Geosyntec consultants

Certification for Selected Statistical Methods

CCR Unit: Brandywine Ash Management Facility Phase II

Certification:

I, **William M. Steier**, a qualified professional engineer registered in the state of **Maryland**, have reviewed the information in the *Statistical Analysis Calculation Package for Background Groundwater – Phase II, Brandywine Ash Storage Facility, Brandywine, Maryland* and based on my review, in my professional opinion find that, the selected statistical methods are appropriate for evaluating groundwater monitoring data for this CCR unit as described in 40 CFR §257.93(f) and (g).

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Signature:

Date: 10/16/2017

Seal: Stamp:

NARRATIVE DESCRIPTION OF STATISTICAL METHODS

Introduction

Basic statistics were calculated for each monitored constituent using the eight rounds of data from the background monitoring well. The following background statistics and population tests were calculated for each Appendix III constituent:

- Distribution type (normal, lognormal, or nonparametric)
- Outliers
- Number of data points used
- Number of non-detects (NDs)
- ND frequency
- Minimum
- Maximum
- Mean
- Median
- Standard deviation
- Trend
- Seasonality

The results for these statistics and tests were then used to calculate background concentrations using the methods listed in the Federal CCR Rule, except that Analysis of Variance (ANOVA) was not considered because the U.S. Environmental Protection Agency (USEPA) *Unified Guidance* does not recommend its use. A description of each of the five statistical methods listed in the Federal CCR Rule is provided below, and the methods selected for the 2017 background dataset are then listed. The selected methods are subject to change as additional monitoring data are generated.

Parametric Analysis of Variance

Parametric Analysis of Variance (ANOVA) uses the F-statistics to test for statistically significant differences in the means between background well samples and samples from individual downgradient compliance wells. ANOVA is useful for inter-well testing schemes. U.S. Environmental Protection Agency (USEPA) *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance* (March 2009, EPA 530-R-09-007) identifies several significant weaknesses of the ANOVA method for groundwater detection monitoring and recommends against its use.

Nonparametric Analysis of Variance

Nonparametric Analysis of Variance (ANOVA) uses the F-statistics to test for statistically significant differences in the medians between background well samples and samples from individual downgradient compliance wells. ANOVA is useful for inter-well testing schemes. U.S. Environmental Protection Agency (USEPA) *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance* (March 2009, EPA 530-R-09-007) (the Unified Guidance) identifies several significant weaknesses of the ANOVA method for groundwater detection monitoring and recommends against its use.

Tolerance Intervals (Tolerance Limits)

Tolerance Intervals are statistical ranges calculated using the background dataset. They are developed to specify a threshold background concentration that contains a certain percentile of the range of background values at a certain probability level. For example, a 95/95 UPL will contain 95 percent of the background concentration range at a 95 percent confidence level. By definition, a small percent of the background population will exceed the Tolerance Limit. Future compliance well sample results that exceed the Upper Tolerance Limit (UTL) are considered to exceed background. Tolerance limits account for the variation in background concentrations and the size of the background dataset. Parametric Tolerance Limits assume the background data follow a normal distribution or can be transformed to a normal distribution. Nonparametric Tolerance Limits assume the background data do not follow a known statistical distribution model. The Unified Guidance indicates that Prediction Intervals are easier to implement and interpret than Tolerance Intervals and therefore generally recommends use of Prediction Intervals over Tolerance Intervals.

Prediction Intervals (Upper Prediction Limits)

Upper Prediction Limits (UPLs) are constructed to contain future sample values of background within a specified probability. They differ from Tolerance Limits because a portion of the background data should not exceed the Tolerance Limit. They are usually constructed to include a resampling test strategy. Compliance well data are compared to the UPL and if they exeed the UPL it is considered to be a statistically significant increase over background. UPLs can be developed for both inter-well and intra-well testing strategies. There are both parametric and nonparametric UPLs but in practice nonparametric tests simply provide the maximum detected value in the background data set.

Control Charts

Control Charts use a control limit that is calculated from the background data. Compliance well data are plotted on a time series chart that includes the control limit. If a compliance measurement exceeds the control limit, it is considered to be a statistically significant increase over background concentrations. Control charts can only be generated for data that fit a parametric distribution (i.e. normal distribution or can be transformed to a normal distribution such as lognormal distributions). They are sometimes more useful than Prediction Intervals because they display a long-term record of the actual compliance point data over time along with the background control limits in graphic form making it easier to identify trends in the data, whereas Prediction Intervals only show a point in time comparison between the most recent data and background limits. Control charts can be used for both inter-well testing and intra-well testing programs.

Selected Statistical Methods

The following statistical methods were selected to calculate the 2017 background concentration estimates:

- Parametric Upper Prediction Limits (UPLs): pH and total dissolved solids;
- Nonparametric Upper Prediction Limits (UPLs): boron, calcium, chloride, sulfate; and
- Double Quantification Rule: fluoride.

These methods are subject to change as additional monitoring data are generated.