ECF-HANFORD-18-0083
Revision 0

CALCULATION OF UPPER CONFIDENCE LIMITS FOR RCRA MONITORING AT THE 183-H SOLAR EVAPORATION BASINS TO SUPPORT THE JULY - DECEMBER 2018 RCRA SEMIANNUAL REPORT

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
Plateau Remediation Company

P.O. Box 1600
Richland, Washington 99352

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By Janis D. Aardal at 3:16 pm, Feb 12, 2019

Release Approval | Date

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ENVIRONMENTAL CALCULATION COVER PAGE

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Calculation of Upper Confidence Limits for RCRA Monitoring at the 183-H Solar Evaporation Basins to Support the July - December 2018 RCRA Semi-Annual Reports

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Brief Narrative of Experience: Dr. DiFilippo has extensive experience addressing the fate and transport of organic and inorganic chemicals in the environment. She has conducted numerous studies of groundwater transport, statistical geochemical analysis, groundwater age-dating, dense non-aqueous phase liquid (DNAPL) dissolution, enhanced DNAPL remediation technologies, and the use of innovative technologies for measuring in-situ concentrations of organic contaminants in sediment pore-water. At Hanford, Dr. DiFilippo has provided remediation support in the form of water-level mapping, evaluation of monitored natural attenuation (MNA) and enhanced attenuation (EA), development of methodology to asses the impact of surface water-groundwater interactions on contaminant concentrations and trends, and assessment of statistical methodologies for evaluating RCRA compliance at both interim and final status sites.

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ENVIRONMENTAL CALCULATION COVER PAGE (Continued)

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SECTION 2 - Completed by Preparer

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ENVIRONMENTAL CALCULATION COVER PAGE (Continued)

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Terms

CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CHPRC	CH2M HILL Plateau Remediation Company
ECF	environmental calculation file
HEIS	Hanford Environmental Information System
mg/L	milligrams per liter
µg/L	micrograms per liter
OU	operable unit
RCRA	*Resource Conservation and Recovery Act of 1976*
UCL	upper confidence limit

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1 Purpose

This environmental calculation file (ECF) presents calculations of 95% upper confidence limits (UCLs) on the mean for filtered total chromium and nitrate at the 183-H Solar Evaporation Basin *Resource Conservation and Recovery Act of 1976* (RCRA) site. The 95% UCLs are compared to the applicable concentration limits in the *Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion for the Treatment, Storage, and Disposal of Dangerous Waste* (hereafter referred to as the Hanford Facility RCRA Permit). Calculations presented in this ECF were based on available results for groundwater samples collected through the end of 2018.

2 Background

The 183-H Solar Evaporation Basins are located within the 100-H Area, overlying the 100-HR-3 Groundwater Operable Unit (OU) (Figure 1) and were used to evaporate various liquid waste streams from 300 Area fuel fabrication facilities. The final status groundwater monitoring plan was incorporated into the Hanford Facility RCRA Permit, Revision 8c, on May 24, 2017. The new plan supersedes PNNL-11573 *Groundwater Monitoring Plan for the 183-H Solar Evaporation Basins*. The new corrective action monitoring plan requires calculation of the 95% UCLs on the mean for filtered total chromium and nitrate based on the last eight (8) to ten (10) independent samples, and comparison of the 95% UCLs, or non-detect data, to the concentration limits established in the Hanford Facility RCRA Permit.

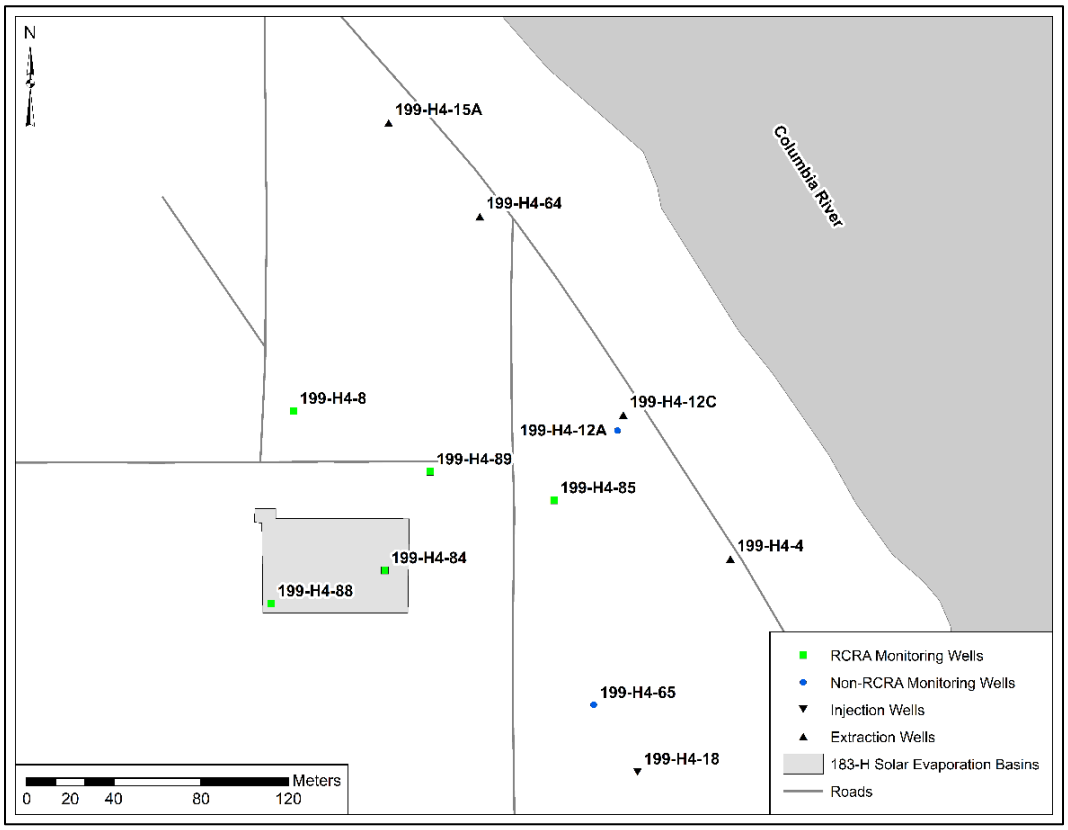

Figure 1. 183-H Solar Evaporation Basins and Associated Monitoring Wells

When all data are non-detects, all data are less than the exceedance level, or there are less than the required number of samples, calculation of the 95% UCL on the mean is not required and the data are evaluated visually to ensure compliance.

3 Methodology

This section discusses the data and methods used to complete the calculations presented in this document.

3.1 Data Acquisition and Processing Prior to 95% UCL Calculation

This section discusses the acquisition and processing of data prior to 95% UCL calculation.

3.1.1 Chemistry Data Acquisition

Groundwater chemistry data were downloaded from the Hanford Environmental Information System (HEIS) database, which is maintained by CH2M HILL Plateau Remediation Company (CHPRC), and exported into a Microsoft Access® database (named HEIS_CHEM_12192018.accdb). The data for this analysis were downloaded from the HEIS database on December 19, 2018. The HEIS database contains one table (HEIS_ADM_PNLGW_STD_RESULT_MV), which contains information on groundwater samples, including laboratory and review data qualifiers, sample medium, sample collection purpose, analytical method, and reporting limits. The fields extracted from the HEIS database for use in calculations described in this document are presented in Table 1.

Table 1. HEIS Database Fields for Chemistry Data

Field Extracted[a]	Definition
WELL_NAME	Location Identification
SAMP_DATE_TIME	Sampling Date
STD_CON_LONG_NAME	Analyte Name
STD_VALUE_RPTD	Reported Concentration
STD_ANAL_UNITS_RPTD	Units for Concentration Measurement
LAB_QUALIFIER	Laboratory Data Qualifier
REVIEW_QUALIFIER	Review Data Qualifier
COLLECTION_PURPOSE	Primary Reason for Sample Collection
VALIDATION_QUALIFIER	Validation Qualifier

[a] Field codes are defined in HNF-38155, *HEIS Sample, Result, and Sampling Site Data Dictionary*.

3.1.2 Daily Averaging

A daily average was calculated for chemistry data with multiple measurements on the same day. When all measurements on the same day were non-detect, the highest detection limit was used for the daily value. For daily duplicates where only one of the samples was non-detect, the detected value was used for the

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daily value. Duplicate daily measurements and the calculated daily average within the last 10 samples dataset are presented in Table 2.

Table 2. Duplicate Daily Measurements and Calculated Daily Averages

Well Name	Constituent	Sample Date	Measured Conc.	Calculated Daily Average
199-H4-84	Nitrate	1/10/2018	79.7 mg/L 75.3 mg/L	77.5 mg/L
199-H4-85	Filtered Total Chromium	8/14/2015	18.4 µg/L 18.3 µg/L	18.35 µg/L
199-H4-89	Filtered Total Chromium	3/30/2016	2.22 µg/L 2U µg/L	2.22* µg/L
199-H4-89	Nitrate	3/30/2016	12.4 mg/L 12.4 mg/L	12.4 mg/L

U: Constituent not detected at the detection limit shown.

µg/L: micrograms per liter

mg/L: milligrams per liter

* Highest detection limit used for daily value.

3.1.3 Data Qualifiers

Non-detects in the chemistry data set were identified using the laboratory qualifier (LAB_QUALIFIER = U or any other qualifier that includes "U"). The method detection limit was substituted for concentration measurements when identified as a non-detect based on the laboratory qualifier. All estimated data (LAB_QUALIFIER = B or J) were treated as detected values. Rejected ("R"-flagged) data in the HEIS database were not included for statistical evaluation.

3.1.4 Wells and Constituents

The list of wells and constituents for this analysis was based on the groundwater monitoring plan incorporated on May 24, 2017 into the Hanford Facility RCRA Permit (WA7890008967), as listed in Table 3.

Table 3. Wells and Constituents

Well Name	Constituent
199-H4-8	Filtered Total Chromium, Nitrate
199-H4-84	Filtered Total Chromium, Nitrate
199-H4-85	Filtered Total Chromium, Nitrate

Table 3. Wells and Constituents

Well Name	Constituent
199-H4-88	Filtered Total Chromium, Nitrate
199-H4-89	Filtered Total Chromium, Nitrate

3.1.5 Time Period of Analysis

Datasets were selected based on the number of available samples and the sampling dates (Table 4). Data were included regardless of the purpose of the sample collection or sampling program (i.e., the datasets contain samples collected under the RCRA sampling program and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sampling program). The last ten samples scheduled to be collected through the end of 2018 were included in the datasets if available.

Table 4. Sampling Data

Well Name	Analyte	Sampling Date Range	Number of Samples
199-H4-8	Filtered Total Chromium	11/01/2012 – 11/13/2018	10
199-H4-84	Filtered Total Chromium	11/10/2017 – 11/13/2018	10*
199-H4-85	Filtered Total Chromium	10/31/2014 – 11/13/2018	10*
199-H4-88	Filtered Total Chromium	1/10/2018 – 11/13/2018	10*
199-H4-89	Filtered Total Chromium	3/30/2016 – 11/13/2018	9*
199-H4-8	Nitrate	11/01/2012 – 11/13/2018	10
199-H4-84	Nitrate	1/10/2018 – 11/13/2018	10*
199-H4-85	Nitrate	11/19/2015 – 11/13/2018	10*
199-H4-88	Nitrate	1/10/2018 – 11/13/2018	10*
199-H4-89	Nitrate	3/30/2016 – 11/13/2018	10*

*Dataset contains both RCRA and CERCLA samples

3.1.6 Outliers

The data sets were evaluated for outliers through visual inspection of timeseries plots. No outliers were identified in the datasets used in this analysis.

3.2 Calculated 95% UCLs on the Mean

A statistical software package, ProUCL version 5.1, was used to calculate the 95% UCL on the mean, in accordance with the new corrective action groundwater monitoring plan. ProUCL is available through the

U.S. Environmental Protection Agency and provides statistical methods and graphical tools that are commonly used in environmental assessments. ProUCL is capable of working with datasets where non-detects are present. There are several methods available in ProUCL for calculating 95% UCLs on the mean. These methods account for the underlying distribution of the data and the presence of non-detects. For datasets with non-detects, ProUCL uses the Kaplan-Meier method, a non-parametric method for calculating the mean and standard deviation. ProUCL highlights a recommended UCL calculation method in its output file; however, it is important to assess all the methods available and independently verify the most appropriate method through visual inspection of the data, evaluation of the number of available data points, and the data distribution.

The 95% UCL calculations were performed on datasets with a minimum of eight samples available and with at least one sample above the concentration limit. When available, the maximum sample size listed in the permit (ten) was used for the calculations. As shown in Table 5 below, only four datasets met these criteria. Calculation of 95% UCLs for the other datasets was not required.

Table 5. Dataset Summary and Criteria to Calculate 95% UCL

Analyte	Conc. Limit	Well Name	Number of Samples	Percent Non-Detect	Number of Samples Exceeding Conc. Limit	95% UCL Calculation Required
Filtered total chromium	48 µg/L	199-H4-8	10	0%	0	No
		199-H4-84	10	0%	1	**Yes**
		199-H4-85	10	0%	0	No
		199-H4-88	10	0%	0	No
		199-H4-89	9	11%	0	No
Nitrate	45 mg/L	199-H4-8	10	0%	0	No
		199-H4-84	10	0%	9	**Yes**
		199-H4-85	10	0%	0	No
		199-H4-88	10	0%	9	**Yes**
		199-H4-89	10	0%	2	**Yes**

4 Assumptions

Given the number of samples required by the permit, UCL calculations assume that:

- Concentrations observed at a well are not significantly affected by active remediation activities at the site for the period over which calculations are made; and,
- There are no concentration trends with time for the datasets used to calculate 95% UCLs. ProUCL does not explicitly test for concentration trends when calculating 95% UCLs. In the presence of a concentration trend, ProUCL will calculate a wider confidence interval on the mean.

In addition, all of the data for a well/analyte pair are from the same statistical distribution. ProUCL tests the data distribution prior to calculating 95% UCLs and ProUCL highlights a recommended 95% UCL method based on the data distribution.

5 Software Applications

95% UCL calculations were performed using ProUCL version 5.1.

6 Calculation

The following input files were used in the implementation of this analysis:

- *qryChemHeis1.txt* and *qryChemHeis2.txt*: Concentration data from the HEIS database
- *ProUCL_Datasets_12192018.xlsx*: datasets for use in ProUCL

Datasets were imported into the ProUCL software and 95% UCLs were calculated using all available methods and accounting for the presence of non-detects. The reported 95% UCL was selected based on the ProUCL results, including evaluation of the data distribution and sample size.

7 Results

The datasets evaluated for 95% UCL calculation and the output files from ProUCL are presented in Appendix A, and the 95% UCL results are presented in Table 6. Results for nitrate were converted to milligrams per liter (mg/L) prior to processing with ProUCL. Timeseries plots for all wells and constituents are presented in Appendix B.

Table 6. Calculated 95% UCLs

Well Name	Analyte	Conc. Limit	95% UCL	95% UCL Result Evaluation
199-H4-84	Chromium[a]	48 µg/L	41.37[b] µg/L	Below Concentration Limit
199-H4-84	Nitrate	45 mg/L	110.8[b] mg/L	Above Concentration Limit
199-H4-88	Nitrate	45 mg/L	80.11[b] mg/L	Above Concentration Limit
199-H4-89	Nitrate	45 mg/L	37.54[c] mg/L	Below Concentration Limit

[a] Filtered total chromium

[b] ProUCL method: 95% Student's-t UCL

[c] ProUCL method: 95% Adjusted Gamma UCL

8 References

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 USC 9601, et seq., Pub. L. 107-377, December 31, 2002. Available at: https://www.csu.edu/cerc/researchreports/documents/CERCLASummary1980.pdf.

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Appendix A

Upper Confidence Limit (UCL) Datasets and ProUCL Output Results

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Table A-1

Dataset for 183-H Solar Evaporation Basins

Well Name	Sample Date	Analyte	Reported Value	Units	Qualifier	ProUCL Non-detect Identification[a]
199-H4-8	11/1/2012	Chromium	16.4	ug/L	B	1
199-H4-8	3/10/2014	Chromium	3.1	ug/L	D	1
199-H4-8	11/5/2014	Chromium	2.8	ug/L	B	1
199-H4-8	12/1/2015	Chromium	4	ug/L	B	1
199-H4-8	11/15/2016	Chromium	7.4	ug/L	B	1
199-H4-8	5/3/2017	Chromium	3.3	ug/L		1
199-H4-8	11/10/2017	Chromium	3	ug/L	BC	1
199-H4-8	2/12/2018	Chromium	2.8	ug/L		1
199-H4-8	5/17/2018	Chromium	4.2	ug/L	BC	1
199-H4-8	11/13/2018	Chromium	3.6	ug/L		1
199-H4-84	11/10/2017	Chromium	2.9	ug/L	BC	1
199-H4-84	2/12/2018	Chromium	83.9	ug/L	D	1
199-H4-84	3/20/2018	Chromium	26	ug/L		1
199-H4-84	4/26/2018	Chromium	22	ug/L		1
199-H4-84	5/17/2018	Chromium	8	ug/L	BC	1
199-H4-84	6/20/2018	Chromium	46	ug/L		1
199-H4-84	7/26/2018	Chromium	33.1	ug/L	D	1
199-H4-84	8/16/2018	Chromium	23	ug/L		1
199-H4-84	9/12/2018	Chromium	14.9	ug/L	D	1
199-H4-84	11/13/2018	Chromium	20	ug/L		1
199-H4-85	10/31/2014	Chromium	23.3	ug/L		1
199-H4-85	2/26/2015	Chromium	19.6	ug/L		1
199-H4-85	5/19/2015	Chromium	17.1	ug/L		1
199-H4-85	8/14/2015	Chromium	18.35	ug/L		1
199-H4-85	11/19/2015	Chromium	18	ug/L		1
199-H4-85	2/10/2016	Chromium	16.1	ug/L		1
199-H4-85	5/22/2016	Chromium	6.76	ug/L	B	1
199-H4-85	2/12/2018	Chromium	4.4	ug/L	B	1
199-H4-85	5/17/2018	Chromium	5.8	ug/L	BC	1
199-H4-85	11/13/2018	Chromium	6.58	ug/L	B	1
199-H4-88	1/10/2018	Chromium	8.9	ug/L	BD	1
199-H4-88	2/12/2018	Chromium	26	ug/L		1
199-H4-88	3/20/2018	Chromium	5.9	ug/L	B	1
199-H4-88	4/26/2018	Chromium	18.8	ug/L		1
199-H4-88	5/17/2018	Chromium	32	ug/L		1
199-H4-88	6/20/2018	Chromium	13.7	ug/L		1
199-H4-88	7/23/2018	Chromium	22	ug/L	C	1

Table A-1

Dataset for 183-H Solar Evaporation Basins

Well Name	Sample Date	Analyte	Reported Value	Units	Qualifier	ProUCL Non-detect Identification[a]
199-H4-88	8/16/2018	Chromium	17	ug/L		1
199-H4-88	9/12/2018	Chromium	15	ug/L	C	1
199-H4-88	11/13/2018	Chromium	12.1	ug/L		1
199-H4-89	3/30/2016	Chromium	2.22	ug/L	CB	1
199-H4-89	11/22/2016	Chromium	2.9	ug/L	B	1
199-H4-89	6/14/2017	Chromium	3	ug/L	U	0
199-H4-89	8/29/2017	Chromium	3.4	ug/L		1
199-H4-89	11/10/2017	Chromium	1.2	ug/L	B	1
199-H4-89	2/12/2018	Chromium	3.6	ug/L	B	1
199-H4-89	5/17/2018	Chromium	3.9	ug/L	BC	1
199-H4-89	8/16/2018	Chromium	3.77	ug/L	B	1
199-H4-89	11/13/2018	Chromium	7.1	ug/L	BD	1
199-H4-8	11/1/2012	Nitrate	18.8	mg/L	D	1
199-H4-8	3/10/2014	Nitrate	15.3	mg/L		1
199-H4-8	11/5/2014	Nitrate	13.7	mg/L	D	1
199-H4-8	12/1/2015	Nitrate	17.7	mg/L	D	1
199-H4-8	11/15/2016	Nitrate	9.3	mg/L	D	1
199-H4-8	5/3/2017	Nitrate	12.4	mg/L		1
199-H4-8	11/10/2017	Nitrate	11.1	mg/L	D	1
199-H4-8	2/12/2018	Nitrate	12.2	mg/L		1
199-H4-8	5/17/2018	Nitrate	11.1	mg/L	D	1
199-H4-8	11/13/2018	Nitrate	13.3	mg/L	D	1
199-H4-84	1/10/2018	Nitrate	77.5	mg/L	D	1
199-H4-84	2/12/2018	Nitrate	100	mg/L	D	1
199-H4-84	3/20/2018	Nitrate	133	mg/L	D	1
199-H4-84	4/26/2018	Nitrate	66.4	mg/L	D	1
199-H4-84	5/17/2018	Nitrate	25.2	mg/L	D	1
199-H4-84	6/20/2018	Nitrate	137	mg/L	D	1
199-H4-84	7/26/2018	Nitrate	133	mg/L	D	1
199-H4-84	8/16/2018	Nitrate	93	mg/L	D	1
199-H4-84	9/12/2018	Nitrate	57.5	mg/L	D	1
199-H4-84	11/13/2018	Nitrate	70.8	mg/L	D	1
199-H4-85	11/19/2015	Nitrate	26.6	mg/L	D	1
199-H4-85	2/10/2016	Nitrate	20.8	mg/L	D	1
199-H4-85	5/22/2016	Nitrate	6.2	mg/L	D	1
199-H4-85	10/7/2016	Nitrate	16.8	mg/L	D	1
199-H4-85	11/20/2016	Nitrate	4.43	mg/L	D	1

Table A-1

Dataset for 183-H Solar Evaporation Basins

Well Name	Sample Date	Analyte	Reported Value	Units	Qualifier	ProUCL Non-detect Identification[a]
199-H4-85	2/14/2017	Nitrate	2.17	mg/L	D	1
199-H4-85	5/25/2017	Nitrate	6.86	mg/L		1
199-H4-85	2/12/2018	Nitrate	9.87	mg/L		1
199-H4-85	5/17/2018	Nitrate	10.2	mg/L	D	1
199-H4-85	11/13/2018	Nitrate	28.8	mg/L	D	1
199-H4-88	1/10/2018	Nitrate	44.3	mg/L	D	1
199-H4-88	2/12/2018	Nitrate	73	mg/L	D	1
199-H4-88	3/20/2018	Nitrate	57.5	mg/L	D	1
199-H4-88	4/26/2018	Nitrate	66.4	mg/L	D	1
199-H4-88	5/17/2018	Nitrate	93	mg/L	D	1
199-H4-88	6/20/2018	Nitrate	88.5	mg/L	D	1
199-H4-88	7/23/2018	Nitrate	79.7	mg/L	D	1
199-H4-88	8/16/2018	Nitrate	79.7	mg/L	D	1
199-H4-88	9/12/2018	Nitrate	75.3	mg/L	D	1
199-H4-88	11/13/2018	Nitrate	53.1	mg/L	D	1
199-H4-89	3/30/2016	Nitrate	12.4	mg/L	D	1
199-H4-89	11/22/2016	Nitrate	10.6	mg/L	D	1
199-H4-89	5/25/2017	Nitrate	13.8	mg/L		1
199-H4-89	6/14/2017	Nitrate	10.4	mg/L		1
199-H4-89	8/29/2017	Nitrate	19.3	mg/L		1
199-H4-89	11/10/2017	Nitrate	48.7	mg/L	D	1
199-H4-89	2/12/2018	Nitrate	22.5	mg/L	DX	1
199-H4-89	5/17/2018	Nitrate	19.9	mg/L	D	1
199-H4-89	8/16/2018	Nitrate	22.1	mg/L	D	1
199-H4-89	11/13/2018	Nitrate	57.5	mg/L	D	1

[a]Value used in ProUCL to identify non-detects (0) and detected values (1).

µg/L: micrograms per liter

mg/L: milligrams per liter

Qualifier Definitions:

B = The analyte was detected at a value less than the contract required detection limit (RDL), but greater than or equal to the Instrument Detection Limit/Method Detection Limit (IDL/MDL) (as appropriate).

C = The analye was detected in both the same and the associated QC blank, and the sample concentration was >= 5X the blank.

D = Analyte was reported at a secondary dilution factor, typically DF>1.

U = Analyzed for but not detected above limiting criteria.

X = The result-specific translation of this qualifier code is provided in the hardcopy data report and/or case narrative.

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183-H Solar Evaporation Basin

ProUCL Chromium Results

	A	B	C	D	E	F	G	H	I	J	K	L
1	**UCL Statistics for Data Sets with Non-Detects**											
2												
3	User Selected Options											
4	Date/Time of Computation			ProUCL 5.112/21/2018 7:10:29 PM								
5	From File			ProUCL_Datasets_12192018_a.xls								
6	Full Precision			OFF								
7	Confidence Coefficient			95%								
8	Number of Bootstrap Operations			2000								
9												
10												
11	**VAL (199-h4-84)**											
12												
13	**General Statistics**											
14	Total Number of Observations					10	Number of Distinct Observations					10
15							Number of Missing Observations					0
16	Minimum					2.9	Mean					27.98
17	Maximum					83.9	Median					22.5
18	SD					23.11	Std. Error of Mean					7.307
19	Coefficient of Variation					0.826	Skewness					1.734
20												
21	**Normal GOF Test**											
22	Shapiro Wilk Test Statistic					0.843	**Shapiro Wilk GOF Test**					
23	5% Shapiro Wilk Critical Value					0.842	Data appear Normal at 5% Significance Level					
24	Lilliefors Test Statistic					0.234	**Lilliefors GOF Test**					
25	5% Lilliefors Critical Value					0.262	Data appear Normal at 5% Significance Level					
26	**Data appear Normal at 5% Significance Level**											
27												
28	**Assuming Normal Distribution**											
29	**95% Normal UCL**						**95% UCLs (Adjusted for Skewness)**					
30	95% Student's-t UCL					41.37	95% Adjusted-CLT UCL (Chen-1995)					44.28
31							95% Modified-t UCL (Johnson-1978)					42.04
32												
33	**Gamma GOF Test**											
34	A-D Test Statistic					0.232	**Anderson-Darling Gamma GOF Test**					
35	5% A-D Critical Value					0.738	Detected data appear Gamma Distributed at 5% Significance Level					
36	K-S Test Statistic					0.141	**Kolmogorov-Smirnov Gamma GOF Test**					
37	5% K-S Critical Value					0.271	Detected data appear Gamma Distributed at 5% Significance Level					
38	**Detected data appear Gamma Distributed at 5% Significance Level**											
39												
40	**Gamma Statistics**											
41	k hat (MLE)					1.695	k star (bias corrected MLE)					1.253
42	Theta hat (MLE)					16.51	Theta star (bias corrected MLE)					22.33
43	nu hat (MLE)					33.9	nu star (bias corrected)					25.06
44	MLE Mean (bias corrected)					27.98	MLE Sd (bias corrected)					24.99
45							Approximate Chi Square Value (0.05)					14.66

	A	B	C	D	E	F	G	H	I	J	K	L
46					Adjusted Level of Significance	0.0267				Adjusted Chi Square Value		13.29
47												
48					**Assuming Gamma Distribution**							
49				95% Approximate Gamma UCL (use when n>=50))		47.84			95% Adjusted Gamma UCL (use when n<50)			52.75
50												
51					**Lognormal GOF Test**							
52					Shapiro Wilk Test Statistic	0.948			**Shapiro Wilk Lognormal GOF Test**			
53					5% Shapiro Wilk Critical Value	0.842			Data appear Lognormal at 5% Significance Level			
54					Lilliefors Test Statistic	0.195			**Lilliefors Lognormal GOF Test**			
55					5% Lilliefors Critical Value	0.262			Data appear Lognormal at 5% Significance Level			
56					**Data appear Lognormal at 5% Significance Level**							
57												
58					**Lognormal Statistics**							
59					Minimum of Logged Data	1.065			Mean of logged Data			3.008
60					Maximum of Logged Data	4.43			SD of logged Data			0.928
61												
62					**Assuming Lognormal Distribution**							
63					95% H-UCL	77.82			90% Chebyshev (MVUE) UCL			56.59
64					95% Chebyshev (MVUE) UCL	68.87			97.5% Chebyshev (MVUE) UCL			85.92
65					99% Chebyshev (MVUE) UCL	119.4						
66												
67					**Nonparametric Distribution Free UCL Statistics**							
68					**Data appear to follow a Discernible Distribution at 5% Significance Level**							
69												
70					**Nonparametric Distribution Free UCLs**							
71					95% CLT UCL	40			95% Jackknife UCL			41.37
72					95% Standard Bootstrap UCL	39.33			95% Bootstrap-t UCL			51.1
73					95% Hall's Bootstrap UCL	107.3			95% Percentile Bootstrap UCL			40.66
74					95% BCA Bootstrap UCL	44.28						
75					90% Chebyshev(Mean, Sd) UCL	49.9			95% Chebyshev(Mean, Sd) UCL			59.83
76					97.5% Chebyshev(Mean, Sd) UCL	73.61			99% Chebyshev(Mean, Sd) UCL			100.7
77												
78					**Suggested UCL to Use**							
79					95% Student's-t UCL	41.37						
80												
81	Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.											
82	Recommendations are based upon data size, data distribution, and skewness.											
83	These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).											
84	However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.											

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183-H Solar Evaporation Basin

ProUCL Nitrate Results

	A	B	C	D	E	F	G	H	I	J	K	L
1	**UCL Statistics for Data Sets with Non-Detects**											
2												
3	User Selected Options											
4	Date/Time of Computation	ProUCL 5.112/21/2018 7:10:49 PM										
5	From File	ProUCL_Datasets_12192018_b.xls										
6	Full Precision	OFF										
7	Confidence Coefficient	95%										
8	Number of Bootstrap Operations	2000										
9												
10												
11	**VAL (199-h4-84)**											
12												
13	**General Statistics**											
14	Total Number of Observations					10	Number of Distinct Observations					9
15							Number of Missing Observations					0
16	Minimum					25.2	Mean					89.34
17	Maximum					137	Median					85.25
18	SD					37.04	Std. Error of Mean					11.71
19	Coefficient of Variation					0.415	Skewness					-0.11
20												
21	**Normal GOF Test**											
22	Shapiro Wilk Test Statistic					0.935	**Shapiro Wilk GOF Test**					
23	5% Shapiro Wilk Critical Value					0.842	Data appear Normal at 5% Significance Level					
24	Lilliefors Test Statistic					0.181	**Lilliefors GOF Test**					
25	5% Lilliefors Critical Value					0.262	Data appear Normal at 5% Significance Level					
26	**Data appear Normal at 5% Significance Level**											
27												
28	**Assuming Normal Distribution**											
29	**95% Normal UCL**						**95% UCLs (Adjusted for Skewness)**					
30	95% Student's-t UCL					110.8	95% Adjusted-CLT UCL (Chen-1995)					108.2
31							95% Modified-t UCL (Johnson-1978)					110.7
32												
33	**Gamma GOF Test**											
34	A-D Test Statistic					0.349	**Anderson-Darling Gamma GOF Test**					
35	5% A-D Critical Value					0.729	Detected data appear Gamma Distributed at 5% Significance Level					
36	K-S Test Statistic					0.166	**Kolmogorov-Smirnov Gamma GOF Test**					
37	5% K-S Critical Value					0.267	Detected data appear Gamma Distributed at 5% Significance Level					
38	**Detected data appear Gamma Distributed at 5% Significance Level**											
39												
40	**Gamma Statistics**											
41	k hat (MLE)					5.153	k star (bias corrected MLE)					3.674
42	Theta hat (MLE)					17.34	Theta star (bias corrected MLE)					24.32
43	nu hat (MLE)					103.1	nu star (bias corrected)					73.47
44	MLE Mean (bias corrected)					89.34	MLE Sd (bias corrected)					46.61
45							Approximate Chi Square Value (0.05)					54.74

	A	B	C	D	E	F	G	H	I	J	K	L
46					Adjusted Level of Significance	0.0267				Adjusted Chi Square Value		51.93
47												
48					**Assuming Gamma Distribution**							
49				95% Approximate Gamma UCL (use when n>=50))		119.9			95% Adjusted Gamma UCL (use when n<50)			126.4
50												
51					**Lognormal GOF Test**							
52					Shapiro Wilk Test Statistic	0.882			**Shapiro Wilk Lognormal GOF Test**			
53					5% Shapiro Wilk Critical Value	0.842			Data appear Lognormal at 5% Significance Level			
54					Lilliefors Test Statistic	0.154			**Lilliefors Lognormal GOF Test**			
55					5% Lilliefors Critical Value	0.262			Data appear Lognormal at 5% Significance Level			
56					**Data appear Lognormal at 5% Significance Level**							
57												
58					**Lognormal Statistics**							
59					Minimum of Logged Data	3.227			Mean of logged Data			4.392
60					Maximum of Logged Data	4.92			SD of logged Data			0.513
61												
62					**Assuming Lognormal Distribution**							
63					95% H-UCL	135.3			90% Chebyshev (MVUE) UCL			136
64					95% Chebyshev (MVUE) UCL	156.4			97.5% Chebyshev (MVUE) UCL			184.8
65					99% Chebyshev (MVUE) UCL	240.4						
66												
67					**Nonparametric Distribution Free UCL Statistics**							
68					**Data appear to follow a Discernible Distribution at 5% Significance Level**							
69												
70					**Nonparametric Distribution Free UCLs**							
71					95% CLT UCL	108.6			95% Jackknife UCL			110.8
72					95% Standard Bootstrap UCL	108			95% Bootstrap-t UCL			111.3
73					95% Hall's Bootstrap UCL	108.2			95% Percentile Bootstrap UCL			108.2
74					95% BCA Bootstrap UCL	108.1						
75					90% Chebyshev(Mean, Sd) UCL	124.5			95% Chebyshev(Mean, Sd) UCL			140.4
76					97.5% Chebyshev(Mean, Sd) UCL	162.5			99% Chebyshev(Mean, Sd) UCL			205.9
77												
78					**Suggested UCL to Use**							
79					95% Student's-t UCL	110.8						
80												
81	Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.											
82	Recommendations are based upon data size, data distribution, and skewness.											
83	These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).											
84	However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.											
85												
86	**Note: For highly negatively-skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be**											
87	**reliable. Chen's and Johnson's methods provide adjustments for positvely skewed data sets.**											
88												
89												
90	**VAL (199-h4-88)**											

	A	B	C	D	E	F	G	H	I	J	K	L
91												
92	**General Statistics**											
93	Total Number of Observations					10	Number of Distinct Observations					9
94							Number of Missing Observations					0
95	Minimum					44.3	Mean					71.05
96	Maximum					93	Median					74.15
97	SD					15.64	Std. Error of Mean					4.945
98	Coefficient of Variation					0.22	Skewness					-0.372
99												
100	**Normal GOF Test**											
101	Shapiro Wilk Test Statistic					0.964	**Shapiro Wilk GOF Test**					
102	5% Shapiro Wilk Critical Value					0.842	Data appear Normal at 5% Significance Level					
103	Lilliefors Test Statistic					0.15	**Lilliefors GOF Test**					
104	5% Lilliefors Critical Value					0.262	Data appear Normal at 5% Significance Level					
105	**Data appear Normal at 5% Significance Level**											
106												
107	**Assuming Normal Distribution**											
108	**95% Normal UCL**						**95% UCLs (Adjusted for Skewness)**					
109	95% Student's-t UCL					80.11	95% Adjusted-CLT UCL (Chen-1995)					78.56
110							95% Modified-t UCL (Johnson-1978)					80.02
111												
112	**Gamma GOF Test**											
113	A-D Test Statistic					0.288	**Anderson-Darling Gamma GOF Test**					
114	5% A-D Critical Value					0.725	Detected data appear Gamma Distributed at 5% Significance Level					
115	K-S Test Statistic					0.178	**Kolmogorov-Smirnov Gamma GOF Test**					
116	5% K-S Critical Value					0.266	Detected data appear Gamma Distributed at 5% Significance Level					
117	**Detected data appear Gamma Distributed at 5% Significance Level**											
118												
119	**Gamma Statistics**											
120	k hat (MLE)					21.08	k star (bias corrected MLE)					14.82
121	Theta hat (MLE)					3.371	Theta star (bias corrected MLE)					4.794
122	nu hat (MLE)					421.5	nu star (bias corrected)					296.4
123	MLE Mean (bias corrected)					71.05	MLE Sd (bias corrected)					18.46
124							Approximate Chi Square Value (0.05)					257.5
125	Adjusted Level of Significance					0.0267	Adjusted Chi Square Value					251.2
126												
127	**Assuming Gamma Distribution**											
128	95% Approximate Gamma UCL (use when n>=50))					81.78	95% Adjusted Gamma UCL (use when n<50)					83.83
129												
130	**Lognormal GOF Test**											
131	Shapiro Wilk Test Statistic					0.939	**Shapiro Wilk Lognormal GOF Test**					
132	5% Shapiro Wilk Critical Value					0.842	Data appear Lognormal at 5% Significance Level					
133	Lilliefors Test Statistic					0.185	**Lilliefors Lognormal GOF Test**					
134	5% Lilliefors Critical Value					0.262	Data appear Lognormal at 5% Significance Level					
135	**Data appear Lognormal at 5% Significance Level**											

	A	B	C	D	E	F	G	H	I	J	K	L
136												
137	**Lognormal Statistics**											
138					Minimum of Logged Data	3.791			Mean of logged Data			4.239
139					Maximum of Logged Data	4.533			SD of logged Data			0.236
140												
141	**Assuming Lognormal Distribution**											
142					95% H-UCL	82.95			90% Chebyshev (MVUE) UCL			87.15
143					95% Chebyshev (MVUE) UCL	94.41			97.5% Chebyshev (MVUE) UCL			104.5
144					99% Chebyshev (MVUE) UCL	124.3						
145												
146	**Nonparametric Distribution Free UCL Statistics**											
147	**Data appear to follow a Discernible Distribution at 5% Significance Level**											
148												
149	**Nonparametric Distribution Free UCLs**											
150					95% CLT UCL	79.18			95% Jackknife UCL			80.11
151					95% Standard Bootstrap UCL	78.63			95% Bootstrap-t UCL			79.7
152					95% Hall's Bootstrap UCL	78.43			95% Percentile Bootstrap UCL			78.79
153					95% BCA Bootstrap UCL	78.14						
154					90% Chebyshev(Mean, Sd) UCL	85.89			95% Chebyshev(Mean, Sd) UCL			92.6
155					97.5% Chebyshev(Mean, Sd) UCL	101.9			99% Chebyshev(Mean, Sd) UCL			120.3
156												
157	**Suggested UCL to Use**											
158					95% Student's-t UCL	80.11						
159												
160	Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.											
161	Recommendations are based upon data size, data distribution, and skewness.											
162	These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).											
163	However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.											
164												
165	**Note: For highly negatively-skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be**											
166	**reliable. Chen's and Johnson's methods provide adjustments for positvely skewed data sets.**											
167												
168												
169	**VAL (199-h4-89)**											
170												
171	**General Statistics**											
172					Total Number of Observations	10			Number of Distinct Observations			10
173									Number of Missing Observations			0
174					Minimum	10.4			Mean			23.72
175					Maximum	57.5			Median			19.6
176					SD	16.26			Std. Error of Mean			5.142
177					Coefficient of Variation	0.685			Skewness			1.516
178												
179	**Normal GOF Test**											
180					Shapiro Wilk Test Statistic	0.769			**Shapiro Wilk GOF Test**			

	A	B	C	D	E	F	G	H	I	J	K	L
181				5% Shapiro Wilk Critical Value		0.842	Data Not Normal at 5% Significance Level					
182				Lilliefors Test Statistic		0.33	**Lilliefors GOF Test**					
183				5% Lilliefors Critical Value		0.262	Data Not Normal at 5% Significance Level					
184	**Data Not Normal at 5% Significance Level**											
185												
186	**Assuming Normal Distribution**											
187	**95% Normal UCL**						**95% UCLs (Adjusted for Skewness)**					
188				95% Student's-t UCL		33.15	95% Adjusted-CLT UCL (Chen-1995)					34.81
189							95% Modified-t UCL (Johnson-1978)					33.56
190												
191	**Gamma GOF Test**											
192				A-D Test Statistic		0.659	**Anderson-Darling Gamma GOF Test**					
193				5% A-D Critical Value		0.732	Detected data appear Gamma Distributed at 5% Significance Level					
194				K-S Test Statistic		0.26	**Kolmogorov-Smirnov Gamma GOF Test**					
195				5% K-S Critical Value		0.268	Detected data appear Gamma Distributed at 5% Significance Level					
196	**Detected data appear Gamma Distributed at 5% Significance Level**											
197												
198	**Gamma Statistics**											
199				k hat (MLE)		3.062	k star (bias corrected MLE)					2.21
200				Theta hat (MLE)		7.746	Theta star (bias corrected MLE)					10.73
201				nu hat (MLE)		61.24	nu star (bias corrected)					44.2
202				MLE Mean (bias corrected)		23.72	MLE Sd (bias corrected)					15.96
203							Approximate Chi Square Value (0.05)					29.96
204				Adjusted Level of Significance		0.0267	Adjusted Chi Square Value					27.93
205												
206	**Assuming Gamma Distribution**											
207			95% Approximate Gamma UCL (use when n>=50)			35	95% Adjusted Gamma UCL (use when n<50)					37.54
208												
209	**Lognormal GOF Test**											
210				Shapiro Wilk Test Statistic		0.891	**Shapiro Wilk Lognormal GOF Test**					
211				5% Shapiro Wilk Critical Value		0.842	Data appear Lognormal at 5% Significance Level					
212				Lilliefors Test Statistic		0.22	**Lilliefors Lognormal GOF Test**					
213				5% Lilliefors Critical Value		0.262	Data appear Lognormal at 5% Significance Level					
214	**Data appear Lognormal at 5% Significance Level**											
215												
216	**Lognormal Statistics**											
217				Minimum of Logged Data		2.342	Mean of logged Data					2.994
218				Maximum of Logged Data		4.052	SD of logged Data					0.59
219												
220	**Assuming Lognormal Distribution**											
221				95% H-UCL		37.73	90% Chebyshev (MVUE) UCL					36.65
222				95% Chebyshev (MVUE) UCL		42.69	97.5% Chebyshev (MVUE) UCL					51.08
223				99% Chebyshev (MVUE) UCL		67.56						
224												
225	**Nonparametric Distribution Free UCL Statistics**											

	A	B	C	D	E	F	G	H	I	J	K	L
226	**Data appear to follow a Discernible Distribution at 5% Significance Level**											
227												
228	**Nonparametric Distribution Free UCLs**											
229					95% CLT UCL	32.18			95% Jackknife UCL			33.15
230					95% Standard Bootstrap UCL	31.77			95% Bootstrap-t UCL			49.19
231					95% Hall's Bootstrap UCL	90.18			95% Percentile Bootstrap UCL			31.98
232					95% BCA Bootstrap UCL	34.15						
233					90% Chebyshev(Mean, Sd) UCL	39.15			95% Chebyshev(Mean, Sd) UCL			46.13
234					97.5% Chebyshev(Mean, Sd) UCL	55.83			99% Chebyshev(Mean, Sd) UCL			74.88
235												
236	**Suggested UCL to Use**											
237					95% Adjusted Gamma UCL	37.54						
238												
239	Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.											
240	Recommendations are based upon data size, data distribution, and skewness.											
241	These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).											
242	However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.											
243												

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Appendix B

Timeseries Plots

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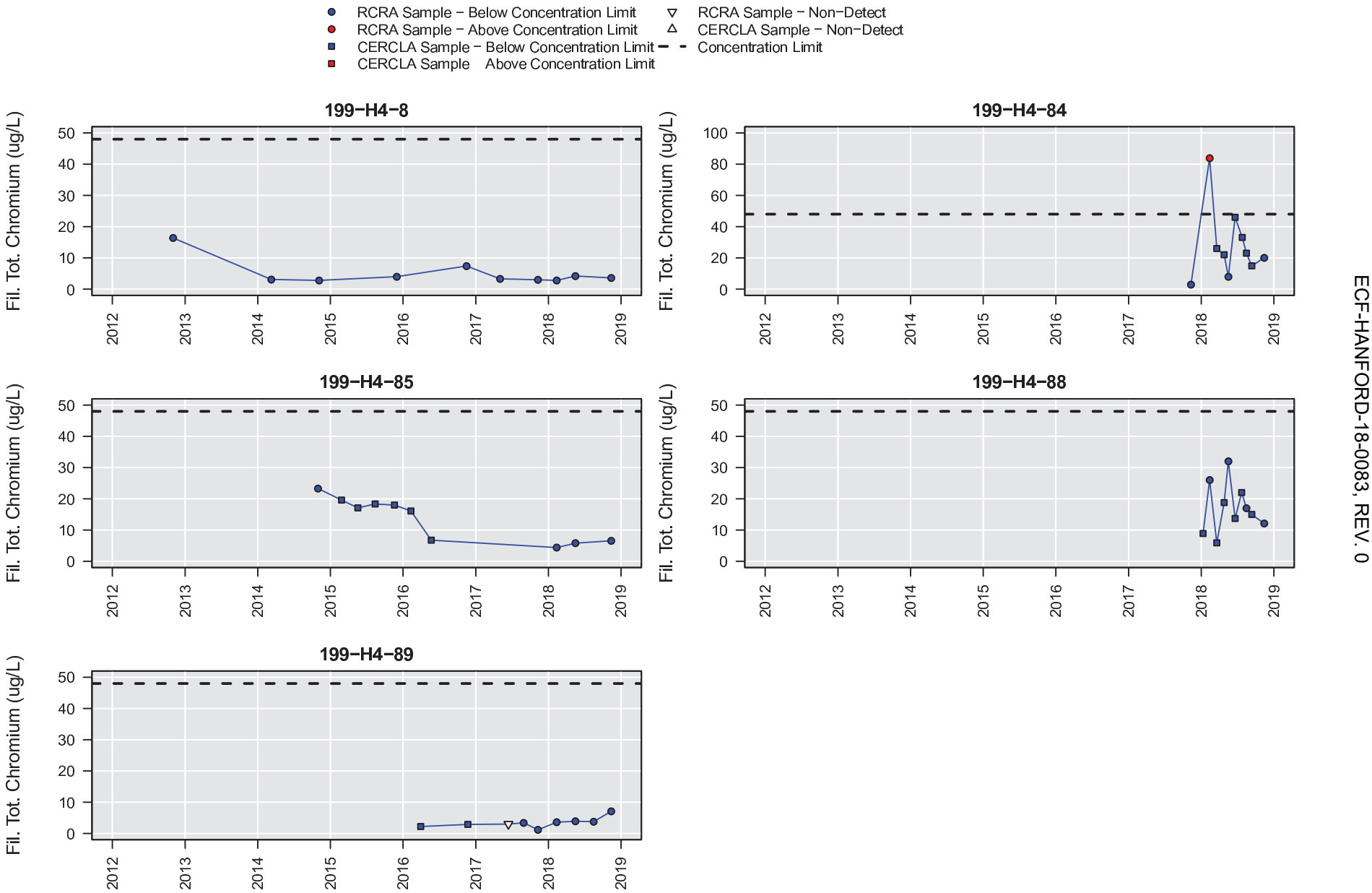
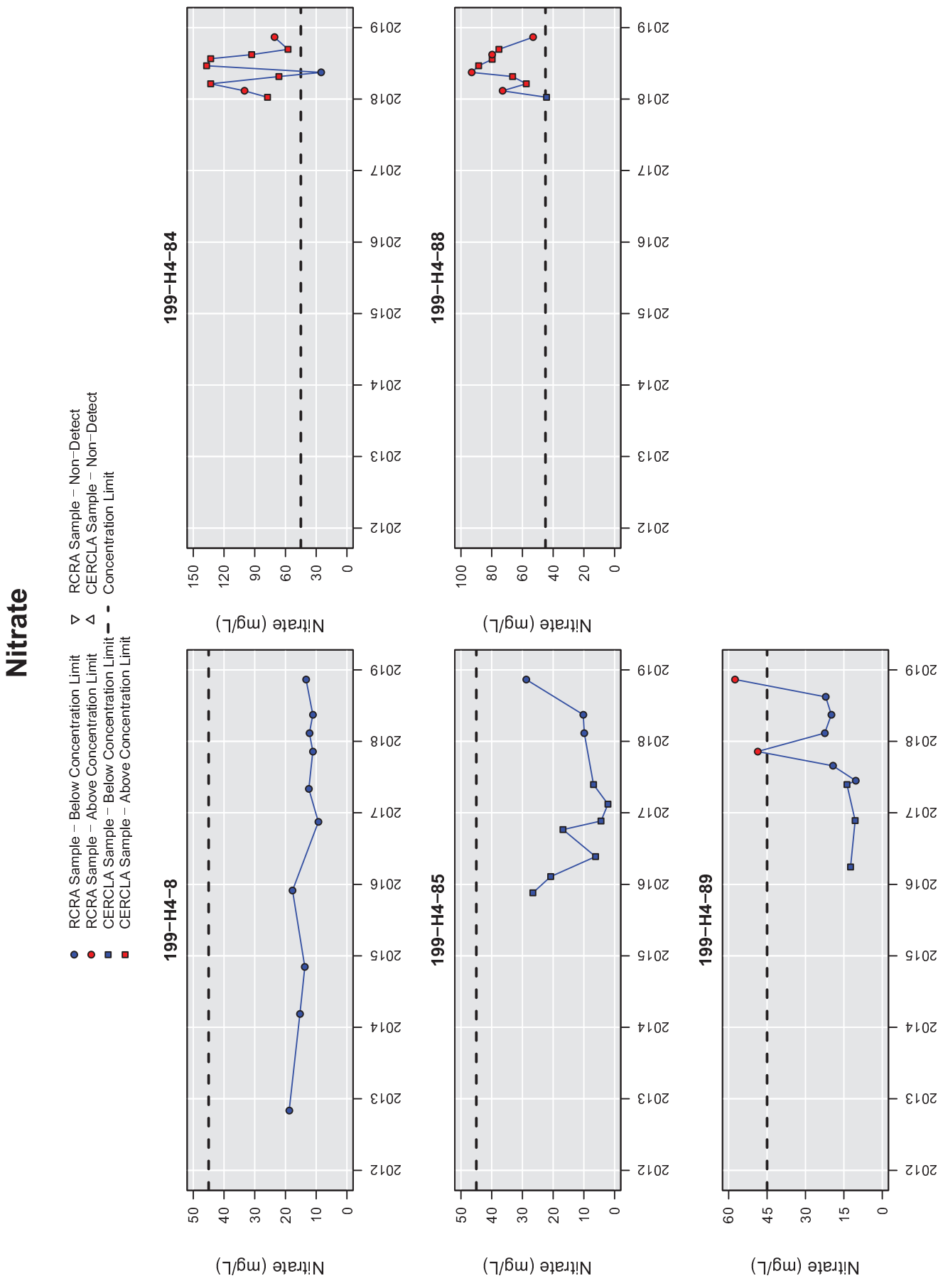
Filtered Total Chromium




Nitrate
RCRA Sample – Below Concentration Limit
RCRA Sample – Above Concentration Limit
CERCLA Sample – Below Concentration Limit
CERCLA Sample – Above Concentration Limit
RCRA Sample – Non–Detect
CERCLA Sample – Non–Detect
Concentration Limit
199–H4–84
199–H4–88
199–H4–8
199–H4–85
199–H4–89
Nitrate (mg/L)
2012
2013
2014
2015
2016
2017
2018
2019