positive rate captures the risk that the UPL test statistic will indicate an SSI for a concentration when it is not true. A typical false positive rate is 5 percent.

The test significance level (∝) is the false positive error rate assigned to an individual test. Adjustments are required for the test significance level (∝) to adjust for the increase in the false positive rate when more than one sample of a constituent is tested for an SSI over background. The aggregation of the individual false positive rates over multiple comparisons should not exceed 10 percent, (i.e., the cumulative significance level) as recommended by the Unified Guidance.

4.0 Test for Statistically Significant Increases

For detection monitoring, the UPL test statistic will be the threshold for determining if a downgradient observation represents an SSI over background or not. Resampling of wells where an SSI has occurred can either verify the initial evidence of a release or disconfirm it, while avoiding unnecessary false positives.

If a downgradient observation is greater than the appropriate UPL during detection monitoring, then that concentration represents an SSI over background. One exception is pH. If a downgradient observation is less than the LPL, then an SSI for pH has occurred over background. The CCR Rule indicates that if an SSI over background is identified at the waste boundary for one or more Appendix III constituents during detection monitoring, then the owner or operator of the CCR unit must, within 90 days: 1) establish an assessment monitoring program, 2) demonstrate that a source other than the CCR unit caused the SSI over background, or 3) demonstrate that the SSI over background resulted from error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality. Written documentation must also be completed and certified by a qualified professional engineer within the 90 day timeframe.

If sources other than the CCR Unit, natural variability or errors have been ruled out as the reason for the SSI, the one-of-m pass method (i.e., verification sampling), as described in the Unified Guidance (see Chapter 19), allows for an efficient plan to confirm if an SSI over background identified during detection monitoring resulted from the CCR unit. Depending on the number of background samples and the desired site-wide false positive rate, and the available time period in which to do the resampling, either a 1-of-2 or 3 pass method is recommended should verification sampling be considered.

5.0 Certification

I, Shane Womack, being a Professional Engineer in good standing in the State of Tennessee, do hereby certify, to the best of my knowledge, information and belief:

1. that the information contained in this certification is prepared in accordance with the accepted practice of engineering;
2. that the information contained herein is accurate as of the date of my signature below; and
3. that the selected statistical methods in this certification report are appropriate for evaluating the groundwater monitoring data for the CCR management area CUF Gypsum Storage Area at the Cumberland Fossil Plant in Stewart County, Tennessee and that these methods meet the requirements described in 40 CFR 257.93.

Signature Shane R. Womack Date October 16, 2017

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Attachment: