ENERGY • WATER • COMMUNITY SERVICES

September 14, 2023

Daniela Ortiz de Montellano, Project Manager
Industrial and Hazardous Waste Permits Section
Waste Permits Division
Texas Commission on Environmental Quality

RE: New Coal Combustion Residuals (CCR) Registration No. CCR1
Technical NOD Response – Request for Clarification
Lower Colorado River Authority – La Grange, Fayette County
Industrial Solid Waste Registration No. 31575
EPA Identification No. TXD083566547
Tracking No. 27214088; RN100226844/CN600253637

Dear Ms. Ortiz de Montellano,

The Lower Colorado River Authority is in receipt of your email dated June 16, 2023, outlining TCEQ's request for additional information and clarification of previously submitted information regarding the Coal Combustion Residuals registration application for the above referenced facility (dated January 24, 2022, revised October 28, 2022). Our responses are outlined below, corresponding to the numbering in your letter. Furthermore, TCEQ has requested that LCRA prepare two stand-alone documents (Background Evaluation Report and the Statistical Analysis Plan) that consolidate information contained in the original registration application. These documents were not contemplated in the original application form prepared by TCEQ and are included as new attachments to the application. In addition, we have included a redline/strike out version of the application changes as well as replacement pages, where necessary.

15. Application Section VI.28

Revise the statistical analysis plan to include narratives to explain the following items listed below. It is recommended that the statistical analysis plan be a unique attachment, instead of within a one-time groundwater monitoring report, to facilitate future updates and revisions.

The statistical analysis plan has been updated and is included as "Attachment 13" of the application.

a. Justification to replace the initial interwell statistical analysis with the intrawell statistical analysis.

   See the attached Statistical Analysis Plan – Section 3.1.

b. How the analytical method selected meets the requirements in 40 CFR 257.93(d), (e), and (g).

   See the attached Statistical Analysis Plan – Sections 1.1 and 3.1.

c. The statistical method selected for detection evaluation, including, but not limited to:

i. Definition of nonparametric prediction limit, normal control limits, prediction limits, baseline threshold values, and CUSUM values.

See the attached Statistical Analysis Plan – Section 3.1.

ii. Establishment of normal control limit, nonparametric prediction limits, baseline threshold values, and CUSUM values.

See the attached Statistical Analysis Plan – Section 3.1.

iii. Statistical Assumptions.

See the attached Statistical Analysis Plan – Section 3.1.

iv. Handling of duplicates, outliers, and non-detects.

See the attached Statistical Analysis Plan – Section 3.1.

v. Assumptions and justification used for methodology implementation and removal of anomalous data.

See the attached Statistical Analysis Plan – Section 3.2.

vi. How the statistically significant increase (SSIs) will be determined and resampling procedures.

See the attached Statistical Analysis Plan – Section 3.2.

vii. How the control limits will be used to evaluate and determine SSIs.

See the attached Statistical Analysis Plan – Sections 4.1, 4.2, 5.1, and 5.2.

16. Application Section VI.29.B

Ensure the background evaluation report includes a statistical evaluation of background data for the following: assumptions, the statistical method selected, spatial or temporal stationarity, trends and/or seasonal variation, homogeneity of variance, outliers, non-detects, and normality. It is recommended that the background evaluation report be a unique attachment to facilitate future updates and revisions. Please also include at a minimum, the following items listed below.

The background evaluation report updated and is included as “Attachment 14” of the application.

a. A narrative explaining how the eight background samples (baseline observations) collected between 2016 and 2017 meet independent sample requirements.

See the attached Background Evaluation Report – Section 1.1.

b. Include the most recent Table 3 – *Groundwater Monitoring Result Summary for Appendices III and IV including background/upgradient well CBL340I, see* pdf pages 2011 - 2012 of the initial registration application submittal, in the background evaluation report attachment.

   See attached revised Table 3.

c. Provide a table that includes a summary of the statistical results for constituents in Appendix III for all monitoring. Explain if the background concentrations are the normal control limits, nonparametric prediction limits, baseline threshold values, and groundwater protection standards.

   See Attachment A, Table 1 in the Background Evaluation Report.

d. A narrative explaining how and why background concentrations/statistical limits will be updated and how often.

   See the attached Background Evaluation Report – Section 2.1.

e. A narrative discussing whether the background concentrations/statistical limits for Appendix III constituents accurately represent the quality of background that has not been affected by leakage from any CCR unit. In addition, provide site-specific evidence to demonstrate and support your discussion.

   See the attached Background Evaluation Report – Section 1.1. and 16(f)(iii)

f. A narrative explaining how the intrawell control charts statistical limits were generated including management of non-detect, outliers, procedures, and assumptions for all the monitoring wells and constituents, for example:

   See the attached Background Evaluation Report and the following specific response as requested. Note, the responses provided herein for Item 16, reference the background data obtained from 2016-2020, provided in the 2022 CCR Application. Please see the attached Background Evaluation Report for the updated 2016-2022 data.

   16 (f)(i)(a) – Boron: Explain how non-detects were used to generate the statistical limits if more than 50% of the sample data was non-detect at CBL301I, CBL302I, and CBL341I what do these limits mean.

   Some groundwater monitoring parameters are not detected at a frequency great enough to generate the combined Shewhart-CUSUM control charts. For constituents that are detected less than 25% of the time at a particular well, the data are plotted as a time series until a sufficient number of data points are available to provide a 99% confidence nonparametric prediction limit. Thirteen independent measurements (with 1 resample) are necessary to achieve a 99% confidence (1% false positive rate) nonparametric prediction limit. Eight

independent measurements (for pass 1 of 2 resamples) are necessary to achieve a 99% confidence nonparametric prediction limit. The nonparametric prediction limit is the largest determination out of the dataset collected for that well and parameter. If the detection frequency is 0% after thirteen samples have been collected, the reporting limit (practical quantitation limit) becomes the nonparametric prediction limit.

The boron data points at CBL-301I (0.0707 mg/L and 0.0801 mg/L) may meet the Dixon criteria for exclusion but are not extreme enough (>3x median background value) to be excluded using the DUMPStat protocol, where every other result is <0.05 mg/L boron. For this test, a value of 0.05 mg/L is substituted for each non-detect. The resulting highest value in the background is 0.0801 mg/L boron, which becomes the 99% nonparametric prediction limit.

The boron data points at CBL-302I (0.156 mg/L and 0.297 mg/L) meet the DUMPStat outlier criteria. These data were not previously excluded by ProUCL and were thus retained as valid data by DUMPStat. Future comparisons will not include these concentrations in the background if they are determined to be outliers. With these outliers removed, the 99% nonparametric prediction limit is now 0.0743 mg/L boron at CBL-302I.

With 5 boron detections out of 14 monitoring events at CBL-341I (36% detections), a normal control limit was computed after checking for outliers. The highest boron concentrations at CBL-341I (0.1020 mg/L, 0.0896 mg/L, or 0.0668 mg/L) did not meet the outlier criteria for both Dixon and extremeness. The control limit is simply defined as:

control limit = (control chart factor)(standard deviation) + mean
= (5)(0.0167) + 0.0584
= 0.1421 mg/L B

Where each ND result is substituted with 0.05 mg/L for the mean concentration and standard deviation calculations.

16 (f)(i)(b) – Boron: Explain how potential outliers reported in the BOX Plots at CBL301I, CBL302I, CBL308, and CBL341I were used in the statistical analysis and why these outliers were not detected with Dixon's test for outliers.

BOX plots were initially used in the January 2018 report (Amec Foster Wheeler, January 2018) as a qualitative tool to screen for spatial heterogeneity among the wells. Some of the BOX plots showed potential outliers. Based on an update to the Background Evaluation, the boron data points at CBL-302I from October 2016 and March 2017(0.156 mg/L and 0.297 mg/L, respectively) meet the established outlier criteria under DUMPStat. These data were not previously excluded by the ProUCL background evaluation and were thus retained as valid data by DUMPStat. Future comparisons will treat these datapoints as outliers and not include these concentrations in background.

Using a background period of 2016 through 2020, the following samples would be excluded from background if only the Dixon outlier test was applied to the data.

Well	Parameter	Result	Date
CBL-301I	Boron	0.0707	5/18/2017
	Boron	0.0801	9/17/2020
CBL-341I	Boron	0.0668	6/20/2017
	Boron	0.0896	5/16/2017
	Boron	0.1020	9/17/2020

These data exemplify why Dr. Gibbons found it necessary to include an additional layer of scrutiny before excluding certain background data. One limitation of the Dixon test is that it assumes normality. The boron results at CBL-301I and CBL-341I listed above would not pass the Dixon test. With these two detections at CBL-301I and the remaining 13 data points being <0.05 mg/L, the Dixon test, standing alone, would call these extreme. Obviously, they are not extreme. The DUMPStat software tests only extreme concentrations that are at least 3x the median background concentration.

16 (f)(ii)(a) – pH: Explain how potential outliers reported in the BOX Plots for wells CBL302I, CBL308, and CBL306I were used in the statistical analysis and why these outliers were not detected with Dixon's test for outliers.

Using a background period of 2016 through 2020, the following samples would be excluded from background if only the Dixon outlier test was applied to the data.

Well	Parameter	Result	Date
CBL-301I	pH	7.16	1/17/2019
CBL-306I	pH	4.41	3/22/2017
	pH	5.61	5/18/2017
CBL-308I	pH	5.54	5/16/2017
	pH	6.83	1/19/2017

These data exemplify why Dr. Gibbons found it necessary to include an additional layer of scrutiny before excluding certain background data. The pH results listed above would not pass the Dixon test. The DUMPStat software tests only extreme concentrations that are at least 3x the median (or 1/3x the median) background concentration.

An option to identify a data point as an outlier manually is available. This may be due to a resample not confirming the original result, known errors in the lab or sampling, or other causes. Unified Guidance §5.3.2 cautions against removing data unless a discrepancy is identified.

Outliers are identified using unique symbols, whether detected statistically or designated manually. Those data points are not included in the determination of statistical limits.

16 (f)(ii)(b) – pH: Explain why wells CBL302I and CBL306 reported a wider range between lower and upper control statistical limits than at the rest of the

downgradient wells. Their statistical limits range between 2.55 to 9.48 and 3.03 to 10.25 respectively.

The statistical limits are a function of the mean and standard deviation of the background data. Since these disputed points are not true statistical outliers, they are included in the background and contribute to the control limits.

16 (f)(iii) – Total Dissolved Solids: Explain why the TDS background concentration at CBL308I is between 1.5 and 4 times greater than at the rest of the downgradient wells.

Significant spatial heterogeneity exists across the site. As described in Section 2.1 of the Geology Summary Report included as Attachment 4 to the original CCR Registration Application, subsurface sediments at the CBL site were deposited in a fluvio-deltaic depositional environment. Sand lenses, channel fills, and sheet splays are common subsurface features and are limited in lateral extent. This creates the spatial heterogeneity that we see in the boring logs of the wells, as well as their geochemistry, including CBL 308I. The Geology Summary Report describes the results of numerous hydrogeology studies conducted at FPP, including those conducted specifically in the CBL area (Amec 2013, 2014). Several noteworthy observations were described in these reports regarding the presence of dissolved anions and cations in groundwater, as follows:

- **Prior to construction of the Lake Fayette Reservoir (serving as the FPP cooling pond), early geotechnical studies identified the shallowest groundwater bearing unit extending across the majority of the FPP site as what is now referenced as the "Middle Sand." It was in the process of completing an Affected Property Assessment in the CBL area (Amec 2014), and a focused hydrogeologic assessment of the CBL area (Amec 2013), that a shallower unit was identified beneath the CBL area. The relatively late identification of this GWBU suggests the unit may not have been a GWBU of note until completion and filling of the Lake Fayette Reservoir in the 1970s.**

- **The two shallowest GWBUs beneath the CBL are the Intermediate Sand and the Middle Sand. These GWBUs are relatively thin sand-dominant transmissive units within the Miocene-age Oakville Sandstone, deposited in a fluvio-deltaic system. These GWBUs are overlain and underlain by thick low permeability clay units. Both GWBUs are limited in lateral extent, both by original depositional limits, and by post-depositional erosion along the flanks of Baylor Creek west of the CBL.**

- **As described in Section 4.2 of the Geology Summary Report and as documented in the soil boring and monitoring well logs contained in Appendices L and N of the report, dozens of geotechnical and environmental borings throughout the CBL area document the presence of nodular calcium carbonates (calcareous nodules), "calcareous horizons," calcite seams, pyrite, gypsum, gypsum seams, and both reduced and oxidized iron-rich layers. The attached Table 1 provides a summary of observations of**

macrocrystalline carbonates, sulfates, pyrite, and oxidized iron recorded in lithologic logs developed from multiple geotechnical and environmental drilling programs occurring in the CBL area dating back to 1983. The attached Figure 1 shows the locations of the borings referenced in Table 1. These types of deposits, when subjected to partial dissolution by surface water and/or groundwater, commonly lead to the transport of cations and anions and re-precipitation elsewhere within the stratigraphic unit. As such, the occurrence of mineralized calcium carbonate (calcite), hydrated calcium sulfate (gypsum), sodium chloride (halite), iron sulfide formed under reducing conditions (pyrite, which decomposes into dissolved sulfate and iron, hematite, and limonite (iron oxides in various states of hydration) is expected; and these minerals are also expected to be present in various localized abundances based on transport, and localized or widespread redox conditions controlled by the presence or absence of air, water, and/or organic matter.

- **As discussed in a 1995 geology and groundwater study conducted at FPP (Radian, 1995), gypsum is observed in veins in soils overlying the shallow groundwater units, suggesting a post-depositional precipitation of the mineral from solution. Precipitation of gypsum indicates that calcium and sulfate ions contributed by calcite dissolution and pyrite oxidation are, or have been at, saturation with respect to gypsum. Re-exposed to groundwater dissolution, these minerals may again serve as sources for the dissolution and transport of these ions, and other evaporite ions such as sodium and chloride in groundwater.**

- **This report (Radian, 1995) concluded that the groundwater geochemical environment in the shallow lithologies at FPP suggests natural cations and anions may contribute significant concentrations of several chemical species which are also in common with coal combustion byproducts, in particular calcium, chloride, sodium, and sulfate.**

Given this geochemical backdrop, total dissolved solids (TDS), calcium, chloride, and sulfates, all of which are Appendix III analytes in the CCR program, are anticipated to be present in a range of concentrations in groundwater based on past and present mineral hydration conditions, groundwater saturation, and past and present redox conditions. The attached Table 2, as an example, summarizes the average concentrations of sulfates in the CBL GWMS wells, in addition to a monitoring well immediately upgradient of the CBL (CBL-401M) screened in the deeper Middle Sand.

With respect to TDS, the values among all of the wells are generally consistent, with one exception: CBL-306I. CBL-306I is a unique well in the CCR GWMS, as it has the shallowest potentiometric surface below the ground surface, which is at times less than four feet below ground surface). This well is also located in the topographically lowest area proximal to the CBL (see geologic cross section in Appendix G, Figure 3 of the Geology Summary Report). Our conclusion is that groundwater in the CBL-306I is subject to greater diffusion from surface

water/shallow groundwater infiltration, and, as such, major anions and cations, such as calcium, chloride, sulfate, and TDS, will have concentrations that are expected to be significantly lower that the upgradient wells.

Regarding groundwater geochemistry in general, a significant observation among all wells in the CBL GWMS is that CBL-308I is the only well screened through the Intermediate Sand, where the Intermediate Sand is not fully saturated. As much as one to three feet of an unconsolidated transmissive Intermediate Sand is present above the fluctuating groundwater surface. This condition results in expected repeated instances of dissolution and remineralization of naturally-occurring evaporite minerals, corresponding with a flux of their associated major ions naturally (calcium, chloride, sulfates, and TDS) and the state of hydration. As such, the higher observed concentrations of these major ions in the vicinity of CBL-308I is not unexpected.

16 (f)(iv) – Sulfate: Explain the presence of greater sulfate concentrations at downgradient monitoring wells CBL302I and CBL308I, which are also the ones closest to the landfill unit footprint, than at the other downgradient wells. The concentration (ranges between 993 to 1390 mg/l at CBL302I, and 1310 to 1580 mg/l at CBL308I) of sulfate at these wells are 3 to 4 times greater than at the rest of the other downgradient wells.

As described in response to comment ID 16(f)(iii) above, sulfate is naturally occurring in the subsurface throughout the CBL. The boring logs for CBL302I and CBL 308I, among other borings/wells, show evaporite and reduced iron minerals present in the subsurface (Table 1). Groundwater monitoring data obtained by analysis of groundwater samples collected during the Affected Property Assessment study for Middle Sand monitoring well CBL-401M, located upgradient of the CBL, and unaffected by CBL operation (see attached Figure 2), show even higher average sulfate concentrations (averaging 1780 mg/L), as shown in comparison to the CCR GWMS wells (see attached Table 2).

Semi-annual statistical reports prepared by LCRA have acknowledged a slight upward trend in sulfate at CBL 302I. However, this was a generalized statement about the data. When examining the data, the slight upward trend occurred in the 2016-2018 time-period. During the time-period following 2018-2022, there is not an upward trend and sulfate values appear to be relatively stable. In addition, analytical data trends observed during the CCR monitoring period 2016-2022 timeframe show declining trends in CBL-302I data for the major ions calcium, chloride, and TDS.

- **No obvious trends in analyte concentrations over time were observed in CBL-308I data (2016-2022).**
- **Neither CBL 302I or 308I have a documented SSI for sulfate.**

Based on observations of multiple lines of evidence (prior geochemical studies and review of the major cation-anion trends) the trend data observed in CBL-302I and CBL-308I suggest the levels in these two wells are naturally occurring. In addition, higher concentrations of sulfate in upgradient well (CBL-401M) screened in the Middle Sand groundwater bearing unit indicate the sulfate concentrations observed in CBL-302I and CBL-308I may be representative of

background conditions, given the lack of data suggesting otherwise. Again, as described in response to comment ID 16 (f) (iii), the presence of these ions is expected, given the Oakville Sandstone mineralogy, and the distribution of these ions (wither in the mineralized state or the dissolve state) is expected to be quite variable over the CBL area.

16 (f)(v) – CBL306I: Clarify what sample constituents from Appendix III from the July 31, 2019, sampling event were used to conduct combined Shewhart-CUSUM Control Charts statistical analysis and explain why. Attachment 10, pdf page 1907 of the registration application, suggests that the sampling results from July 31, 2019, are anomalous across many constituents and should not be included in future statistical analysis.

See Attachment C in the Background Evaluation Report. All data from the July 31, 2019 CBL-306I sampling event were excluded from statistical background evaluation based on review of the initial sampling, which showed anomalous results. The well was resampled and all analytes re-evaluated. This is reflected in the updated Attachment C.

16 (f)(vi)(a) – Attachment 4 of 2 NOD response and Table 4 -Dixon's Test Outliers provide: A narrative explaining the discrepancy in the number of observations used for the input data shown in Appendices E and D, and listed in Table 4: Dixon's Test Outliers, and assumptions used to evaluate the outlier data, as requested 16.f

See Attachments A and C in the Background Evaluation Report. The number of observations identified in the summary table and the graphs have been updated and are now in agreement.

g. Explain what the CUSUM value represents in the control charts for each well and constituents.

In addition to comparing the compliance data to background concentrations using a control chart, the Shewhart-CUSUM control chart used provides additional information. The CUSUM portion identifies cumulative increases over time, as described in Chapter 20 of the *Unified Guidance*.

Compute the standardized concentration Zi for each x_i after background:
Zi = (x_i – mean)/standard deviation
use Zi to compute the standardized CUSUM Si. Set S0 = 0
S_i^* = max [0, Zi-k + S_{i-1}]
where in this case, k = 0.75.
The cumulative sum is expressed as:
S_i = S_i^*(standard deviation) + mean

The CUSUM portion of the control chart is compared to the same control limit as was established for the data concentration. The cumulative sum sequentially analyzes each new measurement with prior compliance data.

The CUSUM value is listed in column Si of the statistical summary table and plotted as a blue circle on the graphs. The CUSUM value is computed on non-background data. The current BER assembled includes only background events so the Si column is empty and there are no CUSUM data points plotted. Previous reports show the data concentrations as red squares and the CUSUM as blue circles, both being compared to a common control limit.

h. Provide the source for this statement: “NE = Not established, EPA considers these compounds are not a concern from a human health standpoint,” see the statement in the notes for Table 3, pdf pages 2011-2012 of the original registration application submittal.

The table note has been updated to say, "NE= Not established." The amended Table 3 is attached.

No maximum contaminant level (MCL) has been established by the EPA for boron, calcium, chloride, fluoride, pH, sulfate, or total dissolved solids (TDS). While secondary MCLs have been established for chloride, fluoride, pH, sulfate, and TDS those guidelines are for managing aesthetic considerations such and taste, color, and odor; no human health concern is associated with these constituents. Neither an MCL nor a secondary MCL has been established for boron or calcium.

17. Application Section VI.29

Provide a narrative explaining the cause of an increased trend of sulfate background concentration at CBL302L. In your discussion include site-specific information and other information to demonstrate that this trend accurately represents the quality of background groundwater that has not been affected by leakage from any CCR unit. This trend was reported in the groundwater reports without further analysis appendix C, pdf page 4 of 2022 groundwater detection monitoring report.

See The Background Evaluation Report and response 16(f)(iv).

18. Application Section VI.29

Address the following:

a. Response to NOD item ID # 8 (received on October 28, 2022): Revise the title of the table to replace " Table VI.D.2" with "Table VI.C-1".
b. Include a footnote in Table VI.C.1 to reference where the narrative of the statistical analysis method explanation to determine concentration limits is in the application.

Table VI.D.2 title has been changed to Table VI.C-1 and a footnote has been added to reference the narrative of the statistical analysis method explanation. A redline and version is also attached.

<u>Additional Applications updates</u>

Application Section 8- Primary Contact Information has been updated and the red line and replacement page is attached.

The Groundwater Sampling and Analysis Plan has been updated to reflect the new Attachments 13 and 14.

If you have any questions or would like additional information, please feel free to contact me at 512-578-2939.

Sincerely,

Nancy Overesch, P.G.
Senior Environmental Coordinator

Enclosures:

The following enclosures apply to responses in this letter:

Table 1 – Soil Boring/Monitor Well Lithologic Log Descriptions Indicating Presence of Macrocrystalline Calcium, Iron, and/or Sulfate Mineralogy
Table 2 – Average Sulfate Concentrations
Figure 1 – Boring Locations Where Observations of Macrocrystalline Calcium, Iron, and/or Sulfate Mineralogy Recorded
Figure 2 – Monitor Well Location CBL-401M
Figure 3 – Major Ion Trends in CBL-302I

The following enclosures apply to CCR Registration Application:

CCR Registration Application – red line and replacement pages and attachments:
    Change of Primary Contact #8
Table 3 – Updated
Table VI.C-1 – Updated (Replaces Table VI.D.2)
Revised Attachment 10 Groundwater Sampling and Analysis Plan
New Attachment 13 – Statistical Analysis Plan
New Attachment 14 Background Evaluation Report

TABLES

TABLE 1
Soil Boring/Monitoring Well Lithologic Log Descriptions Indicating Presence of Macrocrystalline Calcium, Iron, and/or Sulfate Mineralogy
Combustion Byproducts Landfill Area
Fayette Power Project

Firm Conducting Study	Boring/Well ID	Lithologic Description	Depth Interval (ft bgs)
Amec 2014	CBL301I	iron oxide staining	9-13
Amec 2014	CBL302I	iron oxide staining	2-3
		calcareous seams	8, 19
Amec 2014	CBL305B	iron staining	5
		Iron oxide	11
		trace limestone fragments	20-22
		abundant limestone	22.5-23.5
		iron staining	23.5
		calcite and iron nodules	34
		increasing calcite and iron nodule seams	36-37.5
		trace pyrite	47.5-48
		abundant limestone pebbles	72-74
		calcareous nodules	95
Amec 2014	CBL306B/I	iron staining	9, 9
		calcareous nodules	9.5-11
		gypsum crystals	34
		calcareous nodules	59
		calcareous seams	65.5
Amec 2014	CBL 308I	iron oxide	1
		iron and manganese oxide and increasing calcium carbonate	10
		decreasing calcium carbonate	12
		increasing calcium carbonate	15
		iron oxide	16-19
		lenses of calcium carbonate and iron oxide staining	19
		less calcium carbonate	27
		iron oxide	30
		Iron oxide	32-34
Geo 2013	CBL 326	trace iron oxide	9.5
		iron staining	17.5
AFW 2015	CBL 340I	calcareous	5
		iron oxide and calcareous	21
		calcareous	37
AFW 2016	CBL 341I	Iron oxide	7
		iron oxide	13
		iron oxide	27
AFW 2018	CBL 343M	calcareous layer	12
		calcareous seams	32
Amec 2014	CBL-401M	calcareous	10
		iron oxide stained	16-28
		calcareous layer	33-35
J&N 1992	B1	Calcium deposits	18-23
J&N 1992	B2	Calcium particles	3-4
		Calcium deposits	4.5-6
		Calcium particles	6-10
		Calcium deposits	10-15
J&N 1992	B3	Calcium deposits	29-30
J&N 1992	B4	Calcium deposits	2-6
		Calciun deposits and calcium particles	6-8
J&N 1992	B5	Calcium deposits	6-23
J&N 1992	B6	Calcareous deposits	6-14
J&N 1992	B7	Calcareous nodules	23-28
J&N 1992	B8	none	
J&N 1992	B9	Calcium deposits	9-18
J&N 1992	B10	Calcium deposits	18.5-30
J&N 1992	B11	none	
J&N 1992	B-12	Calcium particles	1.5-3.5
		Calcium deposits	3.5-7
		Calcium particles	7-9
J&N 1992	B13	none	
	B14	Calcareous deposits	28-30
J&N 1992	B15	none	
J&N 1992	B16	none	
J&N 1992	B17	none	
	B18	Calcium particles	1-3
		Calcium	3-8
		cemented seams	19-23
J&N 1992	B19	Calcite deposits	5-9
		Calcite deposits	14-18
		Calcium particles	18-28.5
J&N 1992	B20	Calcium deposits	5-14.5
		Calcium deposits	18-24
		Calcium deposits	28-30
J&N 1992	B21	Calcium deposits	4.5-6
		Calcium deposits	6-74
J&N 1992	B22	Calcium deposits	9-18.5
J&N 1992	B23	Calcium deposits	13-24
J&N 1992	B24	Calcium particles	0-4
		Calcite deposits and calcite particles	24-30
J&N 1992	B25	none	
McC 1983	B101	none	
McC 1983	B110	Calcareous nodules and ferrous streaks	2-12
		Gypsum pockets	6-12
		Calcareous deposits	17-19
McC 1983	B111	none	
McC 1983	B112	carbonate deposit	5-6.5
		ferrous nodules	6.5-11
		ferrous nodules	27.5-28.5
		Carbonate deposit	44
		Calcareous nodules	66-70
McC 1983	B113	Ferrous nodules	2.5-3.5
		carbonate deposit	4-6.5
		calcium carbonate	7-8.5
		Calcareous nodules	11-15
McC 1983	B114	Ferrous nodules	8.5-14
McC 1983	B115	Calcareous nodules and ferrous nodules	2.5-7.5
		Calcareous nodules	7.5-10
McC 1983	B116	none	
McC 1983	B120	Calcareous and ferrous nodules	6-11
		Calcareous nodules	29-31
		Calcareous nodules	63-79
McC 1983	B121	Ferrous nodules	4-11
		Calcareous nodules	7.5-11
		Calcareous nodules and ferrous nodules	11-24
		Calcareous nodules	36-60
McC 1983	B122	Calcareous deposits	12-13.5
McC 1983	B123	Calcareous nodules	1.5-12
		gypsum seams	6-12
		calcareous seams and nodules	12-15
		calcareous nodules	20-28.5
		ferrous nodules	32-44
		Calcareous nodules and gypsum seams	52-56
		Carbonate silt pockets	60-70
		mica	63-65
		calcareous nodules	73-77
		Carbonate silt pockets	77-91
		calcareous seams and nodules	94-99
McC 1983	B124	Caliche	4.5-7.5
		Calcareous seams	13-16
McC 1983	B125	Calcareous deposits	6-13
		Calcareous and ferrous nodules	13-16
		Calcareous deposits	16-19
McC 1983	B126	none	
McC 1983	B127	none	
	B128	Caliche	4-6
		Calcareous deposits	6-10
		Calcareous nodules	10-17
		Calcareous seams	18-19
		Calcareous sandstone seams	21-26
		Calcareous and ferrous nodules	26-32
		Calcareous nodules	53-56
		Calcareous nodules	66-69.5
McC 1983	B129	Calcareous deposits	3.5-5.5
		Calcareous and ferrous nodules	5.5-7.5
		Calcareous nodules	7.5-11
		Calcareous and ferrous nodules	11-19
McC 1983	B130	Calcareous silty clay with calcareous deposits (caliche)	22-27
		Ferrous nodules and calcareous deposits	27-32
		Ferrous nodules	32-37
		Calcareous deposits	54-59
		Calcareous and sandy clay seams	59-66
		Calcareous silty clay	66-71
		Clacareous clay	71-82
		Calcareous nodules	82-90
McC 1983	B131	White calcium carbonate with clay	7.5-8.5
		Calcareous deposits	16
McC 1983	B132	Many calcareous deposits	3.5-5.5
		Ferrous nodules with calcarous deposits	7
		Calcareous deposits	19
McC 1983	B133	Calcareous and ferrous nodules	6
		Calcareous deposits	12.5-16
		Calcareous nodules	16-20
McC 1983	B134	none	
McC 1983	B135	Calcareous and ferrous nodules	0-5.5
		Calcareous clay	5.5-7.5
		Cemented sand and calcareous matter	13.5-19
		Calcareous and ferrous nodules	20.5-33
		Gypsum seams	33-41
McC 1983	B136	Calcareous clay with ferrous deposits	12-24
		Calcareous deposits	32-36
		Calcareous silty clay with calcareous silt partings	40-46
		Calcareous clay	46-56
		Calcareous nodules	56-62
		Calcareous clay	67-70
McC 1983	B137	none	
McC 1983	B138	Calcareous sandy clay	31-51
		Ferrous nodules	48
		Calcareous clay	51-62
		Calcareous nodules	62-69
		Calcareous clay with calcareous silt pockets	75-81
		Calcareous silty fine sand	81-90
McC 1983	B139	Calcareous nodules	2-3.5
		Calcareous and ferrous nodules	4-12
		Calcareous sandy clay	12-17.5
		Calcareous deposits	17.5-20
McC 1983	B140	none	
McC 1983	B141	Calcareous deposits	6.5-13
		Ferrous nodules	18-18.5
McC 1983	B142	Calcareous nodules	2-4.5
		Carbonate clay (caliche)	4.5-6
		Calcareous deposits	7-12
		Calcareous silty clay with ferrous streaks	12-13
		Ferrous nodules	13-20
McC 1983	B143	Ferrous nodules	0-5.5
		Calcareous nodules	4-5.5
		Calcareous and ferrous nodules	5.5-11.5
		Calcareous clay with calcareous nodules	11.5-19
McC 1983	B144	Calcareous sandy clay	26-32
		Calcareous clay	32-52
		Gypsum seams	38.5-48
McC 1983	B145	Ferrous nodules	0.5-8
		Calcareous nodules	5-12
		Calcareous silt seams 12-15	
McC 1983	B146	Calcareous deposits	13.5-20
		Calcareous nodules	23-25
		Ferrous nodules	23-25
		Calcareous nodules	33-37
		Calcareous silt pockets	43-45
McC 1983	B147	None	
McC 1983	B148	Calcareous and ferrous nodules	3.5-8.5
		Calcareous silty clay	8.5-11.5
		Calcareous sandy clay	11.5-19
McC 1983	B149	Calcareous sandy clay	4-6
		Calcareous clay seams	18-20.5
		Calcareous clay	20.5-23
		Calcareous deposits	33.5-40
		Calcareous clay	40-41.5

Studies referenced in Table:

McC 1983	McClelland Engineers, Inc.: Geotechnical Investigation
J&N 1992	Jones and Neuse, Inc.: Geotechnical Investigation
Geo 2013	Geosyntec 2013
Amec 2014	Amec: Affected Property Assessment Report Supplement
AFW 2015	Amec Foster Wheeler 2015
AFW 2016	Amec Foster Wheeler 2016
AFW 2018	Amec Foster Wheeler 2017

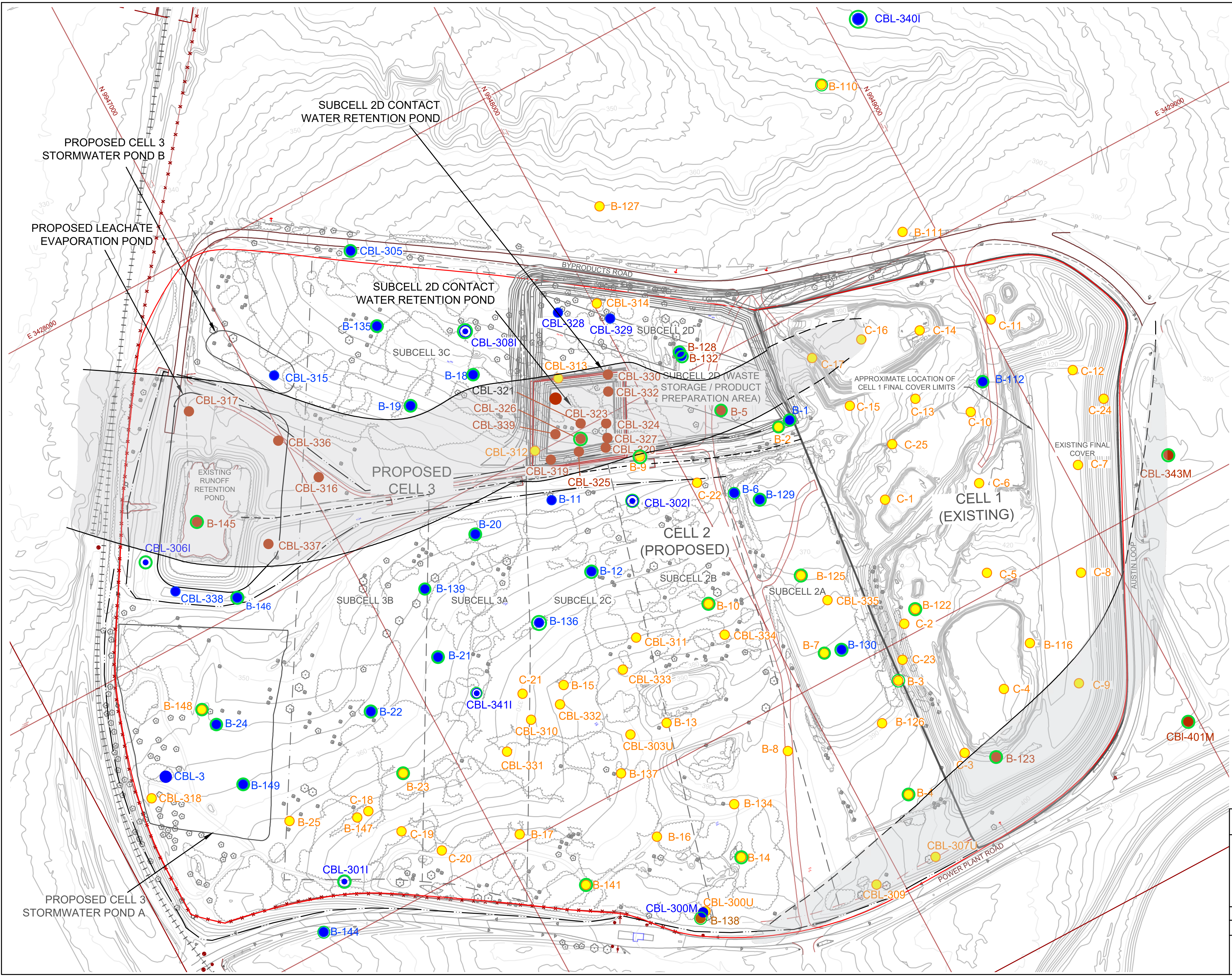
TABLE 2
AVERAGE SULFATE CONCENTRATIONS
Combustion Byproducts Landfill Area
Fayette Power Project

MONITORING WELL	MONITORING WELL LOCATION	SCREENED GROUNDWATER BEARING UNIT	Averaged Data Sampling Time Period	SULFATE AVERAGE (mg/L)
CBL-301I	Downgradient of CCR Unit	Intermediate Sand	2016-2023	**383**
CBL-302I	Downgradient of CCR Unit	Intermediate Sand	2016-2023	**1237**
CBL-306I	Downgradient of CCR Unit	Intermediate Sand	2016-2023	**388**
CBL-308I	Downgradient of CCR Unit	Intermediate Sand	2016-2023	**1374**
CBL-340I	Sidegradient of CCR Unit	Intermediate Sand	2016-2023	**649**
CBL-341I	Downgradient of CCR Unit	Intermediate Sand	2017-2023	**346**
CBL-401M	Upgradient of CCR Unit	Middle Sand	2012-2014	**1780**

mg/L = miligrams per liter

FIGURES

C:\Users\Susan Brown\Dropbox (BBA Engineering)\Jobs\LCRA\21400 LCRA Statistics 2021, Fayette Power\First Semi-Annual Event 2021\Hydrogeology Memo\Figures\All Wells.dwg



LEGEND

▬	CBL FACILITY BOUNDARY
—350—	EXISTING GROUND ELEVATION (FT,MSL) (NOTES 1,2)
—(350)—	EXISTING TOP OF CLAY LINER ELEVATION (FT,MSL) (NOTE 2)
═	EXISTING ROAD
▭	EXISTING BUILDING
┼┼┼┼	EXISTING RAILROAD
N 9949000 E 3428000	COORDINATE GRID (NOTE 2)
—×—×—	EXISTING FENCE
— — —	PROPOSED PHASE BOUNDARY
—·—·—	PROPOSED LIMIT OF WASTE
— P — P — P —	POWER LINE
●	INTERMEDIATE SAND PRESENT
●	INTERMEDIATE SAND ABSENT
●	SOIL BORING/WELL NOT DEEP ENOUGH TO ENCOUNTER INTERMEDIATE SAND
◉ CBL-302I	CCR UNIT MONITORING WELL
○	BORING LOCATION HAVING MICROCRYSTALLINE CALCIUM, IRON, AND/OR SULFATE MINERALS OBSERVED
▭	AREA WHERE INTERMEDIATE SAND IS ABSENT

NOTES:

1. THE EXISTING CONTOUR BASE MAP SHOWN ON THIS DRAWING WAS COMPILED USING AN AERIAL SURVEY BASED ON PHOTOGRAPHY PERFORMED ON 23 OCTOBER 2013 BY SURDEX CORPORATION AND LIDAR DATA PUBLISHED DECEMBER 2008 AND PROVIDED BY LCRA SURVEYING, MAPPING, AND GIS.
2. ELEVATIONS ARE IN FEET (FT) AS DEFINED BY THE NORTH AMERICAN VERTICAL DATUM (NAVD) OF 1988. STATE PLANE COORDINATE GRID CORRESPONDS TO TEXAS STATE PLANE COORDINATE SYSTEM, TEXAS CENTRAL ZONE (4203), NORTH AMERICAN DATUM 83 (NAD-83) 1983.

CRAIG C. MACON
GEOLOGY
1301

9-13-2023

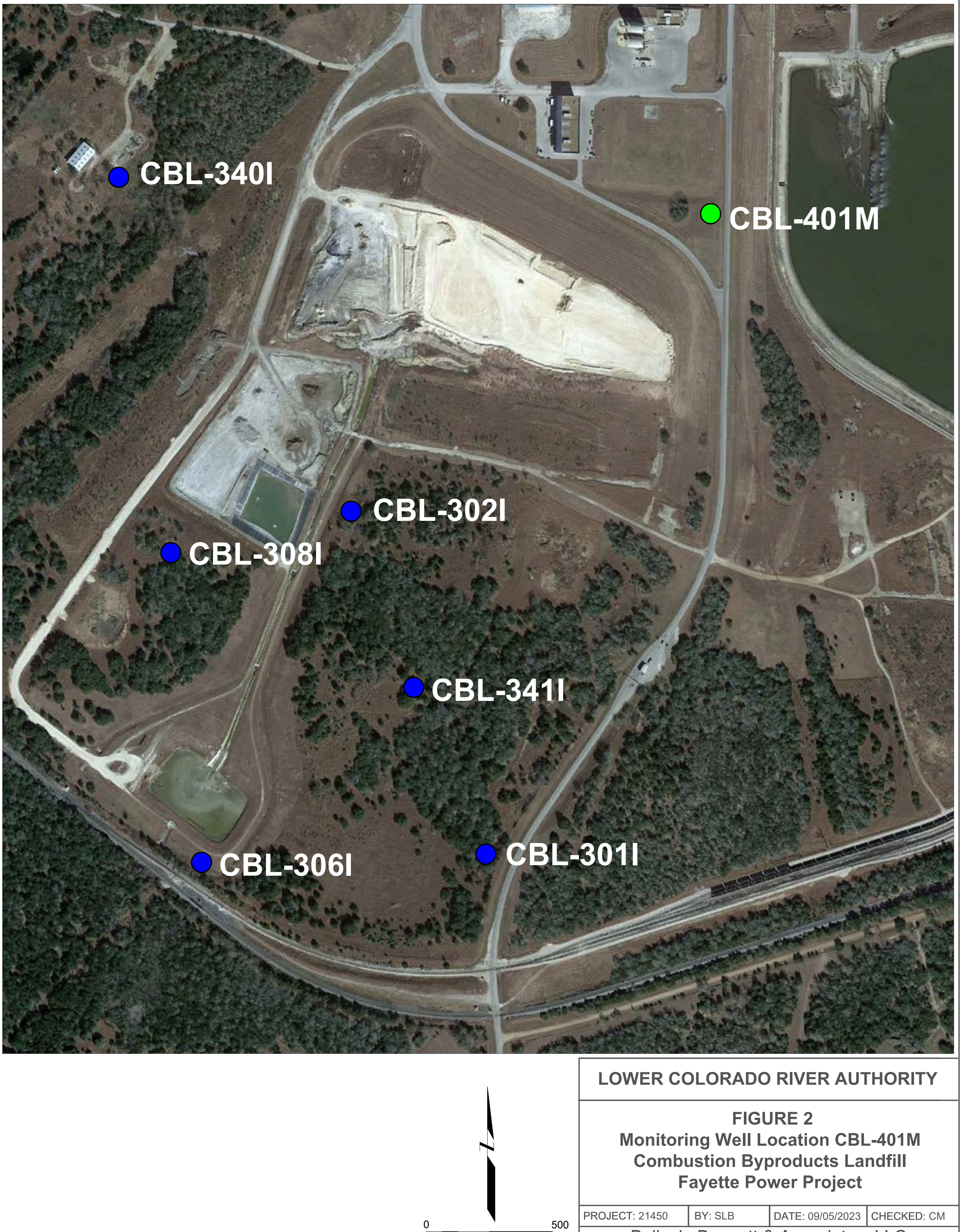
0 140 280
SCALE IN FEET

LOWER COLORADO RIVER AUTHORITY

Figure 1
Boring Locations Where Observations of Macrocrystalline Calcium, Iron, and/or Sulfate Source Mineralogy Recorded
COMBUSTION BYPRODUCTS LANDFILL
FAYETTE POWER PROJECT
LA GRANGE, TEXAS

PROJECT: 21450	BY: SLB	REVISIONS
DATE: 09/12/2023	CHECKED: CCM	

Bullock, Bennet & Associates, LLC
Engineering and Geoscience
Texas Registrations: Engineering F-8542, Geoscience 50127

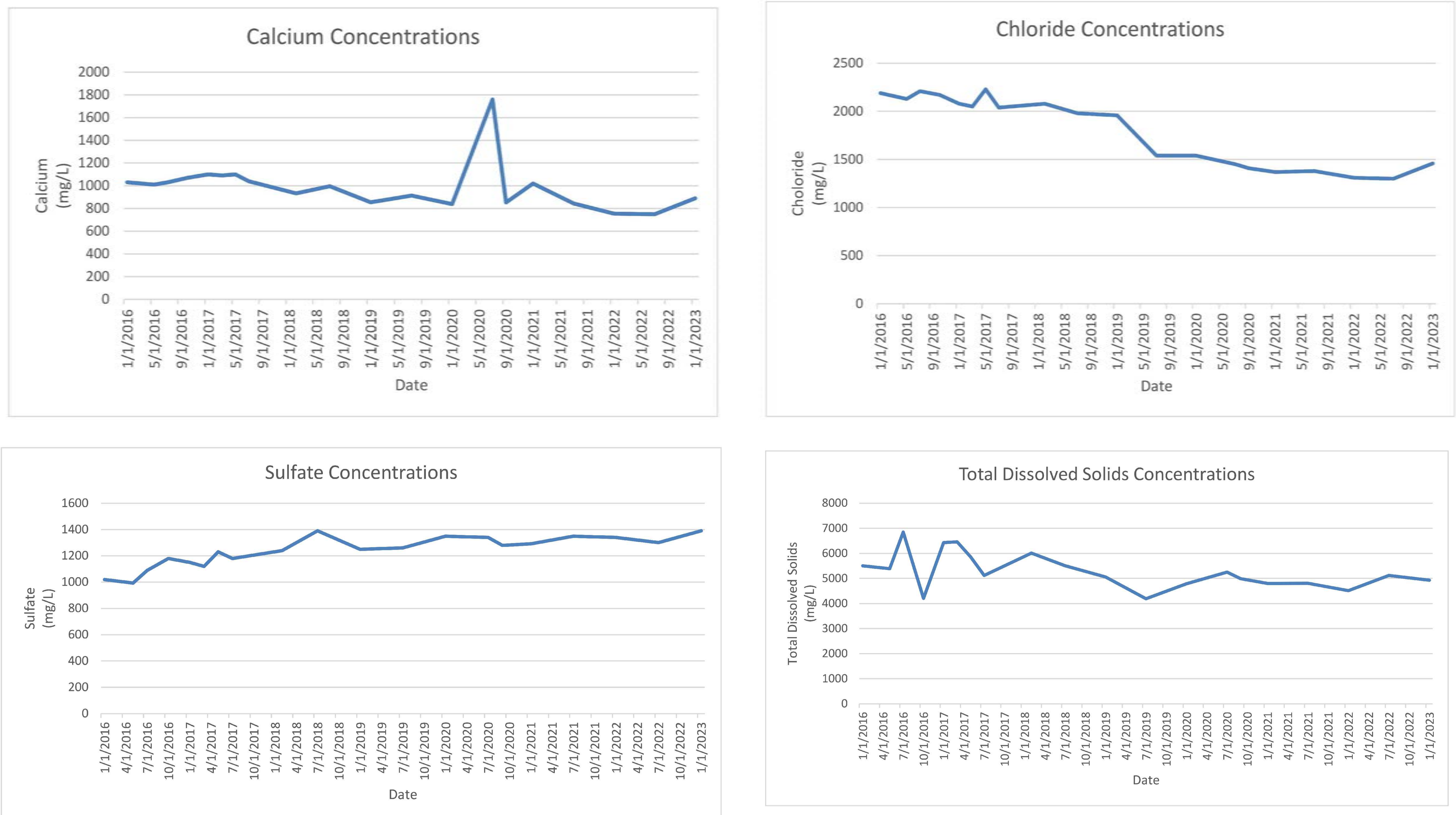


LOWER COLORADO RIVER AUTHORITY

FIGURE 2
Monitoring Well Location CBL-401M
Combustion Byproducts Landfill
Fayette Power Project

PROJECT: 21450	BY: SLB	DATE: 09/05/2023	CHECKED: CM

Bullock, Bennett & Associates, LLC
Engineering and Geoscience
Texas Registrations: Engineering F-8542, Geoscience 50127



LOWER COLORADO RIVER AUTHORITY

FIGURE 3
Major Ion Trends in CBL-302I Groundwater
Combustion Byproducts Landfill
Fayette Power Project

PROJECT: 21450	BY: SLB	DATE: 09/05/2023	CHECKED: CM

Bullock, Bennett & Associates, LLC
Engineering and Geoscience
Texas Registrations: Engineering F-8542, Geoscience 50127

CCR REGISTRATION APPLICATION UPDATES

CCR Registration Application – red line and replacement pages and attachments: Change of Primary Contact #8
Table 3 – Updated
Table VI.C-1 – Updated (Replaces Table VI.D.2)
Revised Attachment 10 Groundwater Sampling and Analysis Plan
New Attachment 13 – Statistical Analysis Plan
New Attachment 14 Background Evaluation Report

CCR Registration Application – red line and replacement pages and attachments: Change of Primary Contact #8

8. Primary Contact Information

Contact Name: ~~Rebecca Jones~~Kate McCarthy, P.G. Title: Senior Environmental Coordinator

Contact mailing address: P.O. Box 220
City: Austin County: Travis State: TX Zip Code: 78767
(Area Code) Telephone Number: 512-578-3205~~393~~

Email Address (optional): ~~Rebecca .Jones~~Kate.McCarthy@lcra.org

9. Notice Publishing

Party responsible for publishing notice:
☒ Applicant ☐ Consultant ☐ Agent in Service

Contact Name: Teresa Angel Title: Manager, Plant Environmental Support

Contact mailing address: P.O. Box E
City: Bastrop County: Bastrop State: TX Zip Code: 78602
(Area Code) Telephone Number: 520-241-5035

10. Alternative Language Notice

Is an alternative language notice required for this application? For determination, refer to Alternative Language Checklist on the Public Notice Verification Form (TCEQ-20244-Waste-NORI).

☐ Yes ☒ No

There is no Spanish language publication in Fayette County; therefore, an alternative language notice is not required.

11. Public Place Location of Application

Name of the Public Place: **Fayette Public Library**
Physical Address: **855 S Jefferson St**
City: **La Grange** County: **Fayette** State: **TX** Zip Code: **78945**
(Area code) Telephone Number: **(979) 968-3765**

12. Ownership Status of the Facility

☐ Corporation ☐ Limited Partnership

☐ Sole Proprietorship ☐ General Partnership ☒ Other (specify): River Authority

Does the Site Owner (Permittee/Registrant) own all the CCR units and all the facility property?

☒ Yes ☐ No

8. Primary Contact Information

Contact Name: Kate McCarthy, P.G. Title: Senior Environmental Coordinator

Contact mailing address: P.O. Box 220
City: Austin County: Travis State: TX Zip Code: 78767
(Area Code) Telephone Number: 512-578-3205

Email Address (optional): Kate.McCarthy@lcra.org

9. Notice Publishing

Party responsible for publishing notice:
☒ Applicant ☐ Consultant ☐ Agent in Service

Contact Name: Teresa Angel Title: Manager, Plant Environmental Support

Contact mailing address: P.O. Box E
City: Bastrop County: Bastrop State: TX Zip Code: 78602
(Area Code) Telephone Number: 520-241-5035

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☐ Corporation ☐ Limited Partnership

☐ Sole Proprietorship ☐ General Partnership ☒ Other (specify): River Authority

Does the Site Owner (Permittee/Registrant) own all the CCR units and all the facility property?

☒ Yes ☐ No

Table 3 – Updated

TABLE 3
GROUNDWATER MONITORING RESULTS SUMMARY

Monitoring Well	Sample Date	Regulatory Phase	Boron	Calcium	Chloride	Fluoride	pH	Sulfate	Total Dissolved Solids (Residue Filterable)	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Lead	Lithium	Mercury	Molybdenum	Selenium	Thallium	Radium 226	Radium 228	Radium Combined	Temp C	DO mg/L	DO %	Specific Conductivity
MCL including EPA Phase 1			NE	NE	NE	4.0	NE	NE	NE	0.006	0.01	2.0	0.004	0.005	0.1	0.006	0.015	0.04	0.002	0.1	0.05	0.002	--	--	5 pCi/l	NE	NE	NE	NE
Analytical Method			SW3010A	SW3010A	E300.0	E300.0	SM4500H+ B	E300.0	DM2450C	SW6020	SW6020	SW6010B	SW6010B	SW6020	SW6020	SW6020	SW6020	SW6020	SM2540C	SW6020	SW6020	SW6020	E903.0	E904.0		--	--	--	--
Method Detection Limit			0.02	0.35	20	0.2	--	20	250	0.0004	0.0007	0.004	0.001	0.0004	0.0004	0.0004	0.0004	0.0004	0.07 ug/L	0.0004	0.0017	0.0004	1	1		--	--	--	--
Practical Quantitation Limit			0.05	1	50	0.5	--	50	250	0.001	0.002	0.01	0.004	0.001	0.001	0.001	0.001	0.001	0.2 ug/L	0.001	0.005	0.001	1	1		--	--	--	--
CBL Background/Up-gradient Well																													
CBL-340I	1/21/2016	B	<0.0500	564	2370	1.09	6.52	652	4990	<0.001	<0.002	0.0267	<0.004	<0.001	0.00116	<0.00100	<0.00100	0.0885	<0.0002	0.00304	<0.005	<0.001	<1.0	1.45	1.45	22.47	4.42	52.4	8121
CBL-340I	5/4/2016	B	0.0832	560	2260	1.92	6.13	616	5230	<0.00100	<0.00200	0.0235	<0.004	<0.001	0.00114	<0.00100	<0.00100	0.085	<0.0002	0.00309	<0.005	<0.001	<1.0	1.22	1.22	22.96	4.12	49.3	8159
CBL-340I	7/27/2016	B	0.081	575	2350	1.06	6.95	668	6250	<0.001	<0.002	0.0271	<0.004	<0.001	0.00146	<0.001	<0.001	0.0711	<0.0002	0.00301	<0.005	<0.001	1.89	1.16	3.05	24.72	6.99	84.4	1272
CBL-340I	10/24/2016	B	0.158	607	2380	1.26	6.19	675	5670	<0.001	<0.002	0.0303	<0.004	<0.001	0.00176	<0.001	<0.001	0.0843	<0.0002	0.00334	0.00725	<0.001	1.47	1.39	2.86	22.76	3.34	39.8	8427
CBL-340I	1/23/2017	B	<0.050	627	2070	0.84	5.46	571	6230	<0.001	<0.002	0.0275	<0.004	<0.001	0.00179	<0.001	<0.001	0.0887	<0.0002	0.00284	<0.005	<0.001	<1.00	<1.00	<1.00	22.79	NA	NA	8259
CBL-340I	3/22/2017	B	0.174	581	2280	8.44	6.49	635	5480	<0.001	<0.002	0.0259	<0.004	<0.001	<0.0001	<0.001	<0.001	0.0684	<0.0002	0.00229	<0.005	<0.001	<1.00	2.71	2.71	22.37	NA	NA	7900
CBL-340I	5/16/2017	B	0.104	584	2520	1.01	5.77	715	5470	<0.001	<0.002	0.027	<0.004	<0.001	0.001	<0.001	<0.001	0.101	<0.0002	0.00248	<0.005	<0.001	<1.00	<1.00	<1.00	22.51	NA	NA	8286
CBL-340I	7/27/2017	B	0.0816	571	2380	0.85	6.42	685	4880	<0.001	<0.002	0.0272	<0.004	<0.001	<0.001	<0.001	<0.001	0.0875	<0.0002	0.00261	<0.005	<0.001	NA	NA	NA	22.73	NA	NA	8292
CBL-340I	2/8/2018	B	0.0638	555	2730	1.00	6.41	752	5290	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	21.61	NA	NA	NA
CBL-340I	7/27/2018	B	<0.0500	544	2450	1.3	6.25	711	5100	NA	NA	NA	NA	NA	NA	NA	NA	0.0968	NA	NA	NA	NA	NA	NA	NA	23.2	NA	NA	8131
CBL-340I	1/22/2019	B	<0.0500	518	2250	0.83	6.59	639	4720	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-340I	7/31/2019	B	0.124	518	2280	0.88	6.45	684	5560	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-340I	1/30/2020	B	0.0562	539	2240	0.87	6.49	637	5080	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-340I	9/18/2020	B	0.146	547	2130	0.725	6.32	608	5430	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-340I	1/28/2021	B	<0.0500	607	2260	0.835	6.32	634	5520	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-340I	7/22/2021	B	0.384	532	2200	0.865	6.24	618	4990	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-340I	1/28/2022	B	0.160	597	2200	1.06	6.42	619	4870	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-340I	7/28/2022	B	0.285	538	2160	0.865	6.35	614	5490	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL Down-gradient Wells																													
CBL-301I	1/21/2016	DM	<0.05	905	2300	<0.250	6.33	336	4380	<0.001	<0.002	0.0436	<0.004	<0.001	0.00371	<0.001	0.00105	0.0949	<0.0002	0.00124	<0.005	<0.001	<1.0	<1.0	<1.0	24.12	0.41	5	7133
CBL-301I	5/4/2016	DM	<0.0500	949	2160	<0.500	6.26	311	5050	<0.00100	<0.00200	0.0423	<0.00400	<0.00100	0.00867	<0.00100	0.00153	0.0847	<0.0002	0.00189	<0.00500	<0.00100	<1.0	<1.0	<1.0	25.02	1.21	15	7202
CBL-301I	7/27/2016	DM	<0.05	925	2290	<0.01	5.95	336	6020	<0.001	<0.002	0.0661	<0.004	<0.001	0.0101	<0.001	0.00171	0.0869	<0.0002	0.00156	<0.005	<0.001	<1.0	<1.0	<1.0	23.47	3.08	37.3	9807
CBL-301I	10/24/2016	DM	<0.05	978	2250	<0.250	6.23	326	4570	<0.001	<0.002	0.0907	<0.004	<0.001	0.0142	<0.001	0.00168	0.0932	<0.0002	0.00252	<0.005	<0.001	<1.0	1.15	1.15	25.09	0.77	9.6	7261
CBL-301I	1/23/2017	DM	<0.05	1000	3200	0.312	6.26	488	6140	<0.001	<0.002	0.0497	<0.004	<0.001	<0.001	<0.001	<0.001	0.091	<0.0002	<0.001	<0.005	<0.001	<1.0	<1.0	<1.0	23.83	NA	NA	7532
CBL-301I	3/22/2017	DM	<0.05	1030	2390	<0.500	6.31	337	6570	<0.001	<0.002	0.0662	<0.004	<0.001	0.00546	<0.001	<0.001	0.095	<0.0002	0.00137	<0.005	<0.001	<1.0	<1.0	<1.0	24.93	NA	NA	7495
CBL-301I	5/18/2017	DM	0.0707	1060	2420	<0.500	5.95	342	6430	<0.001	<0.002	0.0774	<0.004	<0.001	0.0165	0.00133	0.00186	0.116	<0.0002	0.0024	<0.005	<0.001	<1.0	<1.0	<1.0	25.92	NA	NA	7532
CBL-301I	7/26/2017	DM	<0.05	961	2500	<0.01	6.02	381	4290	<0.001	<0.002	0.0467	<0.004	<0.001	0.0022	<0.001	<0.001	0.0941	<0.0002	0.00109	<0.005	<0.001	NA	NA	NA	24.95	NA	NA	7365
CBL-301I	2/8/2018	DM	<0.05	873	2480	<0.01	6.17	344	5120	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	23.37	NA	NA	NA
CBL-301I	7/25/2018	DM	<0.05	993	1330	<0.500	6.04	196	5390	NA	NA	NA	NA	NA	NA	NA	NA	0.0971	NA	NA	NA	NA	NA	NA	NA	24.46	NA	NA	7446
CBL-301I	1/17/2019	DM	<0.05	156	619	0.219	7.16	104	1460	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-301I	5/2/2019	DM	<0.05	762	1910	0.112	6.14	398	5650	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-301I	7/31/2019	DM	<0.05	783	2240	0.051	6.19	332	6040	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-301I	1/28/2020	DM	<0.05	851	2360	0.13	6.26	349	4790	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-301I	9/17/2020	DM	0.0801	1060	2270	<.25	6.13	350	6340	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-301I	1/26/2021	DM	<0.0500	1130	2420	<0.500	6.06	374	6060	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-301I	7/20/2021	DM	0.0826	1100	25910	2.68	6.13	419	5870	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-301I	9/7/2021	DM	<0.0500	NA	NA	<0.500	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-301I	1/26/2022	DM	<0.0500	999	2440	<0.500	6.27	406	4700	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-301I	7/27/2022	DM	0.085	1010	1840	0.156	6.08	285	4590	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-301I	8/30/2022	DM	0.107	NA	NA	NA	6.14	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-301I	10/25/2022	DM	0.0645	NA	NA	NA	6.21	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-301I (split sample)	10/25/2022	DM	0.0769	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

TABLE 3
GROUNDWATER MONITORING RESULTS SUMMARY

Monitoring Well	Sample Date	Regulatory Phase	Boron	Calcium	Chloride	Fluoride	pH	Sulfate	Total Dissolved Solids (Residue Filterable)	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Lead	Lithium	Mercury	Molybdenum	Selenium	Thallium	Radium 226	Radium 228	Radium Combined	Temp C	DO mg/L	DO %	Specific Conductivity
MCL including EPA Phase 1			NE	NE	NE	4.0	NE	NE	NE	0.006	0.01	2.0	0.004	0.005	0.1	0.006	0.015	0.04	0.002	0.1	0.05	0.002	--	--	5 pCi/l	NE	NE	NE	NE
Analytical Method			SW3010A	SW3010A	E300.0	E300.0	SM4500H+ B	E300.0	DM2450C	SW6020	SW6020	SW6010B	SW6010B	SW6020	SW6020	SW6020	SW6020	SW6020	SM2540C	SW6020	SW6020	SW6020	E903.0	E904.0		--	--	--	--
Method Detection Limit			0.02	0.35	20	0.2	--	20	250	0.0004	0.0007	0.004	0.001	0.0004	0.0004	0.0004	0.0004	0.0004	0.07 ug/L	0.0004	0.0017	0.0004	1	1		--	--	--	--
Practical Quantitation Limit			0.05	1	50	0.5	--	50	250	0.001	0.002	0.01	0.004	0.001	0.001	0.001	0.001	0.001	0.2 ug/L	0.001	0.005	0.001	1	1		--	--	--	--
CBL-302I	1/22/2016	DM	<0.05	1030	2190	<0.250	6.29	1020	5500	<0.001	<0.002	0.0226	<0.004	<0.001	<0.001	<0.001	<0.001	0.0487	<0.0002	<0.001	<0.005	<0.001	<1.0	1.98	1.98	20.93	1.42	16.4	7835
CBL-302I	5/4/2016	DM	<0.05	1010	2130	<0.500	6.01	993	5390	<0.001	<0.002	0.0218	<0.004	<0.001	<0.001	<0.001	<0.001	0.042	<0.0002	<0.001	<0.005	<0.001	<1.0	<1.0	<1.0	20.84	1.51	17.3	7911
CBL-302I	7/27/2016	DM	<0.05	1030	2210	<0.500	5.17	1090	6850	<0.001	<0.002	0.0251	<0.004	<0.001	<0.001	<0.001	<0.001	0.0411	<0.0002	<0.001	<0.005	<0.001	<1.0	<1.0	<1.0	21.98	1.13	13.3	7906
CBL-302I	10/24/2016	DM	0.156	1070	2170	<0.250	7.75	1180	4210	<0.001	<0.002	0.0269	<0.004	<0.001	<0.001	<0.001	<0.001	0.0483	<0.0002	<0.001	<0.005	<0.001	<1.0	1.13	1.13	22	8.71	103.3	11017
CBL-302I	1/23/2017	DM	<0.05	1100	2080	0.332	5.36	1150	6430	<0.001	<0.002	0.0269	<0.004	<0.001	<0.001	<0.001	<0.001	0.0402	<0.0002	0.00286	<0.005	<0.001	<1.0	<1.0	<1.0	22.13	NA	NA	7723
CBL-302I	3/22/2017	DM	0.297	1090	2050	<0.500	5.4	1120	6460	<0.001	<0.002	0.0277	<0.004	<0.001	<0.001	<0.001	<0.001	0.0558	<0.0002	<0.001	<0.005	<0.001	<1.0	<1.0	<1.0	21.79	NA	NA	7753
CBL-302I	5/16/2017	DM	<0.05	1100	2230	<0.500	4.94	1230	5860	<0.001	<0.002	0.0275	<0.004	<0.001	<0.001	<0.001	<0.001	0.0611	<0.0002	<0.001	<0.005	<0.001	<1.0	<1.0	<1.0	21.52	NA	NA	7777
CBL-302I	7/27/2017	DM	<0.05	1040	2040	<0.02	6.2	1180	5120	<0.001	<0.002	0.026	<0.004	<0.001	<0.001	<0.001	<0.001	0.0534	<0.0002	<0.001	<0.005	<0.001	NA	NA	NA	22.1	NA	NA	7753
CBL-302I	2/8/2018	DM	<0.05	934	2080	0.112	6.21	1240	6010	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	20.47	NA	NA	NA
CBL-302I	7/27/2018	DM	<0.05	995	1980	<0.500	5.77	1390	5510	NA	NA	NA	NA	NA	NA	NA	NA	0.0489	NA	NA	NA	NA	NA	NA	NA	22.2	NA	NA	NA
CBL-302I	1/22/2019	DM	<0.05	855	1960	0.0402	6.44	1250	5060	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-302I	7/31/2019	DM	<0.05	914	1540	0.0605	6.15	1260	4190	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-302I	1/30/2020	DM	<0.05	838	1540	0.193	6.34	1350	4790	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-302I	9/17/2020	DM	<0.05	853	1410	<0.25	6.2	1280	4990	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-302I	1/28/2021	DM	<0.0500	1020	1370	<0.500	6.21	1290	4800	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-302I	7/21/2021	DM	0.0743	844	1380	2.25	6.06	1350	4810	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-302I	9/7/2021	DM	NA	NA	NA	<0.250	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-302I	1/27/2022	DM	<0.0500	754	1310	<0.500	6.32	1340	4510	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-302I	7/28/2022	DM	<0.0500	750	1300	0.165	6.21	1300	5120	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-306I	1/21/2016	DM	<0.0500	137	155	2.5	7.09	266	1280	<0.001	<0.002	0.0512	<0.004	<0.001	<0.001	<0.001	<0.001	0.0239	<0.0002	0.00532	<0.005	<0.001	<1.0	<1.0	<1.0	20.4	6.6	73.5	1854
CBL-306I	5/4/2016	DM	0.0717	47.2	20.0	1.00	6.69	29.5	431	<0.001	<0.002	0.0313	<0.004	<0.001	<0.001	<0.001	<0.001	0.006	<0.0002	0.00305	<0.005	<0.001	<1.0	<1.0	<1.0	21.13	6.14	69.1	672
CBL-306I	7/26/2016	DM	0.0998	105	114	1.37	6.95	139	790	<0.001	<0.002	0.0976	<0.004	<0.001	<0.001	0.00123	<0.001	0.0127	<0.0002	0.00234	<0.005	<0.001	<1.0	<1.0	<1.0	24.72	6.99	84.4	1272
CBL-306I	10/24/2016	DM	0.0556	198	330	2.38	6.72	432	1150	<0.001	<0.002	0.0841	<0.004	<0.001	<0.001	0.00287	<0.001	0.0265	<0.0002	0.00327	<0.005	<0.001	<1.0	1.05	1.05	26.13	7.93	98.6	2423
CBL-306I	1/19/2017	DM	<0.05	174	197	1.85	7.29	270	1320	<0.001	<0.002	0.0706	<0.004	<0.001	<0.001	<0.001	<0.001	0.0281	<0.0002	<0.001	0.00652	<0.001	<1.0	<1.0	<1.0	20.83	NA	NA	1422
CBL-306I	3/22/2017	DM	0.124	204	231	12.6	4.41	340	1460	<0.001	<0.002	0.0688	<0.004	<0.001	<0.001	<0.001	<0.001	0.0229	<0.0002	0.00266	<0.005	<0.001	<1.0	<1.0	<1.0	22.38	NA	NA	2176
CBL-306I	5/18/2017	DM	0.0832	205	289	2.2	5.61	412	1440	<0.001	<0.002	0.0577	<0.004	<0.001	<0.001	<0.001	<0.001	0.0325	<0.0002	0.00195	<0.005	<0.001	<1.0	<1.0	<1.0	23.6	NA	NA	2151
CBL-306I	7/27/2017	DM	0.0531	234	350	2.91	6.94	513	1280	<0.001	<0.002	0.0648	<0.004	<0.001	<0.001	<0.001	<0.001	0.0332	<0.0002	0.00352	<0.005	<0.001	NA	NA	NA	23.89	NA	NA	2687
CBL-306I	2/8/2018	DM	<0.0500	230	385	2.81	6.67	493	1760	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	19.32	NA	NA	NA
CBL-306I	7/27/2018	DM	<0.0500	275	283	2.95	6.86	406	1450	NA	NA	NA	NA	NA	NA	NA	NA	0.0298	NA	NA	NA	NA	NA	NA	NA	24.05	NA	NA	1996
CBL-306I	1/16/2019	DM	<0.0500	180	215	1.98	6.78	292	1220	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-306I	7/31/2019	DM	0.0824	106	538	9.26	6.92	816	676	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-306I	8/23/2019	DM	0.05	226	318	2.66	6.83	387	1710	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	27.48	NA	NA	2478
CBL-306I	1/29/2020	DM	<0.0500	247	445	2.83	6.7	561	1830	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-306I	9/19/2020	DM	0.0773	260	420	2.72	7.16	506	1730	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-306I	1/28/2021	DM	<0.0500	257	292	2.9	6.84	388	1420	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-306I	7/21/2021	DM	0.0927	216	255	2.42	6.55	336	1320	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-306I	1/27/2022	DM	0.0548	212	384	2.99	6.87	510	1730	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-306I	7/28/2022	DM	0.11	182	261	2.26	6.7	348	1540	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

TABLE 3
GROUNDWATER MONITORING RESULTS SUMMARY

Monitoring Well	Sample Date	Regulatory Phase	Boron	Calcium	Chloride	Fluoride	pH	Sulfate	Total Dissolved Solids (Residue Filterable)	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Lead	Lithium	Mercury	Molybdenum	Selenium	Thallium	Radium 226	Radium 228	Radium Combined	Temp C	DO mg/L	DO %	Specific Conductivity
MCL including EPA Phase 1			NE	NE	NE	4.0	NE	NE	NE	0.006	0.01	2.0	0.004	0.005	0.1	0.006	0.015	0.04	0.002	0.1	0.05	0.002	--	--	5 pCi/l	NE	NE	NE	NE
Analytical Method			SW3010A	SW3010A	E300.0	E300.0	SM4500H+B	E300.0	DM2450C	SW6020	SW6020	SW6010B	SW6010B	SW6020	SW6020	SW6020	SW6020	SW6020	SM2540C	SW6020	SW6020	SW6020	E903.0	E904.0		--	--	--	--
Method Detection Limit			0.02	0.35	20	0.2	--	20	250	0.0004	0.0007	0.004	0.001	0.0004	0.0004	0.0004	0.0004	0.0004	0.07 ug/L	0.0004	0.0017	0.0004	1	1		--	--	--	--
Practical Quantitation Limit			0.05	1	50	0.5	--	50	250	0.001	0.002	0.01	0.004	0.001	0.001	0.001	0.001	0.001	0.2 ug/L	0.001	0.005	0.001	1	1		--	--	--	--
CBL-308I	1/22/2016	DM	<0.0500	903	2760	1.49	6.36	1490	6820	<0.00100	<0.00200	0.0413	<0.00400	<0.00100	<0.00100	<0.001	<0.00100	0.116	<0.0002	0.00106	0.00693	<0.00100	<1.0	1.11	1.11	21.45	2.82	32.9	9772
CBL-308I	5/4/2016	DM	0.121	870	2580	2.3	6.13	1410	6120	<0.00100	<0.00200	0.0395	<0.00400	<0.00100	<0.00100	<0.001	<0.00100	0.134	<0.0002	0.00113	0.00823	<0.00100	<1.0	<1.0	<1.0	22.87	2.81	33.8	9726
CBL-308I	7/26/2016	DM	0.186	911	2680	1.64	5.95	1490	7890	<0.001	<0.002	0.0462	<0.004	<0.001	<0.001	<0.001	<0.001	0.0854	<0.0002	<0.001	0.00793	<0.001	<1.0	1.21	1.21	23.47	3.08	37.3	9807
CBL-308I	10/24/2016	DM	0.256	939	2870	1.59	6.27	1550	10200	<0.001	<0.002	<0.05	<0.004	<0.001	<0.001	<0.001	<0.001	0.106	<0.0002	0.00104	0.00887	<0.001	<1.0	1.66	1.66	23.06	1.6	19.3	10000
CBL-308I	1/19/2017	DM	<0.05	919	2360	1.33	6.83	1320	9620	<0.001	<0.002	0.0458	<0.004	<0.001	<0.001	<0.001	<0.001	0.106	<0.0002	0.0013	0.00995	<0.001	<1.0	1.41	1.41	22.11	NA	NA	9681
CBL-308I	3/22/2017	DM	0.545	947	2530	9.05	6.27	1470	7260	<0.001	<0.002	0.0495	<0.004	<0.001	<0.001	<0.001	<0.001	0.123	<0.0002	0.00105	0.00761	<0.001	<1.0	1.37	1.37	22.67	NA	NA	9659
CBL-308I	5/16/2017	DM	0.109	954	2740	1.7	5.54	1580	6590	<0.001	<0.002	0.0494	<0.004	<0.001	<0.001	<0.001	<0.001	0.13	<0.0002	0.001	0.00779	<0.001	<1.0	1.15	1.15	23.1	NA	NA	9697
CBL-308I	7/26/2017	DM	0.0799	878	2760	1.9	6.27	1550	6480	<0.001	<0.002	0.0436	<0.004	<0.001	<0.001	<0.001	<0.001	0.125	<0.0002	0.00106	0.00769	<0.001	NA	NA	NA	24.75	NA	NA	9929
CBL-308I	2/6/2018	DM	<0.0500	859	2750	1.76	6.26	1570	6200	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	21.73	NA	NA	NA
CBL-308I	7/25/2018	DM	<0.0500	863	2680	2.1	6.07	1540	6320	NA	NA	NA	NA	NA	NA	NA	NA	0.109	NA	NA	NA	NA	NA	NA	NA	23.43	NA	NA	9313
CBL-308I	1/18/2019	DM	<0.0500	760	2240	1.68	6.39	1520	4760	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-308I	7/31/2019	DM	<0.0500	840	2290	1.62	6.25	1420	5820	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-308I	1/29/2020	DM	<0.0500	745	2110	1.6	6.37	1340	5980	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-308I	9/18/2020	DM	0.103	838	2410	1.33	6.22	1310	6860	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-308I	1/28/2021	DM	<0.0500	830	2200	1.44	6.26	1340	6190	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-308I	7/21/2021	DM	0.130	684	1780	1.74	6.16	1240	5270	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-308I	1/27/2022	DM	<0.0500	974	2020	1.75	6.36	1310	5320	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-308I	7/27/2022	DM	0.0790	736	2470	1.43	6.23	1190	6840	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-341I	1/23/2017	DM	<0.05	854	1600	0.53	5.74	307	5000	<0.001	<0.002	0.0703	<0.004	<0.001	<0.001	<0.001	<0.001	0.0858	<0.0002	0.00112	<0.005	<0.001	<1.0	1.23	1.23	21.95	NA	NA	6053
CBL-341I	2/23/2017	DM	<0.05	870	2000	<0.50	5.23	404	4520	<0.001	<0.002	0.0733	<0.004	<0.001	<0.001	<0.001	<0.001	0.0840	<0.0002	<0.001	<0.005	<0.001	1.53	2.19	3.72	22.14	NA	NA	6030
CBL-341I	3/22/2017	DM	<0.05	906	1780	<0.50	5.72	346	5110	<0.001	<0.002	0.0739	<0.004	<0.001	<0.001	<0.001	<0.001	0.0895	<0.0002	<0.001	<0.005	<0.001	<1.00	2.62	2.62	22.08	NA	NA	6014
CBL-341I	4/20/2017	DM	0.0587	898	1770	<0.50	5.73	336	4240	<0.001	<0.002	0.0747	<0.004	<0.001	<0.001	<0.001	<0.001	0.0856	<0.0002	0.00116	<0.005	<0.001	2.21	1.90	4.11	21.88	NA	NA	6038
CBL-341I	5/16/2017	DM	0.0896	860	1900	<0.50	5.54	369	4840	<0.001	<0.002	0.0706	<0.004	<0.001	<0.001	<0.001	<0.001	0.0835	<0.0002	<0.001	<0.005	<0.001	<1.00	1.29	1.29	22.18	NA	NA	6108
CBL-341I	6/20/2017	DM	0.0668	950	1820	0.335	6.19	363	5940	<0.001	<0.002	0.0693	<0.004	<0.001	<0.001	0.00163	<0.001	0.0825	<0.0002	0.00328	0.00692	<0.001	NA	NA	NA	22.86	NA	NA	5931
CBL-341I	7/27/2017	DM	0.0507	829	1970	0.055	6.21	419	4150	<0.001	<0.002	0.0685	<0.004	<0.001	<0.001	<0.001	<0.001	0.0912	<0.0002	<0.001	<0.005	<0.001	NA	NA	NA	23.17	NA	NA	6036
CBL-341I	9/11/2017	DM	<0.05	848	1710	0.367	6.1	354	4860	<0.001	<0.002	0.0662	<0.004	<0.001	<0.001	<0.001	<0.001	0.851	<0.0002	<0.001	<0.005	<0.001	NA	NA	NA	22.7	NA	NA	6102
CBL-341I	2/8/2018	DM	<0.05	810	2110	0.106	6.18	383	4320	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	21.52	NA	NA	4320
CBL-341I	8/24/2018	DM	<0.05	824	1910	0.114	5.82	376	4800	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	23.85	NA	NA	6076
CBL-341I	1/22/2019	DM	<0.05	782	1790	0.0546	6.38	358	3870	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-341I	7/31/2019	DM	<0.05	714	1650	0.1	6.23	329	5370	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-341I	1/30/2020	DM	<0.05	767	1780	0.153	6.27	351	4900	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-341I	9/17/2020	DM	0.102	814	1700	<0.25	6.14	336	4930	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-341I	1/27/2021	DM	<0.0500	874	1800	<0.500	6.06	324	3940	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-341I	7/22/2021	DM	0.111	852	1750	1.16	5.98	316	4520	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-341I	9/7/2021	DM	NA	NA	NA	<0.250	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-341I	1/27/2022	DM	<0.0500	1040	1810	<0.500	6.26	320	3800	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CBL-341I	7/28/2022	DM	0.115	704	1690	0.141	6.16	296	4910	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:

Regulatory Phase: Background (B), Detection Monitoring (DM), Assessment Monitoring (AM), Corrective Action (CA)

All concentrations reported in mg/L (milligrams per liter)

NE = Not established

All concentrations reported in mg/L (milligrams per liter)

NA = Not analyzed in accordance with 40 CFR 257.94

Appendix III to Part 257 Constituents for Detection Monitoring

Appendix IV to Part 257 Constituents for Assessment Monitoring

Table VI.C-1 – Updated (Replaces Table VI.D.2)

Table ~~VI.D-2.~~VI.C-1 – Groundwater Detection Monitoring Parameters

Parameter	Sampling Frequency	Analytical Method	Practical Quantification Limit (units)[3]	Concentration Limit~~[1]~~
Boron	Semi-annual	SW3010A, Metals Prep SW 6010B ICP-AES	0.0500 mg/l	See Note 2
Calcium	Semi-annual	SW3010A, Metals Prep SW 6010B ICP-AES	0.200 mg/l	See Note 2
Chloride	Semi-annual	E300.0 Anions	1 mg/l	See Note 2
Fluoride	Semi-annual	E300.0 Anions	0.0100 mg/l	See Note 2
pH	Semi-annual	Field pH SM 4500H +B TCEQ Vol.1	NA	See Note 2
Sulfate	Semi-annual	E300.0 Anions	1 mg/l	See Note 2
Total Dissolved Solids	Semi-annual	SM 2540C	25.0 mg/l	See Note 2

~~[1] The concentration limit is the basis for determining whether a release has occurred from the CCR unit/area.~~

2 In accordance with 30 TAC 352.914 which adopts 40 CFR 257.94, groundwater concentrations of the listed constituents are analyzed using statistical analyses, specifically, 30 TAC 352.914(b) discusses actions triggered by a statistically significant increase for Appendix III constituents.

3 LCRA Environmental Laboratory Services report the Minimum Reporting Limit instead of PQL.

4 The statistical analysis method can be found in Attachment 13 – Statistical Analysis Plan

Table VI.C-1 – Groundwater Detection Monitoring Parameters

Parameter	Sampling Frequency	Analytical Method	Practical Quantification Limit (units)[3]	Concentration Limit~~[1]~~
Boron	Semi-annual	SW3010A, Metals Prep SW 6010B ICP-AES	0.0500 mg/l	See Note 2
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Fluoride	Semi-annual	E300.0 Anions	0.0100 mg/l	See Note 2
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Sulfate	Semi-annual	E300.0 Anions	1 mg/l	See Note 2
Total Dissolved Solids	Semi-annual	SM 2540C	25.0 mg/l	See Note 2

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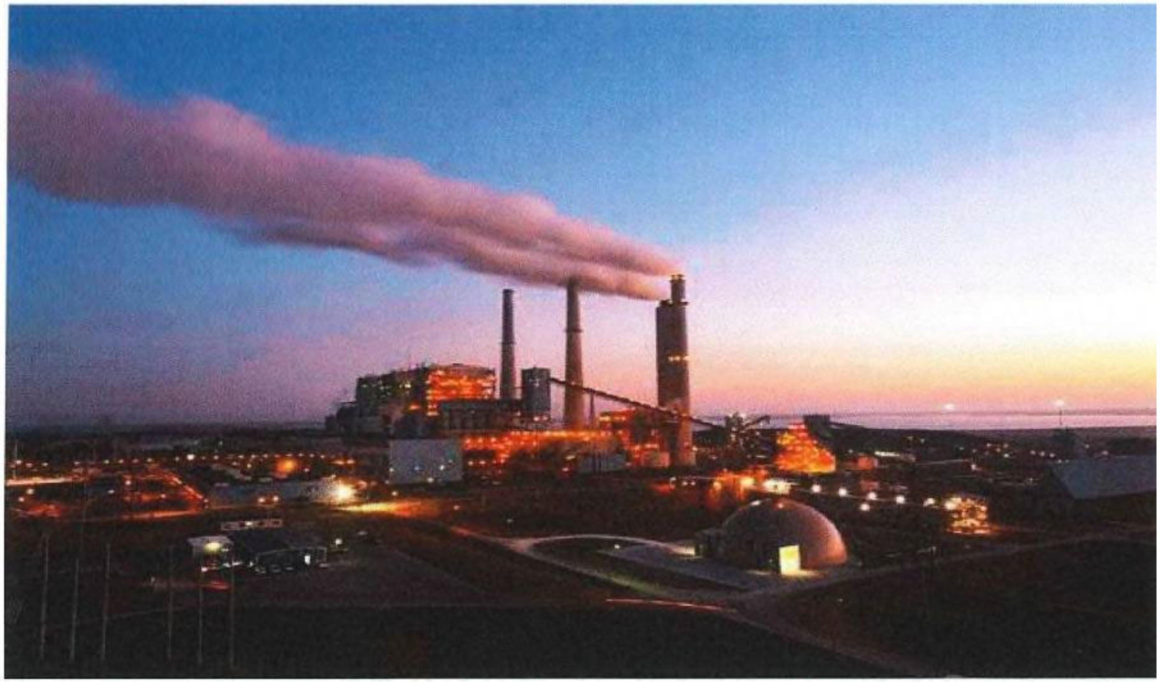
Revised Attachment 10 – Groundwater Sampling and Analysis Plan

Combustion Byproducts Landfill

GROUNDWATER MONITORING PLAN

LOWER COLORADO RIVER AUTHORITY (LCRA) FAYETTE POWER PROJECT, LA GRANGE, TEXAS ~~JUNE 2021~~

September 2023



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1.0 PURPOSE

This Groundwater Monitoring Plan (GWMP) describes standardized groundwater sample collection and analyses protocols associated with the Lower Colorado River Authority's (LCRA's) groundwater monitoring program being implemented at their Fayette Power Plant (FPP) located near La Grange, Texas. Specifically, groundwater monitoring is being conducted pursuant to the Coal Combustion Residuals (CCR) Rule - 40 Code of Federal Regulation (CFR) §257.93. Use of this GWMP is intended to facilitate consistency in sample collection and analyses which, in turn, helps to ensure generation of representative data.

2.0 HISTORY OF MODIFICATIONS TO THE GWMP

In October 2017, the Tolerance or Prediction Interval Procedure statistical method, outlined in 40 CFR §257.93(f)(3), was the preliminarily selected method for evaluating the groundwater monitoring data. In January 2021, it was determined that control chart statistical method is more appropriate for the data set and was selected from the remaining methods listed in 257.93(f).

3.0 GROUNDWATER MONITORING WELLS

The current groundwater monitoring well system consists of six groundwater wells as summarized below and additionally in Table 1:

- Background well: CBL-3401, and
- Downgradient wells: CBL- 3011, 3021, 3061, 3081, and 3411.

The well casing diameter, total depth, screened interval, and the water-bearing unit in which each well is screened is provided in Table 1. Well locations are illustrated in Figure 1.

TABLE 1
CCR GROUNDWATER MONITORING WELLS
FAYETTE POWER PROJECT

Well ID	CBL-340I (Background Well)	CBL-301I	CBL-302I	CBL-306I	CBL-308I	CBL -341I
Installation Date	12/17/2015	5/23/2011	5/24/2011	6/3/2011	12/20/2011	11/14/2016
Hydrogeologic Unit Monitored	Intermediate Sand	Intermediate Sand	Intermediate Sand	Intermediate Sand	Intermediate Sand	Intermediate Sand
Casing Type	2" PVC	2" PVC	2" PVC	2" PVC	2" PVC	2" PVC
Total Well Depth (ft bgs)	37	51	24	12.5	32	43
Screened Interval (ft bgs)	22-37	41-51	14-24	9-14	22-32	33-43
Ground Surface Elevation (ft MSL)	374.69	369.75	355.99	337.93	364.93	364.03
TOC Elevation (ft MSL)	376.98	372.11	358.99	339.96	368.67	366.65
Northing	9949069.45	9946563.44	9947806.017	9946445.582	9947619.46	9947139.86
Easting	3428311.38	3429862.181	3429260.844	3428730.533	3428574.38	3429525.31
Survey Datum	Horizontal Datum: NAD83/2011-EPOCH 2012 Vertical Datum: NAVD88-GEOIDIZA	Horizontal Datum: NAD83/NSRS 007 Vertical Datum: NAVD88	Horizontal Datum: NAD83/NSRS 2007 Vertical Datum: NAVD88	Horizontal Datum: NAD83/NSRS 2007 Vertical Datum: NAVD88	Horizontal Datum: NAD83/NSRS 2007 Vertical Datum: NAVD88	Horizontal Datum: NAD83/2011-EPOCH 2012 Vertical Datum: NAVD88-**GEOIDIZA**

Notes:
ft bgs = feet below ground surface
ft NGVD= feet above the National Geodetic Vertical Datum (NAVD 1988)

4.0 MONITORING FREQUENCY

In accordance with 40 CFR §257.94, a minimum of eight independent samples for each background well and downgradient well will be collected and analyzed for the constituents listed in appendix III and IV prior to October 17, 2017.

During detection monitoring, all wells will be sampled on a semi-annual basis for the constituents listed in appendix III. Detection monitoring samples will be collected in the first and third quarters of each year beginning in 2018.

5.0 LOW-FLOW GROUNDWATER SAMPLING PROCEDURES

Groundwater samples should be collected in accordance with the USEPA Low-Flow Groundwater Sampling Guidance included in Appendix ~~2~~1 and as described in this section.

5.1 Groundwater Sampling Preparation

The person performing groundwater sampling is responsible for ensuring that all the necessary measurement, purging, sampling supplies, and equipment are available, in good working order, and decontaminated prior to initiating sampling. At a minimum, the following equipment is required.

- A water level probe.
- A decontaminated, low-flow peristaltic or flow-controlled submersible pump.
- Dedicated bailers (in case of pump failure).
- Decontamination equipment (buckets, deionized water, Alconox®).
- A water quality meter (YSI 600 XL or similar) with the capability to measure temperature, pH, conductivity, oxidation-reduction potential, and dissolved oxygen.
- A decontaminated flow-through cell for the water quality meter.
- Laboratory-provided pre-cleaned sample containers, preferably pre-preserved.
  - 250 ml preserved with HNO3, for metals, and~~.~~
  - 500 ml plastic bottle, unpreserved, for ~~sulfate~~anions.
- Nitrile gloves.
- Coolers for sample preservation and transportation.
- Sample labels and chains of custody.
- Ice to cool collected samples.
- Field logbook or field information forms.

5.2 Water-Level Measurement Procedure

The groundwater elevation should be measured in each well and recorded prior to any groundwater sampling. The following procedures shall be used:

1. Observe the area around each well and document and/or photograph any above-ground damage that may require repair to ensure the continued integrity of the well at the surface.

2. Open the outer casing top (if bolted, a wrench may be needed) and remove the well cap (may require wrench or key).

3. Measure the depth to groundwater in each well using an electronic water-level probe (e.g. Solinst Water-Level Indicator). **Do not measure the total depth at this time to reduce turbidity.** Take these measurements by carefully lowering the probe to the water level, reading the cable measurement to 0.01-feet accuracy against the surveyed mark or notch at the top of the well casing. Record the measurements and compare them to previous readings to identify any major discrepancies. Repeat the measurements if major discrepancies are identified.

5.3 Groundwater Purging Procedure

The wells should be purged using the low-flow sampling procedure described in the USEPA guidance document attached as Appendix 1. The following procedures should be followed:

1. Obtain well logs and determine the screened interval and~~,~~ previous water levels, ~~previous~~ well yield, and ~~previous~~ purge volumes for each well. The pump or tubing ~~will need to~~ should be placed in the center of the screened interval of the well ~~for proper purging and sampling~~so that the water will be drawn in directly from the formation with little mixing of casing water or disturbance to the sampling zone. In low yield wells the pump may need to be placed lower in the casing. The other information will provide useful guidelines for additional sampling.

2. Purge each well until the discharge becomes clear and water quality parameters including pH, conductivity, temperature, and dissolved oxygen stabilize.~~ Lower a pump into the well such that the pump intake is located at the approximate center of the screened interval of the well~~. Wells should be purged at a rate of ~~Purge each well using a low-flow pump at an approximate flow rate of~~ less than 1.0 liter per minute such that drawdown of groundwater in the formation is minimized as much as possible. This can be performed with a peristaltic pump where the depth to groundwater is relatively shallow (less than 30 feet). A submersible pump with a flow controller is needed where the depth to water is greater than 30 feet.

3. Monitor the purged groundwater for water quality parameters including conductivity, pH, and temperature. This can be done using a YSI 600 XL or water quality probe of similar type. ~~Preferably, the p~~Purge water should be collected and monitored in a flow-through cell as it discharges from the well in order to take these readings. Record the measured water quality parameters either electronically or in the field logbook.

4. During purging, periodically measure the water level in the well. The water column in the well should not be significantly drawn down using the low-flow procedure. Drawdown should be less than 0.5 feet. Record the water level and drawdown measurements in the field logbook.

5. Continue purging until the water quality parameters stabilize or until 3 to 5 well volumes of water have been purged. The water quality parameters ~~most likely will~~should stabilize before 3 to 5 well volumes are reached. Sufficient stabilization has occurred where three successive readings are within ± 2 degrees Celsius temperature, ± 3% conductivity, ± 10% dissolved oxygen, ±10 mV redox potential, and ± 0.1 pH. These are general guidelines; other data quality objectives may be established ~~for a given project~~if needed.

6. In the event that ~~the~~ a well purges dry during the low-flow sampling procedures due to poor well yield, allow the well to recover to the approximate original water level before~~. Then~~ sampl~~e~~ing the well.

7. Record the ~~amount~~ volume of water purged from each well and contain all purge water for disposal according to the requirements of the project.

5.4 Groundwater Sampling Procedure

Groundwater samples should be collected from each well ~~shortly~~ directly after the water quality parameters have sufficiently stabilized or three to five well volumes have been purged. The following groundwater sampling procedures shall be used:

1. Use pre-cleaned sample bottles provided by the laboratory or bottle supplier. The bottles may be pre-preserved for specific analyses, depending on the requirements of the project.

2. Wear appropriate personal protective equipment based on the chemical properties of the contaminants of concern. At a minimum, ~~wear latex~~ nitrile gloves must be worn during sampling to prevent contact with groundwater and minimize the potential for cross-contamination. ~~At a minimum, r~~Replace the gloves between sampling at each well.

3. Collect the groundwater sample directly from the dedicated pump tubing at each well while water continues to be pumped from the well (after purging) under the low-flow (less than 0.5 liters per minute) condition. Fill the sample bottles by allowing pump discharge to flow gently down the side of bottle with minimal entry turbulence.

4. **Do not filter the samples in the field**. If the turbidity of the groundwater purged from the wells is above 10 nephelometric turbidity units (NTU), then the samples for metals analysis only should filtered with a 10-micron filter~~If the sample is turbid (greater that 10 NTU), collect both an unfiltered sample and a filtered sample using a 10-micron filter that will trap the large-diameter solids in the sample~~. In addition, an unfiltered sample should also be collected. ~~Do not use a~~A 0.45-micron filter should not be used. The filtered sample will be held and analyzed only if the unfiltered sample results in a statistically significant increase or as instructed by FPP.

5. Add preservatives to the samples (e.g., nitric acid for metals analyses) as required based on the analyses to be performed.

6. Label each sample immediately upon collection. Ensure that the label contains the sample name, sample location, date, time, preservatives, requested analyses, project identification, and sampler's name. Trip blanks, field blanks and duplicate samples should be numbered such that they are indistinguishable from other samples to be sent to the laboratory.

7. ~~Fill out~~ Complete the chain-of-custody record and indicate each sample on that record. Enter any other pertinent information regarding the sample or requested analyses on the custody record.

8. Carefully package the samples for transportation to the laboratory such that they do not leak~~. Glass bottles should be double-bagged in Ziploc bags before placing them in their respective shipping coolers to contain the water in the event of bottle breakage~~. Use ice to chill each sample cooler ~~with ice,~~ and seal the coolers for delivery to the laboratory.

9. Remove the pump and tubing from the well after sampling. The dedicated pump tubing shall be disposed of or properly stored for future sampling at the same monitoring well and new tubing used for the next monitoring well. Measure the total depth in each well using an electronic water-level probe (e.g. Solinst Water-Level Indicator). Take measurements by carefully lowering the probe first to the bottom of the well, reading the cable measurement to 0.01-feet accuracy against the surveyed mark or notch at the top of the well casing. Record the measurements and compare them to previous readings to identify any major discrepancies. Repeat the measurements if major discrepancies are identified.

10. Replace the well cap and lock the outer casing well top.

11. Decontaminate the pump between wells ~~using~~ following ASTM D5088-02 Standard Practice for Decontamination of Field Equipment at Waste Sites.

12. Promptly deliver the samples to the laboratory either by direct drop off or delivery via a priority overnight service.

6.0 LABORATORY ANALYSES & QUALITY ASSURANCE

To ensure consistent, high-quality results, laboratory analyses must be performed using industry standard methods. To be acceptable to regulatory~~ing~~ agencies, the laboratory must provide quality assurance/quality control (QA/QC) documentation with each laboratory report. The QA/QC documentation must include matrix spike, surrogate recovery, and method blank results, as well as documentation of instrument calibration. The laboratory analytical methods to be used at the FPP CBL are listed in Table 2. At a minimum, one trip blank, one field blank, and one duplicate sample shall be collected in the field to assure quality during each sampling event.

Upon receipt of the laboratory report, the data ~~the results are~~will be evaluated for any unusual values, recording mistakes, number transposition, inconsistency with field data, etc. If an error is found, the lab will be contacted to correct the error. If the suspect data cannot be explained, the well should be immediately resampled for all the constituents and the original data should be rejected.

Furthermore, the laboratory report will be reviewed for any narratives or comments indicating qualified data. Any qualified data will be closely evaluated with the laboratory. Next, the data will be reviewed for results in expected ranges. Anomalous results will be noted for additional review. The laboratory quality control report will also be reviewed to note any qualified data or other indications of anomalous runs. The data will then be deemed validated as appropriate.

Data evaluation procedures are further discussed in the Background Evaluation Report (BBA, September 2023) and the Statistical Analysis Plan (BBA September 2023).

TABLE 2
CCR GROUNDWATER ANALYTICAL METHODS
FAYETTE POWER PROJECT

Preparation Method	Analytical Method	CCR Appendix III Constituents
TCEQ SOP VI	TCEQ SOP VI	pH
SW 3010A	SW6010B	Boron
SW 3010A	SW6010B	Calcium
E300.0	E300.0	Chloride
E300.0	E300.0	Fluoride
E300.0	E300.0	Sulfate
SW 2540C	SW2540C	TDS(2540C)
		CCR Appendix IV Constituents
SW 3010A	SW6010B	Barium
SW 3010A	SW6010B	Beryllium
SW3010A	SW6020 ICP-MS	Antimony
SW3010A	SW6020 ICP-MS	Arsenic
SW3010A	SW6020 ICP-MS	Cadmium
SW3010A	SW6020 ICP-MS	Cobalt
SW3010A	SW6020 ICP-MS	Chromium
SW3010A	SW6020 ICP-MS	Lead
SW3010A	SW6020 ICP-MS	Lithium
SW3010A	SW6020 ICP-MS	Molybdenum
SW3010A	SW6020 ICP-MS	Selenium
SW3010A	SW6020 ICP-MS	Thallium
SW7470A	SW7470A	Mercury (7470)
E903.0	E903.0	Radium 226

E904.0	E904.0	Radium 228

~~7.0 VERIFICATION RESAMPLING~~

~~In a detection monitoring program that incorporates verification resampling, an SSI is not declared unless the resample or resamples also exceed the background limit. The exceedance detected in the initial sample may be referred to as an "initial exceedance." Verification resampling should be conducted to verify or disconfirm an initial exceedance. If a constituent in an original sample from a well exceeds its statistical limit, then one or more resamples are collected from that well and evaluated. A statistical test utilizing resampling is not complete until all necessary resamples have been evaluated.~~

~~The retesting strategy is to allow for one resample for constituents evaluated using a parametric method with eight background measurements which will be all wells and constituents except boron in monitoring wells CBL-301I and CBL-302I. Two resamples for constituents evaluated using a nonparametric method with eight background measurements which is boron in monitoring wells CBL-301I and CBL-302I. If the retesting strategy involves one resample, the initial exceedance is disconfirmed if the constituent concentration in the resample does not exceed the prediction limit (pass one of one resample). If the retesting strategy involves two resamples, the initial exceedance is disconfirmed if the constituent concentration in the first or second resample does not exceed the prediction limit (pass one of two resamples); if the first resample passes, the second resample does not need to be taken. A resampling strategy will be periodically reevaluated and changed as necessary during a background update, which would include new sample results since the previous background evaluation and may include new wells or changes to the list of constituents monitored.~~

~~In accordance with 40 CFR 257.93, if an initial exceedance over a background limit is determined, the owner or operator may conduct verification resampling. The verification resampling results will confirm or disprove the initial exceedance. If an initial exceedance is verified, an SSI is declared, and assessment monitoring is triggered unless an "alternate source demonstration" is submitted and approved. Within 90 days after completing sampling and analysis, the owner or operator must determine whether there has been a statistically significant increase over background for any constituent at each monitoring well. If a verification resample does not confirm an exceedance, routine detection monitoring may continue.~~

~~8.0 STATISTICAL PROCEDURE~~

~~The CCR rule provides several options for evaluating the groundwater data (40 CFR 257.93[f]). As referenced in Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance (EPA 530/R-09-007), the preferred methods for comparing groundwater data are using either prediction limits or using control charts. The control chart procedure offers an advantage over the prediction limits procedure as more data is generated over time, because they generate a graph of compliance data over time and allow for better~~

~~identification of long-term trends. The control chart statistics conform to the Coal Combustion Residual (CCR) rule (40 CFR Part 257), USEPA Guidance document ("Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Unified Guidance," March 2009), and the American Society for Testing and Materials (ASTM) standard D6312-98, Developing Appropriate Statistical Approaches for Ground-Water Detection Monitoring Programs.~~

~~As of this First Quarter 2021 statistical evaluation and moving forward, intrawell analysis will continue, using the control chart methodology referenced in 40 CFR 257.93(f)(4), instead of the prediction limits method previously used. In accordance with 40 CFR 257.93(f)(6), a new certification of the statistical method was issued by a professional engineer in May 2021.~~

Combustion Byproducts Landfill

GROUNDWATER MONITORING PLAN

LOWER COLORADO RIVER AUTHORITY (LCRA) FAYETTE POWER PROJECT, LA GRANGE, TEXAS

September 2023

Prepared by:
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Groundwater Monitoring Plan

Fayette Power Project
La Grange, TX

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- Background well: CBL-3401, and
- Downgradient wells: CBL- 3011, 3021, 3061, 3081, and 3411.

The well casing diameter, total depth, screened interval, and the water-bearing unit in which each well is screened is provided in Table 1. Well locations are illustrated in Figure 1.

TABLE 1
CCR GROUNDWATER MONITORING WELLS
FAYETTE POWER PROJECT

Well ID	CBL-340I (Background Well)	CBL-301I	CBL-302I	CBL-306I	CBL-308I	CBL -341I
Installation Date	12/17/2015	5/23/2011	5/24/2011	6/3/2011	12/20/2011	11/14/2016
Hydrogeologic Unit Monitored	Intermediate Sand	Intermediate Sand	Intermediate Sand	Intermediate Sand	Intermediate Sand	Intermediate Sand
Casing Type	2" PVC	2" PVC	2" PVC	2" PVC	2" PVC	2" PVC
Total Well Depth (ft bgs)	37	51	24	12.5	32	43
Screened Interval (ft bgs)	22-37	41-51	14-24	9-14	22-32	33-43
Ground Surface Elevation (ft MSL)	374.69	369.75	355.99	337.93	364.93	364.03
TOC Elevation (ft MSL)	376.98	372.11	358.99	339.96	368.67	366.65
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Easting	3428311.38	3429862.181	3429260.844	3428730.533	3428574.38	3429525.31
Survey Datum	Horizontal Datum: NAD83/2011-EPOCH 2012 Vertical Datum: NAVD88-GEOIDIZA	Horizontal Datum: NAD83/NSRS 007 Vertical Datum: NAVD88	Horizontal Datum: NAD83/NSRS 2007 Vertical Datum: NAVD88	Horizontal Datum: NAD83/NSRS 2007 Vertical Datum: NAVD88	Horizontal Datum: NAD83/NSRS 2007 Vertical Datum: NAVD88	Horizontal Datum: NAD83/2011-EPOCH 2012 Vertical Datum: NAVD88-**GEOIDIZA**

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ft bgs = feet below ground surface
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4.0 MONITORING FREQUENCY

In accordance with 40 CFR §257.94, a minimum of eight independent samples for each background well and downgradient well will be collected and analyzed for the constituents listed in appendix III and IV prior to October 17, 2017.

During detection monitoring, all wells will be sampled on a semi-annual basis for the constituents listed in appendix III. Detection monitoring samples will be collected in the first and third quarters of each year beginning in 2018.

5.0 LOW-FLOW GROUNDWATER SAMPLING PROCEDURES

Groundwater samples should be collected in accordance with the USEPA Low-Flow Groundwater Sampling Guidance included in Appendix 1 and as described in this section.

5.1 Groundwater Sampling Preparation

The person performing groundwater sampling is responsible for ensuring that all the necessary measurement, purging, sampling supplies, and equipment are available, in good working order, and decontaminated prior to initiating sampling. At a minimum, the following equipment is required.

- A water level probe.
- A decontaminated, low-flow peristaltic or flow-controlled submersible pump.
- Dedicated bailers (in case of pump failure).
- Decontamination equipment (buckets, deionized water, Alconox®).
- A water quality meter (YSI 600 XL or similar) with the capability to measure temperature, pH, conductivity, oxidation-reduction potential, and dissolved oxygen.
- A decontaminated flow-through cell for the water quality meter.
- Laboratory-provided pre-cleaned sample containers, preferably pre-preserved.
    - 250 ml preserved with HNO_3, for metals, and
    - 500 ml plastic bottle, unpreserved, for anions.
- Nitrile gloves.
- Coolers for sample preservation and transportation.
- Sample labels and chains of custody.
- Ice to cool collected samples.
- Field logbook or field information forms.

5.2 Water-Level Measurement Procedure

The groundwater elevation should be measured in each well and recorded prior to any groundwater sampling. The following procedures shall be used:

1. Observe the area around each well and document and/or photograph any above-ground damage that may require repair to ensure the continued integrity of the well at the surface.

2. Open the outer casing top (if bolted, a wrench may be needed) and remove the well cap (may require wrench or key).

3. Measure the depth to groundwater in each well using an electronic water-level probe (e.g. Solinst Water-Level Indicator). **Do not measure the total depth at this time to reduce turbidity.** Take these measurements by carefully lowering the probe to the water level, reading the cable measurement to 0.01-feet accuracy against the surveyed mark or notch at the top of the well casing. Record the measurements and compare them to previous readings to identify any major discrepancies. Repeat the measurements if major discrepancies are identified.

5.3 Groundwater Purging Procedure

The wells should be purged using the low-flow sampling procedure described in the USEPA guidance document attached as Appendix 1. The following procedures should be followed:

1. Obtain well logs and determine the screened interval and previous water levels, well yield, and purge volumes for each well. The pump or tubing should be placed in the center of the screened interval of the well so that the water will be drawn in directly from the formation with little mixing of casing water or disturbance to the sampling zone. In low yield wells the pump may need to be placed lower in the casing. The other information will provide useful guidelines for additional sampling.

2. Purge each well until the discharge becomes clear and water quality parameters including pH, conductivity, temperature, and dissolved oxygen stabilize.. Wells should be purged at a rate of less than 1.0 liter per minute such that drawdown of groundwater in the formation is minimized as much as possible. This can be performed with a peristaltic pump where the depth to groundwater is relatively shallow (less than 30 feet). A submersible pump with a flow controller is needed where the depth to water is greater than 30 feet.

3. Monitor the purged groundwater for water quality parameters including conductivity, pH, and temperature. This can be done using a YSI 600 XL or water quality probe of similar type. Purge water should be collected and monitored in a flow-through cell as it discharges from the well in order to take these readings. Record the measured water quality parameters either electronically or in the field logbook.

4. During purging, periodically measure the water level in the well. The water column in the well should not be significantly drawn down using the low-flow procedure. Drawdown should be less than 0.5 feet. Record the water level and drawdown measurements in the field logbook.

5. Continue purging until the water quality parameters stabilize or until 3 to 5 well volumes of water have been purged. The water quality parameters should stabilize before 3 to 5 well volumes are reached. Sufficient stabilization has occurred where three successive readings are within ± 2 degrees Celsius temperature, ± 3% conductivity, ± 10% dissolved oxygen, ±10 mV redox potential, and ± 0.1 pH.

These are general guidelines; other data quality objectives may be established if needed.

6. In the event that a well purges dry during the low-flow sampling procedures due to poor well yield, allow the well to recover to the approximate original water level before sampling the well.

7. Record the volume of water purged from each well and contain all purge water for disposal according to the requirements of the project.

5.4 Groundwater Sampling Procedure

Groundwater samples should be collected from each well directly after the water quality parameters have sufficiently stabilized or three to five well volumes have been purged. The following groundwater sampling procedures shall be used:

1. Use pre-cleaned sample bottles provided by the laboratory or bottle supplier. The bottles may be pre-preserved for specific analyses, depending on the requirements of the project.

2. Wear appropriate personal protective equipment based on the chemical properties of the contaminants of concern. At a minimum, nitrile gloves must be worn during sampling to prevent contact with groundwater and minimize the potential for cross-contamination. Replace the gloves between sampling at each well.

3. Collect the groundwater sample directly from the dedicated pump tubing at each well while water continues to be pumped from the well (after purging) under the low-flow (less than 0.5 liters per minute) condition. Fill the sample bottles by allowing pump discharge to flow gently down the side of bottle with minimal entry turbulence.

4. **Do not filter the samples in the field**. If the turbidity of the groundwater purged from the wells is above 10 nephelometric turbidity units (NTU), then the samples for metals analysis only should filtered with a 10-micron filter. In addition, an unfiltered sample should also be collected. A 0.45-micron filter should not be used. The filtered sample will be held and analyzed only if the unfiltered sample results in a statistically significant increase or as instructed by FPP.

5. Add preservatives to the samples (e.g., nitric acid for metals analyses) as required based on the analyses to be performed.

6. Label each sample immediately upon collection. Ensure that the label contains the sample name, sample location, date, time, preservatives, requested analyses, project identification, and sampler's name. Trip blanks, field blanks and duplicate samples should be numbered such that they are indistinguishable from other samples to be sent to the laboratory.

7. Complete the chain-of-custody record and indicate each sample on that record. Enter any other pertinent information regarding the sample or requested analyses on the custody record.

8. Carefully package the samples for transportation to the laboratory such that they do not leak. Use ice to chill each sample cooler and seal the coolers for delivery to the laboratory.

9. Remove the pump and tubing from the well after sampling. The dedicated pump tubing shall be disposed of or properly stored for future sampling at the same monitoring well and new tubing used for the next monitoring well. Measure the total depth in each well using an electronic water-level probe (e.g. Solinst Water-Level Indicator). Take measurements by carefully lowering the probe first to the bottom of the well, reading the cable measurement to 0.01-feet accuracy against the surveyed mark or notch at the top of the well casing. Record the measurements and compare them to previous readings to identify any major discrepancies. Repeat the measurements if major discrepancies are identified.

10. Replace the well cap and lock the outer casing well top.

11. Decontaminate the pump between wells following ASTM D5088-02 Standard Practice for Decontamination of Field Equipment at Waste Sites.

12. Promptly deliver the samples to the laboratory either by direct drop off or delivery via a priority overnight service.

6.0 LABORATORY ANALYSES & QUALITY ASSURANCE

To ensure consistent, high-quality results, laboratory analyses must be performed using industry standard methods. To be acceptable to regulatory agencies, the laboratory must provide quality assurance/quality control (QA/QC) documentation with each laboratory report. The QA/QC documentation must include matrix spike, surrogate recovery, and method blank results, as well as documentation of instrument calibration. The laboratory analytical methods to be used at the FPP CBL are listed in Table 2. At a minimum, one trip blank, one field blank, and one duplicate sample shall be collected in the field to assure quality during each sampling event.

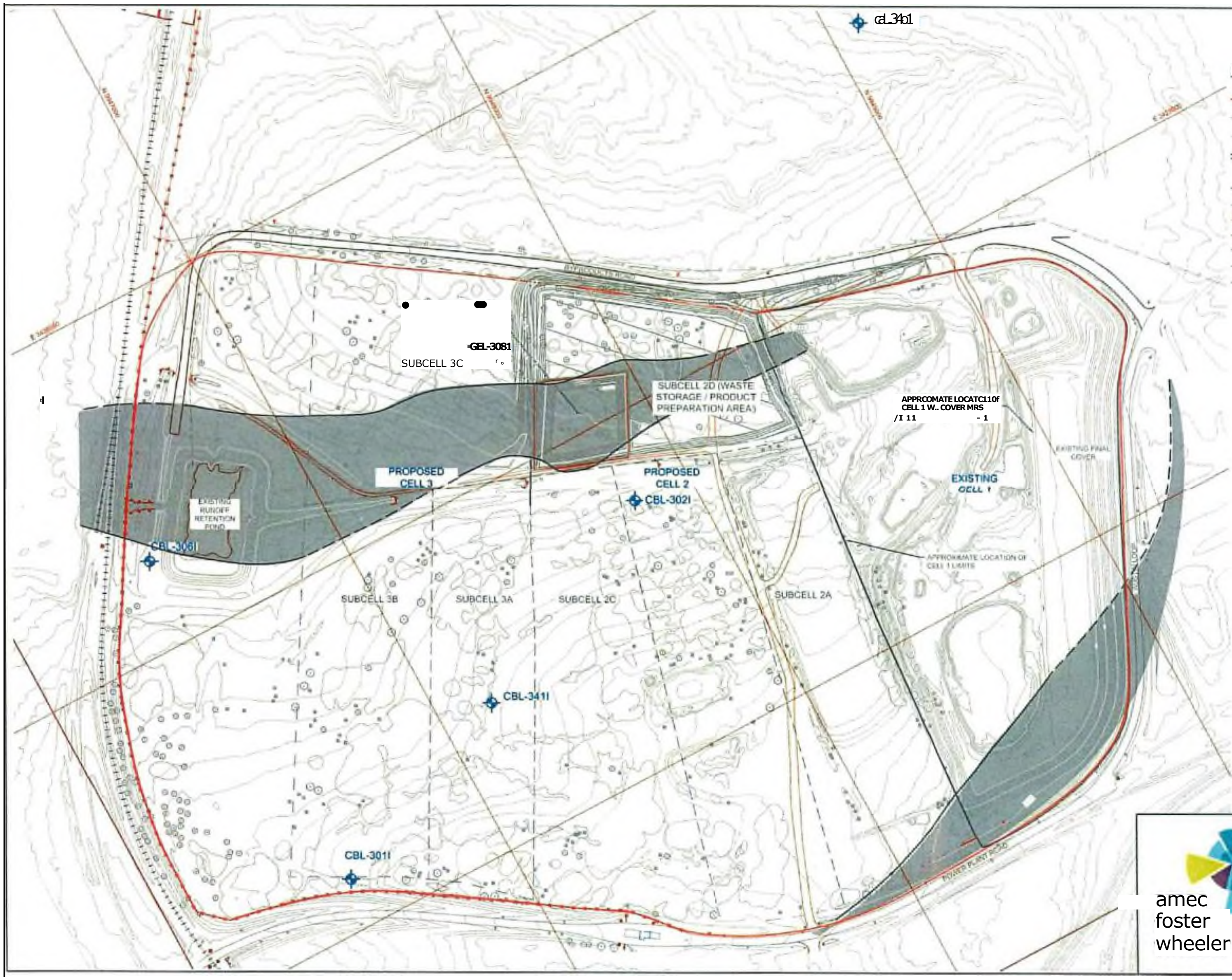
Upon receipt of the laboratory report, the data will be evaluated for any unusual values, recording mistakes, number transposition, inconsistency with field data, etc. If an error is found, the lab will be contacted to correct the error. If the suspect data cannot be explained, the well should be immediately resampled for all the constituents and the original data should be rejected.

Furthermore, the laboratory report will be reviewed for any narratives or comments indicating qualified data. Any qualified data will be closely evaluated with the laboratory. Next, the data will be reviewed for results in expected ranges. Anomalous results will be noted for additional review. The laboratory quality control report will also be reviewed to note any qualified data or other indications of anomalous runs. The data will then be deemed validated as appropriate.

Data evaluation procedures are further discussed in the Background Evaluation Report (BBA, September 2023) and the Statistical Analysis Plan (BBA September 2023).

TABLE 2
CCR GROUNDWATER ANALYTICAL METHODS
FAYETTE POWER PROJECT

Preparation Method	Analytical Method	CCR Appendix III Constituents
TCEQ SOP VI	TCEQ SOP VI	pH
SW 3010A	SW6010B	Boron
SW 3010A	SW6010B	Calcium
E300.0	E300.0	Chloride
E300.0	E300.0	Fluoride
E300.0	E300.0	Sulfate
SW 2540C	SW2540C	TDS(2540C)
		CCR Appendix IV Constituents
SW 3010A	SW6010B	Barium
SW 3010A	SW6010B	Beryllium
SW3010A	SW6020 ICP-MS	Antimony
SW3010A	SW6020 ICP-MS	Arsenic
SW3010A	SW6020 ICP-MS	Cadmium
SW3010A	SW6020 ICP-MS	Cobalt
SW3010A	SW6020 ICP-MS	Chromium
SW3010A	SW6020 ICP-MS	Lead
SW3010A	SW6020 ICP-MS	Lithium
SW3010A	SW6020 ICP-MS	Molybdenum
SW3010A	SW6020 ICP-MS	Selenium
SW3010A	SW6020 ICP-MS	Thallium
SW7470A	SW7470A	Mercury (7470)
E903.0	E903.0	Radium 226
E904.0	E904.0	Radium 228



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APPENDIX 1

USEPA LOW-FLOW GROUNDWATER SAMPLING GUIDANCE

United States
Environmental Protection
Agency

Office of
Research and
Development

Office of Solid Waste
and Emergency
Response

EPA/540/S-95/504
April 1996

Ground Water Issue

LOW-FLOW (MINIMAL DRAWDOWN) GROUND-WATER SAMPLING PROCEDURES

by Robert W. Puls[1] and Michael J. Barcelona[2]

Background

The Regional Superfund Ground Water Forum is a group of ground-water scientists, representing EPA's Regional Superfund Offices, organized to exchange information related to ground-water remediation at Superfund sites. One of the major concerns of the Forum is the sampling of ground water to support site assessment and remedial performance monitoring objectives. This paper is intended to provide background information on the development of low-flow sampling procedures and its application under a variety of hydrogeologic settings. It is hoped that the paper will support the production of standard operating procedures for use by EPA Regional personnel and other environmental professionals engaged in ground-water sampling.

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I. Introduction

The methods and objectives of ground-water sampling to assess water quality have evolved over time. Initially the emphasis was on the assessment of water quality of aquifers as sources of drinking water. Large water-bearing units were identified and sampled in keeping with that objective. These were highly productive aquifers that supplied drinking water via private wells or through public water supply systems. Gradually, with the increasing awareness of subsurface pollution of these water resources, the understanding of complex hydrogeochemical processes which govern the fate and transport of contaminants in the subsurface increased. This increase in understanding was also due to advances in a number of scientific disciplines and improvements in tools used for site characterization and ground-water sampling. Ground-water quality investigations where pollution was detected initially borrowed ideas, methods, and materials for site characterization from the water supply field and water analysis from public health practices. This included the materials and manner in which monitoring wells were installed and the way in which water was brought to the surface, treated, preserved and analyzed. The prevailing conceptual ideas included convenient generalizations of ground-water resources in terms of large and relatively homogeneous hydrologic *units*. With time it became apparent that conventional water supply generalizations of *homogeneity* did not adequately represent field data regarding pollution of these subsurface resources. The important role of *heterogeneity* became increasingly clear not only in geologic terms, but also in terms of complex physical,

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chemical and biological subsurface processes. With greater appreciation of the role of heterogeneity, it became evident that subsurface pollution was ubiquitous and encompassed the unsaturated zone to the deep subsurface and included unconsolidated sediments, fractured rock, and *aquitards* or low-yielding or impermeable formations. Small-scale processes and heterogeneities were shown to be important in identifying contaminant distributions and in controlling water and contaminant flow paths.

It is beyond the scope of this paper to summarize all the advances in the field of ground-water quality investigations and remediation, but two particular issues have bearing on ground-water sampling today: aquifer heterogeneity and colloidal transport. Aquifer heterogeneities affect contaminant flow paths and include variations in geology, geochemistry, hydrology and microbiology. As methods and the tools available for subsurface investigations have become increasingly sophisticated and understanding of the subsurface environment has advanced, there is an awareness that in most cases a primary concern for site investigations is characterization of contaminant flow paths rather than entire aquifers. In fact, in many cases, plume thickness can be less than well screen lengths (e.g., 3-6 m) typically installed at hazardous waste sites to detect and monitor plume movement over time. Small-scale differences have increasingly been shown to be important and there is a general trend toward smaller diameter wells and shorter screens.

The hydrogeochemical significance of colloidal-size particles in subsurface systems has been realized during the past several years (Gschwend and Reynolds, 1987; McCarthy and Zachara, 1989; Puls, 1990; Ryan and Gschwend, 1990). This realization resulted from both field and laboratory studies that showed faster contaminant migration over greater distances and at higher concentrations than flow and transport model predictions would suggest (Buddemeier and Hunt, 1988; Enfield and Bengtsson, 1988; Penrose et al., 1990). Such models typically account for interaction between the mobile aqueous and immobile solid phases, but do not allow for a mobile, reactive solid phase. It is recognition of this third *phase* as a possible means of contaminant transport that has brought increasing attention to the manner in which samples are collected and processed for analysis (Puls et al., 1990; McCarthy and Degueldre, 1993; Backhus et al., 1993; U. S. EPA, 1995). If such a phase is present in sufficient mass, possesses high sorption reactivity, large surface area, and remains stable in suspension, it can serve as an important mechanism to facilitate contaminant transport in many types of subsurface systems.

Colloids are particles that are sufficiently small so that the surface free energy of the particle dominates the bulk free energy. Typically, in ground water, this includes particles with diameters between 1 and 1000 nm. The most commonly observed mobile particles include: secondary clay minerals; hydrous iron, aluminum, and manganese oxides; dissolved and particulate organic materials, and viruses and bacteria. These reactive particles have been shown to be mobile under a variety of conditions in both field studies and laboratory column experiments, and as such need to be included in monitoring programs where identification of the *total* mobile contaminant loading (dissolved + naturally suspended particles) at a site is an objective. To that end, sampling methodologies must be used which do not artificially bias *naturally* suspended particle concentrations.

Currently the most common ground-water purging and sampling methodology is to purge a well using bailers or high speed pumps to remove 3 to 5 casing volumes followed by sample collection. This method can cause adverse impacts on sample quality through collection of samples with high levels of turbidity. This results in the inclusion of otherwise immobile artifactual particles which produce an overestimation of certain analytes of interest (e.g., metals or hydrophobic organic compounds). Numerous documented problems associated with filtration (Danielsson, 1982; Laxen and Chandler, 1982; Horowitz et al., 1992) make this an undesirable method of rectifying the turbidity problem, and include the removal of potentially mobile (contaminant-associated) particles during filtration, thus artificially biasing contaminant concentrations low. Sampling-induced turbidity problems can often be mitigated by using low-flow purging and sampling techniques.

Current subsurface conceptual models have undergone considerable refinement due to the recent development and increased use of field screening tools. So-called hydraulic *push* technologies (e.g., cone penetrometer, Geoprobe®, QED HydroPunch®) enable relatively fast screening site characterization which can then be used to design and install a monitoring well network. Indeed, alternatives to conventional monitoring wells are now being considered for some hydrogeologic settings. The ultimate design of any monitoring system should however be based upon adequate site characterization and be consistent with established monitoring objectives.

If the sampling program objectives include accurate assessment of the magnitude and extent of subsurface contamination over time and/or accurate assessment of subsequent remedial performance, then some information regarding plume delineation in three-dimensional space is necessary prior to monitoring well network design and installation. This can be accomplished with a variety of different tools and equipment ranging from hand-operated augers to screening tools mentioned above and large drilling rigs. Detailed information on ground-water flow velocity, direction, and horizontal and vertical variability are essential baseline data requirements. Detailed soil and geologic data are required prior to and during the installation of sampling points. This includes historical as well as detailed soil and geologic logs which accumulate during the site investigation. The use of borehole geophysical techniques is also recommended. With this information (together with other site characterization data) and a clear understanding of sampling objectives, then appropriate location, screen length, well diameter, slot size, etc. for the monitoring well network can be decided. This is especially critical for new in situ remedial approaches or natural attenuation assessments at hazardous waste sites.

In general, the overall goal of any ground-water sampling program is to collect water samples with no alteration in water chemistry; analytical data thus obtained may be used for a variety of specific monitoring programs depending on the regulatory requirements. The sampling methodology described in this paper assumes that the monitoring goal is to sample monitoring wells for the presence of contaminants and it is applicable whether mobile colloids are a concern or not and whether the analytes of concern are metals (and metalloids) or organic compounds.

II. Monitoring Objectives and Design Considerations

The following issues are important to consider prior to the design and implementation of any ground-water monitoring program, including those which anticipate using low-flow purging and sampling procedures.

A. Data Quality Objectives (DQOs)

Monitoring objectives include four main types: detection, assessment, corrective-action evaluation and resource evaluation, along with *hybrid* variations such as site-assessments for property transfers and water availability investigations. Monitoring objectives may change as contamination or water quality problems are discovered. However, there are a number of common components of monitoring programs which should be recognized as important regardless of initial objectives. These components include:

1) Development of a conceptual model that incorporates elements of the regional geology to the local geologic framework. The conceptual model development also includes initial site characterization efforts to identify hydrostratigraphic units and likely flow-paths using a minimum number of borings and well completions;

2) Cost-effective and well documented collection of high quality data utilizing simple, accurate, and reproducible techniques; and

3) Refinement of the conceptual model based on supplementary data collection and analysis.

These fundamental components serve many types of monitoring programs and provide a basis for future efforts that evolve in complexity and level of spatial detail as purposes and objectives expand. High quality, reproducible data collection is a common goal regardless of program objectives.

High quality data collection implies data of sufficient accuracy, precision, and completeness (i.e., ratio of valid analytical results to the minimum sample number called for by the program design) to meet the program objectives. Accuracy depends on the correct choice of monitoring tools and procedures to minimize sample and subsurface disturbance from collection to analysis. Precision depends on the repeatability of sampling and analytical protocols. It can be assured or improved by replication of sample analyses including blanks, field/lab standards and reference standards.

B. Sample Representativeness

An important goal of any monitoring program is collection of data that is truly representative of conditions at the site. The term *representativeness* applies to chemical and hydrogeologic data collected via wells, borings, piezometers, geophysical and soil gas measurements, lysimeters, and temporary sampling points. It involves a recognition of the statistical variability of individual subsurface physical properties, and contaminant or major ion concentration levels, while explaining extreme values. Subsurface temporal and spatial variability are facts. Good professional practice seeks to maximize representativeness by using proven accurate and reproducible techniques to define limits on the distribution of measurements collected at a site. However, measures of representativeness are dynamic and are controlled by evolving site characterization and monitoring objectives. An evolutionary site characterization model, as shown in Figure 1, provides a systematic approach to the goal of consistent data collection.

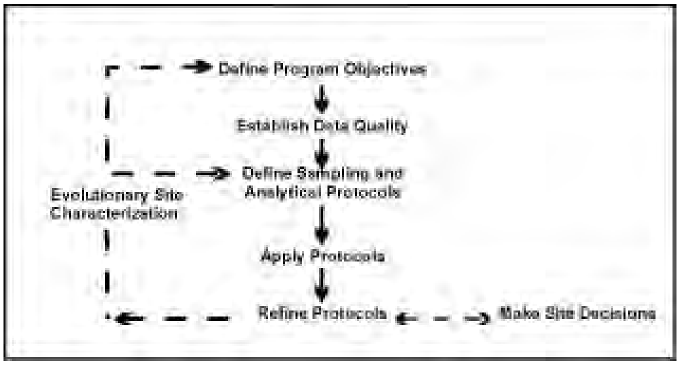

Figure 1. Evolutionary Site Characterization Model

The model emphasizes a recognition of the causes of the variability (e.g., use of inappropriate technology such as using bailers to purge wells; imprecise or operator-dependent methods) and the need to control avoidable errors.

1) Questions of Scale

A sampling plan designed to collect representative samples must take into account the potential scale of changes in site conditions through space and time as well as the chemical associations and behavior of the parameters that are targeted for investigation. In subsurface systems, physical (i.e., aquifer) and chemical properties over time or space are not statistically independent. In fact, samples taken in close proximity (i.e., within distances of a few meters) or within short time periods (i.e., more frequently than monthly) are highly auto-correlated. This means that designs employing high-sampling frequency (e.g., monthly) or dense spatial monitoring designs run the risk of redundant data collection and misleading inferences regarding trends in values that aren't statistically valid. In practice, contaminant detection and assessment monitoring programs rarely suffer these *over-sampling* concerns. In corrective-action evaluation programs, it is also possible that too little data may be collected over space or time. In these cases, false interpretation of the spatial extent of contamination or underestimation of temporal concentration variability may result.

2) Target Parameters

Parameter selection in monitoring program design is most often dictated by the regulatory status of the site. However, background water quality constituents, purging indicator parameters, and contaminants, all represent targets for data collection programs. The tools and procedures used in these programs should be equally rigorous and applicable to all categories of data, since all may be needed to determine or support regulatory action.

C. Sampling Point Design and Construction

Detailed site characterization is central to all decision-making purposes and the basis for this characterization resides in identification of the geologic framework and major hydro-stratigraphic units. Fundamental data for sample point location include: subsurface lithology, head-differences and background geochemical conditions. Each sampling point has a proper use or uses which should be documented at a level which is appropriate for the program's data quality objectives. Individual sampling points may not always be able to fulfill multiple monitoring objectives (e.g., detection, assessment, corrective action).

1) Compatibility with Monitoring Program and Data Quality Objectives

Specifics of sampling point location and design will be dictated by the complexity of subsurface lithology and variability in contaminant and/or geochemical conditions. It should be noted that, regardless of the ground-water sampling approach, few sampling points (e.g., wells, drive-points, screened augers) have zones of influence in excess of a few feet. Therefore, the spatial frequency of sampling points should be carefully selected and designed.

2) Flexibility of Sampling Point Design

In most cases *well-point* diameters in excess of 1 7/8 inches will permit the use of most types of submersible pumping devices for low-flow (minimal drawdown) sampling. It is suggested that *short* (e.g., less than 1.6 m) screens be incorporated into the monitoring design where possible so that comparable results from one device to another might be expected. *Short*, of course, is relative to the degree of vertical water quality variability expected at a site.

3) Equilibration of Sampling Point

Time should be allowed for equilibration of the well or sampling point with the formation after installation. Placement of well or sampling points in the subsurface produces some disturbance of ambient conditions. Drilling techniques (e.g., auger, rotary, etc.) are generally considered to cause more disturbance than *direct-push* technologies. In either case, there may be a period (i.e., days to months) during which water quality near the point may be distinctly different from that in the formation. Proper development of the sampling point and adjacent formation to remove fines created during emplacement will shorten this water quality *recovery* period.

III. Definition of Low-Flow Purging and Sampling

It is generally accepted that water in the well casing is non-representative of the formation water and needs to be purged prior to collection of ground-water samples. However, the water in the screened interval may indeed be representative of the formation, depending upon well construction and site hydrogeology. Wells are purged to some extent for the following reasons: the presence of the air interface at the top of the water column resulting in an oxygen concentration gradient with depth, loss of volatiles up the water column, leaching from or sorption to the casing or filter pack, chemical changes due to clay seals or backfill, and surface infiltration.

Low-flow purging, whether using portable or dedicated systems, should be done using pump-intake located in the middle or slightly above the middle of the screened interval. Placement of the pump too close to the bottom of the well will cause increased entrainment of solids which have collected in the well over time. These particles are present as a result of well development, prior purging and sampling events, and natural colloidal transport and deposition. Therefore, placement of the pump in the middle or toward the top of the screened interval is suggested. Placement of the pump at the top of the water column for sampling is only recommended in unconfined aquifers, screened across the water table, where this is the desired sampling point. Low-flow purging has the advantage of minimizing mixing between the overlying stagnant casing water and water within the screened interval.

A. Low-Flow Purging and Sampling

Low-flow refers to the velocity with which water enters the pump intake and that is imparted to the formation pore water in the immediate vicinity of the well screen. It does not necessarily refer to the flow rate of water discharged at the surface which can be affected by flow regulators or restrictions. Water level drawdown provides the best indication of the stress imparted by a given flow-rate for a given hydrological situation. The objective is to pump in a manner that minimizes stress (drawdown) to the system to the extent practical taking into account established site sampling objectives. Typically, flow rates on the order of 0.1 - 0.5 L/min are used, however this is dependent on site-specific hydrogeology. Some extremely coarse-textured formations have been successfully sampled in this manner at flow rates to 1 L/min. The effectiveness of using low-flow purging is intimately linked with proper screen location, screen length, and well construction and development techniques. The reestablishment of natural flow paths in both the vertical and horizontal directions is important for correct interpretation of the data. For high resolution sampling needs, screens less than 1 m should be used. Most of the need for purging has been found to be due to passing the sampling device through the overlying casing water which causes mixing of these stagnant waters and the dynamic waters within the screened interval. Additionally, there is disturbance to suspended sediment collected in the bottom of the casing and the displacement of water out into the formation immediately adjacent to the well screen. These disturbances and impacts can be avoided using dedicated sampling equipment, which precludes the need to insert the sampling device prior to purging and sampling.

Isolation of the screened interval water from the overlying stagnant casing water may be accomplished using low-flow minimal drawdown techniques. If the pump intake is located within the screened interval, most of the water pumped will be drawn in directly from the formation with little mixing of casing water or disturbance to the sampling zone. However, if the wells are not constructed and developed properly, zones other than those intended may be sampled. At some sites where geologic heterogeneities are sufficiently different within the screened interval, higher conductivity zones may be preferentially sampled. This is another reason to use shorter screened intervals, especially where high spatial resolution is a sampling objective.

B. Water Quality Indicator Parameters

It is recommended that water quality indicator parameters be used to determine purging needs prior to sample collection in each well. Stabilization of parameters such as pH, specific conductance, dissolved oxygen, oxidation-reduction potential, temperature and turbidity should be used to determine when formation water is accessed during purging. In general, the order of stabilization is pH, temperature, and specific conductance, followed by oxidation-reduction potential, dissolved oxygen and turbidity. Temperature and pH, while commonly used as purging indicators, are actually quite insensitive in distinguishing between formation water and stagnant casing water; nevertheless, these are important parameters for data interpretation purposes and should also be measured. Performance criteria for determination of stabilization should be based on water-level drawdown, pumping rate and equipment specifications for measuring indicator parameters. Instruments are available which utilize in-line flow cells to continuously measure the above parameters.

It is important to establish specific well stabilization criteria and then consistently follow the same methods thereafter, particularly with respect to drawdown, flow rate and sampling device. Generally, the time or purge volume required for parameter stabilization is independent of well depth or well volumes. Dependent variables are well diameter, sampling device, hydrogeochemistry, pump flow rate, and whether the devices are used in a portable or dedicated manner. If the sampling device is already in place (i.e., dedicated sampling systems), then the time and purge volume needed for stabilization is much shorter. Other advantages of dedicated equipment include less purge water for waste disposal, much less decontamination of equipment, less time spent in preparation of sampling as well as time in the field, and more consistency in the sampling approach which probably will translate into less variability in sampling results. The use of dedicated equipment is strongly recommended at wells which will undergo routine sampling over time.

If parameter stabilization criteria are too stringent, then minor oscillations in indicator parameters may cause purging operations to become unnecessarily protracted. It should also be noted that turbidity is a very conservative parameter in terms of stabilization. Turbidity is always the last parameter to stabilize. Excessive purge times are invariably related to the establishment of too stringent turbidity stabilization criteria. It should be noted that natural turbidity levels in ground water may exceed 10 nephelometric turbidity units (NTU).

C. Advantages and Disadvantages of Low-Flow (Minimum Drawdown) Purging

In general, the advantages of low-flow purging include:

- samples which are representative of the *mobile* load of contaminants present (dissolved and colloid-associated);
- minimal disturbance of the sampling point thereby minimizing sampling artifacts;
- less operator variability, greater operator control;

- reduced stress on the formation (minimal drawdown);
- less mixing of stagnant casing water with formation water;
- reduced need for filtration and, therefore, less time required for sampling;
- smaller purging volume which decreases waste disposal costs and sampling time;
- better sample consistency; reduced artificial sample variability.

Some disadvantages of low-flow purging are:

- higher initial capital costs,
- greater set-up time in the field,
- need to transport additional equipment to and from the site,
- increased training needs,
- resistance to change on the part of sampling practitioners,
- concern that new data will indicate a *change in conditions* and trigger an *action*.

IV. Low-Flow (Minimal Drawdown) Sampling Protocols

The following ground-water sampling procedure has evolved over many years of experience in ground-water sampling for organic and inorganic compound determinations and as such summarizes the authors' (and others) experiences to date (Barcelona et al., 1984, 1994; Barcelona and Helfrich, 1986; Puls and Barcelona, 1989; Puls et. al. 1990, 1992; Puls and Powell, 1992; Puls and Paul, 1995). High-quality chemical data collection is essential in ground-water monitoring and site characterization. The primary limitations to the collection of *representative* ground-water samples include: mixing of the stagnant casing and *fresh* screen waters during insertion of the sampling device or ground-water level measurement device; disturbance and resuspension of settled solids at the bottom of the well when using high pumping rates or raising and lowering a pump or bailer; introduction of atmospheric gases or degassing from the water during sample handling and transfer, or inappropriate use of vacuum sampling device, etc.

A. Sampling Recommendations

Water samples should not be taken immediately following well development. Sufficient time should be allowed for the ground-water flow regime in the vicinity of the monitoring well to stabilize and to approach chemical equilibrium with the well construction materials. This lag time will depend on site conditions and methods of installation but often exceeds one week.

Well purging is nearly always necessary to obtain samples of water flowing through the geologic formations in the screened interval. Rather than using a general but arbitrary guideline of purging three casing volumes prior to sampling, it is recommended that an in-line water quality measurement device (e.g., flow-through cell) be used to establish the stabilization time for several parameters (e.g. , pH, specific conductance, redox, dissolved oxygen, turbidity) on a well-specific basis. Data on pumping rate, drawdown, and volume required for parameter stabilization can be used as a guide for conducting subsequent sampling activities.

The following are recommendations to be considered before, during and after sampling:

- use low-flow rates (<0.5 L/min), during both purging and sampling to maintain minimal drawdown in the well;
- maximize tubing wall thickness, minimize tubing length;
- place the sampling device intake at the desired sampling point;
- minimize disturbances of the stagnant water column above the screened interval during water level measurement and sampling device insertion;
- make proper adjustments to stabilize the flow rate as soon as possible;
- monitor water quality indicators during purging;
- collect unfiltered samples to estimate contaminant loading and transport potential in the subsurface system.

B. Equipment Calibration

Prior to sampling, all sampling device and monitoring equipment should be calibrated according to manufacturer’s recommendations and the site Quality Assurance Project Plan (QAPP) and Field Sampling Plan (FSP). Calibration of pH should be performed with at least two buffers which bracket the expected range. Dissolved oxygen calibration must be corrected for local barometric pressure readings and elevation.

C. Water Level Measurement and Monitoring

It is recommended that a device be used which will least disturb the water surface in the casing. Well depth should be obtained from the well logs. Measuring to the bottom of the well casing will only cause resuspension of settled solids from the formation and require longer purging times for turbidity equilibration. Measure well depth after sampling is completed. The water level measurement should be taken from a permanent reference point which is surveyed relative to ground elevation.

D. Pump Type

The use of low-flow (e.g., 0.1-0.5 L/min) pumps is suggested for purging and sampling all types of analytes. All pumps have some limitation and these should be investigated with respect to application at a particular site. Bailers are inappropriate devices for low-flow sampling.

1) General Considerations

There are no unusual requirements for ground-water sampling devices when using low-flow, minimal drawdown techniques. The major concern is that the device give consistent results and minimal disturbance of the sample across a range of *low* flow rates (i.e., < 0.5 L/min). Clearly, pumping rates that cause minimal to no drawdown in one well could easily cause *significant* drawdown in another well finished in a less transmissive formation. In this sense, the pump should not cause undue pressure or temperature changes or physical disturbance on the water sample over a reasonable sampling range. Consistency in operation is critical to meet accuracy and precision goals.

2) Advantages and Disadvantages of Sampling Devices

A variety of sampling devices are available for low-flow (minimal drawdown) purging and sampling and include peristaltic pumps, bladder pumps, electrical submersible pumps, and gas-driven pumps. Devices which lend themselves to both dedication and consistent operation at definable low-flow rates are preferred. It is desirable that the pump be easily adjustable and operate reliably at these lower flow rates. The peristaltic pump is limited to shallow applications and can cause degassing resulting in alteration of pH, alkalinity, and some volatiles loss. Gas-driven pumps should be of a type that does not allow the gas to be in direct contact with the sampled fluid.

Clearly, bailers and other *grab* type samplers are ill-suited for low-flow sampling since they will cause repeated disturbance and mixing of *stagnant* water in the casing and the *dynamic* water in the screened interval. Similarly, the use of inertial lift foot-valve type samplers may cause too much disturbance at the point of sampling. Use of these devices also tends to introduce uncontrolled and unacceptable operator variability.

Summaries of advantages and disadvantages of various sampling devices are listed in Herzog et al. (1991), U. S. EPA (1992), Parker (1994) and Thurnblad (1994).

E. Pump Installation

Dedicated sampling devices (left in the well) capable of pumping and sampling are preferred over <u>any</u> other type of device. Any portable sampling device should be slowly and carefully lowered to the middle of the screened interval or slightly above the middle (e.g., 1-1.5 m below the top of a 3 m screen). This is to minimize excessive mixing of the stagnant water in the casing above the screen with the screened interval zone water, and to minimize resuspension of solids which will have collected at the bottom of the well. These two disturbance effects have been shown to directly affect the time required for purging. There also appears to be a direct correlation between size of portable sampling devices relative to the well bore and resulting purge volumes and times. The key is to minimize disturbance of water and solids in the well casing.

F. Filtration

Decisions to filter samples should be dictated by sampling objectives rather than as a *fix* for poor sampling practices, and field-filtering of certain constituents should not be the default. Consideration should be given as to what the application of field-filtration is trying to accomplish. For assessment of truly dissolved (as opposed to operationally *dissolved* [i.e., samples filtered with 0.45 µm filters]) concentrations of major ions and trace metals, 0.1 µm filters are recommended although 0.45 µm filters are normally used for most regulatory programs. Alkalinity samples must also be filtered if significant particulate calcium carbonate is suspected, since this material is likely to impact alkalinity titration results (although filtration itself may alter the CO_2 composition of the sample and, therefore, affect the results).

Although filtration may be appropriate, filtration of a sample may cause a number of unintended changes to occur (e.g. oxidation, aeration) possibly leading to filtration-induced artifacts during sample analysis and uncertainty in the results. Some of these unintended changes may be unavoidable but the factors leading to them must be recognized. Deleterious effects can be minimized by consistent application of certain filtration guidelines. Guidelines should address selection of filter type, media, pore size, etc. in order to identify and minimize potential sources of uncertainty when filtering samples.

In-line filtration is recommended because it provides better consistency through less sample handling, and minimizes sample exposure to the atmosphere. In-line filters are available in both disposable (barrel filters) and non-disposable (in-line filter holder, flat membrane filters) formats and various filter pore sizes (0.1-5.0 µm). Disposable filter cartridges have the advantage of greater sediment handling capacity when compared to traditional membrane filters. Filters must be pre-rinsed following manufacturer's recommendations. If there are no recommendations for rinsing, pass through a minimum of 1 L of ground water following purging and prior to sampling. Once filtration has begun, a filter cake may develop as particles larger than the pore size accumulate on the filter membrane. The result is that the effective pore diameter of the membrane is reduced and particles smaller than the stated pore size are excluded from the filtrate. Possible corrective measures include prefiltering (with larger pore size filters), minimizing particle loads to begin with, and reducing sample volume.

G. Monitoring of Water Level and Water Quality Indicator Parameters

Check water level periodically to monitor drawdown in the well as a guide to flow rate adjustment. The goal is minimal drawdown (<0.1 m) during purging. This goal may be difficult to achieve under some circumstances due to geologic heterogeneities within the screened interval, and may require adjustment based on site-specific conditions and personal experience. In-line water quality indicator parameters should be continuously monitored during purging. The water quality indicator parameters monitored can include pH, redox potential, conductivity, dissolved oxygen (DO) and turbidity. The last three parameters are often most sensitive. Pumping rate, drawdown, and the time or volume required to obtain stabilization of parameter readings can be used as a future guide to purge the well. Measurements should be taken every three to five minutes if the above suggested rates are used. Stabilization is achieved after all parameters have stabilized for three successive readings. In lieu of measuring all five parameters, a minimum subset would include pH, conductivity, and turbidity or DO. Three successive readings should be within ± 0.1 for pH, ± 3% for conductivity, ± 10 mv for redox potential, and ± 10% for turbidity and DO. Stabilized purge indicator parameter trends are generally obvious and follow either an exponential or asymptotic change to stable values during purging. Dissolved oxygen and turbidity usually require the longest time for stabilization. The above stabilization guidelines are provided for rough estimates based on experience.

H. Sampling, Sample Containers, Preservation and Decontamination

Upon parameter stabilization, sampling can be initiated. If an in-line device is used to monitor water quality parameters, it should be disconnected or bypassed during sample collection. Sampling flow rate may remain at established purge rate or may be adjusted slightly to minimize aeration, bubble formation, turbulent filling of sample bottles, or loss of volatiles due to extended residence time in tubing. Typically, flow rates less than 0.5 L/min are appropriate. The same device should be used for sampling as was used for purging. Sampling should occur in a progression from least to most contaminated well, if this is known. Generally, volatile (e.g., solvents and fuel constituents) and gas sensitive (e.g., Fe^{2+}, CH_4, H_2S/HS^-, alkalinity) parameters should be sampled first. The sequence in which samples for most inorganic parameters are collected is immaterial unless filtered (dissolved) samples are desired. Filtering should be done last and in-line filters should be used as discussed above. During both well purging and sampling, proper protective clothing and equipment must be used based upon the type and level of contaminants present.

The appropriate sample container will be prepared in advance of actual sample collection for the analytes of interest and include sample preservative where necessary. Water samples should be collected directly into this container from the pump tubing.

Immediately after a sample bottle has been filled, it must be preserved as specified in the site (QAPP). Sample preservation requirements are based on the analyses being performed (use site QAPP, FSP, RCRA guidance document [U. S. EPA, 1992] or EPA SW-846 [U. S. EPA, 1982]). It may be advisable to add preservatives to sample bottles in a controlled setting prior to entering the field in order to reduce the chances of improperly preserving sample bottles or introducing field contaminants into a sample bottle while adding the preservatives.

The preservatives should be transferred from the chemical bottle to the sample container using a disposable polyethylene pipet and the disposable pipet should be used only once and then discarded.

After a sample container has been filled with ground water, a Teflon™ (or tin)-lined cap is screwed on tightly to prevent the container from leaking. A sample label is filled out as specified in the FSP. The samples should be stored inverted at 4°C.

Specific decontamination protocols for sampling devices are dependent to some extent on the type of device used and the type of contaminants encountered. Refer to the site QAPP and FSP for specific requirements.

I. Blanks

The following blanks should be collected:

(1) field blank: one field blank should be collected from each source water (distilled/deionized water) used for sampling equipment decontamination or for assisting well development procedures.

(2) equipment blank: one equipment blank should be taken prior to the commencement of field work, from each set of sampling equipment to be used for that day. Refer to site QAPP or FSP for specific requirements.

(3) trip blank: a trip blank is required to accompany each volatile sample shipment. These blanks are prepared in the laboratory by filling a 40-mL volatile organic analysis (VOA) bottle with distilled/deionized water.

V. Low-Permeability Formations and Fractured Rock

The overall sampling program goals or sampling objectives will drive how the sampling points are located, installed, and choice of sampling device. Likewise, site-specific hydrogeologic factors will affect these decisions. Sites with very low permeability formations or fractures causing discrete flow channels may require a unique monitoring approach. Unlike water supply wells, wells installed for ground-water quality assessment and restoration programs are often installed in low water-yielding settings (e.g., clays, silts). Alternative types of sampling points and sampling methods are often needed in these types of environments, because low-permeability settings may require extremely low-flow purging (<0.1 L/min) and may be technology-limited. Where devices are not readily available to pump at such low flow rates, the primary consideration is to avoid dewatering of the well screen. This may require repeated recovery of the water during purging while leaving the pump in place within the well screen.

Use of low-flow techniques may be impractical in these settings, depending upon the water recharge rates. The sampler and the end-user of data collected from such wells need to understand the limitations of the data collected; i.e., a strong potential for underestimation of actual contaminant concentrations for volatile organics, potential false negatives for filtered metals and potential false positives for unfiltered metals. It is suggested that comparisons be made between samples recovered using low-flow purging techniques and samples recovered using passive sampling techniques (i.e., two sets of samples). Passive sample collection would essentially entail acquisition of the sample with no or very little purging using a dedicated sampling system installed within the screened interval or a passive sample collection device.

A. Low-Permeability Formations (<0.1 L/min recharge)

1. Low-Flow Purging and Sampling with Pumps

a. “portable or non-dedicated mode” - Lower the pump (one capable of pumping at <0.1 L/min) to mid-screen or slightly above and set in place for minimum of 48 hours (to lessen purge volume requirements). After 48 hours, use procedures listed in Part IV above regarding monitoring water quality parameters for stabilization, etc., but do not dewater the screen. If excessive drawdown and slow recovery is a problem, then alternate approaches such as those listed below may be better.

b. “dedicated mode” - Set the pump as above at least a week prior to sampling; that is, operate in a dedicated pump mode. With this approach significant reductions in purge volume should be realized. Water quality parameters should stabilize quite rapidly due to less disturbance of the sampling zone.

2. Passive Sample Collection

Passive sampling collection requires insertion of the device into the screened interval for a sufficient time period to allow flow and sample equilibration before extraction for analysis. Conceptually, the extraction of water from low yielding formations seems more akin to the collection of water from the unsaturated zone and passive sampling techniques may be more appropriate in terms of obtaining “representative” samples. Satisfying usual sample volume requirements is typically a problem with this approach and some latitude will be needed on the part of regulatory entities to achieve sampling objectives.

B. Fractured Rock

In fractured rock formations, a low-flow to zero purging approach using pumps in conjunction with packers to isolate the sampling zone in the borehole is suggested. Passive multi-layer sampling devices may also provide the most “representative” samples. It is imperative in these settings to identify flow paths or water-producing fractures prior to sampling using tools such as borehole flowmeters and/or other geophysical tools.

After identification of water-bearing fractures, install packer(s) and pump assembly for sample collection using low-flow sampling in “dedicated mode” or use a passive sampling device which can isolate the identified water-bearing fractures.

VI. Documentation

The usual practices for documenting the sampling event should be used for low-flow purging and sampling techniques. This should include, at a minimum: information on the conduct of purging operations (flow-rate, drawdown, water-quality parameter values, volumes extracted and times for measurements), field instrument calibration data, water sampling forms and chain of custody forms. See Figures 2 and 3 and “Ground Water Sampling Workshop -- A Workshop Summary” (U. S. EPA, 1995) for example forms and other documentation suggestions and information. This information coupled with laboratory analytical data and validation data are needed to judge the “useability” of the sampling data.

VII. Notice

The U.S. Environmental Protection Agency through its Office of Research and Development funded and managed the research described herein as part of its in-house research program and under Contract No. 68-C4-0031 to Dynamac Corporation. It has been subjected to the Agency's peer and administrative review and has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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Figure 2. **Ground Water Sampling Log**

Project ________________ **Site** ________________ **Well No.** ______________ **Date** ___________________________
Well Depth _____________ **Screen Length** ___________ **Well Diameter** __________ **Casing Type** _____________
Sampling Device ________________ **Tubing type** ______________________ **Water Level** ___________________
Measuring Point ____________________ **Other Infor** ____
____
Sampling Personnel ____

Time	pH	Temp	Cond.	Dis.O_2	Turb.	[ ]Conc			Notes

Type of Samples Collected

____

Information: 2 in = 617 ml/ft, 4 in = 2470 ml/ft: $Vol_{cyl} = \pi r^2 h$, $Vol_{sphere} = 4/3\pi\ r^3$

Figure 3. **Ground Water Sampling Log** (with automatic data logging for most water quality parameters)

Project ________________ **Site** ________________ **Well No.** ______________ **Date** __________________________

Well Depth _____________ **Screen Length** ___________ **Well Diameter** __________ **Casing Type** ____________

Sampling Device ________________ **Tubing type** ______________________ **Water Level** __________________

Measuring Point ____________________ **Other Infor** ____

____

Sampling Personnel ____

Time	Pump Rate	Turbidity	Alkalinity	[ ] Conc	Notes

Type of Samples Collected

____

Information: 2 in = 617 ml/ft, 4 in = 2470 ml/ft: $\mathrm{Vol}_{cyl} = \pi r^2 h$, $\mathrm{Vol}_{sphere} = 4/3\pi\ r^3$

New Attachment 13 – Statistical Analysis Plan

LOWER COLORADO RIVER AUTHORITY
Austin, Texas

DRAFT STATISTICAL ANALYSIS PLAN
COMBUSTION BYPRODUCTS LANDFILL
FAYETTE POWER PROJECT
LA GRANGE, TEXAS

September 14, 2023

Bullock, Bennett & Associates, LLC
Engineering and Geoscience
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Table of Contents

Attachments

Attachment A: DUMPStat 2.1.8 Statistical Guide
Attachment B: DUMPStat 2.3 Release Notes

1. INTRODUCTION

The Lower Colorado River Authority's (LCRA's) Fayette Power Project (FPP) is a coal-fired power plant located east of La Grange in Fayette County, Texas. The coal combustion residuals (CCR) that are generated at FPP (e.g., fly ash, bottom ash, and synthetic gypsum), and certain other solid waste residuals associated with electric power generation, are managed in the on-site Combustion Byproduct Landfill (CBL). The CBL is a CCR unit subject to the U.S. Environmental Protection Agency's (EPA's) CCR regulations and the Texas Commission on Environmental Quality's (TCEQ's) CCR registration program.

EPA's CCR regulations, also referred to as the "CCR Rule," are codified in 40 CFR Part 257, Subpart D, and have been adopted by TCEQ under Chapter 352 of Title 30 of the Texas Administrative Code (30 TAC Chapter 352). These federal and state CCR regulations require facilities to design and install a groundwater monitoring system (GWMS) to evaluate the uppermost groundwater bearing unit (GWBU) beneath CCR units (landfills and impoundments) for potential effects on groundwater quality. The GWBU beneath the CBL is referred to as the "Intermediate Sand."

The CCR Rule requires statistical analysis of analytical data obtained by periodic collection and analysis of groundwater samples from the GWMS. The objective of the statistical analysis is to identify releases from CCR units, based on data comparisons and trend analyses, should they occur. The CCR Rule allows for use of interwell or intrawell analysis. Interwell analysis is conducted where groundwater data from GWMS wells downgradient of the CCR unit are compared to data from GWMS wells unaffected by the CCR unit (preferably at nearby locations upgradient or sidegradient of the CCR unit). Intrawell analysis is conducted on each independent GWMS well in comparison to previous results, in the absence of having a valid background well for comparison.

The CCR Rule provides several options for statistically evaluating groundwater data, as specified in 40 CFR §257.93(f)(1)-(5) and 30 TAC §352.931. EPA's *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance* (EPA 530/R-09-007), referred herein as the *Unified Guidance*, presents acceptable statistical approaches for such evaluations and analyses.

This Statistical Analysis Plan (SAP) describes the current statistical evaluation approach utilized by LCRA to analyze groundwater chemical data obtained from the CBL GWMS in determining if a statistically significant increase (SSI) is present. This statistical evaluation is conducted in compliance with 40 CFR §§257.93 (30 TAC §352.931), 257.94 (30 TAC §352.941), and 257.95 (30 TAC §352.951) regarding detection and assessment monitoring. This SAP conforms with the *Unified Guidance*. Presently, the CBL is in the detection monitoring program.

1.1 CBL Groundwater Monitoring System

The CBL GWMS consists of six groundwater monitoring wells (CBL-301I, CBL-302I, CBL-306I, CBL-308I, CBL-340I, and CBL-341I) screened within the Intermediate Sand and installed at locations downgradient of the current CBL footprint. The Intermediate Sand has not been encountered upgradient of the CBL. As such, additional well CBL-340I is installed at a sidegradient location relative to the CBL to evaluate Intermediate Sand groundwater that is unaffected by the CBL. This addresses the 40 CFR § 257.93(d) requirement for establishment of background groundwater quality in a hydraulically upgradient or sidegradient well.

In the course of completing an Alternate Source Demonstration (ASD) in 2018, it was concluded that monitoring well CBL-340I is not a viable background monitoring well for use in statistical comparisons due to the observed geochemical heterogeneity within the Intermediate Sand, in major anion and cation signatures [Amec Foster Wheeler, April 2018a, April 2018b)]. The identification of natural aquifer heterogeneity resulted in the determination that CBL-340I could not reliably be used to characterize the background geochemistry of the groundwater flowing beneath the CCR unit. As described in the *Unified Guidance*, such spatially variable natural conditions indicate a need to use intrawell statistical analytical procedures rather than more traditional upgradient/sidegradient-to-downgradient interwell procedures.

Based on the CBL geochemistry findings and EPA's *Unified Guidance*, the GWMS was recertified in April 2018 to indicate that CBL-340I would not be included in future statistical evaluations. Furthermore, the statistical analytical method was changed to an Intrawell Prediction Interval Procedure with a new statistical method certification being completed in April 2018. The use of the Intrawell Prediction Interval Procedure eliminated the need for CBL-340I in the statistical analysis and, accordingly, CBL-340I is still sampled but only used for potentiometric surface gauging. Documentation of the ASD, and the revision to the intrawell statistical method, was certified by a Texas Professional Engineer and a Texas Professional Geoscientist [Amec Foster Wheeler (April 2018b, and April 2018c)].

2. DATA MANAGEMENT

2.1 Management of Duplicate Data

If multiple results are obtained for a select parameter at a well on the same sample date, the results will be averaged and appear as one result in the data summary table. The mean data will be noted with an asterisk. The averaged result would then be compared to background. Field duplicates are typically assigned a unique sample identification and would not be combined and averaged.

Field duplicates and data rejected after data validations are removed from the data set.

2.2 Management of Non-Detect Data

Laboratory reporting limits have been established for each of the parameters monitored. The reporting limit, or practical quantitation limit (PQL), reflects a level of confidence that the parameter is detectable, and the analytical result is reliable at that concentration. If a parameter is not detected above the reporting limit or PQL, it can be reasonably assumed that the constituent is not present. Concentrations above the method detection limit but below the reporting limits or PQLs (J-values) are not considered in the statistical evaluations since there is a higher degree of uncertainty in those values.

2.3 Management of Anomalous Detections

In cases when an anomalously high or low detection cannot be confirmed after resampling a well, the anomalous detection should be considered for removal from the dataset and should be replaced by the resampled concentration so that current conditions are not over- or under-estimated. This is an important step when estimating a baseline or background value to use to compare to future analyte concentrations from the GWMS. An anomalous detection may be identified at any point after analytical laboratory results are available, based on professional judgment or based on the outlier evaluation (see Section 3.4 for more details about testing for outliers). If an analytical result is removed, documentation will be provided in the annual report stating which analytical result was removed and justifying its removal.

3. STATISTICAL PROCEDURE

3.1 Intrawell Analysis Using Control Charts

The CCR Rule provides several options for evaluating groundwater data [40 CFR §257.93(f) and 30 TAC §352.931]. Per the *Unified Guidance*, the preferred methods for comparing groundwater data are using either prediction limits or using control charts.

As discussed in Section 1.1, CBL-340I was initially utilized as a background monitoring well intended to provide a basis for comparison of each groundwater monitoring well's analyte concentrations using Interwell Prediction Limit Method statistical analysis (Amec Foster Wheeler, October 2017). As described in Section 1.2, subsequent evaluation of groundwater conditions following completion of the initial background assessment and initiation of detection monitoring led to the recognition of multiple geochemical facies within the Intermediate Sand groundwater, as documented (Amec Foster Wheeler, April 2018a). As such, CBL-340I is no longer considered appropriate as a background well, and the initial CBL SAP utilizing the Interwell Prediction Limit approach was revised to instead utilize the Intrawell Prediction Limit approach (Amec Foster Wheeler, April 2018b and April 2018c).

The Intrawell Prediction Limit statistical method is considered appropriate when natural spatial variation in groundwater conditions prevents a representative background well designation(s) for groundwater conditions downgradient of the CCR Unit. Intrawell analysis establishes background concentrations at each downgradient groundwater well location using a subset of sample data that reflects a baseline groundwater condition. Future sample data collected from the groundwater well are then compared to its respective baseline groundwater condition to assess if there is an SSI at that location.

Intrawell statistical evaluations assume that: (1) current groundwater conditions (e.g., baseline conditions) at the site are void of constituents leaking from a CCR unit and (2) baseline conditions are representative of natural temporal variations in groundwater quality. At this time, there is no substantial geologic, site operation, or hydrogeologic evidence to suggest these assumptions are invalid with respect to the CBL. It is recognized, however, that two years of sampling are likely inadequate to characterize natural seasonal variations and regional temporal trends in groundwater quality reliably. As such, baseline conditions require updating as sufficient data become available.

Initial baseline conditions were established using the eight initial groundwater samples from each downgradient monitoring well for each constituent in 40 CFR Part 257, Appendix III (detection monitoring parameters) and Appendix IV (assessment monitoring parameters).

In 2021, the SAP was revised to replace the Intrawell Prediction Limit with use of Intrawell Control Charts. The control chart procedure offers an advantage over the prediction limit procedure as more data are generated over time, because the control chart procedure generates a graph of compliance data over time and allows for better identification of long-term trends. This method revision to the GWMS has been certified (Bullock, Bennett & Associates, 2021).

The currently used semiannual groundwater monitoring program and use of the Intrawell Control Charts evaluation procedure meets the requirements of 40 CFR §§ 257.94(e) and (g).

3.2 Intrawell Analysis Using DUMPStat Statistical Program

The intrawell control chart method is now applied to the CBL groundwater analytical data using the DUMPStat® statistical program (DUMPStat, 2003). DUMPStat® is a program for the statistical analysis of groundwater monitoring data using methods described in *Statistical Methods for Groundwater Monitoring* (Gibbons, Bhaumik, and Aryal, 2009). Groundwater statistical analysis is presently conducted on the Appendix III detection monitoring parameters.

Intrawell statistics compare new measurements to the historical data at each groundwater monitoring well independently. The *Unified Guidance*-recommended technique for intrawell comparisons is the combined Shewhart-CUSUM control chart. This control chart procedure detects changes in analyte concentrations both in terms of constituent concentration and cumulative concentration increases. This method is also extremely sensitive to sudden and gradual releases. A requirement for constructing these control charts is that the parameter is detected at a frequency greater than or equal to 25%, otherwise the data variance is not properly defined (ASTM D 6312-98 *Standard Guide for Developing Appropriate Statistical Approaches for Ground-Water Detection Monitoring Programs*). For this method, nondetects can be replaced with the reporting limit without serious consequence. Since reporting limits may vary over time due to the laboratory performing the testing or methodology changes, or sample matrix interferences, the median reporting limit is substituted for non-detects.

The combined Shewhart-CUSUM control chart assumes that the data are independent and normally distributed with a fixed mean and a constant variance. Independent data are much more critical than the normality assumption. To achieve independence, it is recommended that data are collected no more frequently than quarterly to account for seasonal variation. The combined Shewhart-CUSUM control chart is robust to deviations from normality. Because the control charts do not use a specific multiplier based on a normal distribution, it is more conservative to assume normality.

Non-detects

Some groundwater monitoring parameters are not detected at a frequency great enough to generate the combined Shewhart-CUSUM control charts. For constituents that are detected less than 25% of the time at a particular well, the data are plotted as a time series until a sufficient number of data points are available to provide a 99% confidence nonparametric prediction limit. Thirteen independent measurements (with 1 resample) are necessary to achieve a 99% confidence (1% false positive rate) nonparametric prediction limit. The nonparametric prediction limit is the largest determination out of the dataset collected for that well and parameter. If the detection frequency is 0% after thirteen samples have been collected, the reporting limit (PQL) becomes the nonparametric prediction limit. Based on the background evaluation conducted using 2016-2022 data, the one nonparametric prediction limit presently used is for the analyte boron, in monitoring well CBL-302I.

Control Chart Procedure

A minimum of eight rounds of data is recommended to establish an initial background concentration for each well and parameter. In cases where the detection frequency is $\geq$25%, a control limit can be calculated to which future data is compared. The control limit is simply defined as:

control limit = (control chart factor)(standard deviation) + mean

The control chart factor typically ranges from 4.5 to 6.5 for N<12 and from 4.0 to 6.5 for N$\geq$12. A statistical power curve indicates the expected false assessments for the site as a whole. The statistical power is a function of the number of wells included, the number of constituents compared, the detection frequencies, and the data distributions involved. For intrawell comparisons, the recommended site-wide false positive rate is 5%. Evaluating and adjusting the factor to achieve false assessment objectives is done each time the background is established. Generally, the factor is lowered as background is updated to include more data points.

In addition to comparing the compliance data to background concentrations using a control chart, the Shewhart-CUSUM control chart used provides additional information. The CUSUM portions identifies cumulative increases over time as described in Chapter 20 of the *Unified Guidance*.

Compute the standardized concentration Zi for each x_i after background:

$Zi = (x_i - \text{mean})/\text{standard deviation}$

use Zi to compute the standardized CUSUM Si. Set $S0 = 0$

$S_i^* = \max [\, 0, Zi\text{-}k + S_{i-1}]$

where in this case, k = 0.75.

The cumulative sum is expressed as:

$S_i = S_i^*(\text{standard deviation}) + \text{mean}$

The CUSUM portion of the control chart is compared to the same control limit as was established for the data concentration. The cumulative sum sequentially analyzes each new measurement with prior compliance data.

Outliers

In developing the statistical background, the historical data must be thoroughly screened for anomalous data which may be due to sampling error, lab error, transcription error, shipping error, or chance alone. An erroneous data point, if not removed prior to the mean and variance computations, would yield a larger control limit thus increasing the false negative rate. The DUMPStat® program screens for outliers using the Dixon test. If the Dixon test indicates an outlier, the value is compared to three times the median value for intrawell analyses. If the value fails both criteria of the two-stage screening, the value is considered a statistical outlier and will not be used in the mean and variance determinations. Anomalous data will still be plotted on the graphs (with a unique symbol) but will not be included in the calculations.

Additionally, data can be manually designated as an outlier if the statistician has a justifiable reason. The outlier data, either statistically detected or manually selected, will be graphically displayed (with a unique symbol) but not included in background calculations.

Resample Verification

The verification resample plan is an integral function of the statistical plan to reduce the probability that anomalous data obtained after the background has been established are indicative of a landfill release. Should a control limit exceedance be identified, the resampling plan is implemented by the operator to collect a verification sample. If the resample data obtained confirm the control limit exceedance, the exceedance is considered statistically significant.

The CBL resampling/retesting strategy is to allow for one resample for constituents evaluated using a parametric method, which applies to all wells and constituents, except for boron in monitoring well CBL-302I. Two resample events may be conducted for constituents evaluated using a nonparametric method, which applies to boron in CBL-302I. If the retesting strategy involves one resample, the initial exceedance is disconfirmed if the constituent concentration in the resample does not exceed the control limit/prediction limit. If the retesting strategy involves two resamples, the initial exceedance is disconfirmed if the constituent concentration in the first or second resample does not exceed the prediction limit (pass one of two resamples); if the first resample passes, the second resample does not need to be taken.

The resampling strategy will be periodically reevaluated and changed as necessary during a background update, which would include new sample results since the previous background evaluation and may include new wells or changes to the list of constituents monitored.

If an initial exceedance over a background limit is determined, the owner or operator may conduct verification resampling. The verification resampling results will confirm or disprove the initial exceedance. If an initial exceedance is verified, an SSI is declared, and assessment monitoring is triggered unless a successful ASD completed within 90 days of the determination of an SSI. If a verification resample does not confirm an exceedance, routine detection monitoring may continue.

Statistical background includes all data collected for that well and parameter during the background time period indicated. Resample verification data are an integral component of the statistical plan and are considered valid data points. In some cases, an errant data point is replaced with the resample data. In other situations, the resample data confirm the semi-annual data obtained. *Unified Guidance* §5.3.3 and the TCEQ guidance document, *Guidelines for Updating Background Data Sets for Municipal Solid Waste Groundwater Monitoring*, allow for inclusion of both routine monitoring data and resample verification data in future background sets.

Trend Testing

The background data for each well and analyte are assessed for existing trends using Sen's nonparametric estimate of trend.

A significant trend is one in which the 99% lower confidence bound is greater than zero. In this way, even pre-existing trends in the background dataset will be detected. In large databases, very gradual trends can be statistically significant; however, such trends should not preclude the use of intrawell comparisons.

Background Update

Background will be updated periodically with data that are representative of background groundwater quality. The frequency that background should be updated is generally considered to be every four events (if semiannual) or every two years (*Unified Guidance*, Chapter 5.3). As groundwater monitoring at a facility proceeds, it is recommended to update background datasets periodically with valid detection monitoring results that are representative of background groundwater quality not affected by leakage from a monitored unit. The procedures used for a background update must be protective of human health and the environment and must comply with the statistical performance standards specified in 30 TAC §330.233(f) and (g). Failure to update background will exclude factors such as natural temporal variation, changes in field or laboratory methodologies, and changes in the water table due to meteorological conditions or other influences. Ongoing operations at a facility such as excavations or drainage control may affect the groundwater flow direction and water quality. An increase in the number of statistical failures, unrelated to the facility, is routinely observed for sites neglecting to update the statistical background with valid data points.

4. DETECTION MONITORING DATA EVALUATION

Detection monitoring will be performed using the CBL GWMS on a semiannual basis during the active life of the CBL unit and during the post-closure period. Each GWMS well will be sampled for the Appendix III analytes as part of the detection monitoring program. The Appendix III analytes are as follows:

- Boron
- Calcium
- Chloride
- Fluoride
- field-measured pH
- Sulfate
- Total Dissolved Solids (TDS)
-

After every detection monitoring event, the analyte concentrations from each well will be compared to their respective Normal Control Limit or Nonparametric Prediction Limit, as applicable, to ascertain if an SSI exists. Possible outcomes from comparing the detection monitoring constituent concentrations in each well to their respective background values are as follows:

- All detection monitoring analyte concentrations in a GWMS well are less than or equal to their respective background Normal Control Limit or Nonparametric Prediction Limit; or

- One or more detection monitoring analyte concentrations in a GWMS well are above their respective background Normal Control Limit or Nonparametric Prediction Limit.

4.1 No Statistically Significant Increase over Background Values

Background values (Normal Control Limits and Nonparametric Prediction Limits) are based on a 1-of-2 resampling approach, meaning that if zero or one analyte concentration measurements from a series of two independent samples collected from a well do not exceed the appropriate background, then an SSI over background has not occurred. This conclusion will be reached if the data indicate either of the following:

- All detection monitoring analyte concentrations in a GWMS well are less than or equal to their respective background values; or

- At least one detection monitoring analyte concentration in a well is above its respective background value. If this occurs, the well or wells with analyte concentration(s) above the background value(s) will be resampled and analyzed for the detection monitoring analyte(s) with exceedances. If the resample indicates that the target detection monitoring analyte concentration(s) in the well or wells is/are less than or equal to their respective background value(s), then it can be concluded that an SSI over background for all detection monitoring analytes has not occurred, since concentrations in one sample of the two independent samples do not exceed the appropriate background value(s).

If the groundwater monitoring data indicate that an SSI over background has not occurred at the CCR wells, then detection monitoring at all CCR wells will continue on a semi-annual basis.

4.2 Statistically Significant Increase over Background Values

If one or more detection monitoring analyte concentration(s) in any well is/are above their respective background value in both the original detection monitoring sample and the resample, then an SSI over background for the target detection monitoring analyte can be concluded. If an SSI is indicated, within 90 days LCRA will:

- Establish an assessment monitoring program as described in this plan, or
- Demonstrate that a source other than the CCR unit caused the SSI over the background value for an analyte, or that the SSI resulted from error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality. If a successful ASD is completed within the 90-day period, LCRA will continue with the detection monitoring program.

5. ASSESSMENT MONITORING DATA EVALUATION

Assessment monitoring will be conducted using the CBL GWMS should an SSI over background values be confirmed for one or more Appendix III constituent(s), assuming an ASD was unsuccessful in identifying a source other than a release from the CBL. Within 90 days of triggering the assessment monitoring program, and annually thereafter, each CCR monitoring well will be sampled for the Appendix IV analytes as part of the assessment monitoring program. The Appendix IV analytes are as follows:

- Antimony
- Arsenic
- Barium
- Beryllium
- Cadmium
- Chromium
- Cobalt
- Fluoride
- Lead
- Lithium
- Mercury
- Molybdenum
- Selenium
- Thallium
- Radium 226 and 228 combined

Within 90 days of obtaining the results from the initial assessment monitoring sampling event, all wells in the CBL GWMS will be resampled and analyzed for:

- All Appendix III detection monitoring parameters; and
- The Appendix IV assessment monitoring parameters that were detected as part of the assessment monitoring event.

This assessment monitoring will be performed on at least an annual basis thereafter, unless LCRA can demonstrate the need for an alternative monitoring frequency for repeated sampling and analysis for these analytes during the active life and the post-closure care period based on the availability of groundwater.

Within 90 days of obtaining the results from the initial assessment monitoring sampling event, a GWPS will be established for each of the Appendix IV assessment monitoring analyte that were detected in the groundwater monitoring system wells as follows:

- For constituents for which a Maximum Contaminant Level (MCL) has been established, the highest of the MCL, Upper Prediction Limit (UPL), and reporting limit for that constituent; or
- For constituents for which an MCL has not been established, the higher of the UPL, reporting limit, or levels that are equivalent to specified regional screening level (RSL) for that analyte (note: future revisions to the CCR Rule may allow additional flexibility in

establishing GWPS for states with EPA-approved CCR permit programs for Appendix IV analytes that do not have an MCL).

Each assessment monitoring analyte will be evaluated to ascertain if an SSI above the GWPS exists. Possible outcomes are as follows:

- All averages from assessment monitoring analyte concentrations at a well are not statistically greater than to their respective GWPS; or
- One or more averages from assessment monitoring constituent concentrations at a well are statistically greater than their respective GWPS.

6. REPORTING REQUIREMENTS

The results of the CBL groundwater monitoring program performed will be reported yearly in an Annual Groundwater Monitoring and Corrective Action Report. The annual report will document the status of the groundwater monitoring and corrective action programs, summarize key actions completed, describe any problems encountered, discuss actions to resolve the problems, and will project key activities for the upcoming year. At a minimum, the Annual Groundwater Monitoring and Corrective Action Report will contain the following information:

- A map, aerial image, or diagram showing the CCR unit and all background (or upgradient) and downgradient monitoring wells, to include the well identification numbers, that are part of the groundwater monitoring program for the CCR unit;

- Identification of any monitoring wells that were installed or decommissioned during the preceding year, along with a narrative description of why those actions were taken;

- In addition to all the monitoring data obtained under the CCR Rule (40 CFR §§ 257.90 through 257.98), a summary including the number of groundwater samples that were collected for analysis for each background and downgradient well, the dates the samples were collected, and whether the sample was required by the detection monitoring or assessment monitoring program, as well as the basis for the background values and the statistical methods employed to establish the background values;

- A narrative discussion of any transition between monitoring programs (e.g., the date and circumstances for transitioning from detection monitoring to assessment monitoring in addition to identifying the constituent(s) detected at a SSI over background levels); and

- Other information required to be included in the annual report as specified in CCR Rule (40 CFR §§257.90 through 257.98).

The Groundwater Monitoring and Corrective Action Report for the previous calendar year's monitoring program must be placed in the facility operating record no later than January 31. The reports must also be posted to the owner or operator's CCR Rule Compliance Data and Information internet site within 30 days of placing the reports in the operating record.

7. REFERENCES

Amec Foster Wheeler (October 2017): *Groundwater Sampling and Analysis Program, Selection of Statistical Method Certification, Lower Colorado River Authority, Coal Combustion Residuals Unit, Combustion Byproducts Landfill, Fayette Power Project, La Grange, Texas.*

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Amec Foster Wheeler (April 2018b): *Groundwater Monitoring System, Certification of Alternate Source Demonstration, Lower Colorado River Authority, Coal Combustion Residuals Unit: Combustion Byproducts Landfill, Fayette Power Project, La Grange, Texas.*

Amec Foster Wheeler (April 2018c): *Groundwater Monitoring System Addendum Certification, Lower Colorado River Authority, Coal Combustion Residuals Unit, Combustion Byproducts Landfill, Fayette Power Project, La Grange, Texas.*

Bullock, Bennett & Associates (May 2021): *Groundwater Monitoring System Addendum Certification, Lower Colorado River Authority, Coal Combustion Residuals Unit, Combustion Byproducts Landfill, Fayette Power Project, La Grange, Texas.*

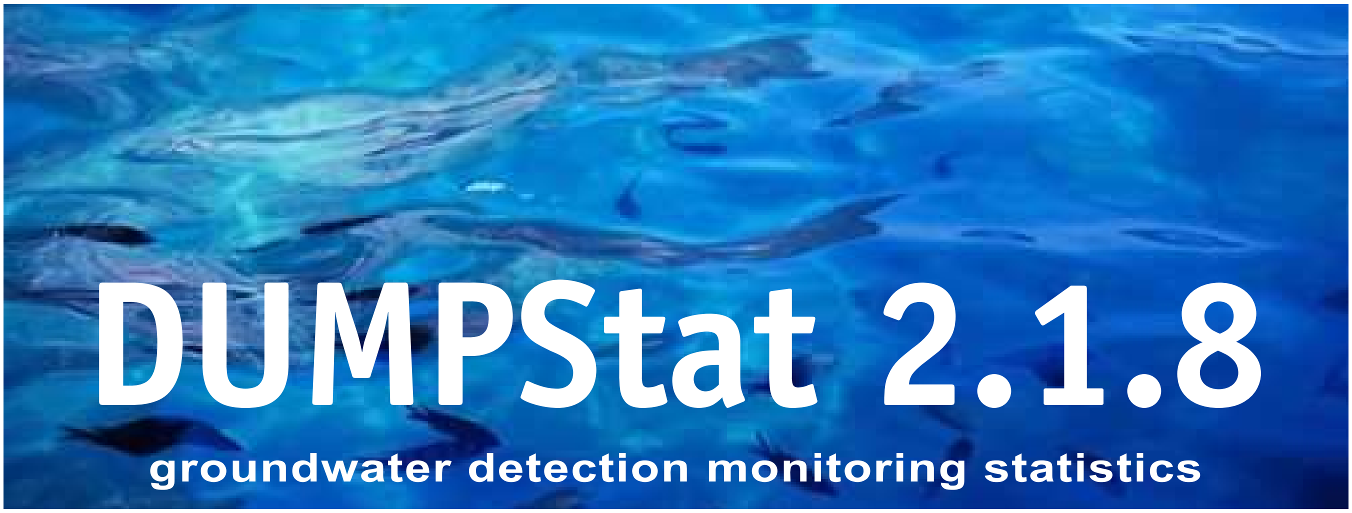
DUMPStat (2003) DUMPStat Statistical Guide, version 2.1.8., by Robert D. Gibbons Ltd., with accompanying DUMPStat 2.3 Release Notes.

EPA (2009): *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance* (EPA 530/R-09-007).

Gibbons, Bhaumik, and Aryal (2009): *Statistical Methods for Groundwater Monitoring, 2nd Edition*, 400 pages.

Attachment A

DUMPStat 2.1.8 Statistical Guide



DUMPStat 2.1.8

groundwater detection monitoring statistics

STATISTICAL GUIDE

DUMPStat

Statistical Guide

Version 2.1.8

contents

Chapter 1 Introduction 1

Introduction 1

In this document, a statistical plan is described that includes an effective verification resampling plan, and selection of appropriate statistical methods (*e.g.*, parametric and nonparametric prediction limits, or control charts for intra-well comparison) that detect contamination when it is present and do not falsely conclude that the site is contaminated. Statistical significance of differences in groundwater quality cannot be properly determined without verification resampling. It is noted from the information presented herein that the final statistical detection monitoring plan cannot be fully specified until background samples for the required list of indicator constituents are available. In general, it is unwise to perform statistical computations on any fewer than eight background samples. This may be four quarterly samples in each of two upgradient wells, or eight samples taken in each well where intra-well comparisons are to be performed. To take any fewer samples will lead to high false negative rates due to the large size of the prediction limit (*i.e.*, with four samples and three degrees of freedom, the uncertainty in the true mean and standard deviation (μ and σ) given the sample based estimates (x and s) is enormous, resulting in extremely high prediction limits). Conversely, with only a few background measurements, our knowledge of the true sampling variability, distributional form and detection frequency may be completely inaccurate leading to a high false positive rate.

Intra-well comparisons

Yet another major concern is whether the upgradient wells accurately characterize the natural spatial variability that is observed in the downgradient wells. The alternative is to perform intra-well comparisons, which are generally preferable; however, we must first demonstrate that the well has not been impacted by the site.

It is noted that when justified, intra-well comparisons are generally more powerful than their inter-well counterparts because they completely eliminate the spatial component of variability. Due to the absence of spatial variability, the uncertainty in measured concentrations is decreased, making intra-well comparisons more sensitive to real releases (*i.e.*, fewer false negative results); and false positive results due to spatial variability are completely eliminated.

The following provides an outline of the general statistical procedure for groundwater monitoring implemented in the DUMPStat program. The references are to the USEPA Subtitle D regulation and associated guidance. Further technical details regarding the specific statistical methods used in DUMPStat are available in Chapter 3, Technical Details page 21 and in Gibbons (1994 and 1996). The DUMPStat algorithm forms the basis for the new ASTM Standard D6312-98.

Detection Monitoring

Upgradient versus Downgradient Comparisons

50-100% background detection frequency

1. Background detection frequency greater than 50%:
- If normal, compute normal prediction limit (40CFR 258.53(h)(4))[1], selecting false positive rate based on number of wells, constituents and verification resamples (40CFR 258.53(h)(2)), adjusting estimates of the sample mean and variance for nondetects.
- If lognormal, compute a lognormal prediction limit (40CFR 258.53(h)(1)).

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[1] 40CFR Part 258 refers to USEPA Subtitle D regulations.

- If neither normal nor lognormal, compute a nonparametric prediction limit (40CFR 258.53(h)(1)) unless background is insufficient to achieve a 5% site-wide false positive rate. In this case, use a normal distribution (40CFR 258.53(h)(1)).

0-50% background detection frequency

2. Background detection frequency is greater than zero but less than 50%: compute a nonparametric prediction limit and determine if the background sample size will provide adequate protection from false positives. If insufficient data exist to provide a site-wide false positive rate of 5%, more background data must be collected (40CFR 258.53(h)(1)).

0% background detection frequency

3. Background detection frequency equals zero: use the laboratory specific Quantification Limit (QL-recommended) or limits required by applicable regulatory agency (40CFR 258.53(h)(5)). This only applies for those wells and constituents that have at least 13 background samples. Thirteen samples provides a 99% confidence nonparametric prediction limit with one resample (see Table 1 on page 26). If less than 13 samples are available, more background data must be collected. Alternatively, select Pass 1 of 2 verification resamples and only 8 background samples are required.
4. As an alternative to 2 and 3, use a Poisson prediction limit which can be computed from only four background measurements regardless of the detection frequency (USEPA, 1992 section 2.2.4).
5. If downgradient wells fail, determine cause.
    - If the downgradient wells fail because of natural or off-site causes, select constituents for intra-well comparisons (40CFR 258.53(h)(3)).
    - If site impacts are found, a site plan for assessment monitoring and detection monitoring (at unaffected wells) may be necessary (40CFR 258.55).

Intra-Well Comparisons

1. For those facilities that meet any of the following conditions, compute intra-well comparisons using combined Shewhart-CUSUM control charts (40CFR 258.53(h)(3))
    - if there is no definable gradient,
    - if there is no existing contamination,
    - if there are too few upgradient wells to meaningfully characterize spatial variability (*e.g.*, a site with one upgradient well or a facility in which upgradient water quality is not representative of downgradient water quality),
    - to satisfy specific hydrogeology criteria (*e.g.*, slow moving groundwater zones, no access to upgradient groundwater, in appropriate groundwater migration pathways) as defined by a groundwater professional.
2. For those wells and constituents that fail upgradient versus downgradient comparisons, compute combined Shewhart-CUSUM control charts. If no Volatile Organic Compounds (VOCs) or hazardous metals are detected and no trend is detected in other indicator constituents, use intra-well comparisons for detection monitoring of those wells and constituents.
3. If data are all nondetects after 13 quarterly sampling events, use the QL as statistical decision limit (40CFR 258.53(h)(5)). Thirteen samples provides a 99% confidence nonparametric prediction limit with one resample (40CFR 258.53(h)(1)) and USEPA 1992 section 5.2.3. Note that 99% confidence is equivalent to a 1% false positive rate and pertains to a single comparison (*i.e.*, one well and constituent). With Pass 1 of 2 verification resamples only eight background samples are required for 99% confidence. With Pass 2 of 2 resamples, 18 background samples are required for 99% confidence.
4. If the detection frequency is greater than zero (*i.e.*, the constituent is detected in at least one background sample) but

less than 25% set the control limit to the largest of at least 8, 13, or 18 background samples, depending on the verification resampling plan.

5. As an alternative to 3 and 4 compute a Poisson prediction limitfollowing collection of a minimum of four background samples (USEPA 1992 section 2.2.4). Since the mean and variance of the Poisson distribution are the same, the Poisson prediction limit is defined even if there is no variability (*e.g.*, even if the constituent is never detected in background.) In this case, the reporting limits are used in place of the measurements and the Poisson prediction limit can be computed directly. Note that the Poisson prediction limits are not invariant with respect to changes in scale (*i.e.*, you get different results if data are in ppb vs. ppm). As such, DUMPStat transforms the data to a scale in which the measurements are greater than one, computes the prediction limit, and then transforms back to the original scale.

Verification Resampling

- Verification resampling is an integral part of the statistical methodology (USEPA 1992 section 5).
- Without verification resampling much larger prediction limits would be required to obtain a site-wide false positive rate of 5%. The resulting false negative rate would be dramatically increased.
- Verification resampling allows sequential application of a much smaller prediction limit, therefore minimizing both false positive and false negative rates.
- A statistically significant exceedance is not declared and should not be reported until the results of the verification resample are known. The probability of an initial exceedance is much higher than 5% for the site as a whole.
- Note that requiring passage of two verification resamples (*e.g.*, in the state of California regulation) will generally lead to higher false negative rates because larger prediction lim-

its are required to achieve a site-wide false positive rate of 5% than for a single verification resample; hence, the preferred methods are passage of one verification resample, or, passage of one of two verification resamples. Also note that for nonparametric limits, requiring passage of two verification resamples may result in need for a larger number of background samples than are typically available (see Gibbons, 1994).

False Positive and False Negative Rates

1. DUMPStat automatically conducts a simulation study based on current monitoring network, constituents, detection frequencies, and distributional form of each monitoring constituent (USEPA 1992 Appendix B).
2. DUMPStat then projects the frequency of false assessments for the site as a whole, for each monitoring event based on the results of the simulation study.
3. As a general guideline, we require a site-wide false positive rate of 5% (*i.e.*, when the true difference is zero) and a false negative rate of approximately 5% for differences on the order of 3 to 4 standard deviation units (see USEPA 1992 Appendix B). Note that following USEPA we simulate the most conservative case of a release that effects a single constituent in a single downgradient well. In practice, multiple constituents in multiple wells will be impacted; therefore, the actual false negative rates will be considerably smaller than estimates obtained via simulation.

Use of DLs and QLs in Groundwater Monitoring

- Detection Limits (DLs) indicate that the analyte is present in the sample with confidence.
- Quantification Limits (QLs) indicate that the true quantitative value of the analyte is close to the measured value.

- For analytes with estimated concentration exceeding the DL but not the QL, it can only be concluded that the true concentration is greater than zero - there is no way of knowing the actual concentration with reasonable certainty.
- If the laboratory-specific DL for a given compound is 3 μg/l, and the QL for the same compound is 6 μg/l, then a detection of that compound at 4 μg/l could actually represent a true concentration of anywhere between 0 and 6 μg/l. The true concentration may well be less than the DL (see Currie 1968, Hubaux and Vos, 1970 and Gibbons 1994).
- Comparison of such a value to a Maximum Contaminant Level (MCL), or any other concentration limit, is generally not meaningful unless the concentration is larger than the QL.
- Verification resampling applies to this case as well.

Assessment or Corrective Action Monitoring

Comparison to Background

1. Define background for any Appendix II compounds detected (*i.e.*, a minimum of four background samples 40CFR 258.55(b)).
2. Compute the appropriate prediction limit based on distributional tests and detection frequency as previously described, based on upgradient data or historical data from each well (40CFR 258.55(e)).
3. Compare any Appendix II constituent concentrations found to the background prediction limit. If all values are below the prediction limit for two consecutive sampling events return to detection monitoring (40CFR 258.55(e)).
4. In Corrective Action (required if background is exceeded) use same statistic until background is achieved for three years (40CFR 258.58(e)(2)) or for the time period specified

in the site permit or state regulation. Use Sen's test to evaluate trends (declining) to demonstrate effectiveness of corrective action.

Comparison to a Standard

- If an MCL or Alternate Concentration Limit (ACL) is used, and the ACL or MCL is greater than the background prediction limit, then new concentrations in the assessment or corrective action wells should be compared to the standard (*i.e.*, ACL or MCL) using the 95% normal confidence limit computed from the last four independent samples (USEPA 1992).
- For assessment monitoring, use a 95% LCL (lower confidence limit) to demonstrate that the onsite mean concentration does not exceed the standard. For corrective action monitoring, use a 95% UCL (upper confidence limit) to demonstrate that the onsite mean concentration is now below the standard. DUMPStat will compute normal LCLs and UCLs for the mean of a single monitoring well. For alternative distributional forms, site-wide analyses and other media, use CARStat.[2]
- In the case of anthropogenic compounds such as VOCs, if the standard is less than the QL, then the standard becomes the QL, since no smaller value can be quantified.
- Use Sen's test to evaluate trends (both increasing and decreasing) to demonstrate the effectiveness of corrective action.

Air and Surface Water Monitoring

Background conditions

The purpose of air and/or surface water monitoring programs at waste disposal facilities is to determine if a site is impacting

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[2] Contact Discerning Systems for information on CARStat.

background air and/or surface water quality levels through release of waste. Factoring critically in air and surface water monitoring programs, background does not necessarily represent pristine conditions but rather the combination of natural background conditions, plus the contribution of a myriad of industrial and other influences as well. As such, background air and surface water quality is a dynamic phenomenon, levels of which may vary dramatically from day to day, season to season, and year to year.

Paired comparisons

Based on these considerations, the primary experimental sampling strategy for evaluating air and surface water quality involves paired comparisons (*i.e.,* taken at the same time) of upwind and downwind air quality samples and upstream and downstream water quality samples. In general, an overall comparison of upwind and downwind or upstream and downstream measurements that were collected on different occasions will be of limited value. Furthermore, the ambient concentrations of air and surface water quality monitoring constituents can vary tremendously over sampling events; therefore, it seems unlikely that a parametric statistical method will be justified in this context.

Perform appropriate test

To begin, a minimum of one pair of upstream/downstream or upwind/downwind monitoring stations should be sampled on a regular basis until a minimum of 8 paired samples are available. A widely used nonparametric test for the comparison of related samples (*e.g.,* paired comparisons of upstream and downstream samples) is the Wilcoxon Matched-Pairs Signed-Ranks test (Wilcoxon, F. 1945). Relative to the parametric alternative (*i.e.*, the paired t-statistic), Mood has shown that the Wilcoxon test has 95.5% asymptotic efficiency and near 95% efficiency for small samples of the size proposed here (Mood, A.M. 1954). This means that the Wilcoxon test will have 95% of the power of a paired t-statistic when the data do in fact arise from a normal distribution. Of course, we cannot assume normality here, since these data are typically riddled with nondetects and when detected, frequently exhibit lognormality or worse. As such, we pay a very small price for the needed generality of this statistical procedure.

Estimate average concentration

Once a statistically significant difference is recorded, we must estimate the average concentration of that particular constituent at both upstream and downstream or upwind and downwind sampling points so that the difference between average downstream and upstream water quality can be determined. DUMPStat automatically computes 95% Upper Confidence Limits, (UCL) for both upstream/downstream and/or upwind/downwind locations.

Finally, DUMPStat also automatically tests for trend in both upstream/downstream and/or upwind/downwind monitoring locations using Sen's test.

Implementation

- DUMPStat implements your detection monitoring plan by encompassing all aspects of the previously presented statistical decision tree.
- DUMPStat automatically selects statistical methods based on the decision tree and all wells and analytes will be input as a complete file and analyzed on the basis of a single instruction.
- Once DUMPStat is configured, no further statistical decisions, choices or selections should be made so that it can be run by someone with or without adequate statistical background to make these decisions.
- DUMPStat has a graphical user interface that allows you to specify the format of each new data file, and add those data to your existing database rather than requiring a complete new database each quarter.

Commonly Asked Questions

2

Do I have to take four independent samples from downgradient wells per semi-annual monitoring event?

The requirement for four semi-annual samples is for ANOVA only. All other methods require a single semi-annual sample once the background is established.

Over what period of time can I take my background samples?

A minimum of eight background samples must be taken for prediction limits, tolerance limits, and control charts. The samples must be independent and representative of seasonal and spatial variability at the site. Spatial and seasonal variability apply to naturally occurring constituents only (*e.g.,* inorganics). Spatial variability is addressed by either using intra-well comparisons and/or having multiple upgradient wells. Seasonal variability is addressed by collecting samples over a period of time that includes the seasons at which downgradient samples will be collected. For this reason, the eight background samples should be collected over a period of no less than one year, and preferably over a two year period in which a constant sampling interval is used (*e.g.,* quarterly sampling over a two year period for intra-well comparisons, and quarterly sampling over a one year period from at least two upgradient wells for inter-well comparisons). However, all samples required to establish background should be collected prior to the date of statistical comparison as required by the regulations.

What can I do if I have only one upgradient well?

With only one upgradient well, spatial variability and potential contamination are completely confounded (*i.e.,* you can't tell one from the other). To perform upgradient versus downgradient comparisons and consider spatial variability you need a minimum of two upgradient wells.

If I am using intra-well comparisons should I continue to monitor the upgradient well(s)?

Yes. It is always wise to perform intra-well comparisons on both upgradient and downgradient wells. If an exceedance is seen in both upgradient and downgradient wells, it is usually good evidence that the potential impact is not from the site. Any data which help in evaluating off-site and/or seasonal, regional and climactic changes should be collected and investigated.

What is the difference between tolerance limits and prediction limits?

Tolerance limits provide coverage of a percentage of the total distribution of measurements (*e.g.*, 95%) with a certain degree of confidence (*e.g.*, 95%). Prediction limits provide coverage of 100% of the next k measurements with a given level of confidence (*e.g.*, 95%). With 95% coverage, tolerance limits should be exceeded by 5% of the measurements with 95% confidence whereas prediction limits should fail for none of the next k measurements with 95% confidence.

When are nonparametric prediction limits appropriate?

Nonparametric prediction limits are optimal in the sense that they make no assumptions regarding the specific form of the underlying distribution. However, as the number of wells and constituents increase, large numbers of background measurements are required in order to have reasonable confidence (*e.g.,* 16 or more). When the site-wide confidence level is poor (*i.e.,* lower than 90%) alternatives based on Poisson prediction limits are often useful. Poisson prediction limits can be used regardless of detection frequency and their associated level of confidence is independent of number of background measurements. Note that Poisson prediction limits are approximate in that many constituents will not have a Poisson distribution. For this reason, Poisson prediction limits should only be used when statistical power analysis reveals that there is an insufficient number of background measurements to justify the nonparametric approach. In addition, Poisson prediction limits should only be used with constituents with detection frequencies of less than 50% whereas nonparametric prediction limits are valid regardless of detection frequency.

I don't want nonparametric limits, but DUMPStat automatically uses them when the data are neither normally nor lognormally distributed—what can I do?

In the DUMPStat statistical options, the "Rare Event Statistics" setting can be used to override the choice of nonparametric limits, even for events with high detection frequencies. (When "Poisson" is selected, you will never get a nonparametric limit.) When computing a prediction limit, if the detection frequency is insufficient to compute a parametric limit (a "Rare event"), you will either get a nonparametric limit or a Poisson limit, depending on the "Rare Event Statistics" setting in your statistical options. For inter-well comparisons, if the detection frequency is sufficient to compute a parametric limit, the background data are tested for normality.

- If they pass this test, you will get a normal limit.
- If they fail, the data are tested for lognormality.
- If they pass the lognormal test, you will get a lognormal limit.
- If they fail both tests, then the "Rare events" setting is checked, even though the detection frequency is high.
    - If "Nonparametric" is selected you will get a nonparametric limit

- If "Poisson" is selected, you will get a normal limit even though the data failed the normality test.

How do control charts deal with multiple comparisons?

As described, combined Shewhart-CUSUM control charts do not explicitly adjust for multiple comparisons. The effects of verification resampling and increasing number of comparisons produced by multiple wells and constituents generally balance the site-wide false positive and false negative rates at reasonable levels; however, there is no statistical guarantee that they will. Please note that when using control charts it is particularly important to determine site-wide false positive and false negative rates via simulation. Certain states (*e.g.,* California) require that you select the control chart factor based on generating a 5% site-wide false positive rate. DUMPStat allows the user to input the factor in the Statistical Options item of the Settings Menu and the Intra-well Control Chart. Power Analysis can be used to determine the site-wide false positive rate for varying choices of the control chart factor[1].

When can I use intra-well comparisons?

Intra-well comparisons should ***always*** be used when predisposal data are available. When no data prior to disposal of waste are available, then the owner/operator must provide empirical justification that use of intra-well comparisons will not mask existing contamination at the facility. One good approach is to show that constituents of concern (*e.g.,* VOCs) are not present in the wells and that naturally occurring constituents show no evidence of increasing trend (*e.g.,* using Sen's test).

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[1] See Gibbons, 1999, "Use of combined Shewhart-CUSUM control charts for groundwater monitoring applications." *Groundwater.* vol. 37 (5), pp. 682-691.

How do I adjust for seasonal variability?

In general, you can't adjust for seasonal variability because you typically do not have enough samples in each season to provide a reliable estimate of the effect. This is not a big problem because seasonal variability is incorporated into the usual estimate of the background standard deviation, even if it is not explicitly modeled as a separate variance component. Gibbons (1994) and Gilbert (1987) provide methods for seasonally adjusted trend estimators and this topic is also discussed in the new ASTM guidance D6312-98. Note that sample collection over a 12 month period is generally sufficient to incorporate seasonal variability into the background standard deviation.

Should I ever use ANOVA?

ANOVA is an extremely useful statistical tool for designed experiments with random sampling. Unfortunately, groundwater monitoring data do not enjoy such luxuries. Spatial variability becomes confounded with upgradient versus downgradient comparisons; and in general, ANOVA can be more sensitive to spatial variability (*i.e.,* small but consistent differences) than a real release (*i.e.,* a large but highly variable increase). The reason is that ANOVA compares between-well variability to within-well variability. In the absence of contamination, within-well variability is a combination of temporal variability and analytic variability whereas between-well variability is due to spatial variability. Since spatial variability is invariably large relative to the combination of temporal and analytic variability, the ANOVA will conclude that the ratio of between-well variability to within-well variability is significantly larger than zero. Of course, the assumption of ANOVA is that under the null hypothesis (*i.e.,* no contamination) all wells are drawn from the same distribution with the same population mean. This assumption is justifiable under random sampling. However, this assumption is not justified in natural systems in which initial conditions are already different, for example due to natural spatial variability. One good application of ANOVA is in testing whether or not the amount of spatial variability is statistically significant. Here we simply restrict the analysis to the upgradient or background wells (which could not be affected by a release from the site) and if a significant F-statistic results then we can conclude that there is significant spatial variability. However, even in the absence of a significant ANOVA, spatial variability may still be appreciable but simply not present in the small number of available upgradient or background wells.

Does nonparametric ANOVA correct the limitations of its parametric counterpart?

The only difference between nonparametric and parametric ANOVA is that the nonparametric ANOVA does not assume a specific distributional form for the concentration measurements whereas the parametric ANOVA assumes normality. Both models assume independence of the measurements and homogeneity of variance and both models are severely compromised by spatial variability.

Should I use MDLs or PQLs for statistical analysis?

The detection limit is used to determine if an analyte is present in a sample and the quantification limit is used to make a quantitative determination of the amount of the analyte in the sample. USEPA has used the terms MDL (method detection limit) and PQL (practical quantitation limit) to describe two specific approaches of estimating the detection and quantification limits respectively. If we are comparing a concentration directly to a standard then it must be greater than the quantification limit in order to provide a reliable estimate of whether or not the standard has actually been exceeded. If all that we care about is whether or not the analyte is present or absent in the sample, then measurements above the detection limit will provide that information. Measurements above the quantification limit can be used directly in the previously described statistical methods; however, measurements below the quantification limit are considered to be censored and the appropriate adjustments for censored data should be used. DUMPStat uses Aitchison's method to adjust for nondetects in computing normal and lognormal prediction limits. No statistical adjustment is required for nonparametric or Poisson prediction limits. The primary advantage of Aitchison's method over other alternatives (*e.g.,* Cohen's method) is that it can accommodate varying reporting limits which are quite common in practice.

What should I do for VOCs?

VOCs are not naturally occurring and therefore they should not be found in background groundwater samples. For VOCs, verified exceedance of the appropriate quantification limit is an indication of a significant exceedance. Do not apply the previously described statistical methods to VOCs unless you are doing assessment or corrective action monitoring and are attempting to determine if a known release of these compounds is getting better or worse or exceeds a standard. Alternatively, if VOCs are detected in upgradient wells due to an offsite source, statistical comparison (*i.e.,* up vs. down) may be appropriate.

Are different methods required for comparison to ACLs and MCLs?

When comparing measurements to a standard, the same approach is used (*e.g.,* a 95% confidence limit for the mean of the last four measurements) regardless of how the standard was derived. In assessment monitoring we use the LCL, and in corrective action monitoring we use the UCL.

When computing tests of normality and lognormality, what data should be used?

Tests of distributional form should only be performed on background data or data that are known with certainty not to be influenced by the facility. This would typically exclude use of downgradient data.

If I have constituents with detection frequencies less than 25% for intra-well or less than 50% for inter-well comparisons, do I have to wait until I have a minimum of 13 background samples before I begin computing statistics?

No. For inter-well comparisons, remember that the number of background samples is pooled over all upgradient wells, so with eight samples in each of two wells you have 16 background samples. For intra-well comparisons 13 background samples are required for a nonparametric prediction limit with one verification resample, but only eight background samples are required with two verification resamples (*i.e.,* fail the first and pass either one of two verification resamples). Alternatively, Poisson prediction limits can be used with as few as four background samples regardless of detection frequency.

Do I have to conduct a statistical analysis if VOCs are detected only in the downgradient wells?

Verified quantification of VOCs in a downgradient well is a statistical exceedance in and of itself. No statistical comparisons are required.

What is the minimum background sample size required to compute detection monitoring statistics?

A minimum of eight background samples (*e.g.*, eight samples in each well for intra-well comparisons or four samples in each of two upgradient wells for inter-well comparisons) are required for a meaningful statistical evaluation.

Do I need to compute statistics when all of the background data are below the MDL/PQL/LOQ?

The LOQ and PQL are both quantification limit estimates whereas the MDL is an estimate of a detection limit. For statistical purposes, the smallest measured concentration is the quantification limit (*e.g.,* PQL or LOQ) therefore if all values in the upgradient wells are nonquantifiable, the prediction limit becomes the QL. Our level of confidence in this decision rule is based on the number of background measurements, the number of comparisons and the verification resampling strategy. If we have a small background sample size (*e.g.,* the minimum of eight background measurements) and nothing is detected, there is still appreciable probability that the true detection frequency is greater than zero. Since there are typically far more downgradient wells than upgradient wells, we will have a greater chance of detecting the constituent in a downgradient well, therefore giving the appearance of a potential release. For this reason, even when nothing is detected in background, confidence levels associated with using the QL as the nonparametric prediction limit should be determined. Note that this does not apply to VOCs which should not be detected in clean background wells with any frequency.

Do I need to compute statistics when all of the downgradient data are below the MDL/PQL/LOQ?

Statistical computations are based on background data only. The fact that a constituent has never been detected and/or quantified in a downgradient well is irrelevant to the statistical analysis; however, it may indicate that the constituent adds little to the monitoring program and should be eliminated from the suite of constituents used for statistical analysis.

Technical Details 3

The purpose of this section is to provide a description of the specific statistical methods used in DUMPStat. Please note, however, that specific recommendations for any given facility require an interdisciplinary site-specific study that encompasses knowledge of the facility, its hydrogeology, geochemistry, and study of the false positive and false negative error rates that will result. In general, the appropriate statistical methods are available in DUMPStat; however, the program must be properly configured for each site to insure that the methods are properly implemented. Performing a correct statistical analysis, such as nonparametric prediction limits, in the wrong situation (*e.g.*, when there are too few background measurements) can lead to disaster. It is for this reason that DUMPStat's simulation capabilities are so important. In the following, the general DUMPStat algorithm is described.

Upgradient versus Downgradient Comparisons

For those wells and constituents that show similar variability in upgradient and downgradient monitoring zones, inter-well comparisons can be performed by computing limits based on historical upgradient data to which individual new downgradient monitoring measurements can be compared. In the following, the decision rules by which various prediction limits can be computed is outlined. The decision points are based on detection frequency and distributional form of the upgradient data.

Compounds Quantified in All Background Samples

1. Test normality of distribution using the multiple group version of the Shapiro-Wilk test (Wilk and Shapiro, 1968) applied to *n* background measurements. The multiple group version of the original Shapiro-Wilk test (Shapiro and Wilk, 1965) takes into consideration that upgradient measurements are nested within different upgradient monitoring wells, hence the original Shapiro-Wilk test does not apply (USEPA, 1992 section 1.1.4), unless the mean difference between the wells have already been removed.
2. If normality is not rejected, compute the 95% prediction limit as:

   $$x + t_{n-(1,\alpha)} s \sqrt{1 + \frac{1}{n}}$$

   where $x = \sum_{i=1}^{n} \frac{x_i}{n}$, $s = \sqrt{\sum_{i=1}^{n} \frac{(x_i - x)^2}{n-1}}$,

   α is the false positive rate for an individual test, $t_{[n-1,\alpha]}$ is the one-sided $(1-\alpha)100\%$ point of Student's *t* distribution on *n*-1 degrees of freedom, and *n* is the number of background measurements.
3. Select α as the minimum of 0.01 or one of the following:
   - a. Pass the first or one of one verification resample

     $$\alpha = \sqrt{1 - 0.95^{1/k}}$$

   - b. Pass the first or one of two verification resample

     $$\alpha = \sqrt[3]{1 - 0.95^{1/k}}$$

   - c. Pass the first or two of two verification resample

     $$\alpha = \sqrt{1 - 0.95^{1/k}}\,\sqrt{1/2}$$

     where *k* is the number of comparisons (*i.e.,* monitoring wells times constituents—see USEPA 1992 section 5.2.2).

4. If normality is rejected, take natural logarithms of the *n* background measurements and recompute the multiple group Shapiro-Wilk test.
5. If the transformation results in a nonsignificant *G* statistic (*i.e.*, the values $log_e(x)$ are normally distributed—see USEPA 1992 section 1.1), compute the lognormal prediction limit as:

$$exp\left(y + t_{[n-(1,\alpha)]} s_y \sqrt{1 + \frac{1}{n}}\right)$$

where

$$y = \sum_{i=1}^{n} \frac{\log_e(x_i)}{n} \quad \text{and} \quad s_y = \sqrt{\sum_{i=1}^{n} \frac{(\log_e(x_i) - y)^2}{n-1}} .$$

If log transformation does not bring about normality (*i.e.*, the probability of *G* is less than 0.01), compute nonparametric prediction limits as in section 3 (USEPA 1992 section 5.2.3). (Option: compute Poisson prediction limits as in section 3.4—see USEPA 1992 section 2.2.4.)

Compounds Quantified in at Least 50% of All Background Samples

1. Apply the multiple group version Shapiro-Wilk test to the n_1 quantified measurements only.
2. If the data are normally distributed compute the mean of the *n* background samples as:

$$x = \left(1 - \frac{n_0}{n}\right)x'$$

where x' is the average of the n_1 detected values and n_0 is the number of samples in which the compound is not detected or is below the QL. The standard deviation is:

$$s = \sqrt{\left(1 - \frac{n_0}{n}\right)s'^2 + \frac{n_0}{n}\left(1 - \frac{n_0 - 1}{n - 1}\right)\bar{x}'}$$

where s' is the standard deviation of n_1 quantifiable measurements. The normal prediction limit can then be computed as previously described. This method is due to Aitchison (1955)—see USEPA 1992 Section 2.2.2.

3. If the multiple group Shapiro-Wilk test reveals that the data are lognormally distributed, replace $\bar{x}'$ with $\bar{y}'$, and s' with s_y' in the equations for $\bar{x}$ and s.
4. Note that if the measurements are less than 1.0 as is often the case when metals are reported in mg/l, then $y = \log_e(x) < 0$ and the previous equations do not apply. In this case we use the transformation $y = \log_e(x + 1)$ which is always positive for any nonzero concentration. The lognormal prediction limit is then computed as:

   $$\exp\left(\bar{y} + t_{[n+1,\alpha]} s_y \sqrt{1 + \frac{1}{n}}\right) - 1$$

5. If the data are neither normally or lognormally distributed, compute a nonparametric prediction limit. (Option: compute normal prediction limit.)

Compounds Quantified in Less Than 50% of All Background Samples

1. In this application, the nonparametric prediction limit is the largest concentration found in n upgradient measurements (USEPA 1992 section 4.2.1).
2. Gibbons (1990a, 1991b) has shown that the confidence associated with this decision rule, following one or more verification resamples, is a function of the multivariate

extension of the hypergeometric distribution (USEPA 1992 section 5.2.3).

3. Complete tabulations of confidence levels for $n = 4,\ldots,100$, $k = 1,\ldots, 100$ future comparisons (*e.g.*, monitoring wells), and a variety of verification resampling plans are presented in Gibbons (1994). For example, with 5 monitoring wells and 10 constituents (*i.e.*, 50 comparisons), we would require 40 background measurements to provide 95% confidence (USEPA 1992 section 5.2.3). Table 1 displays confidence levels for a single verification resample.
4. As an option to the nonparametric prediction limits, DUMPStat can compute Poisson prediction limits. Poisson prediction limits are useful for those cases in which there are too few background measurements to achieve an adequate site-wide false positive rate using the nonparametric approach. Gibbons (1987b) derived the Poisson prediction limit as:

$$\text{Poisson PL} = \frac{y}{n} + \frac{z^2}{2n} + \frac{z}{n}\sqrt{y(1+n) + \frac{z^2}{4}}$$

where y is the sum of the detected measurements or reporting limit for those samples in which the constituent was not detected, and z is the $(1-\alpha)100$ upper percentage point of the normal distribution. (USEPA 1992 section 2.2.4)

Previous	**Number of Monitoring Wells (k)**														
n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
4	.933	.881	.838	.802	.771	.744	.720	.698	.679	.661	.645	.630	.617	.604	.592
5	.952	913	.879	.849	.823	.800	.779	.760	.742	.726	.711	.697	.684	.672	.661
6	.964	.933	.906	.882	.860	.840	.822	.805	.789	.774	.761	.748	.736	.725	.714
7	.972	.947	.925	.905	.886	.869	.853	.838	.825	.812	.799	.788	.777	.766	.757
8	.978	.958	.939	.922	.906	.891	.878	.864	.852	.841	.830	.819	.809	.800	.791
9	.982	.965	.949	.935	.921	.908	.896	.885	.874	.864	.854	.844	.835	.827	.818
10	.985	.971	.957	.945	.933	.922	.911	.901	.891	.882	.873	.865	.857	.849	.841
11	.987	.975	.964	.953	.942	.933	.923	.914	.906	.897	.889	.882	.874	.867	.860
12	.989	.979	.969	.959	.950	.941	.933	.925	.917	.910	.902	.896	.889	.882	.876
13	.990	.981	.973	.964	.956	.948	.941	.934	.927	.920	.914	.907	.901	.895	.889
14	.992	.984	.976	.969	.961	.954	.948	.941	.935	.929	.923	.917	.912	.906	.901
15	.993	.986	.979	.972	.966	.959	.953	.947	.942	.936	.931	.926	.920	.915	.910
16	.993	.987	.981	.975	.969	.964	.958	.953	.948	.943	.938	.933	.928	.923	.919
17	.994	.988	.983	.978	.972	.967	.962	.957	.953	.948	.943	.939	.935	.930	.926
18	.995	.990	.985	.980	.975	.970	.966	.961	.957	.953	.949	.944	.940	.937	.933
19	.995	.991	.986	.982	.977	.973	.969	.965	.961	.957	.953	.949	.946	.942	.938
20	.996	.991	.987	.983	.979	.975	.972	.968	.964	.960	.957	.953	.950	.947	.943
25	.997	.994	.992	.989	.986	.984	.981	.978	.976	.973	.971	.968	.966	.964	.961
30	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.974	.972
35	.998	.997	.996	.994	.993	.991	.990	.988	.987	.986	.984	.983	.981	.980	.979
40	.999	.998	.997	.995	.994	.993	.992	.991	.990	.989	.988	.987	.985	.984	.983
45	.999	.998	.997	.996	.995	.995	.994	.993	.992	.991	.990	.989	.988	.987	.987
50	.999	.998	.998	.997	.996	.996	.995	.994	.993	.993	.992	.991	.990	.990	.989
60	.999	.999	.998	.998	.997	.997	.996	.996	.995	.995	.994	.994	.993	.993	.992
70	1.000	.999	.999	.998	.998	.998	.997	.997	.997	.996	.996	.995	.995	.995	.994
80	1.000	.999	.999	.999	.998	.998	.998	.998	.997	.997	.997	.996	.996	.996	.996
90	1.000	1.000	.999	.999	.999	.999	.998	.998	.998	.998	.997	.997	.997	.997	.996
100	1.000	1.000	.999	.999	.999	.999	.999	.998	.998	.998	.998	.998	.997	.997	.997

Table 1: Probability that the first sample or the verification resample will be below the maximum of ***n*** background measurements at each of ***k*** monitoring wells for a single constituent.

Previous	Number of Monitoring Wells (k)													
n	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**90**	**100**
4	.542	.504	.474	.449	.428	.410	.394	.380	.367	.356	.345	.336	.327	.312	.299
5	.612	.574	.543	.517	.495	.476	.459	.443	.430	.417	.406	.396	.386	.369	.355
6	.668	.631	.600	.574	.552	.532	.514	.499	.484	.472	.460	.449	.439	.420	.405
7	.713	.678	.648	.623	.600	.580	.563	.547	.532	.519	.507	.496	.485	.466	.450
8	.750	.717	.688	.664	.642	.622	.605	.589	.574	.561	.549	.537	.527	.507	.490
9	.781	.750	.723	.699	.678	.659	.642	.626	.612	.598	.586	.574	.564	.544	.527
10	.807	.777	.752	.729	.709	.691	.674	.659	.644	.631	.619	.608	.597	.578	.560
11	.828	.801	.777	.755	.736	.718	.702	.687	.674	.661	.649	.638	.627	.608	.590
12	.847	.821	.799	.778	.760	.743	.727	.713	.700	.687	.675	.664	.654	.635	.618
13	.862	.839	.817	.798	.781	.764	.750	.736	.723	.711	.699	.689	.678	.660	.643
14	.876	.854	.834	.816	.799	.784	.769	.756	.744	.732	.721	.710	.701	.682	.666
15	.888	.867	.848	.831	.815	.801	.787	.774	.762	.751	.740	.730	.721	.703	.686
16	.898	.879	.861	.845	.830	.816	.803	.791	.779	.768	.758	.748	.739	.722	.706
17	.907	.889	.872	.857	.843	.830	.817	.806	.794	.784	.774	.765	.756	.739	.723
18	.914	.898	.882	.868	.855	.842	.830	.819	.808	.798	.789	.780	.771	.754	.739
19	.921	.906	.891	.878	.865	.853	.842	.831	.821	.811	.802	.793	.785	.769	.754
20	.928	.913	.899	.886	.874	.863	.852	.842	.832	.823	.814	.806	.798	.782	.768
25	.950	.939	.929	.919	.910	.901	.892	.884	.876	.869	.862	.855	.848	.835	.823
30	.963	.955	.947	.940	.932	.925	.919	.912	.906	.900	.894	.888	.882	.872	.861
35	.972	.966	.959	.954	.948	.942	.937	.931	.926	.921	.916	.911	.907	.898	.889
40	.978	.973	.968	.963	.958	.954	.949	.945	.941	.936	.932	.928	.924	.917	.909
45	.982	.978	.974	.970	.966	.962	.959	.955	.951	.948	.944	.941	.938	.931	.925
50	.985	.982	.979	.975	.972	.969	.966	.963	.959	.956	.954	.951	.948	.942	.937
60	.990	.987	.985	.982	.980	.978	.975	.973	.971	.968	.966	.964	.962	.958	.954
70	.992	.990	.989	.987	.985	.983	.981	.980	.978	.976	.974	.973	.971	.968	.965
80	.994	.993	.991	.990	.988	.987	.986	.984	.983	.981	.980	.979	.977	.975	.972
90	.995	.994	.993	.992	.991	.990	.988	.987	.986	.985	.984	.983	.982	.980	.978
100	.996	.995	.994	.993	.992	.991	.991	.990	.989	.988	.987	.986	.985	.983	.982

Table 1 (continued)

Intra-Well Comparisons

One particularly good method for computing intra-well comparisons is the combined Shewhart-CUSUM control chart. (USEPA 1992 section 6.1) The method is sensitive to both gradual and rapid releases and is also useful as a method of detecting 'trends' in data. Note that this method should be used on wells unaffected by the landfill. There are several approaches to implementing the method and in the following one useful way is described as well as discussion of some statistical properties.

Assumptions

The combined Shewhart-CUSUM control chart procedure assumes that the data are ***independent*** and ***normally*** distributed with a ***fixed*** mean μ and constant variance σ^2. The most important assumption is independence, and as a result wells should be sampled ***no more*** frequently than quarterly. In some cases, where groundwater moves relatively quickly, it may be possible to accelerate background sampling to eight samples in a single year; however, this should only be done to establish background and not for routine monitoring. The assumption of normality is somewhat less of a concern, and if problematic, natural log or square root transformation of the observed data should be adequate for most practical applications. For this method, nondetects can be replaced by the QL without serious consequence. This procedure should ***only*** be applied to those constituents that are quantified in at least 25% of all samples; otherwise, σ^2 is not adequately defined.

Nondetects

1. For those well and constituent combinations in which the detection frequency is less than 25%, DUMPStat will graphically display these data until a sufficient number of measurements are available to provide 99% confidence (*i.e.*, 1% false positive rate) for an individual well and constituent

using a nonparametric prediction limit; which, in this context, is the maximum quantified value out of the *n* historical measurements. As previously discussed, this amounts to 13 background samples for 1 resample, 8 background samples for pass 1 of 2 resamples and 18 background samples for pass 2 of 2 resamples. It should be obvious that if nonparametric prediction limits are to be used for intra-well comparisons of rarely detected constituents, two verification resamples will often be required and failure will only be indicated if ***both*** measurements exceed the limit (*i.e.*, the maximum of the first 8 samples).

2. For those cases in which the detection frequency is greater than 25%, DUMPStat substitutes the median reporting limit for the nondetects. In this way, changes in reporting limits do not appear to be significant trends. If manual reporting limits are selected, all nondetects will be replaced with the manual reporting limit.
3. If nothing is detected in 8, 13 or 18 independent samples (depending on resampling strategy), DUMPStat uses the reporting limit as the control limit.
4. As in the previously described inter-well comparisons, DUMPStat provides optional use of Poisson prediction limits as an alternative to nonparametric prediction limits for rarely detected constituents (*i.e.*, less than 25% detects). Poisson prediction limits can be computed after 4 background measurements regardless of detection frequency.

Procedure

1. DUMPStat requires that at least 4 historical independent samples are available to provide reliable estimates of the mean μ and standard deviation σ, of the constituent's concentration in each well, and a minimum of 8 background samples is recommended.
2. DUMPStat selects the three Shewhart-CUSUM parameters *h* (the value against which the cumulative sum will be com-

pared), k (a parameter related to the displacement that should be quickly detected), and SCL (the upper Shewhart limit which is the number of standard deviation units for an immediate release). Lucas (1982) and Starks (1988) suggest that $k = 1$, $h = 5$, and $SCL = 4.5$ are most appropriate for groundwater monitoring applications. This sentiment is echoed by USEPA in their interim final guidance document *Statistical analysis of ground-water monitoring data at RCRA facilities* (April, 1989). Also see USEPA 1992 section 6.1. For ease of application, however, we have selected $h = SCL = 4.5$ as a default, which is slightly more conservative than the value of $h = 5$ suggested by USEPA. To add increased statistical power, when $n \geq 12$, we set as defaults $h = SCL = 4.0$ and $k = 0.75$.

Note that the user can select any multiplier for h and SCL between 2 and 10. In California, for example, facilities are required to select values of h and SCL that produce a site wide false positive rate of 5%. By selecting various values of h and SCL in the Statistical Options item of the Settings Menu, and running Intra-Well control charts and corresponding statistical power, the appropriate control factors can be empirically determined for a specific site. (See Gibbons, 1999.)

3. Denote the new measurement at time-point t_i as x_i.
4. Compute the standardized value z_i:

$$z_i = \frac{x_i - x}{s}$$

where x and s mean and standard deviation of the at least 8 historical measurements for that well and constituent (collected in a period of no less than one year.)

5. 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 starting with S_0=0.

6. Plot the values of S_i (y-axis) versus t_i (x-axis) on a time chart. Declare an "out-of-control" situation on sampling period t_i if for the first time, $S_i \geq h$ or $z_i \geq SCL$. Any such designation, however, must be verified on the next round of sampling, before further investigation is indicated.
7. The reader should note that unlike prediction limits which provide a fixed confidence level (*e.g.*, 95%) for a given number of future comparisons, control charts do not provide explicit confidence levels, and do not adjust for the number of future comparisons. The default selection of $h = SCL = 4.5$ and k=1 is based on USEPA's own review of the literature and simulations (see Lucas, 1982; Starks, 1988; and USEPA, 1989). USEPA indicates that these values "allow a displacement of two standard deviations to be detected quickly." Since 1.96 standard deviation units corresponds to 95% confidence on a normal distribution, we can have approximately 95% confidence for this method as well. Note that this logic applies only to a single well and constituent. Gibbons (1999) suggests alternative multipliers as a function of the number of background samples, comparisons, and resampling plan.
8. In terms of plotting the results, it is more intuitive to plot values in their original metric (*e.g.*, µg/l) rather than in standard deviation units. In this case $h = SCL = \bar{x} + 4.5s$ and the S_i are converted to the concentration metric by the transformation $S_i * s + \bar{x}$, noting that when normalized (*i.e.*, in standard deviation units) $\bar{x} = 0$ and $s = 1$ so that $h = SCL = 4.5$ and $S_i * 1 + 0 = S_i$.
9. In computing the CUSUM (S_i), nondetects are set to zero to insure that an elevated QL does not increase the CUSUM.
10. You may compute the CUSUM for all measurements (starting at the beginning of the background), or only for post-background monitoring data. (recommended).

Outliers

1. From time to time, inconsistently large or small values (outliers) can be observed due to sampling, laboratory, transportation, transcription errors, or even by chance alone. The verification resampling procedure that we have proposed will tremendously reduce the probability of concluding that an impact has occurred if such an anomalous value is obtained for any of these reasons. However, nothing has eliminated the chance that such errors might be included in the background measurements for a particular well and constituent. If such erroneous values (either too high or too low) are included in the background database, the result would be an artificial increase in the magnitude of the control limit, and a corresponding increase in the false negative rate of the statistical test (*i.e.*,the conclusion that there is no site impact when in fact there is).
2. To remove the possibility of this type of error, the background data are screened for each well and constituent for the existence of outliers (USEPA 1992 section 6.2) using the well known method described by Dixon (1953).These outlying data points are indicated on the control charts (using a different symbol), but are excluded from the measurements that are used to compute the background mean and standard deviation. In the future, new measurements that turn out to be outliers, in that they exceed the control limit, will be dealt with by verification resampling in downgradient wells only.
3. This same outlier detection algorithm is applied to each upgradient well and constituent to screen outliers for interwell comparisons as well.
4. The purpose of automatic outlier rejection in DUMPStat is to eliminate extreme values that will bias the statistical limits (*i.e.,* make them too high). To this end, we use a two-stage screening criteria. First we use Dixon's test. If Dixon's test indicates an outlier we then determine if the value is ten

times the median value for inter-well comparisons or three times the median value for intra-well comparisons. An outlier is indicated only if both tests indicate the value is an outlier. The different factors used for inter-well and intra-well screening are due to the presence of spatial variability for inter-well comparisons. If another outlier screening tool is used outside of DUMPStat (see Gibbons 1994 for a review), outliers can be set manually within DUMPStat as desired. DUMPStat also declares extreme reporting limits as outliers if they are ten times the median reporting limit.

Existing Trends

If contamination is pre-existing, trends will often be observed in the background database from which the mean and variance are computed. This will lead to upward biased estimates and grossly inflated control limits. To remove this possibility, we first screen the background data for each well and constituent for trend using Sen's (1968) nonparametric estimate of trend. Confidence limits for this trend estimate are given by Gilbert (1987). A significant trend is one in which the 99% lower confidence bound is greater than zero. In this way, even pre-existing trends in the background dataset will be detected. In large databases, very gradual trends can be statistically significant; however, such trends should not preclude the use of intra-well comparisons.

A Note on Verification Sampling

1. It should be noted that when a new monitoring value is an outlier, perhaps due to an error in transcription, sampling, or analysis; the Shewhart and CUSUM portions of the control chart are affected quite differently. The Shewhart portion of the control chart compares each individual new measurement to the control limit, therefore, the next monitoring event measurement constitutes an independent verification of the original result. In contrast, however, the CUSUM procedure incorporates ***all*** historical values in the

computation; therefore, the effect of the outlier will be present for both the initial and verification sample; hence the statistical test will be invalid.

2. For example, assume $x = 50$ and $s = 10$. On quarter 1 the new monitoring value is 50, so $z = (50\text{-}50)/10 = 0$ and $S_i = \max[0, (z\text{-}1)+0] = 0$. On quarter 2, a sampling error occurs and the reported value is 200, yielding $z = (200\text{-}50)/10 = 15$ and $S_i = \max[0, (15\text{ -}1)+0] = 14$, which is considerably larger than 4.5; hence an initial exceedance is recorded. On the next round of sampling, the previous result is not confirmed, because the result is back to 50. Inspection of the CUSUM, however, yields $z = (50\text{-}50)/10 = 0$ and $S_i = \max[0, (0\text{-}1)+14] = 13$, which would be taken as a confirmation of the exceedance, when in fact, no such confirmation was observed. For this reason, the verification must ***replace*** the suspected result in order to have an unbiased confirmation.

Updating the Control Chart

1. As monitoring continues and the process is shown to be in control, the background mean and variance should be updated periodically to incorporate these new data. Every two years, all new data that are ***in control*** should be pooled with the initial samples and x and s recomputed. These new values of x and s will then be used in constructing future control charts. This updating process should continue for the life of the facility and/or monitoring program (USEPA 1992 section 6.2).
2. DUMPStat allows the user to update background by changing the time window menu option. This option sets a window of time for which background summary statistics are computed. Changing the maximum date will incorporate new data into the background limit estimate. Note that this time window applies to computing background for both inter-well and intra-well comparisons, and can be set

uniquely for each well and pooled upgradient background. For inter-well comparisons all available data should be used in computing the prediction limit.

An Alternative Based on Prediction Limits

1. An alternative approach to intra-well comparisons involves computation of well-specific prediction limits. Prediction limits are somewhat more sensitive to immediate releases but less sensitive to gradual releases than the combined Shewhart-CUSUM control charts. Prediction limits are also less robust to deviations from distributional assumptions.
2. As an alternative to combined Shewhart-CUSUM control charts, DUMPStat can compute normal prediction limit for detection frequencies > 25%, or rare-event prediction limits otherwise, as described in the previous section on inter-well comparisons.
3. For detection frequencies greater than 25%, nondetects are replaced with the median reporting limit or manual reporting limit depending on whether one has been selected. For detection frequencies less than 25%, either nonparametric or Poisson prediction limits are computed depending on what option the user has selected (*i.e.*, rare-event statistic window).

Comparison to a Standard

1. For assessment or corrective action, it is often required that samples from a potentially impacted well be compared to a groundwater quality protection standard such as a Maximum Contaminant Level (MCL) or Alternate Concentration Limit (ACL). DUMPStat's assessment monitoring module provides tabular and graphical display of this comparison based on tests of increasing and decreasing trends, and comparison of the standard to the upper or lower 95%

normal confidence limit applied to the last 4–16 (user-selectable) independent samples.

2. The 95% confidence limit for the mean of the last m measurements is computed as:

   $$x + t_{[m-1,\, 0.05]}\frac{s}{\sqrt{m}}$$

3. Nondetects are replaced by one-half of the reporting limit.

Methods to be Avoided 4

The following sections present descriptions of some statistical methods that should be avoided. These methods are not available in DUMPStat.

Analysis of Variance—ANOVA

Application of ANOVA procedures to groundwater detection monitoring programs, both parametric and nonparametric, is inadvisable for the following reasons.

1. Univariate ANOVA procedures do not adjust for multiple comparisons due to multiple constituents which can be devastating to the site-wide false positive rate. As such, a site with 10 indicator constituents will have a 40% chance of failing at least one on every monitoring event (USEPA 1992 section 5.2.1).
2. ANOVA is more sensitive to spatial variability than contamination. Spatial variability affects mean concentrations but typically not the variance, hence small yet consistent differences will achieve statistical significance. In contrast, contamination affects both variability and mean concentration, therefore a much larger effect is required to achieve statistical significance. In fact, application of ANOVA methods to pre-disposal groundwater monitoring data can result in statistically significant differences between upgradient and downgradient wells, despite the fact that there is no waste in between. The reasons for this are:
    a. The overall F-statistic tests the null hypothesis of no differences among any of the wells regardless of gradi-

ent (*i.e.*, it will be significant if two downgradient wells are different), and

b. The distribution of the mean of 4 measurements (*i.e.*, four measurements collected from the same well within a six month period) is normal with mean μ and variance $\sigma^2/4$ whereas the distribution of each of the individual measurements is normal with mean μ and variance σ^2. This means that the standard deviation of the mean of four measurements is one-half the size of the standard deviation of the individual measurements themselves. As a result, small but consistent geochemical differences that are invariably observed naturally across a waste disposal facility will be attributed to contamination. To make matters worse, since there are far more downgradient than upgradient wells at these facilities, spatial variation has a far greater chance of occurrence downgradient than upgradient further increasing the likelihood of falsely concluding that contamination is present. While spatial variation is also a problem for prediction limits and tolerance limits for single future measurements, it is not nearly as severe a problem as for ANOVA since the distribution of the individual measurement is considered and not the more restrictive distribution of the sample mean.

3. Nonparametric ANOVA is often presented as if it protects the user from all of the weaknesses of its parametric counterpart. This is ***not*** the case. Both methods assume identical distributions for the analyte in ***all*** monitoring wells. The only difference is that the parametric ANOVA assumes that the distribution is normal and the nonparametric ANOVA is indifferent to what the distribution is. Both parametric and nonparametric ANOVA assume homogeneity of variance, a condition that almost never occurs in practice. This is not a weakness of methods for single future samples (*i.e.*, prediction and tolerance limits) since the variance estimates rely solely on the background data. Why would anyone want to use downgradient data from an existing site (which could be affected by the site) to characterize natural variability? Yet this is exactly what the ANOVA does. Furthermore, ANOVA is not a good statistical technique for detecting a narrow plume that might effect only one of 10 or 20 monitoring wells (USEPA 1992 section 5.2.1).

4. ANOVA requires the pooling of downgradient data. Specifically, USEPA has suggested that four samples per semi-annual monitoring event be collected (*i.e.*, eight samples per year). As such, on average, it will never most rapidly detect a release, since only a subset of the required four semi-annual samples will be affected by a site impact. This heterogeneity will decrease the mean concentration and dramatically increase the variance for the affected well thereby limiting the ability of the statistical test to detect contamination when it occurs. This is not true for tolerance limits, prediction limits and control charts, which can and ***should*** be applied to individual measurements. For these reasons, when applied to groundwater detection monitoring, ANOVA will maximize both false positive and false negative rates, and double the cost of monitoring (*i.e.*, ANOVA requires four samples per semi-annual event or eight per year versus a maximum of four quarterly samples per year for prediction or tolerance limits that test each new individual measurement and more typically only two samples per year).

To illustrate, consider the data in Table 2, which were obtained from a facility in which no disposal of waste has yet occurred (see Gibbons, 1994).

Well	Event	TOC	TKN	COD	ALK
MW01	1	5.2000	0.8000	44.0000	58.0000
MW01	2	6.8500	0.9000	13.0000	49.0000
MW01	3	4.1500	0.5000	13.0000	40.0000
MW01	4	15.1500	0.5000	40.0000	42.0000
MW02	1	1.6000	1.6000	11.0000	59.0000
MW02	2	6.2500	0.3000	10.0000	82.0000
MW02	3	1.4500	0.7000	10.0000	54.0000
MW02	4	1.0000	0.2000	13.0000	51.0000
MW03	1	1.0000	1.8000	28.0000	39.0000
MW03	2	1.9500	0.4000	10.0000	70.0000
MW03	3	1.5000	0.3000	11.0000	42.0000
MW03	4	4.8000	0.5000	26.0000	42.0000
MW04	1	4.1500	1.5000	41.0000	54.0000
MW04	2	1.0000	0.3000	10.0000	40.0000
MW04	3	1.9500	0.3000	24.0000	32.0000
MW04	4	1.2500	0.4000	45.0000	28.0000
MW05	1	2.1500	0.6000	39.0000	51.0000
MW05	2	1.0000	0.4000	26.0000	55.0000
MW05	3	19.6000	0.3000	31.0000	60.0000
MW05	4	1.0000	0.2000	48.0000	52.0000
MW06	1	1.4000	0.8000	22.0000	118.0000
MW06	2	1.0000	0.2000	23.0000	66.0000
MW06	3	1.5000	0.5000	25.0000	59.0000
MW06	4	20.5500	0.4000	28.0000	63.0000
P14	1	2.0500	0.2000	10.0000	79.0000
P14	2	1.0500	0.3000	10.0000	96.0000
P14	3	5.1000	0.5000	10.0000	89.0000

Table 2: Raw data for all detection monitoring wells and constituents (mg/l). This facility has no garbage in it.

Results of applying both parametric and nonparametric ANOVA to these predisposal data yielded an effect that approached significance for Chemical Oxygen Demand (COD) ($p < 0.072$ parametric and $p < 0.066$ nonparametric) and a significant difference for Alkalinity (ALK) ($p < 0.002$ parametric and $p < 0.009$ nonparametric). In terms of individual comparisons, significantly increased COD levels were found for well MW05 ($p < 0.026$) and significantly increased ALK was found for wells MW06 ($p < 0.026$) and P14 ($p < 0.003$) relative to upgradient wells. Of course, these results represent false positives due to spatial variability, since there is no garbage. What is perhaps most remarkable, however, is the absence of any significant results for TOC, where some of the values are as much as 20 times higher than the others. The reason, of course, is that these extreme values tremendously increase the within-well variance estimate, rendering the ANOVA powerless to detect any differences regardless of magnitude. This is yet another testimonial to why it is environmentally negligent to average measurements from downgradient monitoring wells, a problem that is inherent to ANOVA-type analyses when applied to dynamic groundwater quality measurements. The elevated TOC data are clearly inconsistent with chance expectations and should be investigated. In this case, however, they are likely due to insects getting into the wells since this greenfield facility is in the middle of the Mohave desert.

Cochran's Approximation to the Behrens Fisher t-test

Although no longer required, for years the RCRA regulation was based on application of the Cochran's approximation to the Behrens Fisher (CABF) *t*-test. The test was incorrectly implemented by requiring that four quarterly upgradient samples from a single well and single samples from a minimum of three downgradient wells each be divided into four aliquots and treated as if there were $4n$ independent measurements. The net result was that every hazardous waste disposal facility regulated under RCRA was declared "leaking." As an illustration consider the data in Table 3.

Date	**Replicate**				**Average**
	1	2	3	4	
Background					
11/81	7.77	7.76	7.78	7.78	7.77
02/82	7.74	7.80	7.82	7.85	7.80
05/82	7.40	7.40	7.40	7.40	7.40
08/82	7.50	7.50	7.50	7.50	7.50
x_B	7.62				7.62
sd_B	0.18				0.20
n_B	16				4
Monitoring					
09/83	7.39	7.40	7.38	7.42	7.40
x_B	7.40				7.40
sd_B	0.02				
n_B	4				1

Table 3: Illustration of pH data used in computing the CABF ***t***-test

Note that the aliquots are almost perfectly correlated and add virtually no independent information, yet they are assumed to be completely independent by the statistic. The CABF *t*-test is computed as:

$$t = \frac{x_B - x_M}{\sqrt{\frac{s^2{}_B}{n_B} + \frac{s^2{}_M}{n_M}}} = \frac{7.62 - 7.40}{\sqrt{\frac{0.032}{16} + \frac{0.0004}{4}}} = \frac{0.22}{0.05} = 4.82$$

The associated probability of this test statistic is 1 in 10,000 indicating that the chance that the new monitoring measurement came from the same population as the background measurements is 1 in 10,000. Note that in fact, the mean concentration of the four aliquots for the new monitoring measurement is identical to one of the four mean values for background (*i.e.,* 7.4), suggesting that intuitively the probability is closer to 1 in 4 rather than 1 in 10,000. Averaging the aliquots, which should have never been split in the first place, yields the statistic:

$$t = \frac{x_B - x_M}{s_B\sqrt{\frac{1}{n_B} + 1}} = \frac{7.62 - 7.40}{0.20\sqrt{\frac{1}{4} + 1}} = \frac{0.22}{0.22} = 1$$

which has an associated probability of 1 in 2. Had the sample size been increased to N_B=20 the probability would have decreased to 1 in 3. In 1988 U.S. EPA recognized this flaw and changed this regulation (see USEPA 1988).

Control of False Positive Rate by Constituent

Site-wide false positive and false negative rates are more important than choice of statistic; nonetheless, certain statistics make it impossible to control the site-wide false positive rate because the rate is controlled separately for each constituent (*e.g.*, parametric and nonparametric ANOVA—see USEPA 1992 section 5.2.1). The only important false positive rate is the one which includes all monitoring wells and all constituents, since any single exceedance can trigger an assessment. This criterion impacts greatly on the selection of statistical method. These error rates are dependent on the number of wells, number of constituents, number of background measurements, type of comparison (*i.e.*, intra-well versus inter-well), distributional form of the constituents, detection frequency of the constituents and the individual comparison false positive rate of the statistic being used. Invariably, this leads to a problem in interval estimation the solution of which is typically a prediction limit that incorporates the effects of verification resampling as well as multiple comparisons introduced by both multiple monitoring wells and multiple monitoring constituents.

Restriction of Background Samples

Certain states have interpreted the Subtitle D regulation as indicating that background be confined to the first four samples collected in a day or a semi-annual monitoring event or a year. The first approach (*i.e.*, four samples in a day) violates the assumption of independence and confounds day-to-day temporal and seasonal variability with potential contamination. As an analogy, consider setting limits on yearly ambient temperatures in Chicago by taking four temperature readings on July 4th. Say the temperature varied between 75 and 85 degrees on that day yielding a prediction interval from 70 to 90 degrees. As I write this, the temperature in Chicago is -20 degrees. Something is clearly amiss. In the second example of restricting background to the first four events taken in 6 months, the measurements may be independent if ground water flows fast enough, but seasonal variability is confounded with contamination. The net result is that comparisons of background water quality in the summer may not be representative of point of compliance water quality in the winter (*e.g.*, disposal of road salts increasing conductivity in the winter). In the third example in which background is restricted to the first four quarterly measurements, independence is typically not an issue and background versus point-of-compliance monitoring well comparisons are not confounded with season. However, as previously pointed out, restriction of background to only four samples dramatically increases the size of the statistical prediction limit thereby increasing the false negative rate of the test (*i.e.*, the prediction limit is over five standard deviation units above the background mean concentration). The reason for this is that the uncertainty in the true mean concentration covers the majority of the normal distribution. As such we could obtain virtually any mean and standard deviation by chance alone. If by chance the values are low, false positive results will occur. If by chance the values are high, false negative results will occur. By increasing the background sample size, uncertainty in the sample based mean and standard deviation decrease as does the size of the prediction limit, therefore both false positive and false negative rates are minimized. Furthermore, use of statistical outlier detection procedures applied to the background data will remove the possibility of spurious background results falsely inflating the size of the prediction limit.

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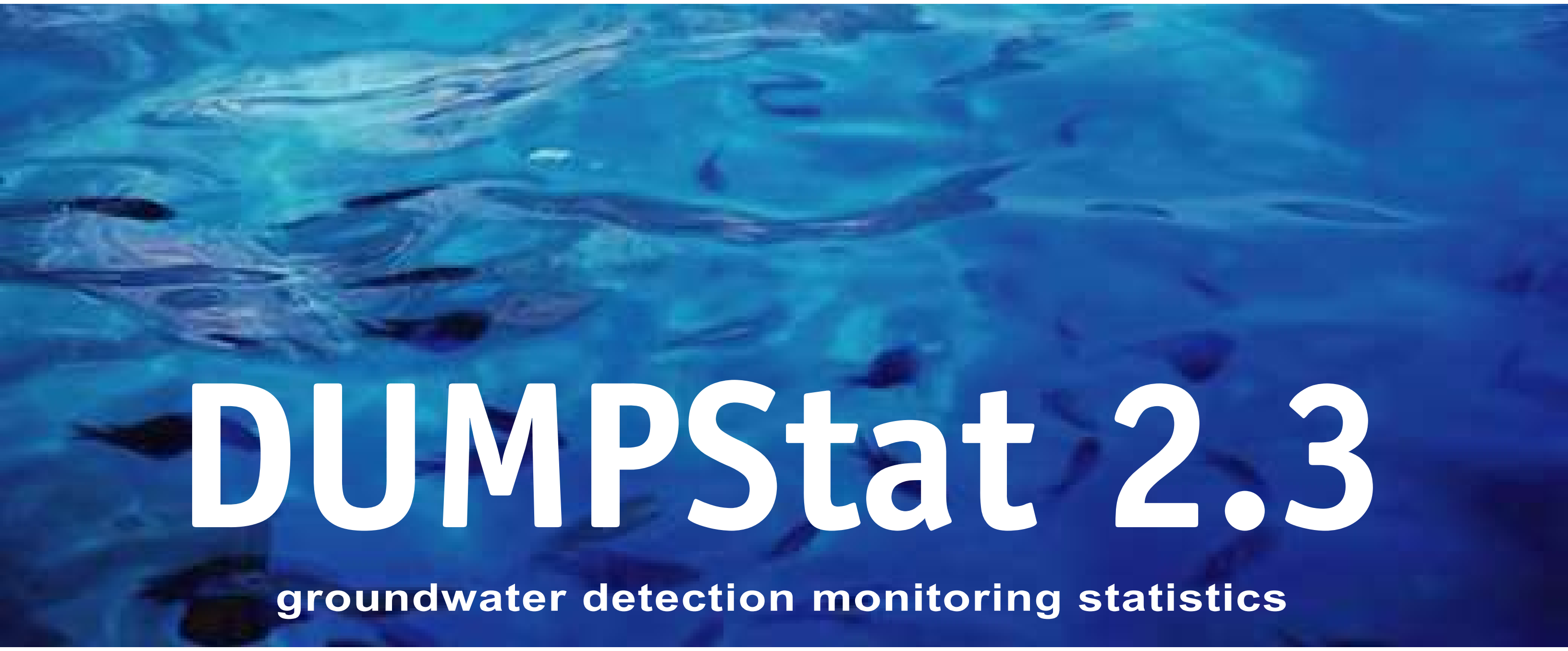
Attachment B

DUMPStat 2.3 Release Notes



DUMPStat 2.3

groundwater detection monitoring statistics

RELEASE NOTES

DUMPStat

Release Notes

Version 2.3

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Changes since version 2.1.8 7

DUMPStat 2.3 Release Notes

These release notes cover all the changes made to DUMPStat since version 2.1.8 as well as documentation updates from the 2.1.8 User's and Statistical Guides.

Changes since version 2.1.8

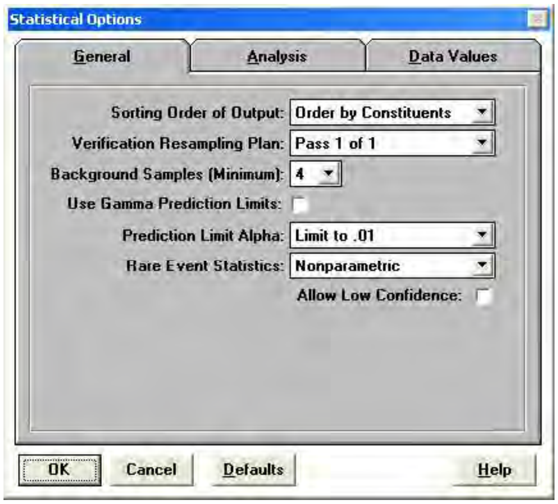
Statistical Options

See "Statistical Options" on page 37 of the *User's Guide.*

The Statistical Options dialog's new layout includes three new tabs, General, Analysis and Data Values. These provide better organization of the existing statistical options, and of the new ones described below.

General Options

The General tab contains settings that affect the majority of the analyses and their output.



Sorting Order of Output: Order by Constituents
Verification Resampling Plan: Pass 1 of 1
Background Samples (Minimum): 4
Use Gamma Prediction Limits: ☐
Prediction Limit Alpha: Limit to .01
Rare Event Statistics: Nonparametric
Allow Low Confidence: ☐

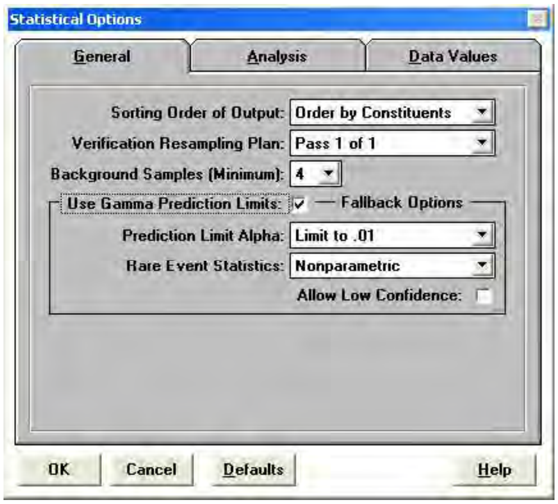
Figure 1

Use Gamma Prediction Limits

See "Use Gamma Prediction Limits" on page 38 of the *User's Guide.*

The Use Gamma Prediction Limits option specifies that an upper prediction limit based on a gamma distribution should be computed instead of a normal distribution, nonparametric or Poisson prediction limit in the Up vs. Down and Intra-Well Prediction Limits, and Intra-Well Control Charts analyses.

When Use Gamma Prediction Limits is checked, the Prediction Limit Alpha, Rare Event Statistics and Allow Low Confidence options are labelled Fallback Options to indicate that they may be used to determine the type of limit to calculate in those cases where a gamma limit cannot be computed (*e.g.* due to very small variance in the data).



Sorting Order of Output: Order by Constituents

Verification Resampling Plan: Pass 1 of 1

Background Samples (Minimum): 4

Use Gamma Prediction Limits: ☑

Fallback Options

Prediction Limit Alpha: Limit to .01

Rare Event Statistics: Nonparametric

Allow Low Confidence: ☐

Figure 2

The default setting is unchecked to preserve consistency with previous versions.

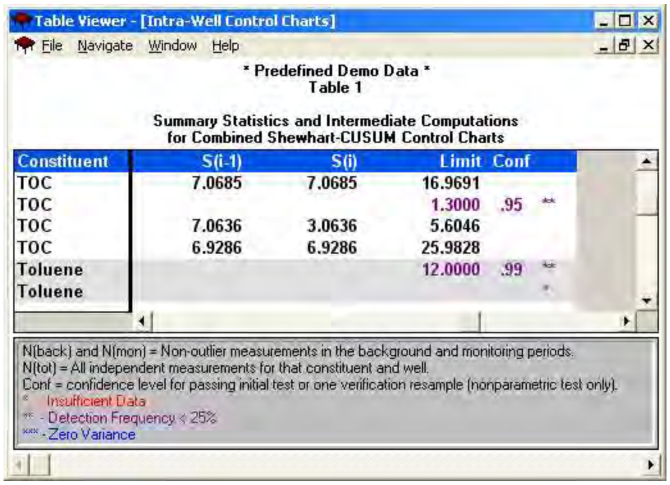
Allow Low Confidence

See “Allow Low Confidence” on page 39 of the *User’s Guide.*

Allow Low Confidence eliminates the requirement that enough background samples are present for computing nonparametric prediction limits with 99% confidence in Intra-well analyses.

This option is available only when the Rare Event Statistics selection is Nonparametric.

The confidence level for the computed nonparametric limit is shown in a new Conf column in the summary tables.



* Predefined Demo Data *
Table 1

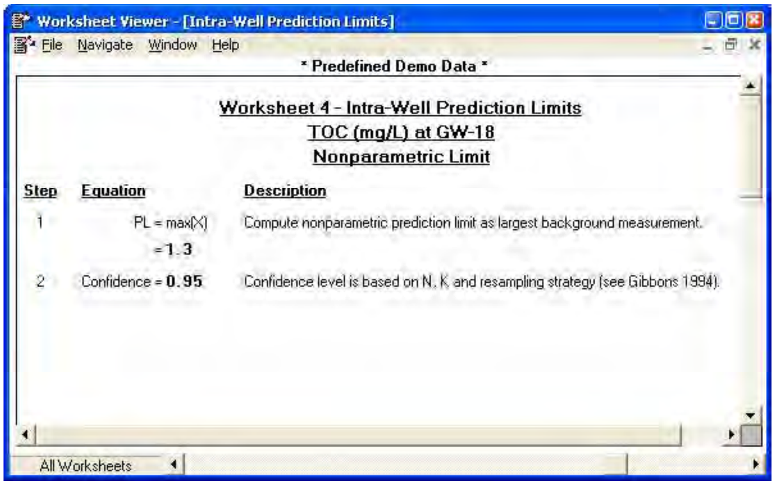
Summary Statistics and Intermediate Computations
for Combined Shewhart-CUSUM Control Charts

Constituent	S(i-1)	S(i)	Limit	Conf	
TOC	7.0685	7.0685	16.9691		
TOC			1.3000	.95	**
TOC	7.0636	3.0636	5.6046		
TOC	6.9286	6.9286	25.9828		
Toluene			12.0000	.99	**
Toluene					*

N(back) and N(mon) = Non-outlier measurements in the background and monitoring periods.
N(tot) = All independent measurements for that constituent and well.
Conf = confidence level for passing initial test or one verification resample (nonparametric test only).
* Insufficient Data
** - Detection Frequency < 25%
*** - Zero Variance

Figure 3

The confidence level is also displayed on the worksheets.



* Predefined Demo Data *

Worksheet 4 - Intra-Well Prediction Limits
TOC (mg/L) at GW-18
Nonparametric Limit

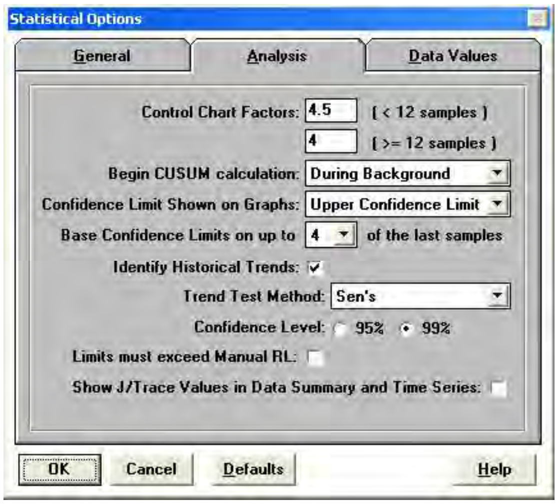
Step	Equation	Description
1	PL = max(X) = **1.3**	Compute nonparametric prediction limit as largest background measurement.
2	Confidence = **0.95**	Confidence level is based on N, K and resampling strategy (see Gibbons 1994).

Figure 4

The default setting is unchecked to preserve consistency with previous versions.

Analysis Options

The Analysis tab contains settings that allow further customization of the parameters and statistical methods used in the statistical analyses.



Control Chart Factors: 4.5 (< 12 samples)
4 (>= 12 samples)
Begin CUSUM calculation: During Background
Confidence Limit Shown on Graphs: Upper Confidence Limit
Base Confidence Limits on up to 4 of the last samples
Identify Historical Trends: ☑
Trend Test Method: Sen's
Confidence Level: ○ 95% ● 99%
Limits must exceed Manual RL: ☐
Show J/Trace Values in Data Summary and Time Series: ☐

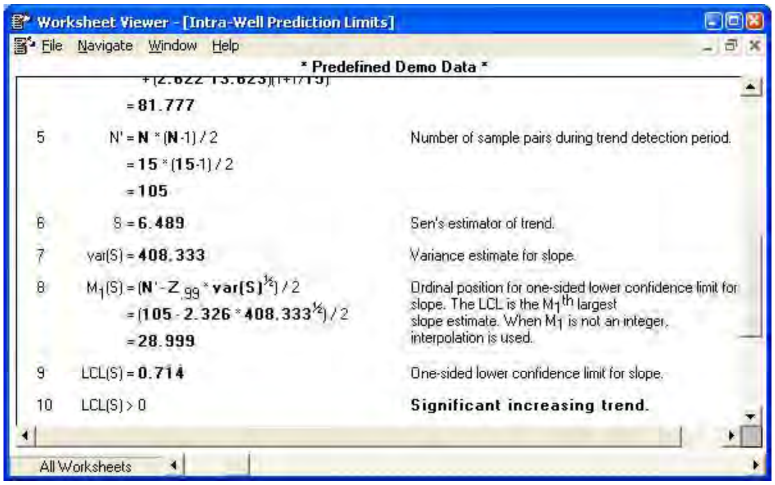
Figure 5

Trend Test Method

See "Trend Test Method" on page 41 of the *User's Guide.*

Trend Test Method specifies whether to perform the Sen's test of trend or the Mann-Kendall test when identifying historical trends.

Detailed trend test information is displayed on the worksheets.



* Predefined Demo Data *

```
         =81.777

5      N' = N * (N-1) / 2                Number of sample pairs during trend detection period.
          = 15 * (15-1) / 2
          = 105

6       S = 6.489                        Sen's estimator of trend.

7  var(S) = 408.333                      Variance estimate for slope.

8   M1(S) = (N' - Z.99 * var(S)½) / 2    Ordinal position for one-sided lower confidence limit for
          = (105 - 2.326 * 408.333½) / 2 slope. The LCL is the M1th largest
          = 28.999                       slope estimate. When M1 is not an integer,
                                         interpolation is used.

9  LCL(S) = 0.714                        One-sided lower confidence limit for slope.

10 LCL(S) > 0                            Significant increasing trend.
```

Figure 6

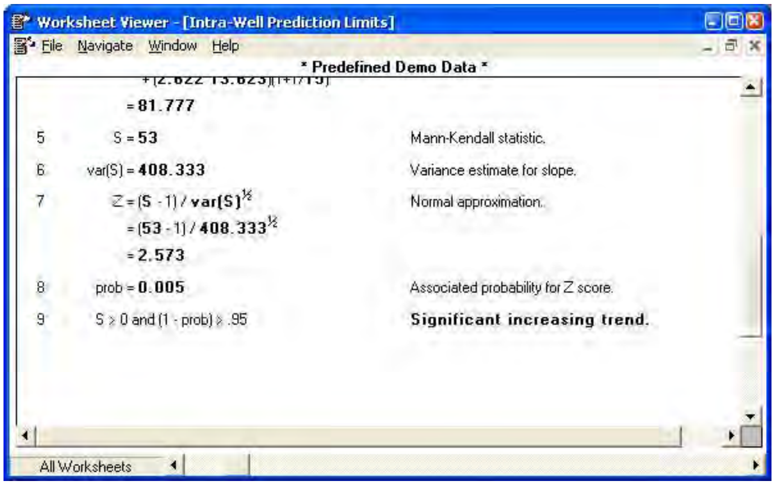
The default setting is Sen's to preserve consistency with previous versions.

Confidence Level

See “Confidence Level” on page 41 of the *User’s Guide.*

Confidence Level specifies whether 95% or 99% confidence is required when identifying historical trends.

Detailed trend test information is displayed on the worksheets.



* Predefined Demo Data *

```
            =81.777
5        S = 53                          Mann-Kendall statistic.
6   var(S) = 408.333                     Variance estimate for slope.
7        Z = (S - 1) / var(S)½           Normal approximation.
           = (53 - 1) / 408.333½
           = 2.573
8     prob = 0.005                       Associated probability for Z score.
9     S > 0 and (1 - prob) > .95         Significant increasing trend.
```

Figure 7

The default setting is 99% to preserve consistency with previous versions.

Limits must exceed Manual RL

See “Limits must exceed Manual RL” on page 41 of the *User’s Guide.*

When ‘Limits must exceed Manual RL’ is checked and the manual reporting limit is greater than the computed limit, the constituent’s manual reporting limit is displayed on graphs and worksheets instead of the computed limit. The constituent must have a manual reporting limit specified and Enable Manual Reporting Limits must also be checked.

Reporting Limits:

Search for:

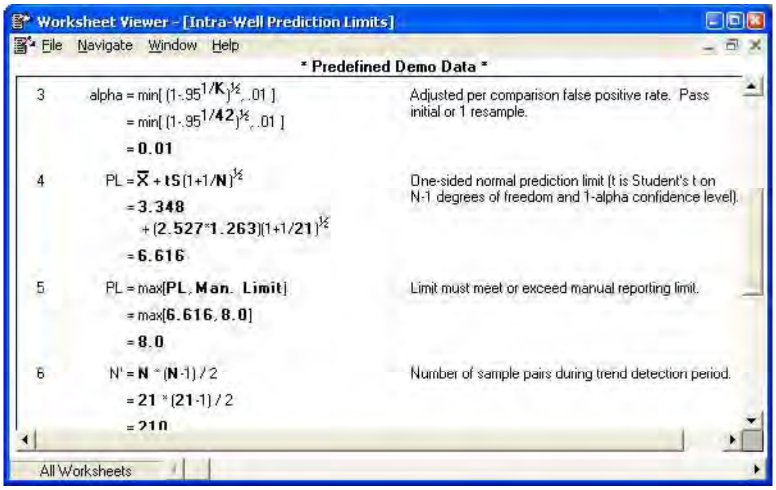
Limit	Unit	Constituent
	ug/L	Benzene
	mg/L	Chloride
	ppm	CO2
	ppm	Methane
		pH
	ppm	SO2
	mg/L	Sodium
	umho	Sp cond
	mg/L	Sulfate

Manual Limit: 8 mg/L

Enable Manual Reporting Limits: ☑

Figure 8

In the previous example, when the computed limit is less than 8 mg/L for Chloride at a particular sample point, the limit is shown on the graph as a horizontal line at 8 and more detail is provided in steps 4 and 5 of the worksheet.



* Predefined Demo Data *

3 $\text{alpha} = \min[\,(1-.95^{1/K})^{½}, .01\,]$
$= \min[\,(1-.95^{1/42})^{½}, .01\,]$
$= 0.01$
Adjusted per comparison false positive rate. Pass initial or 1 resample.

4 $PL = \bar{X} + tS(1+1/N)^{½}$
$= 3.348 + (2.527*1.263)(1+1/21)^{½}$
$= 6.616$
One-sided normal prediction limit (t is Student's t on N-1 degrees of freedom and 1-alpha confidence level).

5 PL = max[PL, Man. Limit]
= max[6.616, 8.0]
= 8.0
Limit must meet or exceed manual reporting limit.

6 $N' = N * (N-1) / 2$
$= 21 * (21-1) / 2$
$= 210$
Number of sample pairs during trend detection period.

Figure 9

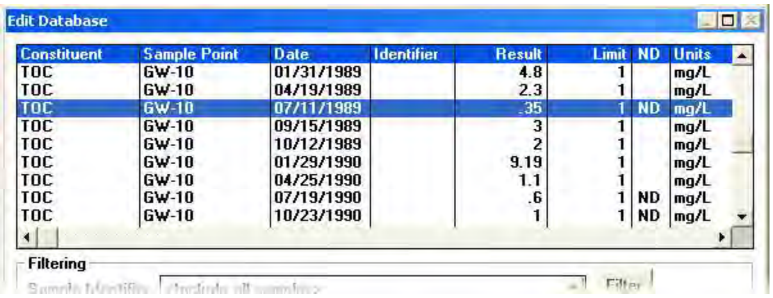
The default setting is unchecked to preserve consistency with previous versions.

Show J/Trace Values in Data Summaries and Time Series

See "Show J/Trace Values in Data Summary and Time Series" on page 42 of the *User's Guide.*

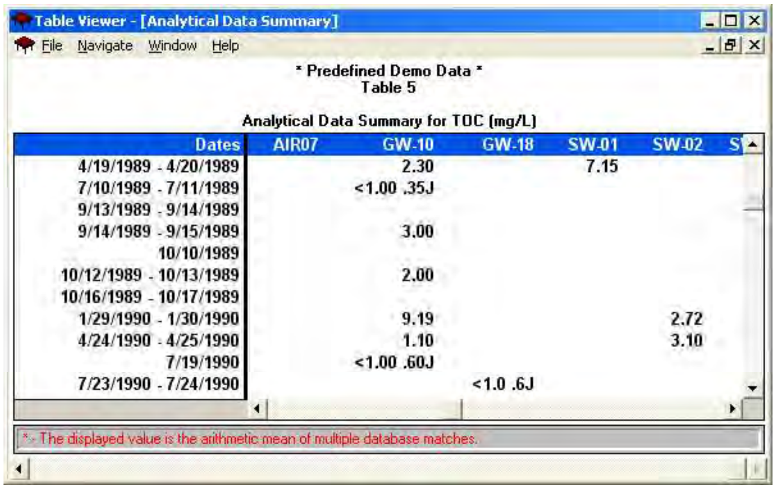
When 'Show J/Trace Values in Data Summaries and Time Series' is checked the Analytical Data Summary table displays both the Limit and the Result values of a nondetect sample that has a non-zero Result value that is different from its Limit.

> *Example: <1.0 .35J will be displayed for a nondetect TOC sample at GW-10 on 7/11/1989 that has a reporting limit of 1.0 and a result of .35. See Fig. 11.*



Constituent	Sample Point	Date	Identifier	Result	Limit	ND	Units
TOC	GW-10	01/31/1989		4.8	1		mg/L
TOC	GW-10	04/19/1989		2.3	1		mg/L
TOC	GW-10	07/11/1989		.35	1	ND	mg/L
TOC	GW-10	09/15/1989		3	1		mg/L
TOC	GW-10	10/12/1989		2	1		mg/L
TOC	GW-10	01/29/1990		9.19	1		mg/L
TOC	GW-10	04/25/1990		1.1	1		mg/L
TOC	GW-10	07/19/1990		.6	1	ND	mg/L
TOC	GW-10	10/23/1990		1	1	ND	mg/L

Figure 10



* Predefined Demo Data *
Table 5

Analytical Data Summary for TOC (mg/L)

Dates	AIR07	GW-10	GW-18	SW-01	SW-02	S
4/19/1989 - 4/20/1989		2.30		7.15		
7/10/1989 - 7/11/1989		<1.00 .35J				
9/13/1989 - 9/14/1989						
9/14/1989 - 9/15/1989		3.00				
10/10/1989						
10/12/1989 - 10/13/1989		2.00				
10/16/1989 - 10/17/1989						
1/29/1990 - 1/30/1990		9.19			2.72	
4/24/1990 - 4/25/1990		1.10			3.10	
7/19/1990		<1.00 .60J				
7/23/1990 - 7/24/1990			<1.0 .6J			

* - The displayed value is the arithmetic mean of multiple database matches.

Figure 11

The Time Series graph displays the J/Trace symbol ▣ at the sample's Result value and the line connecting the samples is drawn through the sample's Limit value.

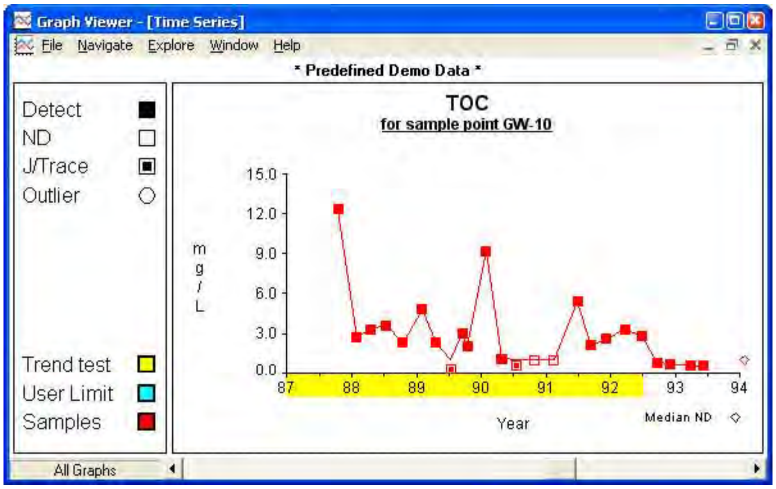
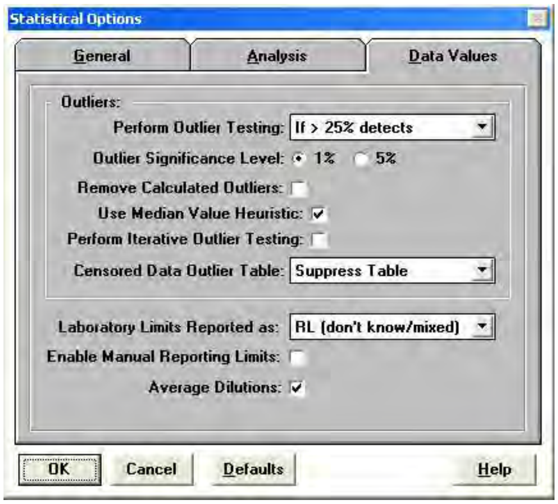


Figure 12

The default setting is unchecked to preserve consistency with previous versions.

Data Value Options

The Data Values tab contains settings that specify how samples are treated in the analyses or displayed on the analysis output.



Outliers:

Perform Outlier Testing: If > 25% detects

Outlier Significance Level: ● 1% ○ 5%

Remove Calculated Outliers: ☐

Use Median Value Heuristic: ☑

Perform Iterative Outlier Testing: ☐

Censored Data Outlier Table: Suppress Table

Laboratory Limits Reported as: RL (don't know/mixed)

Enable Manual Reporting Limits: ☐

Average Dilutions: ☑

Figure 13

Outlier Significance Level

See “Outlier Significance Level” on page 43 of the *User’s Guide.*

Outlier Significance Level allows the selection of 1% or 5% for the significance level used in the Dixon’s outlier test. The selected significance level is displayed in the subtitle of the Dixon’s Test Outliers table in the Up vs Down and Intra-Well analyses.

The default selection is 1% to preserve consistency with previous versions.

Remove Calculated Outliers

See “Remove Calculated Outliers” on page 43 of the *User’s Guide.*

Remove Calculated Outliers excludes samples identified as outliers from further statistical tests, such as the calculation of a prediction limit.

When unchecked, two additional statistical options become available: Use Median Value Heuristic and Perform Iterative Outlier Testing. Outlier testing is still performed and a report of the samples identified as outliers is provided in the Dixon’s Test Outliers table, but these samples are not excluded from statistical tests.

The default setting is checked to preserve consistency with previous versions.

Use Median Value Heuristic

See “Use Median Value Heuristic” on page 43 of the *User’s Guide.*

Use Median Value Heuristic ensures that only Dixon’s test outliers that are also greater than or equal to three times the median or less than or equal to a third of the median are treated as calculated outliers.

This option can only be unchecked when calculated outliers are not excluded from statistical tests. When unchecked, Dixon's Test Outliers table provides a report of samples that meet the Dixon's outlier test criteria, but do not need to be larger or lower with respect to the median value.

Previously a median value heuristic of 10 was used in the Up vs. Down Prediction Limits analysis.

The default setting is checked to preserve consistency with previous versions. If the Remove Calculated Outliers option is checked the additional median value test is performed regardless of the Use Median Value Heuristic setting.

Perform Iterative Outlier Testing

See "Perform Iterative Outlier Testing" on page 43 of the *User's Guide.*

When calculated outliers are not excluded from statistical tests, Perform Iterative Outlier Testing causes the Dixon's outlier test to be performed repeatedly on a data set after eliminating the outliers found in each previous test instance. Whether the median value heuristic is performed as part of this test depends on the Use Median Value Heuristic selection.

The default setting is unchecked to preserve consistency with previous versions. If the Remove Calculated Outliers option is checked outlier testing is performed only once regardless of the Perform Iterative Outlier Testing setting.

Censored Data Outlier Table

See "Censored Data Outlier Table" on page 44 of the *User's Guide.*

When Show All Results or Show Relevant Only is selected, an additional test is performed to identify potential outliers in data sets that are comprised of 75% or more nondetects as per the Ohio Environmental Protection Agency's guidance. The potential outliers identified by this test are reported in the Censored Data Outliers Test table, but are not excluded from statistical tests.

The default setting is Suppress Table to preserve consistency with previous versions.

Field Codes

See "Field Codes" on page 180 of the *User's Guide.*

The following field codes have been added to help indicate the selection status of several new statistical options in table titles or analysis headers:

- **<TrendEstimator>** – Trend Test Method: 'Sen's Test' or 'Mann-Kendall'
- **<TrendConfLevel>** – Confidence Level: '95%' or '99%'
- **<DixonSigLevel>** – Outlier Significance Level: '1%' or '5%'
- **<GammaPL>** – Use Gamma Prediction Limits: enabled or disabled
- **<ManualOverridesRL>** – Limits must exceed Manual RL

See “Sample Identifiers” on page 25.

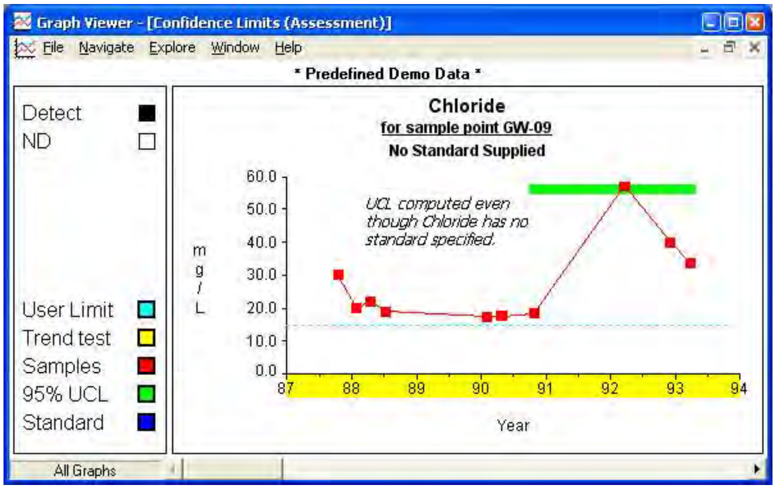
The **<ManualOutliers>** field code has become obsolete due to the introduction of Sample Identifiers. If previously in use, it will be evaluated to ‘Manual Outliers are now ID specific.’

A new **<TableItem>** field code is evaluated to the ‘Base tables on a unique...’ selection on the Set Analytical Data Summary Layout dialog.

Analyses

Confidence Limits (Assessment)

The Confidence Limits (Assessment) analysis can now be performed on constituents that do not have a standard specified on the Select Assessment Constituents and Standards dialog. This is indicated on the graph through a ‘No Standard Supplied’ third title line.



Chloride
for sample point GW-09
No Standard Supplied

UCL computed even though Chloride has no standard specified.

Figure 14

Intra-Well Control Charts

The title displayed on printed graphs and worksheets has been changed to “Intra-Well Control Charts / Prediction Limits” to account for either a nonparametric prediction limit or a Poisson limit being computed when the detection frequency is less than 25%.

Previously the title was “Intra-Well Control Charts.”

Statistical Methods

Dixon's Outlier Test

See "Outlier Detection" on page 22 of the *Statistical Guide.*

The Dixon's Outlier Test has been modified to analyze all background samples, as opposed to the most recent 25 background samples.

Additional improvements include increased critical value precision and the ability to choose between a 1% and a 5% outlier significance level. Previously a 1% outlier significance level was used.

The results are displayed in a Dixon's Test Outliers table (Fig. 18).

Censored Data Outlier Testing

See "Censored Data Outlier Testing" on page 23 of the *Statistical Guide.*

The Censored Data Outlier Test was developed as per the Ohio Environmental Protection Agency's guidance, to provide an automated way of performing one of the tests used to identify outliers in data sets that are comprised of 75% or more nondetects.

Whether a detected measurement is identified as a potential outlier by this test depends on:

- the number of detected measurements,
- the percentage of detections above the MDL (Method Detection Limit),
- and the detected sample being either the highest value, or higher than the PQL (Practical Quantitation Limit) by a certain factor.

All the potential outliers found are reported in the Censored Data Outliers Test table (Fig. 19), but are not excluded from other statistical tests.

Trend Testing

See "Trend Detection" on page 24 of the *Statistical Guide.*

Trend testing has been modified to allow the selection of the trend test method from Sen's or Mann-Kendall, and the confidence level as 95% or 99%. Previously a 99% confidence Sen's test of trend was performed when identifying historical trends.

More detailed information is provided in the worksheets to better illustrate the steps taken in determining whether a trend is significant.

Sen's Test of Trend

The Sen's Test of Trend was modified to take into consideration the sampling date of each measurement when computing the slope estimate. Previously the slope estimate was based on the order of the measurement within the chronologically sorted set of measurements, and assumed that all measurements were sampled at regular intervals.

Mann-Kendall Test

The Mann-Kendall test was developed as per methodology described in Statistical Methods for Groundwater Monitoring by Robert D. Gibbons.

Gamma Prediction Limits

See “Gamma Prediction Limits” on page 26 of the *Statistical Guide.*

The Gamma Prediction Limits test was developed as per methodology described in “Simultaneous Gamma Prediction Limits for Ground Water Monitoring Applications” by Robert D. Gibbons and Dulal K. Bhaumik. It provides a more statistically powerful alternative to the normal, lognormal and nonparametric approaches commonly used, in those cases where the data are not normally distributed.

Gamma prediction limits are remarkably robust to censoring of the data based on limits of detection, and the use of the gamma distribution permits association between the mean and variance of the distribution, a phenomenon commonly observed in practice. Furthermore, the gamma distribution permits analysis of skewed distributions, only some of which were previously amenable to computation based on a lognormal assumption.

Gamma Prediction Limits can be computed in the following analyses:

- Up vs. Down Prediction Limits and Power
- Intra-Well Control Charts, Sublist and Power for those comparisons where the detection frequency is less than 25%
- Intra-Well Prediction Limits, Sublist and Power

Nonparametric Prediction Limits

See “Nonparametric Prediction Limits” on page 27 of the *Statistical Guide.*

When the background period consists entirely of nondetected samples (*i.e.,* 100% NDs), a detected sample in the monitoring period that has a Result value equal to the nonparametric prediction limit will be flagged as an exceedance.

Graph Viewer

New Options

Vertical Axis Offset

See “Vertical Offset” on page 182 of the *User’s Guide.*

Vertical Axis Offset specifies where the vertical axis starts when displaying or printing a graph that uses linear vertical scaling. The selections available are Fixed at 0, Floating and Auto. When Floating, the vertical axis starts and ends such that all data are included for the current graph, with minimal blank space at the bottom and top. This is useful for data sets comprised of large closely related values.

In the graph below, the vertical axis starts at 400 instead of 0, just below the lowest sample value. This results in a clearer picture of all the samples and their relation to the standard and confidence limit, rather than having them all compressed in the top half of a 0 to 1000 vertical axis.

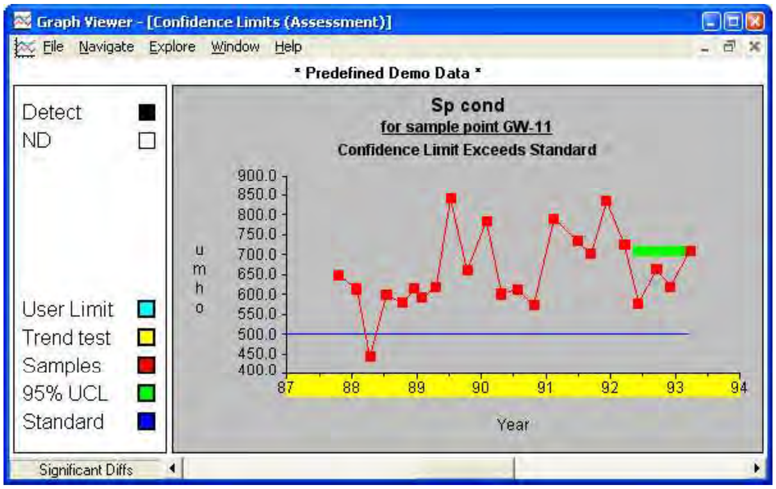


Figure 15

Vertical Axis Offset can be found on the Graph Viewer's File menu and on the Page Layout dialog.

Order By

See "Order By" on page 143 of the *User's Guide.*

The graphs produced by a specific analysis can be ordered by Constituent or Sample Point from within the Graph Viewer without having to re-run that analysis. Previously this change could only be made through the Sorting Order of Output setting on the Statistical Options dialog, but the analysis had to be performed again in order for the change to be reflected in the output.

Order By can be found on the Graph Viewer's Navigate menu.

Export Current Graph

See "Export Current Graph" on page 140 of the *User's Guide.*

Export Current Graph saves the current graph in the Windows Metafile (*.wmf) graphics file format. The saved file can be imported into other applications such as word processors or presentation programs.

Export Current Graph can be found on the Graph Viewer's File menu.

Copy to Clipboard

See "Copy to Clipboard" on page 140 of the *User's Guide.*

Copy to Clipboard allows the pasting of an image of the current graph into other applications such as word processors, presentation or image editing programs.

Copy to Clipboard can be found on the Graph Viewer's File menu.

Symbol Size

See "Page Layout" on page 137 of the *User's Guide.*

Symbol Size on the Page Layout dialog allows customization of printed output.

Line Thickness

See "Page Layout" on page 137 of the *User's Guide.*

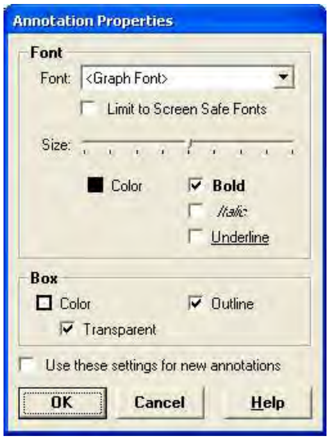
Line Thickness on the Page Layout dialog allows customization of printed output.

Annotations

See "Annotations" on page 143 of the *User's Guide.*

Annotations provide a way to display and print customizable text notes on graphs. They can be edited, moved, resized, brought to front or sent to back, and deleted from a particular graph.

Properties such as font, font size, color and style, and box outline, background color and transparency can also be configured for a specific annotation on the Annotation Properties dialog, and used as default settings for all future annotations added.



Annotation Properties

Font

Font: <Graph Font>

☐ Limit to Screen Safe Fonts

Size:

■ Color

☑ **Bold**

☐ *Italic*

☐ Underline

Box

□ Color

☑ Transparent

☑ Outline

☐ Use these settings for new annotations

Figure 16

In Fig. 17, the following three annotations were added, each with different display properties:

- Limit - Helvetica Italic font, transparent box without an outline
- Lab error - Helvetica blue font, light yellow box without an outline
- Rainfall - Bold <Graph font>, transparent box with outline

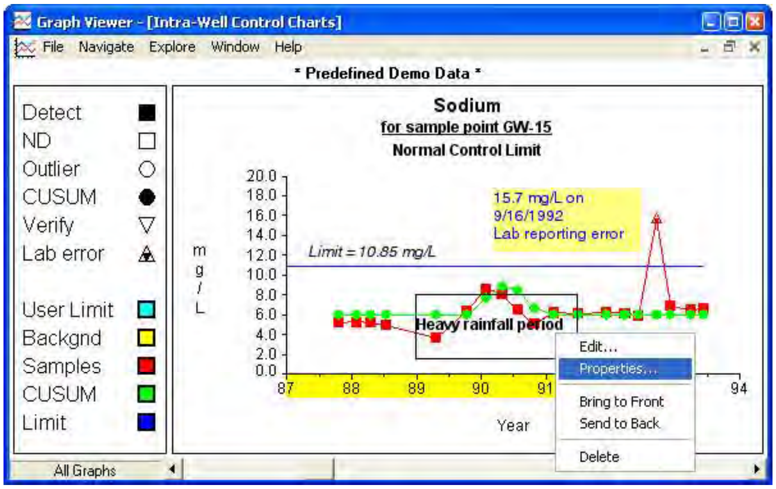


Figure 17

Annotations are saved for the current analysis, constituent and sample point, so that even if the Graph Viewer is closed, the analysis is performed again, or the associated constituent or sample point is aliased, the annotations are still present the next time the analysis output file is opened in the Graph Viewer.

Modifications

Vertical Axis Override

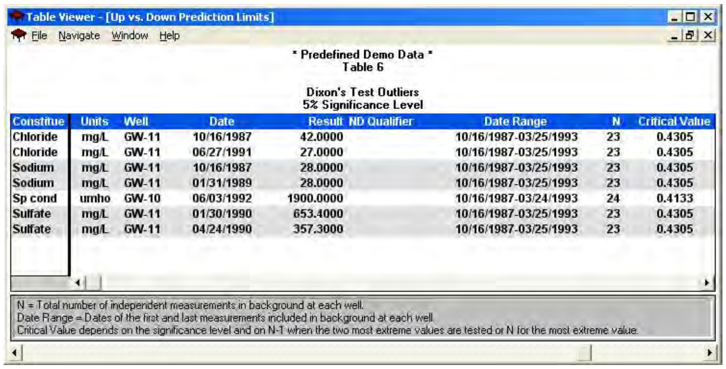
The vertical axis scaling and offset selected can be overridden for the current graph by clicking anywhere in the label section to the left of the vertical axis. This cycles through the linear fixed at 0, logarithmic and linear floating display modes.

To ensure consistency in display when navigating from the current graph to another, the scaling and offset settings are reset to those selected on the File menu or on the Page Layout dialog.

New Tables

Dixon’s Test Outliers

Dixon’s Test Outliers is a new table produced by the Up vs Down Prediction Limits and Intra-Well analyses. It displays all the samples identified as outliers by the Dixon’s test.



* Predefined Demo Data *
Table 6

Dixon's Test Outliers
5% Significance Level

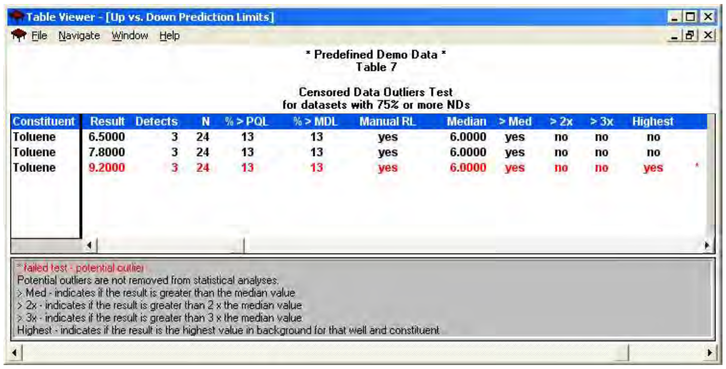
Constitue	Units	Well	Date	Result	ND Qualifier	Date Range	N	Critical Value
Chloride	mg/L	GW-11	10/16/1987	42.0000		10/16/1987-03/25/1993	23	0.4305
Chloride	mg/L	GW-11	06/27/1991	27.0000		10/16/1987-03/25/1993	23	0.4305
Sodium	mg/L	GW-11	10/16/1987	28.0000		10/16/1987-03/25/1993	23	0.4305
Sodium	mg/L	GW-11	01/31/1989	28.0000		10/16/1987-03/25/1993	23	0.4305
Sp cond	umho	GW-10	06/03/1992	1900.0000		10/16/1987-03/24/1993	24	0.4133
Sulfate	mg/L	GW-11	01/30/1990	653.4000		10/16/1987-03/25/1993	23	0.4305
Sulfate	mg/L	GW-11	04/24/1990	357.3000		10/16/1987-03/25/1993	23	0.4305

N = Total number of independent measurements in background at each well.
Date Range = Dates of the first and last measurements included in background at each well.
Critical Value depends on the significance level and on N-1 when the two most extreme values are tested or N for the most extreme value.

Figure 18

Censored Data Outliers Test

Censored Data Outliers Test is a new table produced by the Up vs Down Prediction Limits and Intra-Well analyses. It displays all the samples identified as potential outliers in data sets that are comprised of 75% or more nondetects as per the Ohio Environmental Protection Agency's guidance.



* Predefined Demo Data *
Table 7

Censored Data Outliers Test
for datasets with 75% or more NDs

Constituent	Result	Detects	N	% > PQL	% > MDL	Manual RL	Median	> Med	> 2x	> 3x	Highest	
Toluene	6.5000	3	24	13	13	yes	6.0000	yes	no	no	no	
Toluene	7.8000	3	24	13	13	yes	6.0000	yes	no	no	no	
Toluene	9.2000	3	24	13	13	yes	6.0000	yes	no	no	yes	*

* failed test - potential outlier
Potential outliers are not removed from statistical analyses.
\> Med - indicates if the result is greater than the median value
\> 2x - indicates if the result is greater than 2 x the median value
\> 3x - indicates if the result is greater than 3 x the median value
Highest - indicates if the result is the highest value in background for that well and constituent

Figure 19

Analytical Data and CUSUM Summary

Analytical Data and CUSUM Summary is a new table produced by the Intra-Well Control Charts and Intra-Well Sublist Control Charts analyses. It displays a detailed report of all the samples and their associated CUSUM values for each constituent and sample point pair, indicating which samples are outliers, in background, or nondetect values replaced by either the median or the manual reporting limit.

Table Improvements

Summary Statistics

The following columns were added to the 'Summary Statistics and Intermediate Computations for Combined Shewart-CUSUM Control Charts' and the 'Summary Statistics and Intermediate Computations for Intra-Well Prediction Limits' tables:

- N(back) – non-outlier measurements in the background period
- N(mon) – non-outlier measurements in the monitoring period
- N(tot) – all independent measurements, including outliers
- R(i-1) and R(i) – the result values of the two most recent samples
- Conf – confidence level for a nonparametric limit

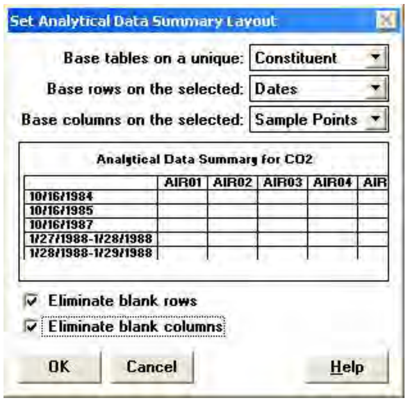
See "Prediction Limit Alpha" on page 39 of the *User's Guide.*

A new column, alpha – indicating the false positive rate, was added to the 'Summary Statistics and Prediction Limits' and the 'Summary Statistics and Intermediate Computations for Intra-Well Prediction Limits' tables.

Analytical Data Summary

Values are displayed using only the required number of decimal places for a constituent and well pair over the entire range of dates, instead of the automatic four decimal places previously used. This greatly improves clarity and saves space when both viewing and printing the Analytical Data Summary table.

The table size can be additionally reduced for both the viewing and printing of tables by choosing to 'Eliminate blank rows' and / or 'Eliminate blank columns', two new options on the Data Summary Layout dialog, prior to running the Analytical Data Summary analysis.



Base tables on a unique: Constituent

Base rows on the selected: Dates

Base columns on the selected: Sample Points

Analytical Data Summary for CO2

	AIR01	AIR02	AIR03	AIR04	AIR
10/16/1984					
10/16/1985					
10/16/1987					
1/27/1988-1/28/1988					
1/28/1988-1/29/1988					

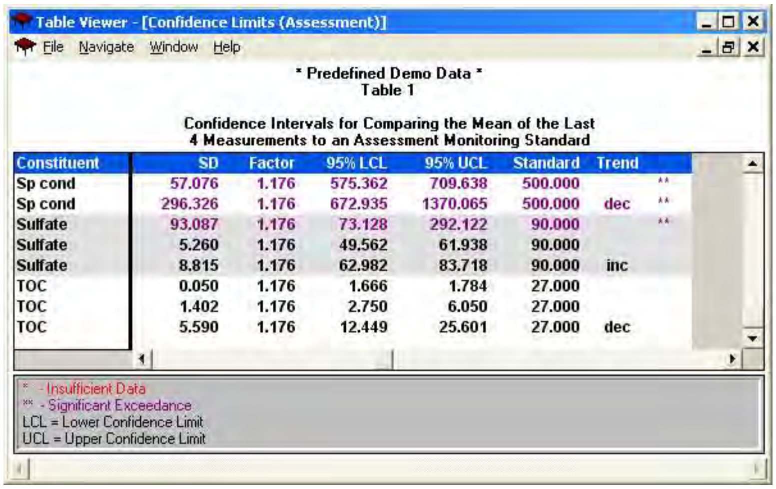
☑ Eliminate blank rows

☑ Eliminate blank columns

Figure 20

Confidence Limits (Assessment)

A Trend column, indicating the detection of a significantly increasing or decreasing trend, was added to the ‘Confidence Intervals for Comparing the Mean of the Last 4 Measurements to an Assessment Monitoring Standard’ table. The Trend column is not displayed when the statistical option Identify Historical Trends is unchecked.



* Predefined Demo Data *
Table 1

Confidence Intervals for Comparing the Mean of the Last
4 Measurements to an Assessment Monitoring Standard

Constituent	SD	Factor	95% LCL	95% UCL	Standard	Trend	
Sp cond	57.076	1.176	575.362	709.638	500.000		**
Sp cond	296.326	1.176	672.935	1370.065	500.000	dec	**
Sulfate	93.087	1.176	73.128	292.122	90.000		**
Sulfate	5.260	1.176	49.562	61.938	90.000		
Sulfate	8.815	1.176	62.982	83.718	90.000	inc	
TOC	0.050	1.176	1.666	1.784	27.000		
TOC	1.402	1.176	2.750	6.050	27.000		
TOC	5.590	1.176	12.449	25.601	27.000	dec	

* - Insufficient Data
** - Significant Exceedance
LCL = Lower Confidence Limit
UCL = Upper Confidence Limit

Figure 21

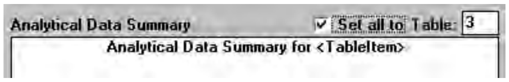
Historical Downgradient Data

Samples tagged with a Sample Identifier whose Exclude property is checked are flagged as ‘*** - Manual exclusion.’ in the Up vs. Down Prediction Limits analysis ‘Historical Downgradient Data for Constituent-Well Combinations that Failed the Current Statistical Evaluation or are in Verification Resampling Mode’ table.

Table Titles

New customizable table titles were added to the Table Titles tab of the Program Option dialog for the new tables previously outlined.

Analytical Data Summary tables can have the same table number, which is easily configurable through the new ‘Set all to ...’ checkbox on the Table Titles tab. In addition, their title can be customized as well.



Analytical Data Summary ☑ Set all to Table: 3
Analytical Data Summary for <TableItem>

Figure 22

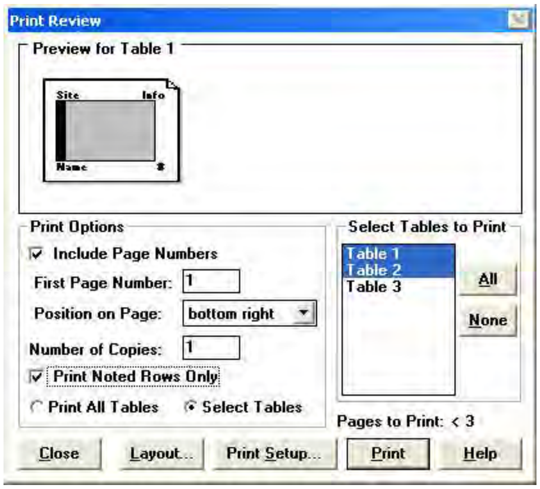
Site Settings

The Statistical Options table has been updated to include the new options described starting on page 7.

Print Noted Rows Only

Print Noted Rows Only specifies that only rows marked with one or more asterisks (*) in the last column will be printed.

This option is available from the Print option on the File menu in the Table Viewer and is unchecked by default to preserve consistency with previous versions.



Print Review

Preview for Table 1

Print Options

☑ Include Page Numbers

First Page Number: 1

Position on Page: bottom right

Number of Copies: 1

☑ Print Noted Rows Only

○ Print All Tables ● Select Tables

Select Tables to Print

Table 1 (selected)

Table 2 (selected)

Table 3

Pages to Print: < 3

Figure 23

Worksheets

Trend Detection

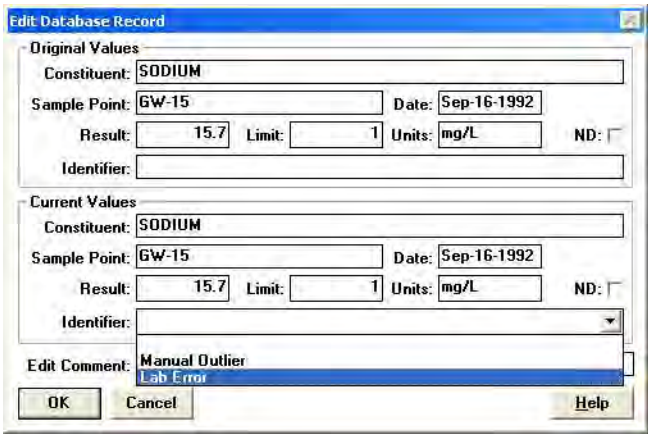
Added intermediate calculations to the trend detection section to provide more detailed information on the trend test method selected, Sen's or Mann-Kendall test, and on the factors taken into consideration when identifying a trend as significant. See Fig. 6 and Fig. 7.

Database

Sample Identifiers

See "Set Sample Identifiers" on page 74 of the *User's Guide.*

When adding or editing a record in the analytical database, an identifier can be specified for that particular sample (Fig. 24).



Edit Database Record

Original Values

Constituent: SODIUM

Sample Point: GW-15 Date: Sep-16-1992

Result: 15.7 Limit: 1 Units: mg/L ND: ☐

Identifier:

Current Values

Constituent: SODIUM

Sample Point: GW-15 Date: Sep-16-1992

Result: 15.7 Limit: 1 Units: mg/L ND: ☐

Identifier:

Edit Comment:

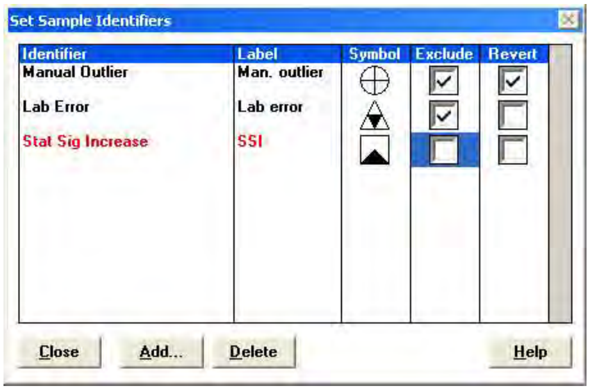
Manual Outlier

Lab Error

Figure 24

A sample identifier's label, symbol, and whether samples tagged with that identifier are being excluded from statistical tests, can be specified on the Set Sample Identifiers dialog. New sample identifiers can be added to help differentiate samples such as statistically significant increases (SSI) on graphs.

In the example below, a Lab Error identifier was previously added to flag laboratory reporting errors and a Statistically Significant Increase identifier is in the process of being added. All points tagged with an identifier can be excluded or included in the statistical tests. Here, SSI samples are being included.



Set Sample Identifiers

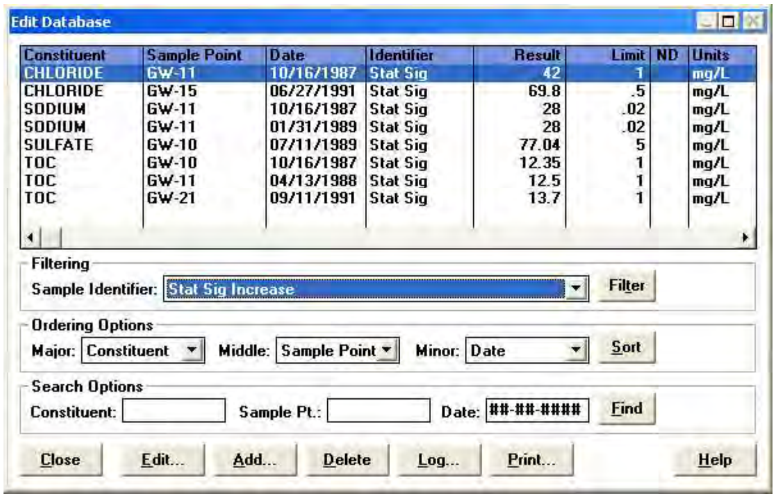
Identifier	Label	Symbol	Exclude	Revert
Manual Outlier	Man. outlier	⊕	☑	☑
Lab Error	Lab error	▲	☑	☐
Stat Sig Increase	SSI	▲	☐	☐

Figure 25

See Appendix A for an example of a printed graph that includes a sample flagged as a Statistically Significant Increase.

Samples that have been previously specified as manual outliers in the database will automatically be converted to a Manual Outlier sample identifier. The Manual Outlier identifier label, symbol and statistical test exclusion setting will be initially set to preserve consistency with previous versions, but can be later modified just like any other newly created sample identifiers.

The database records displayed on the Edit Database menu can now be filtered by sample identifier. The Outlier column was replaced by an Identifier column.



Constituent	Sample Point	Date	Identifier	Result	Limit	ND	Units
CHLORIDE	GW-11	10/16/1987	Stat Sig	42	1		mg/L
CHLORIDE	GW-15	06/27/1991	Stat Sig	69.8	.5		mg/L
SODIUM	GW-11	10/16/1987	Stat Sig	28	.02		mg/L
SODIUM	GW-11	01/31/1989	Stat Sig	28	.02		mg/L
SULFATE	GW-10	07/11/1989	Stat Sig	77.04	5		mg/L
TOC	GW-10	10/16/1987	Stat Sig	12.35	1		mg/L
TOC	GW-11	04/13/1988	Stat Sig	12.5	1		mg/L
TOC	GW-21	09/11/1991	Stat Sig	13.7	1		mg/L

Sample Identifier: Stat Sig Increase

Major: Constituent Middle: Sample Point Minor: Date

Constituent: Sample Pt.: Date: ##-##-####

Figure 26

Edit / Add Comment

See “Editing Records” on page 71 *and* “Adding Records” on page 72 of the *User’s Guide.*

When editing or adding a record in the database a comment can be entered to provide a brief description of that specific database change. The comment can later be viewed when reviewing database changes on the Edit Database Log dialog.

Edit Database Log

See “Print / Export Database Changes” on page 73 of the *User’s Guide.*

The log of database changes available on the Edit Database dialog can now be printed or exported to a text file. The output can be limited to database modifications, additions and / or deletions.

Data Merge

Nondetect records with a blank Result and 0 Limit or a 0 Result and blank Limit can be merged into the database.

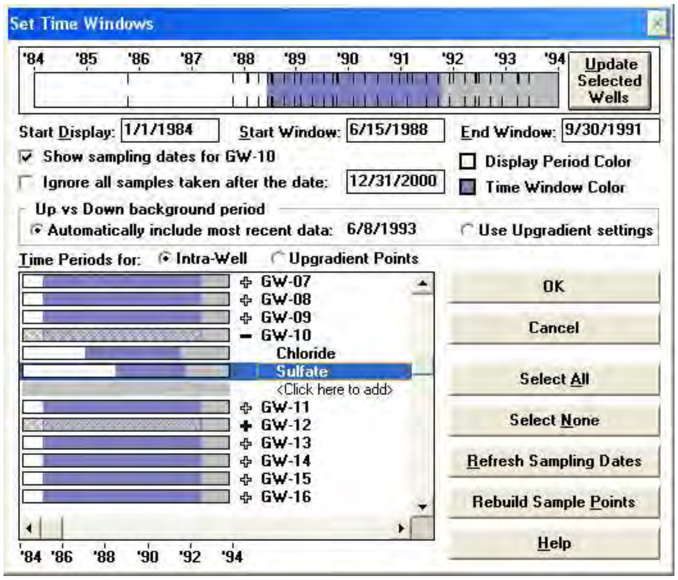
Time Windows

Date Changes

All the dates on the Set Time Windows dialog can be specified to include the day and are displayed in the mm/dd/yyyy format. Dates can still be entered in the previous month-only format, and in many other formats as well: *e.g. 3-6-93; 3/6/93; March 27, 1993; Mar 27, 93; 4 April 1993.*

Per Well Per Constituent

Different Time Windows can be specified for each constituent at a sample point. This is indicated by a plus sign to the left of the sample point name in the Time Periods for Sample Points list. Expanding the plus sign allows the selection of a constituent from a list of available constituents.



Set Time Windows

Start Display: 1/1/1984
Start Window: 6/15/1988
End Window: 9/30/1991
☑ Show sampling dates for GW-10
☐ Ignore all samples taken after the date: 12/31/2000
☐ Display Period Color
▨ Time Window Color
Up vs Down background period
● Automatically include most recent data: 6/8/1993
○ Use Upgradient settings
Time Periods for: ● Intra-Well ○ Upgradient Points

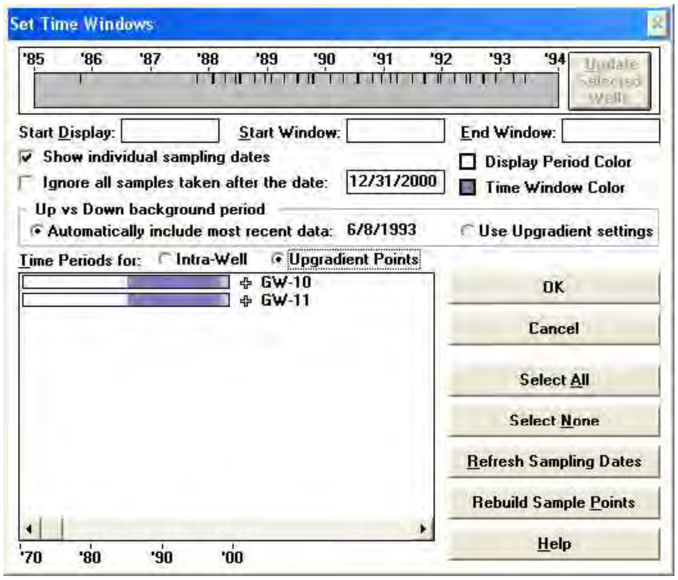
Figure 27

Sample Points that have at least one constituent window specified are displayed with a patterned window graphic and a filled-in plus sign.

Individual Upgradient Time Windows

See “Set Time Windows” on page 97 of the *User’s Guide.*

Time Windows can now be specified for individual upgradient wells, with per constituent overrides, instead of using the site-wide Up vs Down time window. The Time Periods for Sample Points list has been divided into two lists: Intra-Well and Upgradient Points (Fig. 28).



Start Display:

Start Window:

End Window:

☑ Show individual sampling dates

☐ Ignore all samples taken after the date: 12/31/2000

☐ Display Period Color

▨ Time Window Color

Up vs Down background period

● Automatically include most recent data: 6/8/1993 ○ Use Upgradient settings

Time Periods for: ○ Intra-Well ● Upgradient Points

- GW-10
- GW-11

Figure 28

To preserve consistency with previous versions, all upgradient points are initially set to the previously specified Up vs. Down time window, including any constituent overrides.

Zones

When working with a zone file, changing any settings on the Set Time Windows dialog results in the addition of ' (altered)' to the zone name displayed in the lower right corner of the main window.

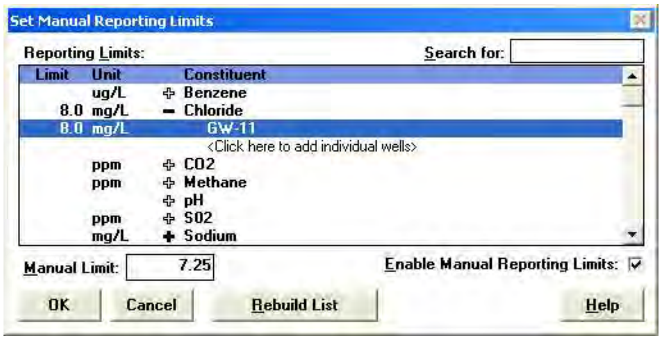
Manual Reporting Limits

Per Constituent Per Individual Well

See "Set Manual Reporting Limits" on page 92 of the *User's Guide.*

Different manual reporting limits can be specified for a constituent at each individual well. This is indicated by a plus sign to the left of the constituent name in the Reporting Limits list. Expanding the plus sign allows the selection of a specific well from a list of available wells.

Constituents that have at least one individual well override specified are displayed with a filled-in plus sign.



Reporting Limits:

Search for:

Limit	Unit	Constituent
	ug/L	+ Benzene
8.0	mg/L	− Chloride
8.0	mg/L	GW-11
		<Click here to add individual wells>
	ppm	+ CO2
	ppm	+ Methane
		+ pH
	ppm	+ SO2
	mg/L	+ Sodium

Manual Limit: 7.25

Enable Manual Reporting Limits: ☑

Figure 29

Individual legend markings identify the Median ND and Manual ND on the Surface Water Monitoring and Air Monitoring graphs to allow for the case in which the constituent has a manual reporting limit defined at one of the two wells, but not the other.

Printing

Print Setup

On certain versions of Microsoft Windows clicking on OK on the Print Setup dialog even if no changes had been made, caused printing of the analysis output to halt. In some instances graphs could be printed, but nothing happened when trying to print tables. The problem persisted until the default printer was reset from Printers and Faxes under the Control Panel.

This issue has been resolved and Print Setup can be used to view or select the destination printer.

Miscellaneous

License Transfer

See “Transfer License” on page 128 of the *User's Guide.*

The software license can be transferred from one computer to another via any type of storage device. Previously the software license could only be transferred via floppy diskette.

Serial Number

In some cases transferring the software license from one computer to another could result in a modified serial number. This serial number was different from the one originally assigned to that software installation.

This issue has been corrected to prevent the modification of the serial number during the license transfer. Any already modified serial numbers (displayed on the System Information dialog) can be reset by contacting Discerning Systems.

Documentation Updates

The following documentation updates contain references to the appropriate page numbers in the PDF versions of the User's and Statistical Guides. As of version 2.3, these guides are distributed in electronic format only.

Printing Format

The page size was changed from 7 x 8.5 inches to 8.5 x 11 to allow printing to standard 8.5 x 11 paper.

Statistical Options

See "Statistical Options" on page 37 of the *User's Guide.*

The Statistical Options section of the User's Guide was updated to reflect the Statistical Options dialog's new tabbed format and options (see "Statistical Options" on page 7).

Statistical Methods

See "Statistical Methods" on page 22 of the *Statistical Guide.*

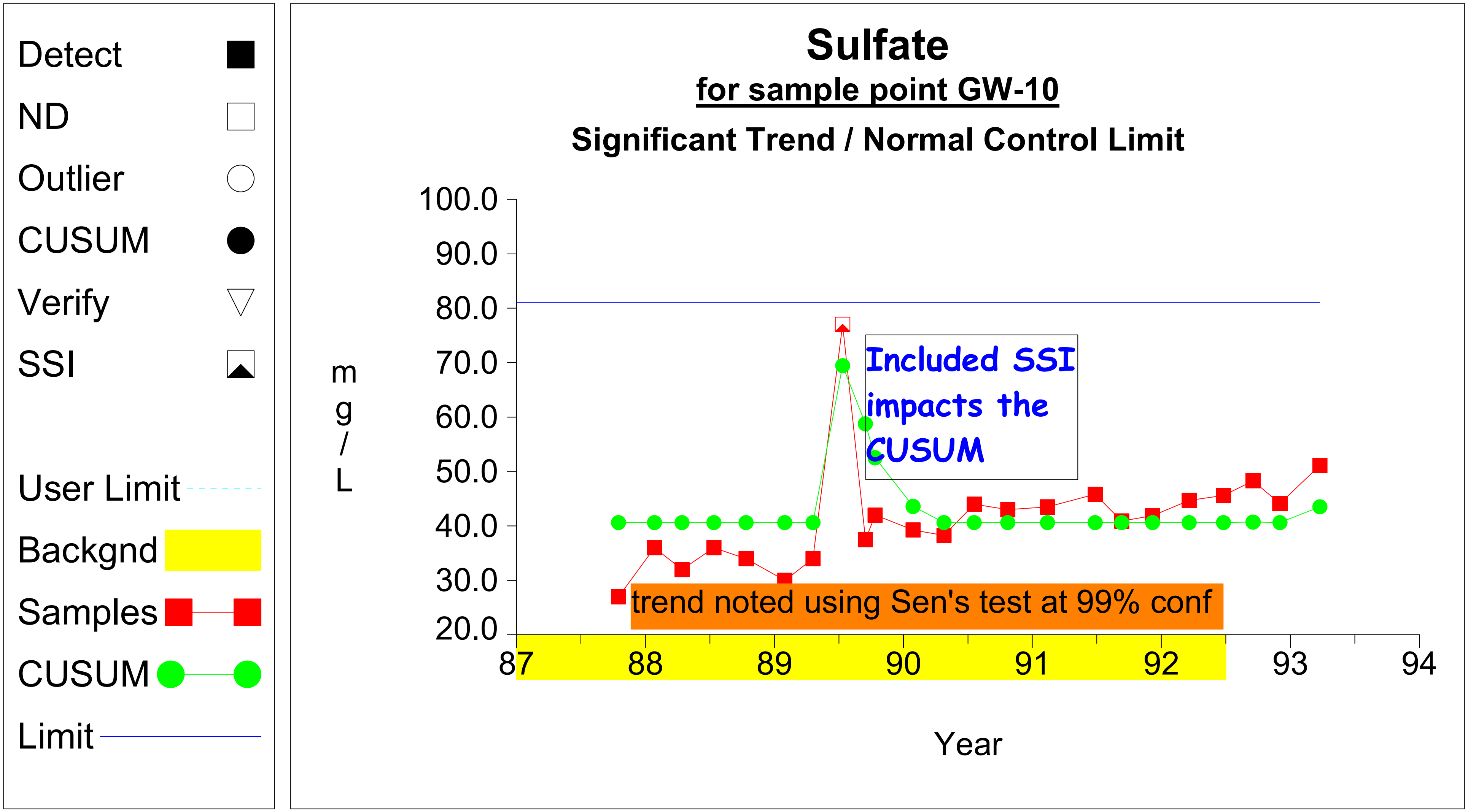
A new Statistical Methods section was added to Chapter 3, Technical Details, of the *Statistical Guide* to provide more detail on how statistical methods such as outlier detection, censored data outlier testing, trend detection, gamma prediction limits and rare event statistics are performed in DUMPStat.

Appendix A

* Predefined Demo Data *

Analysis prepared on: 11/8/2010

Intra-Well Control Charts / Prediction Limits



Sulfate

for sample point GW-10

Significant Trend / Normal Control Limit

New Attachment 14 Background Evaluation Report

LOWER COLORADO RIVER AUTHORITY
Austin, Texas

DRAFT BACKGROUND EVALUATION REPORT
COMBUSTION BYPRODUCTS LANDFILL
FAYETTE POWER PROJECT
LA GRANGE, TEXAS

September 14, 2023

Bullock, Bennett & Associates, LLC
Engineering and Geoscience
Registrations: Engineering F-8542, Geoscience 50127
www.bbaengineering.com

Table of Contents

Attachments

1. INTRODUCTION

This report describes the groundwater data background evaluation conducted at the Lower Colorado River Authority's (LCRA's) Fayette Power Project (FPP) Combustion Byproducts Landfill (CBL) from 2016-2022. The CBL is a coal combustion residuals (CCR) landfill subject to the U.S. Environmental Protection Agency's (EPA's) CCR regulations and the Texas Commission on Environmental Quality's (TCEQ's) CCR registration program. EPA's CCR regulations, also referred to as the "CCR Rule," are codified in 40 CFR Part 257, Subpart D, and have been adopted by TCEQ under Chapter 352 of Title 30 of the Texas Administrative Code (30 TAC Ch. 352).

The uppermost groundwater bearing unit (GWMU) beneath the CBL is identified as the "Intermediate Sand" and is monitored by the CBL's groundwater monitoring system (GWMS), consisting of wells CBL-301I, CBL-302I, CBL-306I, CBL-308I, CBL-340I, and CBL-341I, which are all screened within the Intermediate Sand. The background evaluation, including statistical analysis of background data documented herein, has been conducted as required by 40 CFR § 257.93.

Statistical comparisons and evaluation for statistically significant increases (SSIs) are conducted on all wells with the exception of former background (side-gradient) monitoring well CBL-340I. Based on the Alternative Source Determination (ASD) study conducted in 2018 (Amec Foster Wheeler, April 2018a, and 2018b), the identification of natural aquifer heterogeneity resulted in the determination that CBL-340I could not be reliably used to characterize the background geochemistry of the groundwater flowing beneath the CCR unit. As such, intrawell analysis of wells potentially affected by CCR operations was selected at that time, and the need for use of CBL-340I geochemical data for statistical comparison was negated. A Groundwater Monitoring System Addendum Certification was prepared in 2018 (Amec Foster Wheeler, April 2018c), documenting the transition from former interwell analysis to intrawell analysis.

1.1 Background Groundwater Monitoring Program

The CCR Rule went into effect on October 19, 2015, and required the installation, certification and collection of eight independent groundwater samples from each well by October 17, 2017. Although the groundwater monitoring system contained the required number of wells in accordance with 40 CFR § 257.90, an additional well (CBL 341I) was installed late in 2016 and the only way to satisfy the requirement for eight samples by October 2017 was to institute monthly sampling.

Initial background groundwater quality data for wells CBL-301I, CBL-302I, CBL-306I, CBL-308I, and CBL-340I were obtained in 2016 and 2017. Quarterly monitoring is generally accepted for background because the samples are distinct and collected at times to account for seasonal variation. Background groundwater quality data for monitoring well CBL-341 were collected in 2017 at monthly intervals. Given the site hydrogeology data, monthly monitoring is believed to provide sufficiently distinct groundwater at this well. An average horizontal flow velocity of 50 feet per year is equivalent to 4 feet every 30 days, producing a unique water column between events. Groundwater flow rate is not a statistical test and not everything moves in the groundwater at the same speed. Because of this, the monitoring data from each well were tested for independence using the Rank von Neumann Ratio Test as described in *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance* (EPA 530/R-09-007) (*"Unified Guidance"*) §14.2.4. Based on this testing, the data are considered statistically independent.

The conclusion reached after conducting the 2016-2017 background monitoring evaluation was that Intermediate Sand groundwater has not been impacted by a release from the CBL. This finding was also reached at the conclusion of the Affected Property Assessment, and the CBL hydrogeologic study conducted prior to promulgation of the CCR Rule (Amec 2013, 2014). TCEQ reviewed and approved the conclusions reached in both of those reports. The detection monitoring program was implemented in 2018, and sampling frequency transitioned to semiannual monitoring. During the 2018-2020 detection monitoring period, as background evaluation continued, there were trends and uncharacteristic data points reported, which were resolved by conducting an ASD. No SSIs or trends were identified which suggested a CBL release. Some data points were documented as outliers.

Regarding the background assumption of spatial and temporal stationarity, the spatial stationarity component is not considered applicable to intrawell analyses, which was the statistical analysis method adopted in 2018 (Amec Foster Wheeler, April 2018b, and 2018c). The temporal stationarity component is considered addressed after evaluation of the 2016-2020 background data as a whole, showing general consistency with the data obtained.

In January of 2018, box plots were used as a qualitative tool to screen for spatial heterogeneity in the sample data. This analysis suggested spatial heterogeneity within the groundwater monitoring system (Amec Foster Wheeler, January 2018), which was confirmed when the ASD was conducted in2018_and the system moved to intra-well statistics. Therefore, the continued use of box plots is not necessary or appropriate.

Each of the CBL GWMS groundwater monitoring wells is to be sampled at least semiannually and analyzed for the detection monitoring parameters (also referenced as analytes) listed in Appendix III of 40 CFR Part 257, consisting of: boron, calcium, chloride, fluoride, pH, sulfate, and total dissolved solids (TDS).

Statistical analysis is conducted on data from all GWMS wells with the exception of former background well CBL-340I, as described above. The initial background evaluation conducted in 2017 to meet the October 2017 deadline for GWMS certification was established with the ProUCL software using data collected during the background sampling conducted in 2016 and 2017. This background was used to compute baseline threshold values (BTVs), to which future data were compared. These BTVs were used, with some adjustments, through the 2020 monitoring events.

Monitoring well background datasets must be periodically updated with valid detection monitoring results that are representative of background groundwater quality. Failure to update background datasets will exclude factors such as natural temporal variation, changes in field or laboratory methodologies, and changes in the water table due to meteorological conditions or other influences. Since it has been concluded that there have been no SSIs attributed to releases from the CBL, the background data in this evaluation documented herein include historical data obtained from 2016 through 2022 for wells CBL-301I, CBL-302I, CBL-306I, CBL-308I, and CBL-341I. Historical Appendix III data are summarized in Attachment A. Time series plots of these data are shown in Attachment B.

2. STATISTICAL METHODOLOGIES FOR DETECTION MONITORING

The CCR Rule provides several options for evaluating groundwater data [40 CFR 257.93(f)]. As referenced in the *Unified Guidance*, the preferred methods for comparing groundwater data are using either prediction limits or using control charts. The control chart procedure offers an advantage over the prediction limits procedure as more data are generated over time, because the control chart procedure generates a graph of compliance data over time and allows for better identification of long-term trends.

In 2021, an intrawell control chart method was applied to the CBL data using the DUMPStat® statistical program. DUMPStat® is a program for the statistical analysis of groundwater monitoring data using methods described in *Statistical Methods for Groundwater Monitoring* by Dr. Robert D. Gibbons.

The statistical plan is designed to detect a release from the facility at the earliest indication. An intrawell methodology is described and then applied to the FPP data. The statistical method conforms with the CCR Rule (40 CFR Part 257), the *Unified Guidance*, and the American Society for Testing and Materials (ASTM) Standard D 6312-98, *Standard Guide for Developing Appropriate Statistical Approaches for Ground-Water Detection Monitoring Programs*.

2.1 Intrawell statistics

Intrawell statistics compare new measurements to the historical data at each groundwater monitoring well independently. The *Unified Guidance*-recommended technique for intrawell comparisons is the combined Shewhart-CUSUM control chart. This control chart procedure detects changes in analyte concentrations both in terms of constituent concentration and cumulative concentration increases. This method is also extremely sensitive to sudden and gradual releases. A requirement for constructing these control charts is that the parameter is detected at a frequency greater than or equal to 25%, otherwise the data variance is not properly defined (ASTM D 6312-98).

The combined Shewhart-CUSUM control chart assumes that the data are independent and normally distributed with a fixed mean and a constant variance. Independent data are much more critical than the normality assumption. To achieve independence, it is recommended that data are collected no more frequently than quarterly to account for seasonal variation. The combined Shewhart-CUSUM control chart is robust to deviations from normality. Because the control charts do not use a specific multiplier based on a normal distribution, it is more conservative to assume normality.

Some groundwater monitoring parameters are not detected at a frequency great enough to generate the combined Shewhart-CUSUM control charts. For constituents that are detected less than 25% of the time at a particular well, the data are plotted as a time series until a sufficient number of data points are available to provide a 99% confidence nonparametric prediction limit. Thirteen independent measurements (with 1 resample) are necessary to achieve a 99% confidence (1% false positive rate) nonparametric prediction limit. Eight independent measurements (for pass 1 of 2 resamples) are necessary to achieve a 99% confidence nonparametric prediction limit. The nonparametric prediction limit is the largest determination out of the dataset collected for that well and parameter. If the detection frequency is 0% after thirteen samples have been collected, the reporting limit (practical quantitation limit) becomes the nonparametric prediction limit.

In developing the statistical background, the historical data must be thoroughly screened for anomalous data (too high or too low) due to a sampling error, lab error, transcription error, or shipping error. An erroneous data point, if not removed prior to the mean and variance computations, would yield a larger control limit thus increasing the false negative rate. The DUMPStat® program screens for outliers using the Dixon test. If the Dixon test indicates an outlier, the value is compared to three times the median concentration of the background data for intrawell analyses. If the value fails both criteria of the two-stage screening, the value is considered a statistical outlier and will not be used in the mean and variance determinations. Anomalous data will still be plotted on the graphs (with a unique symbol) but will not be included in the calculations.

The verification resample plan is an integral function of the statistical plan to reduce the probability that anomalous data obtained after the background has been established are indicative of a landfill release. Should a control limit exceedance be identified, the resampling plan is implemented by the operator to collect a verification sample. If the resample data obtained confirm the control limit exceedance, the exceedance is considered statistically significant.

Statistical background includes all data collected for that well and parameter during the background time period indicated. Resample verification data are considered valid data points. In some cases, an errant data point is replaced with the resample data. In other situations, the resample data confirms the semi-annual data obtained. *Unified Guidance* §5.3.3 and the TCEQ document, *Guidelines for Updating Background Data Sets for Municipal Solid Waste Groundwater Monitoring*, allow for inclusion of both routine monitoring data and resample verification data in future background sets.

The background data for each well and analyte are tested for existing trends using Sen's nonparametric estimate of trend. As documented in the DUMPStat software manual, a significant trend is one in which the 99% lower confidence bound is greater than zero. In this way, even pre-existing trends in the background dataset will be detected. In large databases, very gradual trends can be statistically significant; however, such trends should not preclude the use of intrawell comparisons.

Background should be updated periodically with data that are representative of background groundwater quality. The frequency that background should be updated is generally considered to be every four events (if semiannual) or every two years (*Unified Guidance*, Chapter 5.3). The procedures used for a background update must be protective of human health and the environment and must comply with the statistical performance standards specified in 30 TAC §330.233(f) and (g). Ongoing operations at a facility such as excavations or drainage control may affect the groundwater flow direction and water quality. An increase in the number of statistical failures, unrelated to the facility, is routinely observed for sites neglecting to update the statistical background with valid data points.

3. ESTABLISHING BACKGROUND CONCENTRATIONS USING DUMPSTAT

The Appendix III parameter data from wells CBL-301I, CBL-302I, CBL-306I, CBL-308I, and CBL-341I were evaluated using the combined Shewhart-CUSUM control chart method as described above. The background dataset used to determine updated control limits includes data obtained from 2016 through 2022. A summary of the intrawell statistics is included in Attachment C, Table 1 “Summary Statistics and Intermediate Computations for Combined Shewhart-CUSUM Control Charts.” The control charts or time series graphs follow the summary table.

Prior to calculating control limits, the data were screened for outliers as described above.

Summary of outliers determined using DUMPstat

Well	Parameter	Result	Date
CBL-301I	Calcium	156	1/17/2019
	Chloride	619	1/17/2019
	Sulfate	104	1/17/2019
	TDS	1460	1/17/2019
CBL-302I	Boron	0.156	10/24/2016
	Boron	0.297	3/22/2017
CBL-306I	Chloride	20.0	5/4/2016
	Fluoride	12.6	3/22/2017
	Sulfate	29.5	5/4/2016
	TDS	431	5/4/2016
CBL-308I	Fluoride	9.05	3/22/2017

Outliers detected by the program are summarized in Table 4: “Dixon's Test Outliers 1% Significance Level” of the statistical report in Attachment C. The boron data points at CBL-302I (0.156 mg/L and 0.297 mg/L) meet the outlier criteria. These data were not previously excluded by ProUCL and were thus retained as valid data by DUMPstat. This Background Evaluation Report does not include these concentrations in the background.

Additionally, data can be manually designated as outliers in the opinion of a qualified statistician. Manual outliers were previously assigned to calcium and chloride data points at CBL-306I and a pH data point at CBL-341I. The July 2019 monitoring data at CBL-306I were not used due to an anomaly during sampling. The well was later resampled.

Summary of previously defined manual outliers

Well	Parameter	Result	Date
CBL-306I	Boron	0.0824	7/31/2019
	Calcium	47.2	5/4/2016
	Calcium	105	7/26/2016
	Calcium	106	7/31/2019
	Chloride	114	7/26/2016
	Chloride	538	7/31/2019
	Fluoride	9.26	7/31/2019
	pH	6.92	7/31/2019
	Sulfate	816	7/31/2019
	TDS	676	7/31/2019
CBL-341I	pH	5.23	2/23/2017

Outliers are identified using unique symbols whether detected statistically or designated manually. Those data points are not included in the determination of statistical limits.

For cases where the detection frequency for a parameter at a well during background is $\geq$ 25%, the control limit is simply defined as:

control limit = (control chart factor)(standard deviation) + mean

The control chart factor typically ranges from 4.5 to 6.5 for N<12 and from 4.0 to 6.5 for $N \geq 12$. In this case, the control chart factor utilized was 5.0. A statistical power curve indicates the expected false assessments for the site as a whole. The statistical power is a function of the number of wells included, the number of constituents compared, the detection frequencies, and the data distributions involved. For intrawell comparisons, the recommended site-wide false positive rate is 5%. Evaluating and adjusting the factor to achieve false assessment objectives is done each time background is established. Generally, the factor is lowered as background is updated to include more data points.

In addition to comparing the compliance data to background concentrations using a control chart, the Shewhart-CUSUM control chart used provides additional information. The CUSUM portion identifies cumulative increases over time as described in Chapter 20 of the *Unified Guidance*.

Compute the standardized concentration Zi for each x_i after background:

Zi = (x_i – mean)/standard deviation

use Zi to compute the standardized CUSUM Si. Set S0 = 0

$S_i^* = \max [\ 0, Zi\text{-}k + S_{i-1}]$
where in this case, k = 0.75.

The cumulative sum is expressed as:

$S_i = S_i^*$(standard deviation) + mean

The CUSUM portion of the control chart is compared to the same control limit as was established for the data concentration. The cumulative sum sequentially analyzes each new measurement with prior compliance data.

The only rare events, where the detection frequency was <25%, were for boron at CBL-301I and boron at CBL-302I. Nonparametric prediction limits were used in these cases.

The background data for each well and analyte are tested for existing trends using Sen's nonparametric estimate of trend. A slight increasing trend was detected in the background data for sulfate at CBL-302I. The trend was evaluated and was determined to be attributed to the initial few rounds of data in 2016-2017. The more recent data do not demonstrate this increase and are not believed to contribute to an artificially high control limit due to the trend. Trends such as this do not preclude the use of intrawell comparisons.

A control chart factor was selected to provide a balance of the site-wide false positive and false negative rates. A statistical power curve indicates the expected false assessments for the site as a whole. The site-wide false positive rate is 3% and the test becomes sensitive to 3 standard deviation units over background.

4. REFERENCES

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Amec Foster Wheeler (April 2018d): *Groundwater Monitoring System Addendum Certification, Lower Colorado River Authority, Coal Combustion Residuals Unit, Combustion Byproducts Landfill, Fayette Power Project, La Grange, Texas.*

Bullock, Bennett & Associates (May 2021): *Groundwater Monitoring System Addendum Certification, Lower Colorado River Authority, Coal Combustion Residuals Unit, Combustion Byproducts Landfill, Fayette Power Project, La Grange, Texas.*

DUMPStat (2003) DUMPStat Statistical Guide, version 2.1.8., by Robert D. Gibbons Ltd.,with accompanying DUMPStat 2.3 Release Notes.

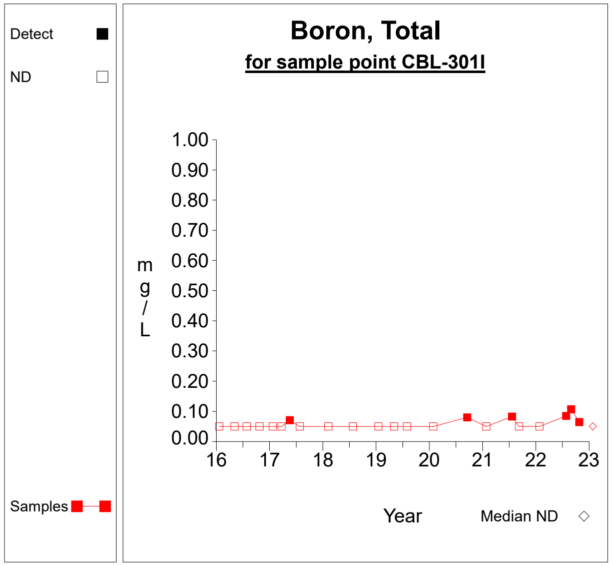
EPA (2009): *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance* (EPA 530/R-09-007).

Gibbons, Bhaumik, and Aryal (2009): *Statistical Methods for Groundwater Monitoring, 2nd Edition*, 400 pages.

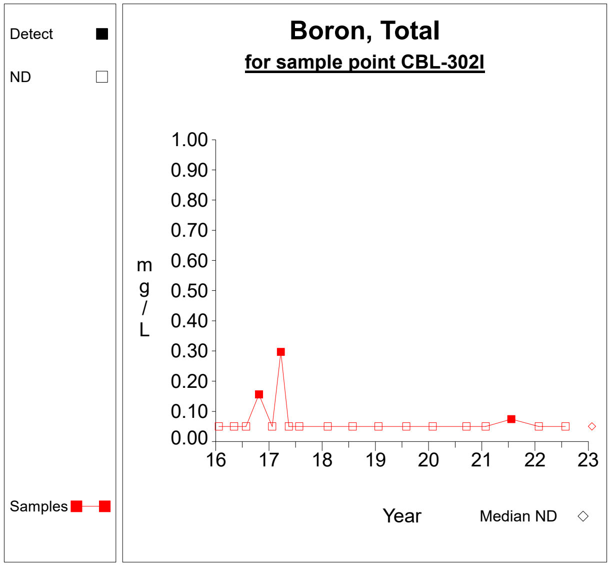
Attachment A

Time Series Graphs

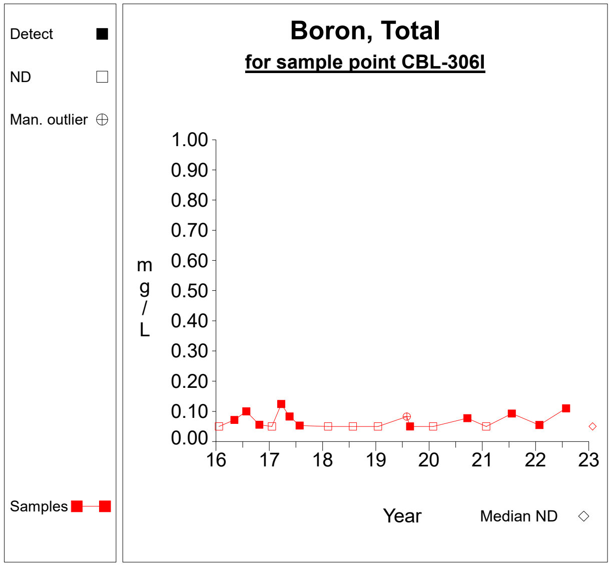
Time Series



Graph 1



Graph 2



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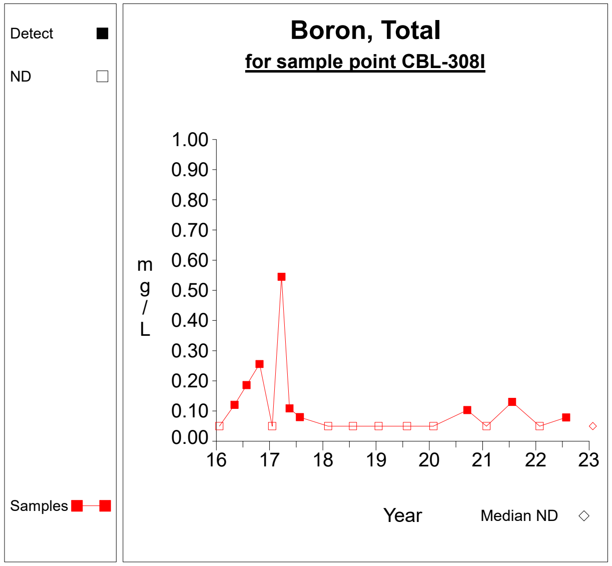
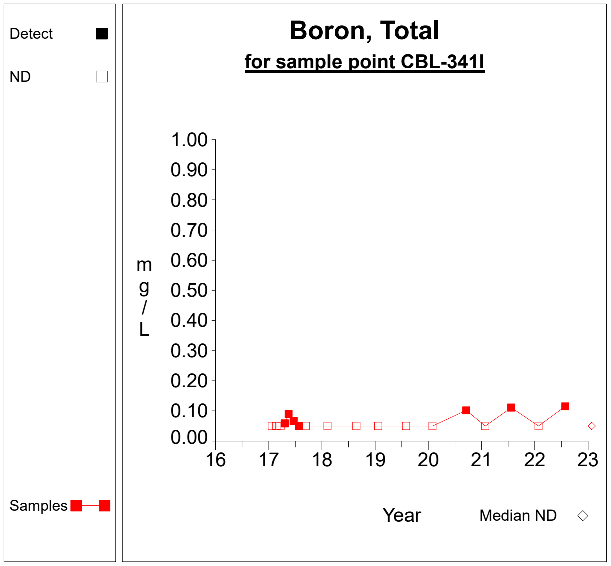
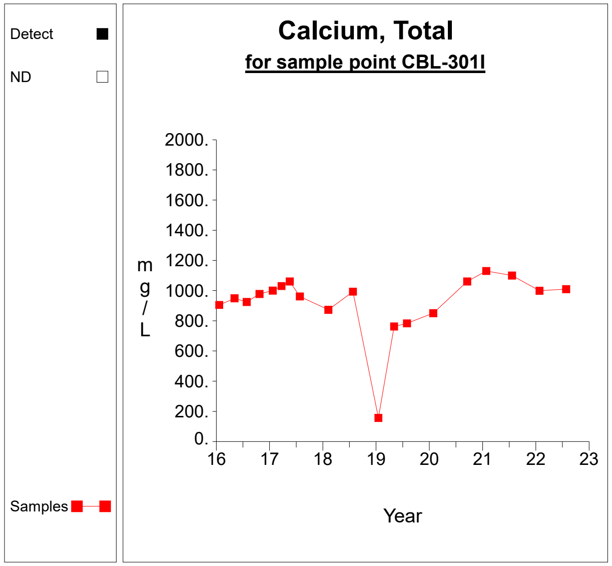


Graph 4



Graph 5

Time Series



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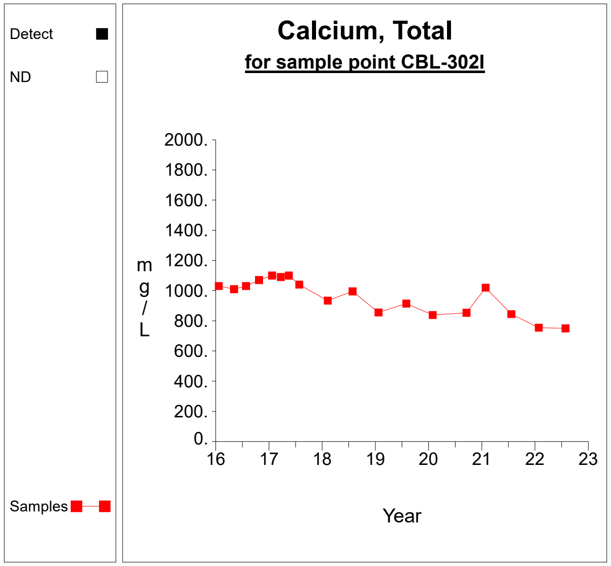

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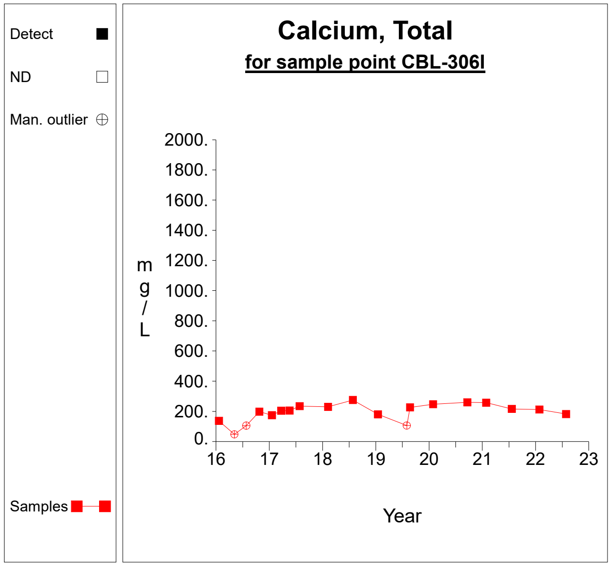

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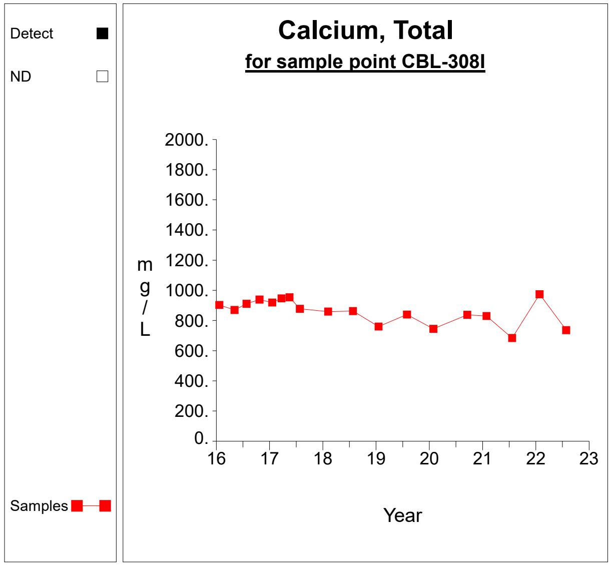

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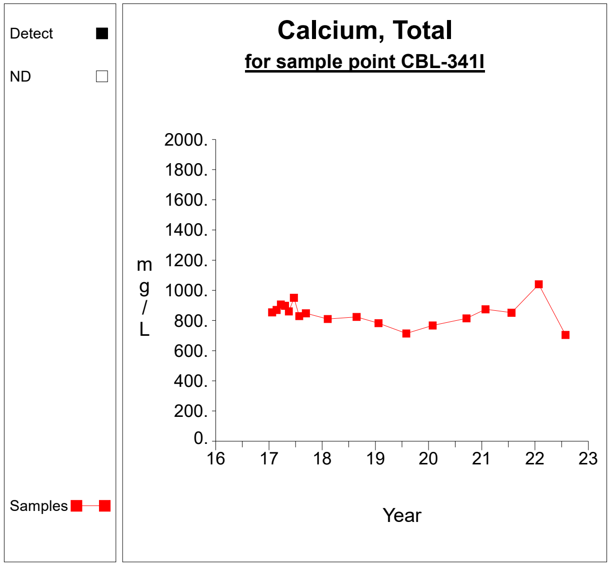
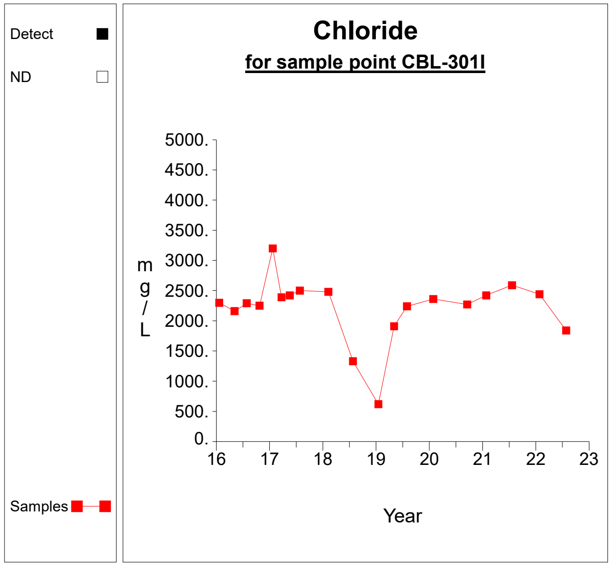
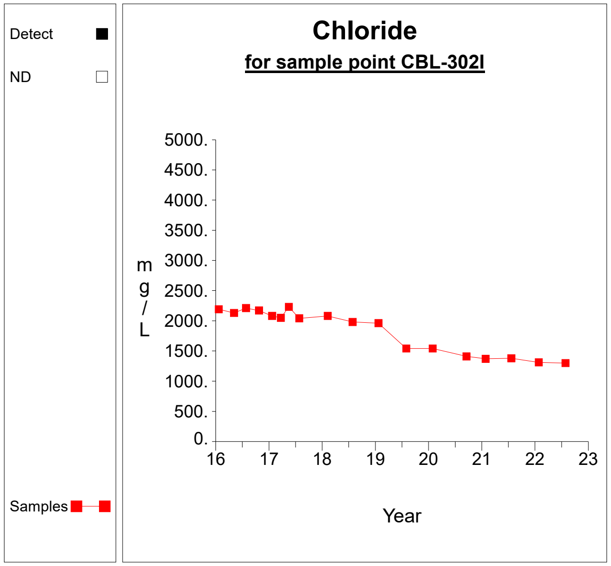


Graph 10

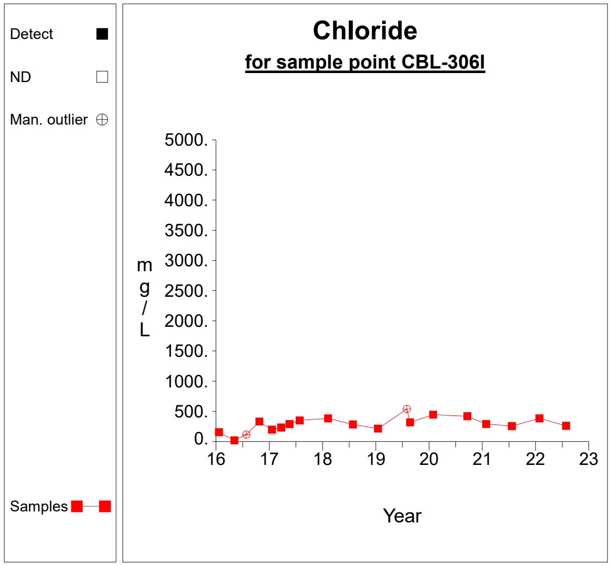
Time Series



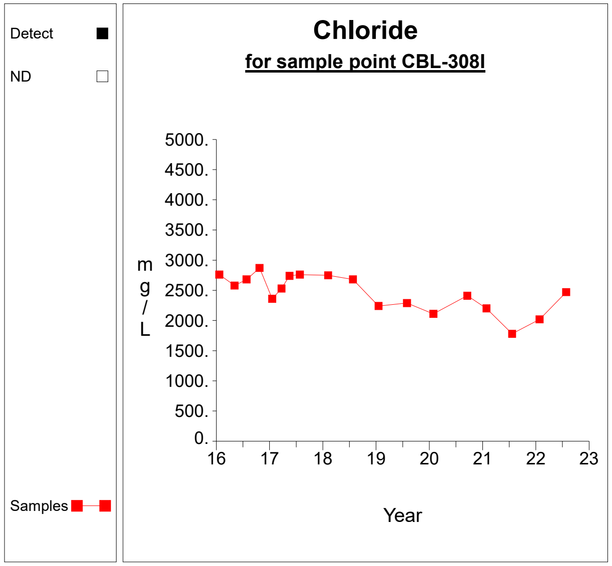
Graph 11



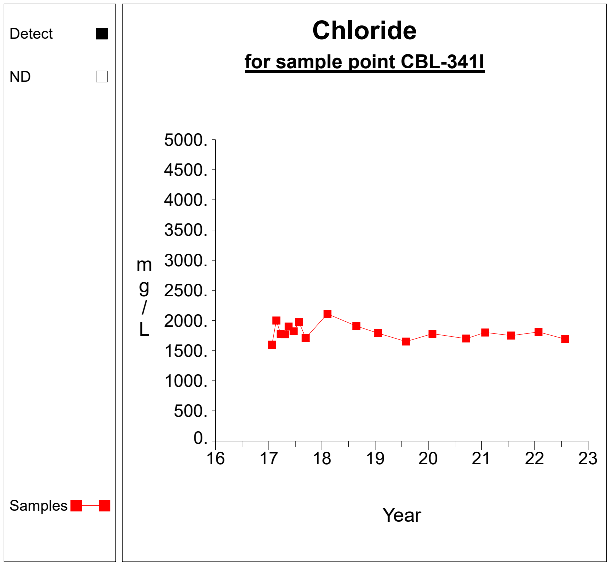
Graph 12



Graph 13

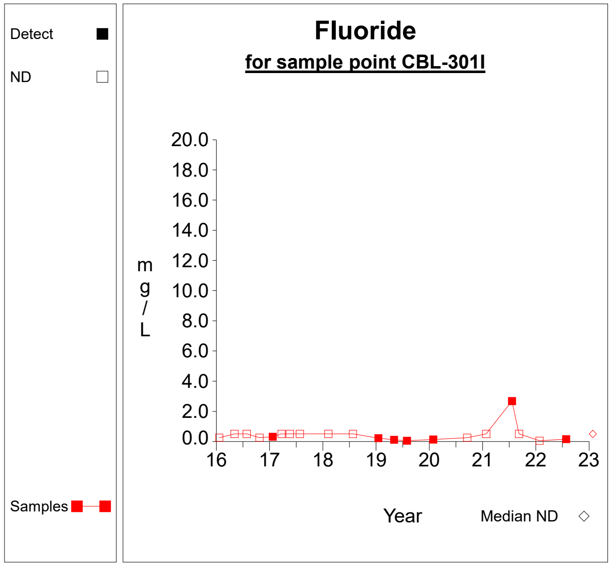


Graph 14



Graph 15

Time Series



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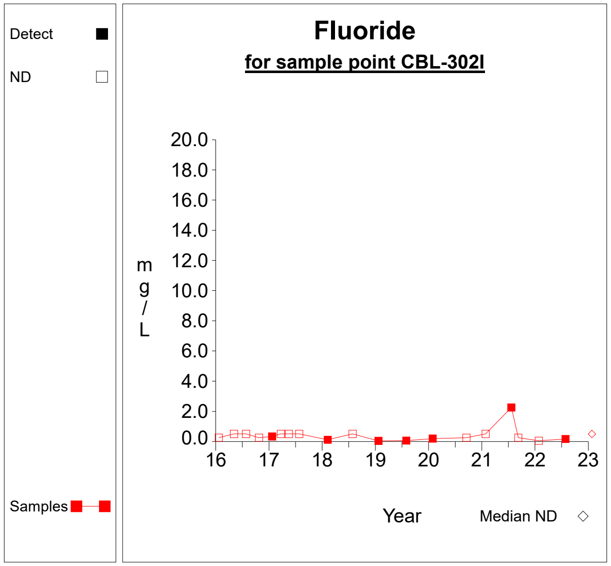

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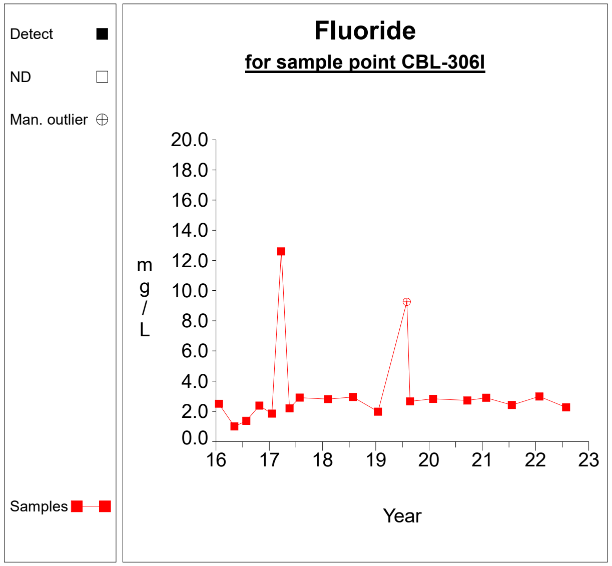

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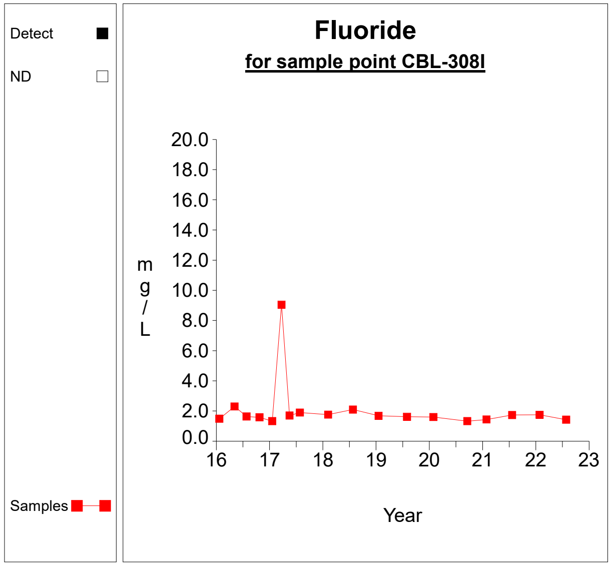

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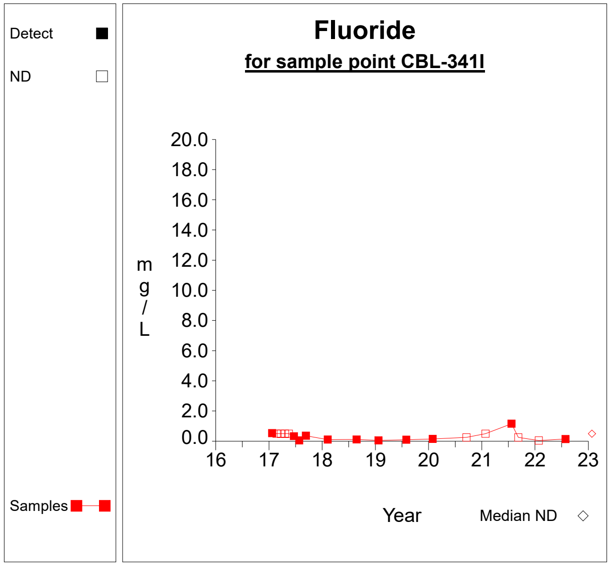

Graph 20

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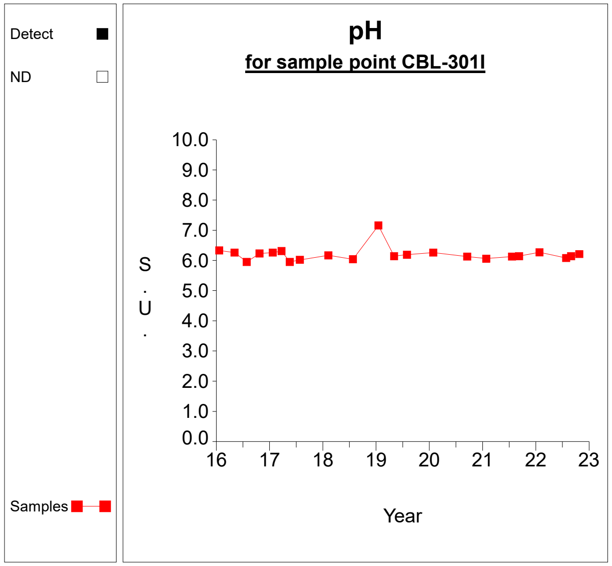
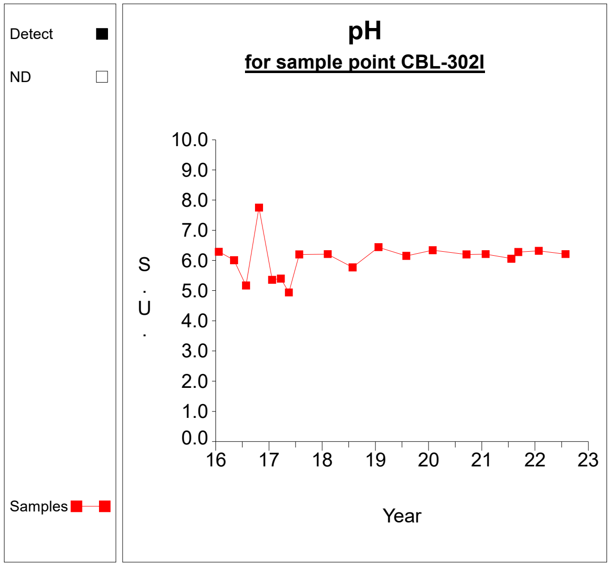
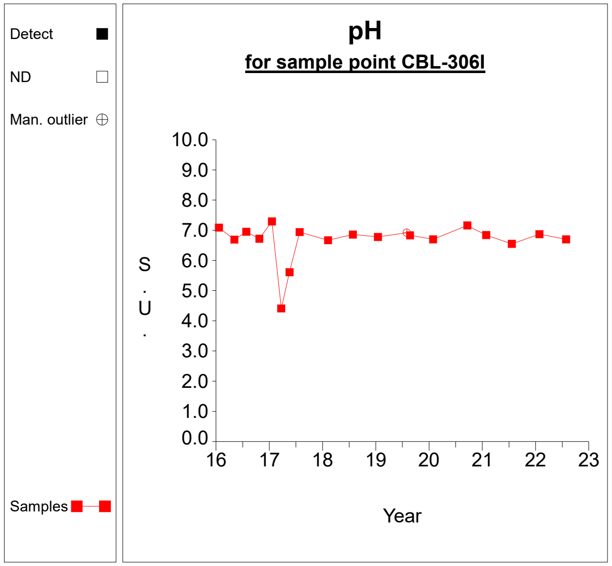

pH
for sample point CBL-301I

Graph 21


pH
for sample point CBL-302I

Graph 22


pH
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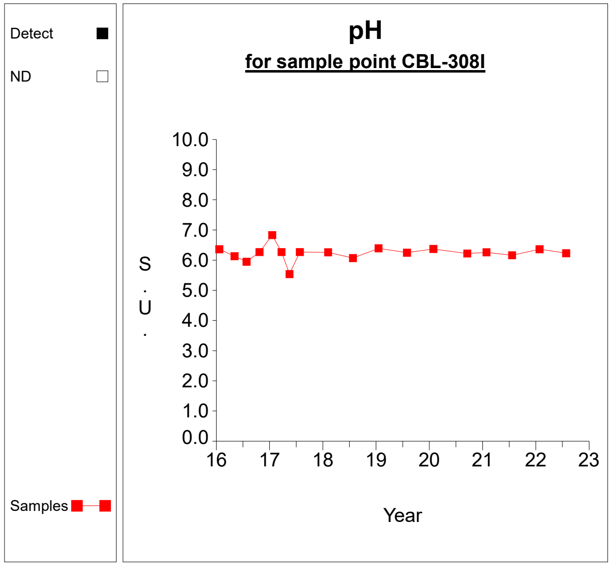
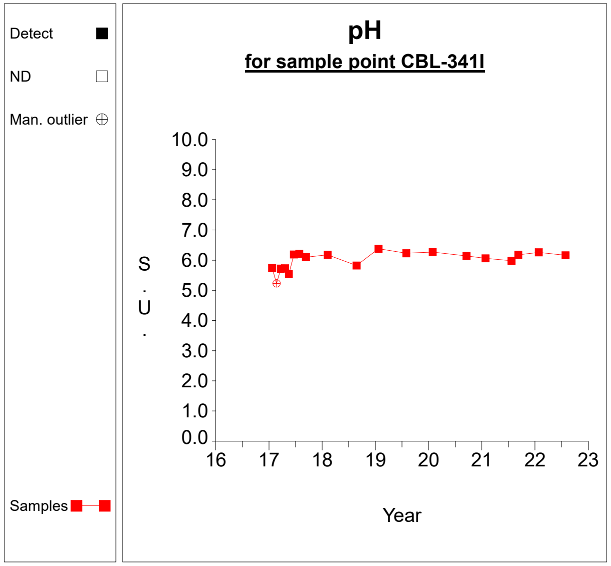
Graph 23

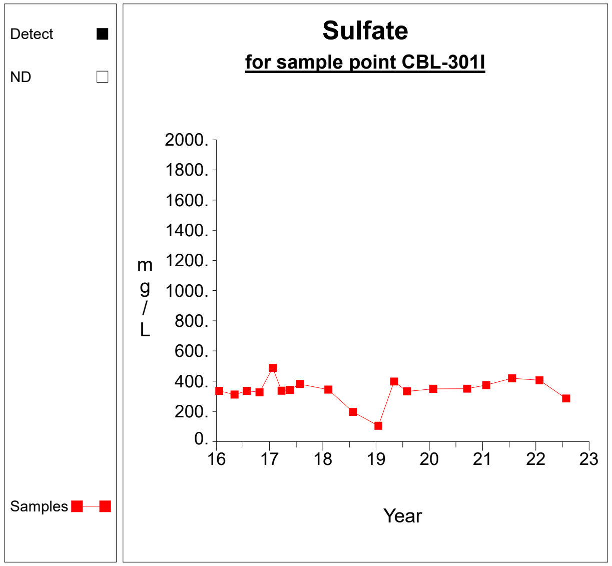

pH
for sample point CBL-308I

Graph 24


pH
for sample point CBL-341I

Graph 25

Time Series



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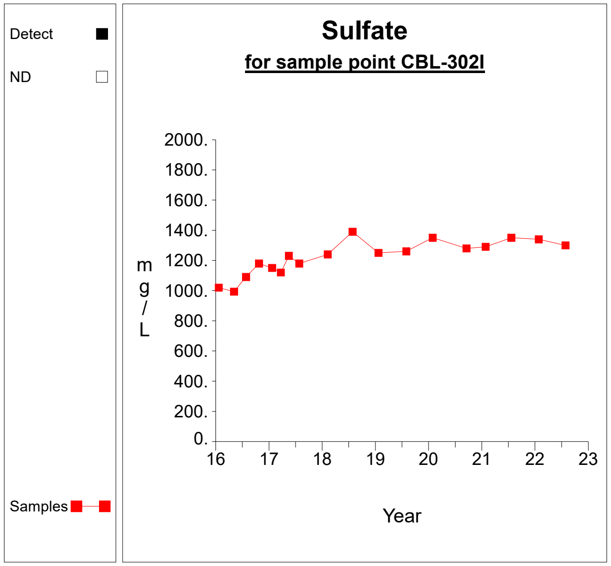

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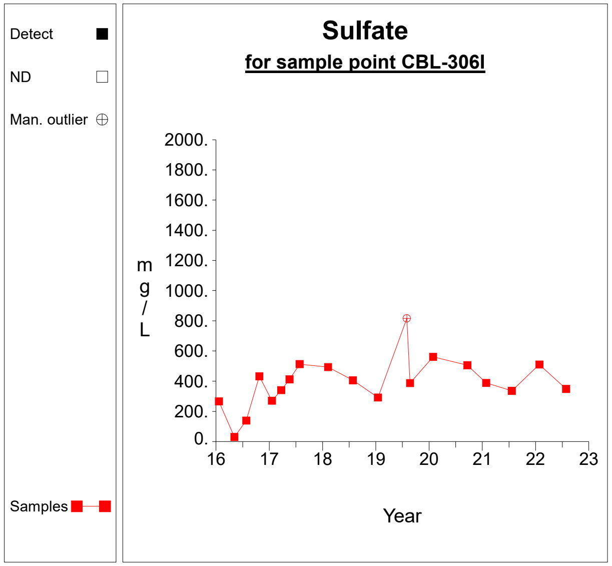

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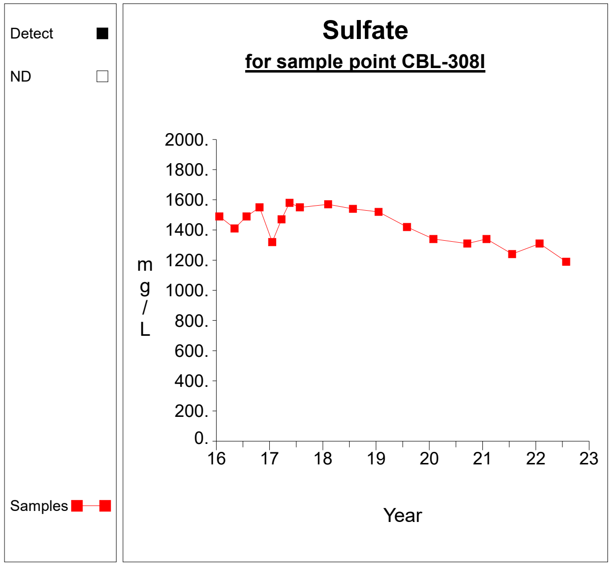

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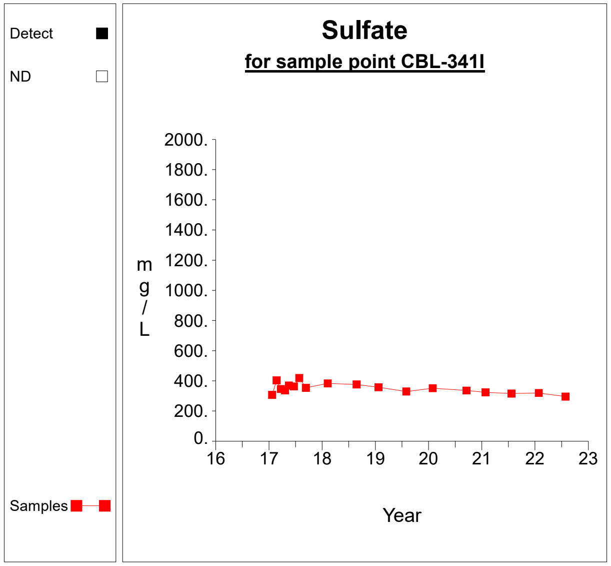

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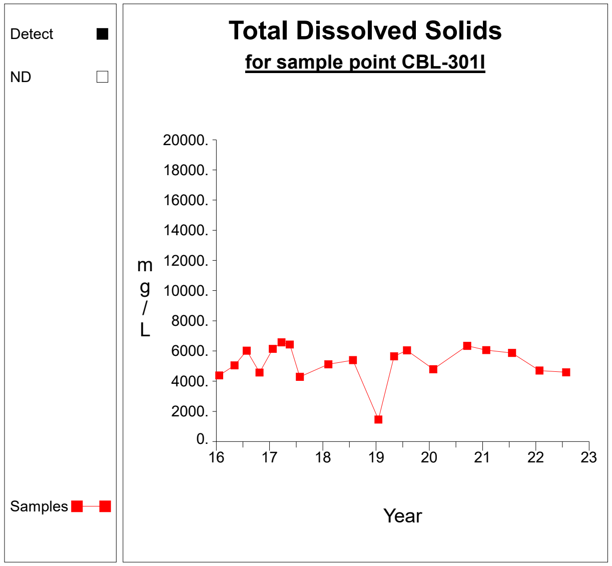
Time Series



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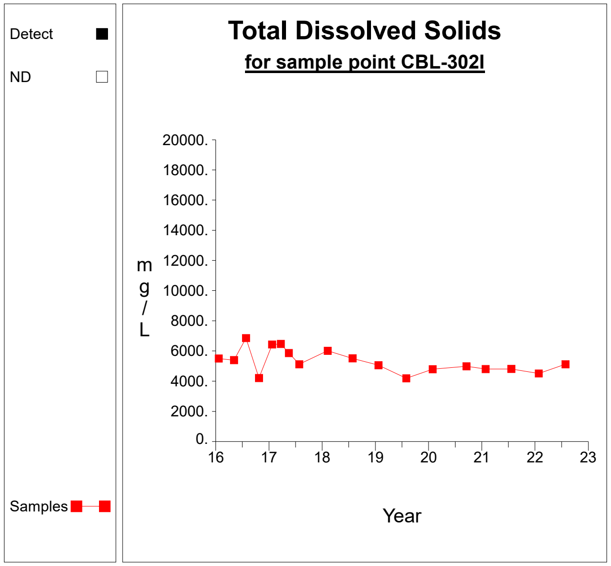

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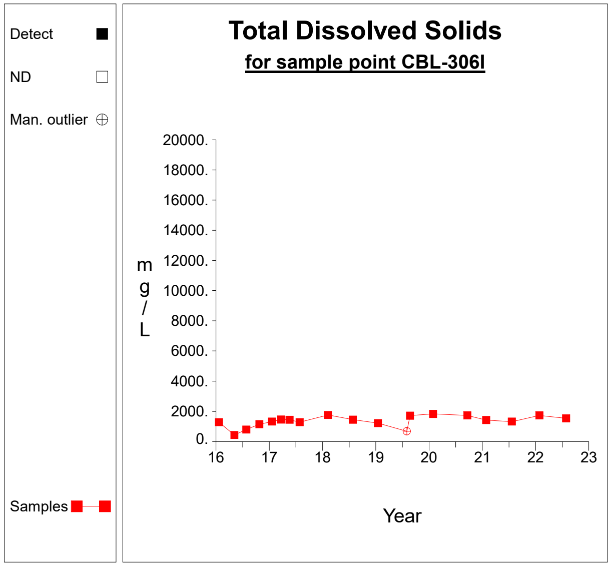

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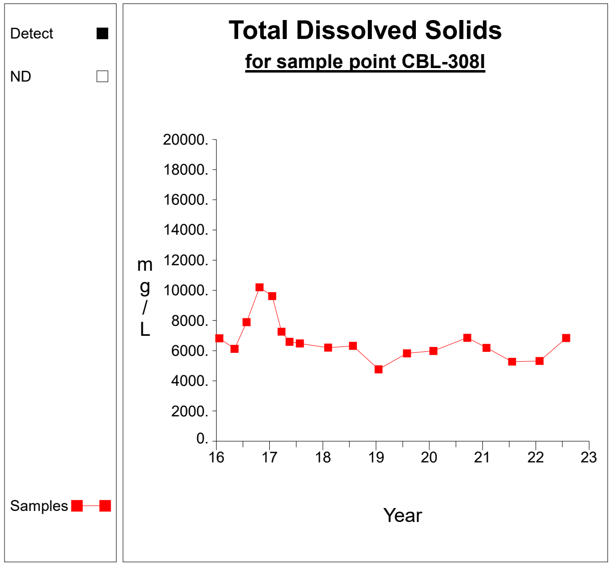

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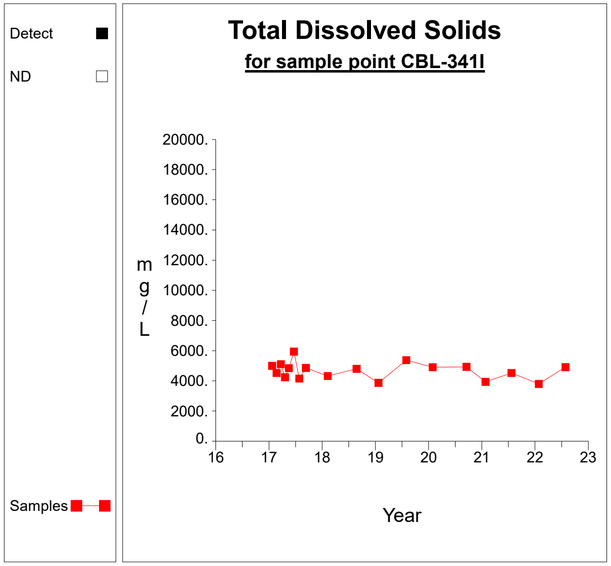

Graph 35

Attachment B

Analytical Data Summary Tables 1-6

Table 1

Analytical Data Summary for CBL-301I

Constituents	Units	1/21/2016	5/4/2016	7/27/2016	10/24/2016	1/23/2017	3/22/2017	5/18/2017	7/26/2017	2/8/2018	7/25/2018	1/17/2019	5/2/2019	7/31/2019
Boron, Total	mg/L	<.0500	<.0500	<.0500	<.0500	<.0500	<.0500	.0707	<.0500	<.0500	<.0500	<.0500	<.0500	<.0500
Calcium, Total	mg/L	905	949	925	978	1000	1030	1060	961	873	993	156	762	783
Chloride	mg/L	2300	2160	2290	2250	3200	2390	2420	2500	2480	1330	619	1910	2240
Fluoride	mg/L	<.250	<.500	<.500	<.250	.312	<.500	<.500	<.500	<.500	<.500	.219	.112	.051
pH	S.U.	6.33	6.26	5.95	6.23	6.26	6.31	5.95	6.02	6.17	6.04	7.16	6.14	6.19
Sulfate	mg/L	336	311	336	326	488	337	342	381	344	196	104	398	332
Total Dissolved Solids	mg/L	4380	5050	6020	4570	6140	6570	6430	4290	5120	5390	1460	5650	6040

* - The displayed value is the arithmetic mean of multiple database matches.

Table 1

Analytical Data Summary for CBL-301I

Constituents	1/28/2020	9/17/2020	1/26/2021	7/20/2021	9/7/2021	1/26/2022	7/27/2022	8/30/2022	10/25/2022
Boron, Total	<.0500	.0801	<.0500	.0826	<.0500	<.0500	.0850	.1070	.0645
Calcium, Total	851	1060	1130	1100		999	1010		
Chloride	2360	2270	2420	2590		2440	1840		
Fluoride	.130	<.250	<.500	2.680	<.500	<.050	.156		
pH	6.26	6.13	6.06	6.13	6.14	6.27	6.08	6.14	6.21
Sulfate	349	350	374	419		406	285		
Total Dissolved Solids	4790	6340	6060	5870		4700	4590		

* - The displayed value is the arithmetic mean of multiple database matches.

Table 2

Analytical Data Summary for CBL-302I

Constituents	Units	1/22/2016	5/4/2016	7/27/2016	10/24/2016	1/23/2017	3/22/2017	5/16/2017	7/27/2017	2/8/2018	7/27/2018	1/22/2019	7/31/2019	1/30/2020
Boron, Total	mg/L	<.0500	<.0500	<.0500	.1560	<.0500	.2970	<.0500	<.0500	<.0500	<.0500	<.0500	<.0500	<.0500
Calcium, Total	mg/L	1030	1010	1030	1070	1100	1090	1100	1040	934	995	855	914	838
Chloride	mg/L	2190	2130	2210	2170	2080	2050	2230	2040	2080	1980	1960	1540	1540
Fluoride	mg/L	<.2500	<.5000	<.5000	<.2500	.3320	<.5000	<.5000	<.5000	.1120	<.5000	.0402	.0605	.1930
pH	S.U.	6.29	6.01	5.17	7.75	5.36	5.40	4.94	6.20	6.21	5.77	6.44	6.15	6.34
Sulfate	mg/L	1020	993	1090	1180	1150	1120	1230	1180	1240	1390	1250	1260	1350
Total Dissolved Solids	mg/L	5500	5390	6850	4210	6430	6460	5860	5120	6010	5510	5060	4190	4790

* - The displayed value is the arithmetic mean of multiple database matches.

Table 2

Analytical Data Summary for CBL-302I

Constituents	9/17/2020	1/28/2021	7/21/2021	9/7/2021	1/27/2022	7/28/2022
Boron, Total	<.0500	<.0500	.0743		<.0500	<.0500
Calcium, Total	853	1020	844		754	750
Chloride	1410	1370	1380		1310	1300
Fluoride	<.2500	<.5000	2.2500	<.2500	<.0500	.1650
pH	6.20	6.21	6.06	6.28	6.32	6.21
Sulfate	1280	1290	1350		1340	1300
Total Dissolved Solids	4990	4800	4810		4510	5120

* - The displayed value is the arithmetic mean of multiple database matches.

Table 3

Analytical Data Summary for CBL-306I

Constituents	Units	1/21/2016	5/4/2016	7/26/2016	10/24/2016	1/19/2017	3/22/2017	5/18/2017	7/27/2017	2/8/2018	7/27/2018	1/16/2019	7/31/2019	8/23/2019
Boron, Total	mg/L	<.0500	.0717	.0998	.0556	<.0500	.1240	.0832	.0531	<.0500	<.0500	<.0500	.0824	.0500
Calcium, Total	mg/L	137.0	47.2	105.0	198.0	174.0	204.0	205.0	234.0	230.0	275.0	180.0	106.0	226.0
Chloride	mg/L	155	20	114	330	197	231	289	350	385	283	215	538	318
Fluoride	mg/L	2.50	1.00	1.37	2.38	1.85	12.60	2.20	2.91	2.81	2.95	1.98	9.26	2.66
pH	S.U.	7.09	6.69	6.95	6.72	7.29	4.41	5.61	6.94	6.67	6.86	6.78	6.92	6.83
Sulfate	mg/L	266.0	29.5	139.0	432.0	270.0	340.0	412.0	513.0	493.0	406.0	292.0	816.0	387.0
Total Dissolved Solids	mg/L	1280	431	790	1150	1320	1460	1440	1280	1760	1450	1220	676	1710

* - The displayed value is the arithmetic mean of multiple database matches.

Table 3

Analytical Data Summary for CBL-306I

Constituents	1/29/2020	9/19/2020	1/28/2021	7/21/2021	1/27/2022	7/28/2022
Boron, Total	<.0500	.0773	<.0500	.0927	.0548	.1100
Calcium, Total	247.0	260.0	257.0	216.0	212.0	182.0
Chloride	445	420	292	255	384	261
Fluoride	2.83	2.72	2.90	2.42	2.99	2.26
pH	6.70	7.16	6.84	6.55	6.87	6.70
Sulfate	561.0	506.0	388.0	336.0	510.0	348.0
Total Dissolved Solids	1830	1730	1420	1320	1730	1540

* - The displayed value is the arithmetic mean of multiple database matches.

Table 4

Analytical Data Summary for CBL-308I

Constituents	Units	1/22/2016	5/4/2016	7/26/2016	10/24/2016	1/19/2017	3/22/2017	5/16/2017	7/26/2017	2/6/2018	7/25/2018	1/18/2019	7/31/2019	1/29/2020
Boron, Total	mg/L	<.0500	.1210	.1860	.2560	<.0500	.5450	.1090	.0799	<.0500	<.0500	<.0500	<.0500	<.0500
Calcium, Total	mg/L	903	870	911	939	919	947	954	878	859	863	760	840	745
Chloride	mg/L	2760	2580	2680	2870	2360	2530	2740	2760	2750	2680	2240	2290	2110
Fluoride	mg/L	1.49	2.30	1.64	1.59	1.33	9.05	1.70	1.90	1.76	2.10	1.68	1.62	1.60
pH	S.U.	6.36	6.13	5.95	6.27	6.83	6.27	5.54	6.27	6.26	6.07	6.39	6.25	6.37
Sulfate	mg/L	1490	1410	1490	1550	1320	1470	1580	1550	1570	1540	1520	1420	1340
Total Dissolved Solids	mg/L	6820	6120	7890	10200	9620	7260	6590	6480	6200	6320	4760	5820	5980

* - The displayed value is the arithmetic mean of multiple database matches.

Table 4

Analytical Data Summary for CBL-308I

Constituents	9/18/2020	1/28/2021	7/21/2021	1/27/2022	7/27/2022
Boron, Total	.1030	<.0500	.1300	<.0500	.0790
Calcium, Total	838	830	684	974	736
Chloride	2410	2200	1780	2020	2470
Fluoride	1.33	1.44	1.74	1.75	1.43
pH	6.22	6.26	6.16	6.36	6.23
Sulfate	1310	1340	1240	1310	1190
Total Dissolved Solids	6860	6190	5270	5320	6840

* - The displayed value is the arithmetic mean of multiple database matches.

Table 5

Analytical Data Summary for CBL-340I

Constituents	Units	1/21/2016	5/4/2016	7/27/2016	10/24/2016	1/23/2017	3/22/2017	5/16/2017	7/27/2017	2/8/2018	7/27/2018	1/22/2019	7/31/2019	1/30/2020
Boron, Total	mg/L	<.0500	.0832	.0810	.1580	<.0500	.1740	.1040	.0816	.0638	<.0500	<.0500	.1240	.0562
Calcium, Total	mg/L	564	560	575	607	627	581	584	571	555	544	518	518	539
Chloride	mg/L	2370	2260	2350	2380	2070	2280	2520	2380	2730	2450	2250	2280	2240
Fluoride	mg/L	1.090	1.920	1.060	1.260	.840	8.440	1.010	.850	1.000	1.300	.830	.880	.870
pH	S.U.	6.52	6.13	6.95	6.19	5.46	6.49	5.77	6.42	6.41	6.25	6.59	6.45	6.49
Sulfate	mg/L	652	616	668	675	571	635	715	685	752	711	639	684	637
Total Dissolved Solids	mg/L	4990	5230	6250	5670	6230	5480	5470	4880	5290	5100	4720	5560	5080

* - The displayed value is the arithmetic mean of multiple database matches.

Table 5

Analytical Data Summary for CBL-340I

Constituents	9/18/2020	1/28/2021	7/22/2021	1/28/2022	7/28/2022
Boron, Total	.1460	<.0500	.3840	.1600	.2850
Calcium, Total	547	607	532	597	538
Chloride	2130	2260	2200	2200	2160
Fluoride	.725	.835	.865	1.060	.865
pH	6.32	6.32	6.24	6.42	6.35
Sulfate	608	634	618	619	614
Total Dissolved Solids	5430	5520	4990	4870	5490

* - The displayed value is the arithmetic mean of multiple database matches.

Table 6

Analytical Data Summary for CBL-341I

Constituents	Units	1/23/2017	2/23/2017	3/22/2017	4/20/2017	5/16/2017	6/20/2017	7/27/2017	9/11/2017	2/8/2018	8/24/2018	1/22/2019	7/31/2019	1/30/2020
Boron, Total	mg/L	<.0500	<.0500	<.0500	.0587	.0896	.0668	.0507	<.0500	<.0500	<.0500	<.0500	<.0500	<.0500
Calcium, Total	mg/L	854	870	906	898	860	950	829	848	810	824	782	714	767
Chloride	mg/L	1600	2000	1780	1770	1900	1820	1970	1710	2110	1910	1790	1650	1780
Fluoride	mg/L	.5300	<.5000	<.5000	<.5000	<.5000	.3350	.0550	.3670	.1060	.1140	.0546	.1000	.1530
pH	S.U.	5.74	5.23	5.72	5.73	5.54	6.19	6.21	6.10	6.18	5.82	6.38	6.23	6.27
Sulfate	mg/L	307	404	346	336	369	363	419	354	383	376	358	329	351
Total Dissolved Solids	mg/L	5000	4520	5110	4240	4840	5940	4150	4860	4320	4800	3870	5370	4900

* - The displayed value is the arithmetic mean of multiple database matches.

Table 6

Analytical Data Summary for CBL-341I

Constituents	9/17/2020	1/27/2021	7/22/2021	9/7/2021	1/27/2022	7/28/2022
Boron, Total	.1020	<.0500	.1110		<.0500	.1150
Calcium, Total	814	874	852		1040	704
Chloride	1700	1800	1750		1810	1690
Fluoride	<.2500	<.5000	1.1600	<.2500	<.0500	.1410
pH	6.14	6.06	5.98	6.18	6.26	6.16
Sulfate	336	324	316		320	296
Total Dissolved Solids	4930	3940	4520		3800	4910

* - The displayed value is the arithmetic mean of multiple database matches.

Attachment C

Summary Statistics, Raw Data, Calculations, and Control Charts

Table 1

Summary Statistics and Intermediate Computations for Combined Shewhart-CUSUM Control Charts

Constituent	Units	Well	N(back)	N(mon)	N(tot)	Mean	SD	R(i-1)	R(i)	S(i-1)	S(i)	Limit	Type	Conf	
Boron, Total	mg/L	CBL-301I	22	0	22	0.0586	0.0161	0.1070	0.0645			0.1391	normal		
Boron, Total	mg/L	CBL-302I	16	0	18			0.0500	0.0500			0.0743	nonpar	.99	**
Boron, Total	mg/L	CBL-306I	18	0	19	0.0679	0.0242	0.0548	0.1100			0.1891	normal		
Boron, Total	mg/L	CBL-308I	18	0	18	0.1144	0.1215	0.0500	0.0790			0.7217	normal		
Boron, Total	mg/L	CBL-341I	18	0	18	0.0635	0.0234	0.0500	0.1150			0.1803	normal		
Calcium, Total	mg/L	CBL-301I	18	0	19	964.9444	101.2710	999.0000	1010.0000			1471.2996	normal		
Calcium, Total	mg/L	CBL-302I	18	0	18	957.0556	116.7478	754.0000	750.0000			1540.7947	normal		
Calcium, Total	mg/L	CBL-306I	16	0	19	214.8125	36.2569	212.0000	182.0000			396.0970	normal		
Calcium, Total	mg/L	CBL-308I	18	0	18	858.3333	82.3615	974.0000	736.0000			1270.1407	normal		
Calcium, Total	mg/L	CBL-341I	18	0	18	844.2222	79.4752	1040.0000	704.0000			1241.5980	normal		
Chloride	mg/L	CBL-301I	18	0	19	2299.4444	372.4241	2440.0000	1840.0000			4161.5647	normal		
Chloride	mg/L	CBL-302I	18	0	18	1831.6667	360.2654	1310.0000	1300.0000			3632.9938	normal		
Chloride	mg/L	CBL-306I	16	0	19	300.6250	82.0828	384.0000	261.0000			711.0389	normal		
Chloride	mg/L	CBL-308I	18	0	18	2457.2222	303.1755	2020.0000	2470.0000			3973.0995	normal		
Chloride	mg/L	CBL-341I	18	0	18	1807.7778	129.1399	1810.0000	1690.0000			2453.4775	normal		
Fluoride	mg/L	CBL-301I	20	0	20	0.5080	0.5367	0.5000	0.1560			3.1915	normal		
Fluoride	mg/L	CBL-302I	19	0	19	0.4817	0.4622	0.5000	0.1650			2.7929	normal		
Fluoride	mg/L	CBL-306I	17	0	19	2.3959	0.5730	2.9900	2.2600			5.2610	normal		
Fluoride	mg/L	CBL-308I	17	0	18	1.6706	0.2554	1.7500	1.4300			2.9477	normal		
Fluoride	mg/L	CBL-341I	19	0	19	0.3745	0.2679	0.5000	0.1410			1.7141	normal		
pH	S.U.	CBL-301I	22	0	22	6.2014	0.2396	6.1400	6.2100			5.00 - 7.40	normal		
pH	S.U.	CBL-302I	19	0	19	6.0689	0.5972	6.3200	6.2100			3.08 - 9.05	normal		
pH	S.U.	CBL-306I	18	0	19	6.6478	0.6569	6.8700	6.7000			3.36 - 9.93	normal		
pH	S.U.	CBL-308I	18	0	18	6.2328	0.2475	6.3600	6.2300			5.00 - 7.47	normal		
pH	S.U.	CBL-341I	18	0	19	6.0494	0.2377	6.2600	6.1600			4.86 - 7.24	normal		
Sulfate	mg/L	CBL-301I	18	0	19	350.5556	60.2936	406.0000	285.0000			652.0236	normal		
Sulfate	mg/L	CBL-302I	18	0	18	1222.9444	114.1137	1340.0000	1300.0000			1793.5130	normal		
Sulfate	mg/L	CBL-306I	17	0	19	388.1765	110.3564	510.0000	348.0000			939.9583	normal		
Sulfate	mg/L	CBL-308I	18	0	18	1424.4444	121.4240	1310.0000	1190.0000			2031.5645	normal		
Sulfate	mg/L	CBL-341I	18	0	18	349.2778	32.8898	320.0000	296.0000			513.7270	normal		
Total Dissolved Solids	mg/L	CBL-301I	18	0	19	5444.4444	767.6950	4700.0000	4590.0000			9282.9193	normal		
Total Dissolved Solids	mg/L	CBL-302I	18	0	18	5311.6667	764.8702	4510.0000	5120.0000			9136.0178	normal		
Total Dissolved Solids	mg/L	CBL-306I	17	0	19	1437.0588	267.0853	1730.0000	1540.0000			2772.4853	normal		
Total Dissolved Solids	mg/L	CBL-308I	18	0	18	6696.6667	1385.2713	5320.0000	6840.0000			13623.0230	normal		
Total Dissolved Solids	mg/L	CBL-341I	18	0	18	4667.7778	554.0180	3800.0000	4910.0000			7437.8678	normal		

N(back) and N(mon) = Non-outlier measurements in the background and monitoring periods.
N(tot) = All independent measurements for that constituent and well.
For transformed data, mean and SD in transformed units and control limit in original units.
Conf = confidence level for passing initial test or one verification resample (nonparametric test only).
* - Insufficient Data.
** - Detection Frequency < 25%.
*** - Zero Variance.

Table 2

Analytical Data and CUSUM Summary

Constituent	Units	Well	Date	Background	Result		Outlier	CUSUM	Adjusted	
Boron, Total	mg/L	CBL-301I	01/21/2016	yes	0.0500	ND				
Boron, Total	mg/L	CBL-301I	05/04/2016	yes	0.0500	ND				
Boron, Total	mg/L	CBL-301I	07/27/2016	yes	0.0500	ND				
Boron, Total	mg/L	CBL-301I	10/24/2016	yes	0.0500	ND				
Boron, Total	mg/L	CBL-301I	01/23/2017	yes	0.0500	ND				
Boron, Total	mg/L	CBL-301I	03/22/2017	yes	0.0500	ND				
Boron, Total	mg/L	CBL-301I	05/18/2017	yes	0.0707					
Boron, Total	mg/L	CBL-301I	07/26/2017	yes	0.0500	ND				
Boron, Total	mg/L	CBL-301I	02/08/2018	yes	0.0500	ND				
Boron, Total	mg/L	CBL-301I	07/25/2018	yes	0.0500	ND				
Boron, Total	mg/L	CBL-301I	01/17/2019	yes	0.0500	ND				
Boron, Total	mg/L	CBL-301I	05/02/2019	yes	0.0500	ND				
Boron, Total	mg/L	CBL-301I	07/31/2019	yes	0.0500	ND				
Boron, Total	mg/L	CBL-301I	01/28/2020	yes	0.0500	ND				
Boron, Total	mg/L	CBL-301I	09/17/2020	yes	0.0801					
Boron, Total	mg/L	CBL-301I	01/26/2021	yes	0.0500	ND				
Boron, Total	mg/L	CBL-301I	07/20/2021	yes	0.0826					
Boron, Total	mg/L	CBL-301I	09/07/2021	yes	0.0500	ND				
Boron, Total	mg/L	CBL-301I	01/26/2022	yes	0.0500	ND				
Boron, Total	mg/L	CBL-301I	07/27/2022	yes	0.0850					
Boron, Total	mg/L	CBL-301I	08/30/2022	yes	0.1070					
Boron, Total	mg/L	CBL-301I	10/25/2022	yes	0.0645					
Boron, Total	mg/L	CBL-302I	01/22/2016	yes	0.0500	ND				
Boron, Total	mg/L	CBL-302I	05/04/2016	yes	0.0500	ND				
Boron, Total	mg/L	CBL-302I	07/27/2016	yes	0.0500	ND				
Boron, Total	mg/L	CBL-302I	10/24/2016	yes	0.1560		yes			*
Boron, Total	mg/L	CBL-302I	01/23/2017	yes	0.0500	ND				
Boron, Total	mg/L	CBL-302I	03/22/2017	yes	0.2970		yes			*
Boron, Total	mg/L	CBL-302I	05/16/2017	yes	0.0500	ND				
Boron, Total	mg/L	CBL-302I	07/27/2017	yes	0.0500	ND				
Boron, Total	mg/L	CBL-302I	02/08/2018	yes	0.0500	ND				
Boron, Total	mg/L	CBL-302I	07/27/2018	yes	0.0500	ND				
Boron, Total	mg/L	CBL-302I	01/22/2019	yes	0.0500	ND				
Boron, Total	mg/L	CBL-302I	07/31/2019	yes	0.0500	ND				
Boron, Total	mg/L	CBL-302I	01/30/2020	yes	0.0500	ND				
Boron, Total	mg/L	CBL-302I	09/17/2020	yes	0.0500	ND				
Boron, Total	mg/L	CBL-302I	01/28/2021	yes	0.0500	ND				
Boron, Total	mg/L	CBL-302I	07/21/2021	yes	0.0743					
Boron, Total	mg/L	CBL-302I	01/27/2022	yes	0.0500	ND				
Boron, Total	mg/L	CBL-302I	07/28/2022	yes	0.0500	ND				
Boron, Total	mg/L	CBL-306I	01/21/2016	yes	0.0500	ND				
Boron, Total	mg/L	CBL-306I	05/04/2016	yes	0.0717					
Boron, Total	mg/L	CBL-306I	07/26/2016	yes	0.0998					
Boron, Total	mg/L	CBL-306I	10/24/2016	yes	0.0556					
Boron, Total	mg/L	CBL-306I	01/19/2017	yes	0.0500	ND				
Boron, Total	mg/L	CBL-306I	03/22/2017	yes	0.1240					
Boron, Total	mg/L	CBL-306I	05/18/2017	yes	0.0832					
Boron, Total	mg/L	CBL-306I	07/27/2017	yes	0.0531					
Boron, Total	mg/L	CBL-306I	02/08/2018	yes	0.0500	ND				
Boron, Total	mg/L	CBL-306I	07/27/2018	yes	0.0500	ND				

* - Outlier for that well and constituent.
** - Non-outlier detected sample Result and / or CUSUM value exceeds limit.
*** - ND value replaced with median RL.
**** - ND value replaced with manual RL.
ND = Not detected, Result = detection limit.

Table 2

Analytical Data and CUSUM Summary

Constituent	Units	Well	Date	Background	Result		Outlier	CUSUM	Adjusted	
Boron, Total	mg/L	CBL-306I	01/16/2019	yes	0.0500	ND				
Boron, Total	mg/L	CBL-306I	07/31/2019	yes	0.0824		yes			*
Boron, Total	mg/L	CBL-306I	08/23/2019	yes	0.0500					
Boron, Total	mg/L	CBL-306I	01/29/2020	yes	0.0500	ND				
Boron, Total	mg/L	CBL-306I	09/19/2020	yes	0.0773					
Boron, Total	mg/L	CBL-306I	01/28/2021	yes	0.0500	ND				
Boron, Total	mg/L	CBL-306I	07/21/2021	yes	0.0927					
Boron, Total	mg/L	CBL-306I	01/27/2022	yes	0.0548					
Boron, Total	mg/L	CBL-306I	07/28/2022	yes	0.1100					
Boron, Total	mg/L	CBL-308I	01/22/2016	yes	0.0500	ND				
Boron, Total	mg/L	CBL-308I	05/04/2016	yes	0.1210					
Boron, Total	mg/L	CBL-308I	07/26/2016	yes	0.1860					
Boron, Total	mg/L	CBL-308I	10/24/2016	yes	0.2560					
Boron, Total	mg/L	CBL-308I	01/19/2017	yes	0.0500	ND				
Boron, Total	mg/L	CBL-308I	03/22/2017	yes	0.5450					
Boron, Total	mg/L	CBL-308I	05/16/2017	yes	0.1090					
Boron, Total	mg/L	CBL-308I	07/26/2017	yes	0.0799					
Boron, Total	mg/L	CBL-308I	02/06/2018	yes	0.0500	ND				
Boron, Total	mg/L	CBL-308I	07/25/2018	yes	0.0500	ND				
Boron, Total	mg/L	CBL-308I	01/18/2019	yes	0.0500	ND				
Boron, Total	mg/L	CBL-308I	07/31/2019	yes	0.0500	ND				
Boron, Total	mg/L	CBL-308I	01/29/2020	yes	0.0500	ND				
Boron, Total	mg/L	CBL-308I	09/18/2020	yes	0.1030					
Boron, Total	mg/L	CBL-308I	01/28/2021	yes	0.0500	ND				
Boron, Total	mg/L	CBL-308I	07/21/2021	yes	0.1300					
Boron, Total	mg/L	CBL-308I	01/27/2022	yes	0.0500	ND				
Boron, Total	mg/L	CBL-308I	07/27/2022	yes	0.0790					
Boron, Total	mg/L	CBL-341I	01/23/2017	yes	0.0500	ND				
Boron, Total	mg/L	CBL-341I	02/23/2017	yes	0.0500	ND				
Boron, Total	mg/L	CBL-341I	03/22/2017	yes	0.0500	ND				
Boron, Total	mg/L	CBL-341I	04/20/2017	yes	0.0587					
Boron, Total	mg/L	CBL-341I	05/16/2017	yes	0.0896					
Boron, Total	mg/L	CBL-341I	06/20/2017	yes	0.0668					
Boron, Total	mg/L	CBL-341I	07/27/2017	yes	0.0507					
Boron, Total	mg/L	CBL-341I	09/11/2017	yes	0.0500	ND				
Boron, Total	mg/L	CBL-341I	02/08/2018	yes	0.0500	ND				
Boron, Total	mg/L	CBL-341I	08/24/2018	yes	0.0500	ND				
Boron, Total	mg/L	CBL-341I	01/22/2019	yes	0.0500	ND				
Boron, Total	mg/L	CBL-341I	07/31/2019	yes	0.0500	ND				
Boron, Total	mg/L	CBL-341I	01/30/2020	yes	0.0500	ND				
Boron, Total	mg/L	CBL-341I	09/17/2020	yes	0.1020					
Boron, Total	mg/L	CBL-341I	01/27/2021	yes	0.0500	ND				
Boron, Total	mg/L	CBL-341I	07/22/2021	yes	0.1110					
Boron, Total	mg/L	CBL-341I	01/27/2022	yes	0.0500	ND				
Boron, Total	mg/L	CBL-341I	07/28/2022	yes	0.1150					
Calcium, Total	mg/L	CBL-301I	01/21/2016	yes	905.0000					
Calcium, Total	mg/L	CBL-301I	05/04/2016	yes	949.0000					
Calcium, Total	mg/L	CBL-301I	07/27/2016	yes	925.0000					
Calcium, Total	mg/L	CBL-301I	10/24/2016	yes	978.0000					
Calcium, Total	mg/L	CBL-301I	01/23/2017	yes	1000.0000					

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Table 2

Analytical Data and CUSUM Summary

Constituent	Units	Well	Date	Background	Result		Outlier	CUSUM	Adjusted	
Calcium, Total	mg/L	CBL-301I	03/22/2017	yes	1030.0000					
Calcium, Total	mg/L	CBL-301I	05/18/2017	yes	1060.0000					
Calcium, Total	mg/L	CBL-301I	07/26/2017	yes	961.0000					
Calcium, Total	mg/L	CBL-301I	02/08/2018	yes	873.0000					
Calcium, Total	mg/L	CBL-301I	07/25/2018	yes	993.0000					
Calcium, Total	mg/L	CBL-301I	01/17/2019	yes	156.0000		yes			*
Calcium, Total	mg/L	CBL-301I	05/02/2019	yes	762.0000					
Calcium, Total	mg/L	CBL-301I	07/31/2019	yes	783.0000					
Calcium, Total	mg/L	CBL-301I	01/28/2020	yes	851.0000					
Calcium, Total	mg/L	CBL-301I	09/17/2020	yes	1060.0000					
Calcium, Total	mg/L	CBL-301I	01/26/2021	yes	1130.0000					
Calcium, Total	mg/L	CBL-301I	07/20/2021	yes	1100.0000					
Calcium, Total	mg/L	CBL-301I	01/26/2022	yes	999.0000					
Calcium, Total	mg/L	CBL-301I	07/27/2022	yes	1010.0000					
Calcium, Total	mg/L	CBL-302I	01/22/2016	yes	1030.0000					
Calcium, Total	mg/L	CBL-302I	05/04/2016	yes	1010.0000					
Calcium, Total	mg/L	CBL-302I	07/27/2016	yes	1030.0000					
Calcium, Total	mg/L	CBL-302I	10/24/2016	yes	1070.0000					
Calcium, Total	mg/L	CBL-302I	01/23/2017	yes	1100.0000					
Calcium, Total	mg/L	CBL-302I	03/22/2017	yes	1090.0000					
Calcium, Total	mg/L	CBL-302I	05/16/2017	yes	1100.0000					
Calcium, Total	mg/L	CBL-302I	07/27/2017	yes	1040.0000					
Calcium, Total	mg/L	CBL-302I	02/08/2018	yes	934.0000					
Calcium, Total	mg/L	CBL-302I	07/27/2018	yes	995.0000					
Calcium, Total	mg/L	CBL-302I	01/22/2019	yes	855.0000					
Calcium, Total	mg/L	CBL-302I	07/31/2019	yes	914.0000					
Calcium, Total	mg/L	CBL-302I	01/30/2020	yes	838.0000					
Calcium, Total	mg/L	CBL-302I	09/17/2020	yes	853.0000					
Calcium, Total	mg/L	CBL-302I	01/28/2021	yes	1020.0000					
Calcium, Total	mg/L	CBL-302I	07/21/2021	yes	844.0000					
Calcium, Total	mg/L	CBL-302I	01/27/2022	yes	754.0000					
Calcium, Total	mg/L	CBL-302I	07/28/2022	yes	750.0000					
Calcium, Total	mg/L	CBL-306I	01/21/2016	yes	137.0000					
Calcium, Total	mg/L	CBL-306I	05/04/2016	yes	47.2000		yes			*
Calcium, Total	mg/L	CBL-306I	07/26/2016	yes	105.0000		yes			*
Calcium, Total	mg/L	CBL-306I	10/24/2016	yes	198.0000					
Calcium, Total	mg/L	CBL-306I	01/19/2017	yes	174.0000					
Calcium, Total	mg/L	CBL-306I	03/22/2017	yes	204.0000					
Calcium, Total	mg/L	CBL-306I	05/18/2017	yes	205.0000					
Calcium, Total	mg/L	CBL-306I	07/27/2017	yes	234.0000					
Calcium, Total	mg/L	CBL-306I	02/08/2018	yes	230.0000					
Calcium, Total	mg/L	CBL-306I	07/27/2018	yes	275.0000					
Calcium, Total	mg/L	CBL-306I	01/16/2019	yes	180.0000					
Calcium, Total	mg/L	CBL-306I	07/31/2019	yes	106.0000		yes			*
Calcium, Total	mg/L	CBL-306I	08/23/2019	yes	226.0000					
Calcium, Total	mg/L	CBL-306I	01/29/2020	yes	247.0000					
Calcium, Total	mg/L	CBL-306I	09/19/2020	yes	260.0000					
Calcium, Total	mg/L	CBL-306I	01/28/2021	yes	257.0000					
Calcium, Total	mg/L	CBL-306I	07/21/2021	yes	216.0000					
Calcium, Total	mg/L	CBL-306I	01/27/2022	yes	212.0000					

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Table 2

Analytical Data and CUSUM Summary

Constituent	Units	Well	Date	Background	Result		Outlier	CUSUM	Adjusted	
Calcium, Total	mg/L	CBL-306I	07/28/2022	yes	182.0000					
Calcium, Total	mg/L	CBL-308I	01/22/2016	yes	903.0000					
Calcium, Total	mg/L	CBL-308I	05/04/2016	yes	870.0000					
Calcium, Total	mg/L	CBL-308I	07/26/2016	yes	911.0000					
Calcium, Total	mg/L	CBL-308I	10/24/2016	yes	939.0000					
Calcium, Total	mg/L	CBL-308I	01/19/2017	yes	919.0000					
Calcium, Total	mg/L	CBL-308I	03/22/2017	yes	947.0000					
Calcium, Total	mg/L	CBL-308I	05/16/2017	yes	954.0000					
Calcium, Total	mg/L	CBL-308I	07/26/2017	yes	878.0000					
Calcium, Total	mg/L	CBL-308I	02/06/2018	yes	859.0000					
Calcium, Total	mg/L	CBL-308I	07/25/2018	yes	863.0000					
Calcium, Total	mg/L	CBL-308I	01/18/2019	yes	760.0000					
Calcium, Total	mg/L	CBL-308I	07/31/2019	yes	840.0000					
Calcium, Total	mg/L	CBL-308I	01/29/2020	yes	745.0000					
Calcium, Total	mg/L	CBL-308I	09/18/2020	yes	838.0000					
Calcium, Total	mg/L	CBL-308I	01/28/2021	yes	830.0000					
Calcium, Total	mg/L	CBL-308I	07/21/2021	yes	684.0000					
Calcium, Total	mg/L	CBL-308I	01/27/2022	yes	974.0000					
Calcium, Total	mg/L	CBL-308I	07/27/2022	yes	736.0000					
Calcium, Total	mg/L	CBL-341I	01/23/2017	yes	854.0000					
Calcium, Total	mg/L	CBL-341I	02/23/2017	yes	870.0000					
Calcium, Total	mg/L	CBL-341I	03/22/2017	yes	906.0000					
Calcium, Total	mg/L	CBL-341I	04/20/2017	yes	898.0000					
Calcium, Total	mg/L	CBL-341I	05/16/2017	yes	860.0000					
Calcium, Total	mg/L	CBL-341I	06/20/2017	yes	950.0000					
Calcium, Total	mg/L	CBL-341I	07/27/2017	yes	829.0000					
Calcium, Total	mg/L	CBL-341I	09/11/2017	yes	848.0000					
Calcium, Total	mg/L	CBL-341I	02/08/2018	yes	810.0000					
Calcium, Total	mg/L	CBL-341I	08/24/2018	yes	824.0000					
Calcium, Total	mg/L	CBL-341I	01/22/2019	yes	782.0000					
Calcium, Total	mg/L	CBL-341I	07/31/2019	yes	714.0000					
Calcium, Total	mg/L	CBL-341I	01/30/2020	yes	767.0000					
Calcium, Total	mg/L	CBL-341I	09/17/2020	yes	814.0000					
Calcium, Total	mg/L	CBL-341I	01/27/2021	yes	874.0000					
Calcium, Total	mg/L	CBL-341I	07/22/2021	yes	852.0000					
Calcium, Total	mg/L	CBL-341I	01/27/2022	yes	1040.0000					
Calcium, Total	mg/L	CBL-341I	07/28/2022	yes	704.0000					
Chloride	mg/L	CBL-301I	01/21/2016	yes	2300.0000					
Chloride	mg/L	CBL-301I	05/04/2016	yes	2160.0000					
Chloride	mg/L	CBL-301I	07/27/2016	yes	2290.0000					
Chloride	mg/L	CBL-301I	10/24/2016	yes	2250.0000					
Chloride	mg/L	CBL-301I	01/23/2017	yes	3200.0000					
Chloride	mg/L	CBL-301I	03/22/2017	yes	2390.0000					
Chloride	mg/L	CBL-301I	05/18/2017	yes	2420.0000					
Chloride	mg/L	CBL-301I	07/26/2017	yes	2500.0000					
Chloride	mg/L	CBL-301I	02/08/2018	yes	2480.0000					
Chloride	mg/L	CBL-301I	07/25/2018	yes	1330.0000					
Chloride	mg/L	CBL-301I	01/17/2019	yes	619.0000		yes			*
Chloride	mg/L	CBL-301I	05/02/2019	yes	1910.0000					
Chloride	mg/L	CBL-301I	07/31/2019	yes	2240.0000					

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Table 2

Analytical Data and CUSUM Summary

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Chloride	mg/L	CBL-301I	01/28/2020	yes	2360.0000					
Chloride	mg/L	CBL-301I	09/17/2020	yes	2270.0000					
Chloride	mg/L	CBL-301I	01/26/2021	yes	2420.0000					
Chloride	mg/L	CBL-301I	07/20/2021	yes	2590.0000					
Chloride	mg/L	CBL-301I	01/26/2022	yes	2440.0000					
Chloride	mg/L	CBL-301I	07/27/2022	yes	1840.0000					
Chloride	mg/L	CBL-302I	01/22/2016	yes	2190.0000					
Chloride	mg/L	CBL-302I	05/04/2016	yes	2130.0000					
Chloride	mg/L	CBL-302I	07/27/2016	yes	2210.0000					
Chloride	mg/L	CBL-302I	10/24/2016	yes	2170.0000					
Chloride	mg/L	CBL-302I	01/23/2017	yes	2080.0000					
Chloride	mg/L	CBL-302I	03/22/2017	yes	2050.0000					
Chloride	mg/L	CBL-302I	05/16/2017	yes	2230.0000					
Chloride	mg/L	CBL-302I	07/27/2017	yes	2040.0000					
Chloride	mg/L	CBL-302I	02/08/2018	yes	2080.0000					
Chloride	mg/L	CBL-302I	07/27/2018	yes	1980.0000					
Chloride	mg/L	CBL-302I	01/22/2019	yes	1960.0000					
Chloride	mg/L	CBL-302I	07/31/2019	yes	1540.0000					
Chloride	mg/L	CBL-302I	01/30/2020	yes	1540.0000					
Chloride	mg/L	CBL-302I	09/17/2020	yes	1410.0000					
Chloride	mg/L	CBL-302I	01/28/2021	yes	1370.0000					
Chloride	mg/L	CBL-302I	07/21/2021	yes	1380.0000					
Chloride	mg/L	CBL-302I	01/27/2022	yes	1310.0000					
Chloride	mg/L	CBL-302I	07/28/2022	yes	1300.0000					
Chloride	mg/L	CBL-306I	01/21/2016	yes	155.0000					
Chloride	mg/L	CBL-306I	05/04/2016	yes	20.0000		yes			*
Chloride	mg/L	CBL-306I	07/26/2016	yes	114.0000		yes			*
Chloride	mg/L	CBL-306I	10/24/2016	yes	330.0000					
Chloride	mg/L	CBL-306I	01/19/2017	yes	197.0000					
Chloride	mg/L	CBL-306I	03/22/2017	yes	231.0000					
Chloride	mg/L	CBL-306I	05/18/2017	yes	289.0000					
Chloride	mg/L	CBL-306I	07/27/2017	yes	350.0000					
Chloride	mg/L	CBL-306I	02/08/2018	yes	385.0000					
Chloride	mg/L	CBL-306I	07/27/2018	yes	283.0000					
Chloride	mg/L	CBL-306I	01/16/2019	yes	215.0000					
Chloride	mg/L	CBL-306I	07/31/2019	yes	538.0000		yes			*
Chloride	mg/L	CBL-306I	08/23/2019	yes	318.0000					
Chloride	mg/L	CBL-306I	01/29/2020	yes	445.0000					
Chloride	mg/L	CBL-306I	09/19/2020	yes	420.0000					
Chloride	mg/L	CBL-306I	01/28/2021	yes	292.0000					
Chloride	mg/L	CBL-306I	07/21/2021	yes	255.0000					
Chloride	mg/L	CBL-306I	01/27/2022	yes	384.0000					
Chloride	mg/L	CBL-306I	07/28/2022	yes	261.0000					
Chloride	mg/L	CBL-308I	01/22/2016	yes	2760.0000					
Chloride	mg/L	CBL-308I	05/04/2016	yes	2580.0000					
Chloride	mg/L	CBL-308I	07/26/2016	yes	2680.0000					
Chloride	mg/L	CBL-308I	10/24/2016	yes	2870.0000					
Chloride	mg/L	CBL-308I	01/19/2017	yes	2360.0000					
Chloride	mg/L	CBL-308I	03/22/2017	yes	2530.0000					
Chloride	mg/L	CBL-308I	05/16/2017	yes	2740.0000					

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Table 2

Analytical Data and CUSUM Summary

Constituent	Units	Well	Date	Background	Result		Outlier	CUSUM	Adjusted	
Chloride	mg/L	CBL-308I	07/26/2017	yes	2760.0000					
Chloride	mg/L	CBL-308I	02/06/2018	yes	2750.0000					
Chloride	mg/L	CBL-308I	07/25/2018	yes	2680.0000					
Chloride	mg/L	CBL-308I	01/18/2019	yes	2240.0000					
Chloride	mg/L	CBL-308I	07/31/2019	yes	2290.0000					
Chloride	mg/L	CBL-308I	01/29/2020	yes	2110.0000					
Chloride	mg/L	CBL-308I	09/18/2020	yes	2410.0000					
Chloride	mg/L	CBL-308I	01/28/2021	yes	2200.0000					
Chloride	mg/L	CBL-308I	07/21/2021	yes	1780.0000					
Chloride	mg/L	CBL-308I	01/27/2022	yes	2020.0000					
Chloride	mg/L	CBL-308I	07/27/2022	yes	2470.0000					
Chloride	mg/L	CBL-341I	01/23/2017	yes	1600.0000					
Chloride	mg/L	CBL-341I	02/23/2017	yes	2000.0000					
Chloride	mg/L	CBL-341I	03/22/2017	yes	1780.0000					
Chloride	mg/L	CBL-341I	04/20/2017	yes	1770.0000					
Chloride	mg/L	CBL-341I	05/16/2017	yes	1900.0000					
Chloride	mg/L	CBL-341I	06/20/2017	yes	1820.0000					
Chloride	mg/L	CBL-341I	07/27/2017	yes	1970.0000					
Chloride	mg/L	CBL-341I	09/11/2017	yes	1710.0000					
Chloride	mg/L	CBL-341I	02/08/2018	yes	2110.0000					
Chloride	mg/L	CBL-341I	08/24/2018	yes	1910.0000					
Chloride	mg/L	CBL-341I	01/22/2019	yes	1790.0000					
Chloride	mg/L	CBL-341I	07/31/2019	yes	1650.0000					
Chloride	mg/L	CBL-341I	01/30/2020	yes	1780.0000					
Chloride	mg/L	CBL-341I	09/17/2020	yes	1700.0000					
Chloride	mg/L	CBL-341I	01/27/2021	yes	1800.0000					
Chloride	mg/L	CBL-341I	07/22/2021	yes	1750.0000					
Chloride	mg/L	CBL-341I	01/27/2022	yes	1810.0000					
Chloride	mg/L	CBL-341I	07/28/2022	yes	1690.0000					
Fluoride	mg/L	CBL-301I	01/21/2016	yes	0.2500	ND			0.5000	***
Fluoride	mg/L	CBL-301I	05/04/2016	yes	0.5000	ND				
Fluoride	mg/L	CBL-301I	07/27/2016	yes	0.5000	ND				
Fluoride	mg/L	CBL-301I	10/24/2016	yes	0.2500	ND			0.5000	***
Fluoride	mg/L	CBL-301I	01/23/2017	yes	0.3120					
Fluoride	mg/L	CBL-301I	03/22/2017	yes	0.5000	ND				
Fluoride	mg/L	CBL-301I	05/18/2017	yes	0.5000	ND				
Fluoride	mg/L	CBL-301I	07/26/2017	yes	0.5000	ND				
Fluoride	mg/L	CBL-301I	02/08/2018	yes	0.5000	ND				
Fluoride	mg/L	CBL-301I	07/25/2018	yes	0.5000	ND				
Fluoride	mg/L	CBL-301I	01/17/2019	yes	0.2190					
Fluoride	mg/L	CBL-301I	05/02/2019	yes	0.1120					
Fluoride	mg/L	CBL-301I	07/31/2019	yes	0.0510					
Fluoride	mg/L	CBL-301I	01/28/2020	yes	0.1300					
Fluoride	mg/L	CBL-301I	09/17/2020	yes	0.2500	ND			0.5000	***
Fluoride	mg/L	CBL-301I	01/26/2021	yes	0.5000	ND				
Fluoride	mg/L	CBL-301I	07/20/2021	yes	2.6800					
Fluoride	mg/L	CBL-301I	09/07/2021	yes	0.5000	ND				
Fluoride	mg/L	CBL-301I	01/26/2022	yes	0.0500	ND			0.5000	***
Fluoride	mg/L	CBL-301I	07/27/2022	yes	0.1560					
Fluoride	mg/L	CBL-302I	01/22/2016	yes	0.2500	ND			0.5000	***

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Table 2

Analytical Data and CUSUM Summary

Constituent	Units	Well	Date	Background	Result		Outlier	CUSUM	Adjusted	
Fluoride	mg/L	CBL-302I	05/04/2016	yes	0.5000	ND				
Fluoride	mg/L	CBL-302I	07/27/2016	yes	0.5000	ND				
Fluoride	mg/L	CBL-302I	10/24/2016	yes	0.2500	ND			0.5000	***
Fluoride	mg/L	CBL-302I	01/23/2017	yes	0.3320					
Fluoride	mg/L	CBL-302I	03/22/2017	yes	0.5000	ND				
Fluoride	mg/L	CBL-302I	05/16/2017	yes	0.5000	ND				
Fluoride	mg/L	CBL-302I	07/27/2017	yes	0.5000	ND				
Fluoride	mg/L	CBL-302I	02/08/2018	yes	0.1120					
Fluoride	mg/L	CBL-302I	07/27/2018	yes	0.5000	ND				
Fluoride	mg/L	CBL-302I	01/22/2019	yes	0.0402					
Fluoride	mg/L	CBL-302I	07/31/2019	yes	0.0605					
Fluoride	mg/L	CBL-302I	01/30/2020	yes	0.1930					
Fluoride	mg/L	CBL-302I	09/17/2020	yes	0.2500	ND			0.5000	***
Fluoride	mg/L	CBL-302I	01/28/2021	yes	0.5000	ND				
Fluoride	mg/L	CBL-302I	07/21/2021	yes	2.2500					
Fluoride	mg/L	CBL-302I	09/07/2021	yes	0.2500	ND			0.5000	***
Fluoride	mg/L	CBL-302I	01/27/2022	yes	0.0500	ND			0.5000	***
Fluoride	mg/L	CBL-302I	07/28/2022	yes	0.1650					
Fluoride	mg/L	CBL-306I	01/21/2016	yes	2.5000					
Fluoride	mg/L	CBL-306I	05/04/2016	yes	1.0000					
Fluoride	mg/L	CBL-306I	07/26/2016	yes	1.3700					
Fluoride	mg/L	CBL-306I	10/24/2016	yes	2.3800					
Fluoride	mg/L	CBL-306I	01/19/2017	yes	1.8500					
Fluoride	mg/L	CBL-306I	03/22/2017	yes	12.6000		yes			*
Fluoride	mg/L	CBL-306I	05/18/2017	yes	2.2000					
Fluoride	mg/L	CBL-306I	07/27/2017	yes	2.9100					
Fluoride	mg/L	CBL-306I	02/08/2018	yes	2.8100					
Fluoride	mg/L	CBL-306I	07/27/2018	yes	2.9500					
Fluoride	mg/L	CBL-306I	01/16/2019	yes	1.9800					
Fluoride	mg/L	CBL-306I	07/31/2019	yes	9.2600		yes			*
Fluoride	mg/L	CBL-306I	08/23/2019	yes	2.6600					
Fluoride	mg/L	CBL-306I	01/29/2020	yes	2.8300					
Fluoride	mg/L	CBL-306I	09/19/2020	yes	2.7200					
Fluoride	mg/L	CBL-306I	01/28/2021	yes	2.9000					
Fluoride	mg/L	CBL-306I	07/21/2021	yes	2.4200					
Fluoride	mg/L	CBL-306I	01/27/2022	yes	2.9900					
Fluoride	mg/L	CBL-306I	07/28/2022	yes	2.2600					
Fluoride	mg/L	CBL-308I	01/22/2016	yes	1.4900					
Fluoride	mg/L	CBL-308I	05/04/2016	yes	2.3000					
Fluoride	mg/L	CBL-308I	07/26/2016	yes	1.6400					
Fluoride	mg/L	CBL-308I	10/24/2016	yes	1.5900					
Fluoride	mg/L	CBL-308I	01/19/2017	yes	1.3300					
Fluoride	mg/L	CBL-308I	03/22/2017	yes	9.0500		yes			*
Fluoride	mg/L	CBL-308I	05/16/2017	yes	1.7000					
Fluoride	mg/L	CBL-308I	07/26/2017	yes	1.9000					
Fluoride	mg/L	CBL-308I	02/06/2018	yes	1.7600					
Fluoride	mg/L	CBL-308I	07/25/2018	yes	2.1000					
Fluoride	mg/L	CBL-308I	01/18/2019	yes	1.6800					
Fluoride	mg/L	CBL-308I	07/31/2019	yes	1.6200					
Fluoride	mg/L	CBL-308I	01/29/2020	yes	1.6000					

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Table 2

Analytical Data and CUSUM Summary

Constituent	Units	Well	Date	Background	Result		Outlier	CUSUM	Adjusted	
Fluoride	mg/L	CBL-308I	09/18/2020	yes	1.3300					
Fluoride	mg/L	CBL-308I	01/28/2021	yes	1.4400					
Fluoride	mg/L	CBL-308I	07/21/2021	yes	1.7400					
Fluoride	mg/L	CBL-308I	01/27/2022	yes	1.7500					
Fluoride	mg/L	CBL-308I	07/27/2022	yes	1.4300					
Fluoride	mg/L	CBL-341I	01/23/2017	yes	0.5300					
Fluoride	mg/L	CBL-341I	02/23/2017	yes	0.5000	ND				
Fluoride	mg/L	CBL-341I	03/22/2017	yes	0.5000	ND				
Fluoride	mg/L	CBL-341I	04/20/2017	yes	0.5000	ND				
Fluoride	mg/L	CBL-341I	05/16/2017	yes	0.5000	ND				
Fluoride	mg/L	CBL-341I	06/20/2017	yes	0.3350					
Fluoride	mg/L	CBL-341I	07/27/2017	yes	0.0550					
Fluoride	mg/L	CBL-341I	09/11/2017	yes	0.3670					
Fluoride	mg/L	CBL-341I	02/08/2018	yes	0.1060					
Fluoride	mg/L	CBL-341I	08/24/2018	yes	0.1140					
Fluoride	mg/L	CBL-341I	01/22/2019	yes	0.0546					
Fluoride	mg/L	CBL-341I	07/31/2019	yes	0.1000					
Fluoride	mg/L	CBL-341I	01/30/2020	yes	0.1530					
Fluoride	mg/L	CBL-341I	09/17/2020	yes	0.2500	ND			0.5000	***
Fluoride	mg/L	CBL-341I	01/27/2021	yes	0.5000	ND				
Fluoride	mg/L	CBL-341I	07/22/2021	yes	1.1600					
Fluoride	mg/L	CBL-341I	09/07/2021	yes	0.2500	ND			0.5000	***
Fluoride	mg/L	CBL-341I	01/27/2022	yes	0.0500	ND			0.5000	***
Fluoride	mg/L	CBL-341I	07/28/2022	yes	0.1410					
pH	S.U.	CBL-301I	01/21/2016	yes	6.3300					
pH	S.U.	CBL-301I	05/04/2016	yes	6.2600					
pH	S.U.	CBL-301I	07/27/2016	yes	5.9500					
pH	S.U.	CBL-301I	10/24/2016	yes	6.2300					
pH	S.U.	CBL-301I	01/23/2017	yes	6.2600					
pH	S.U.	CBL-301I	03/22/2017	yes	6.3100					
pH	S.U.	CBL-301I	05/18/2017	yes	5.9500					
pH	S.U.	CBL-301I	07/26/2017	yes	6.0200					
pH	S.U.	CBL-301I	02/08/2018	yes	6.1700					
pH	S.U.	CBL-301I	07/25/2018	yes	6.0400					
pH	S.U.	CBL-301I	01/17/2019	yes	7.1600					
pH	S.U.	CBL-301I	05/02/2019	yes	6.1400					
pH	S.U.	CBL-301I	07/31/2019	yes	6.1900					
pH	S.U.	CBL-301I	01/28/2020	yes	6.2600					
pH	S.U.	CBL-301I	09/17/2020	yes	6.1300					
pH	S.U.	CBL-301I	01/26/2021	yes	6.0600					
pH	S.U.	CBL-301I	07/20/2021	yes	6.1300					
pH	S.U.	CBL-301I	09/07/2021	yes	6.1400					
pH	S.U.	CBL-301I	01/26/2022	yes	6.2700					
pH	S.U.	CBL-301I	07/27/2022	yes	6.0800					
pH	S.U.	CBL-301I	08/30/2022	yes	6.1400					
pH	S.U.	CBL-301I	10/25/2022	yes	6.2100					
pH	S.U.	CBL-302I	01/22/2016	yes	6.2900					
pH	S.U.	CBL-302I	05/04/2016	yes	6.0100					
pH	S.U.	CBL-302I	07/27/2016	yes	5.1700					
pH	S.U.	CBL-302I	10/24/2016	yes	7.7500					

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Table 2

Analytical Data and CUSUM Summary

Constituent	Units	Well	Date	Background	Result		Outlier	CUSUM	Adjusted	
pH	S.U.	CBL-302I	01/23/2017	yes	5.3600					
pH	S.U.	CBL-302I	03/22/2017	yes	5.4000					
pH	S.U.	CBL-302I	05/16/2017	yes	4.9400					
pH	S.U.	CBL-302I	07/27/2017	yes	6.2000					
pH	S.U.	CBL-302I	02/08/2018	yes	6.2100					
pH	S.U.	CBL-302I	07/27/2018	yes	5.7700					
pH	S.U.	CBL-302I	01/22/2019	yes	6.4400					
pH	S.U.	CBL-302I	07/31/2019	yes	6.1500					
pH	S.U.	CBL-302I	01/30/2020	yes	6.3400					
pH	S.U.	CBL-302I	09/17/2020	yes	6.2000					
pH	S.U.	CBL-302I	01/28/2021	yes	6.2100					
pH	S.U.	CBL-302I	07/21/2021	yes	6.0600					
pH	S.U.	CBL-302I	09/07/2021	yes	6.2800					
pH	S.U.	CBL-302I	01/27/2022	yes	6.3200					
pH	S.U.	CBL-302I	07/28/2022	yes	6.2100					
pH	S.U.	CBL-306I	01/21/2016	yes	7.0900					
pH	S.U.	CBL-306I	05/04/2016	yes	6.6900					
pH	S.U.	CBL-306I	07/26/2016	yes	6.9500					
pH	S.U.	CBL-306I	10/24/2016	yes	6.7200					
pH	S.U.	CBL-306I	01/19/2017	yes	7.2900					
pH	S.U.	CBL-306I	03/22/2017	yes	4.4100					
pH	S.U.	CBL-306I	05/18/2017	yes	5.6100					
pH	S.U.	CBL-306I	07/27/2017	yes	6.9400					
pH	S.U.	CBL-306I	02/08/2018	yes	6.6700					
pH	S.U.	CBL-306I	07/27/2018	yes	6.8600					
pH	S.U.	CBL-306I	01/16/2019	yes	6.7800					
pH	S.U.	CBL-306I	07/31/2019	yes	6.9200		yes			*
pH	S.U.	CBL-306I	08/23/2019	yes	6.8300					
pH	S.U.	CBL-306I	01/29/2020	yes	6.7000					
pH	S.U.	CBL-306I	09/19/2020	yes	7.1600					
pH	S.U.	CBL-306I	01/28/2021	yes	6.8400					
pH	S.U.	CBL-306I	07/21/2021	yes	6.5500					
pH	S.U.	CBL-306I	01/27/2022	yes	6.8700					
pH	S.U.	CBL-306I	07/28/2022	yes	6.7000					
pH	S.U.	CBL-308I	01/22/2016	yes	6.3600					
pH	S.U.	CBL-308I	05/04/2016	yes	6.1300					
pH	S.U.	CBL-308I	07/26/2016	yes	5.9500					
pH	S.U.	CBL-308I	10/24/2016	yes	6.2700					
pH	S.U.	CBL-308I	01/19/2017	yes	6.8300					
pH	S.U.	CBL-308I	03/22/2017	yes	6.2700					
pH	S.U.	CBL-308I	05/16/2017	yes	5.5400					
pH	S.U.	CBL-308I	07/26/2017	yes	6.2700					
pH	S.U.	CBL-308I	02/06/2018	yes	6.2600					
pH	S.U.	CBL-308I	07/25/2018	yes	6.0700					
pH	S.U.	CBL-308I	01/18/2019	yes	6.3900					
pH	S.U.	CBL-308I	07/31/2019	yes	6.2500					
pH	S.U.	CBL-308I	01/29/2020	yes	6.3700					
pH	S.U.	CBL-308I	09/18/2020	yes	6.2200					
pH	S.U.	CBL-308I	01/28/2021	yes	6.2600					
pH	S.U.	CBL-308I	07/21/2021	yes	6.1600					

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Table 2

Analytical Data and CUSUM Summary

Constituent	Units	Well	Date	Background	Result		Outlier	CUSUM	Adjusted	
pH	S.U.	CBL-308I	01/27/2022	yes	6.3600					
pH	S.U.	CBL-308I	07/27/2022	yes	6.2300					
pH	S.U.	CBL-341I	01/23/2017	yes	5.7400					
pH	S.U.	CBL-341I	02/23/2017	yes	5.2300		yes			*
pH	S.U.	CBL-341I	03/22/2017	yes	5.7200					
pH	S.U.	CBL-341I	04/20/2017	yes	5.7300					
pH	S.U.	CBL-341I	05/16/2017	yes	5.5400					
pH	S.U.	CBL-341I	06/20/2017	yes	6.1900					
pH	S.U.	CBL-341I	07/27/2017	yes	6.2100					
pH	S.U.	CBL-341I	09/11/2017	yes	6.1000					
pH	S.U.	CBL-341I	02/08/2018	yes	6.1800					
pH	S.U.	CBL-341I	08/24/2018	yes	5.8200					
pH	S.U.	CBL-341I	01/22/2019	yes	6.3800					
pH	S.U.	CBL-341I	07/31/2019	yes	6.2300					
pH	S.U.	CBL-341I	01/30/2020	yes	6.2700					
pH	S.U.	CBL-341I	09/17/2020	yes	6.1400					
pH	S.U.	CBL-341I	01/27/2021	yes	6.0600					
pH	S.U.	CBL-341I	07/22/2021	yes	5.9800					
pH	S.U.	CBL-341I	09/07/2021	yes	6.1800					
pH	S.U.	CBL-341I	01/27/2022	yes	6.2600					
pH	S.U.	CBL-341I	07/28/2022	yes	6.1600					
Sulfate	mg/L	CBL-301I	01/21/2016	yes	336.0000					
Sulfate	mg/L	CBL-301I	05/04/2016	yes	311.0000					
Sulfate	mg/L	CBL-301I	07/27/2016	yes	336.0000					
Sulfate	mg/L	CBL-301I	10/24/2016	yes	326.0000					
Sulfate	mg/L	CBL-301I	01/23/2017	yes	488.0000					
Sulfate	mg/L	CBL-301I	03/22/2017	yes	337.0000					
Sulfate	mg/L	CBL-301I	05/18/2017	yes	342.0000					
Sulfate	mg/L	CBL-301I	07/26/2017	yes	381.0000					
Sulfate	mg/L	CBL-301I	02/08/2018	yes	344.0000					
Sulfate	mg/L	CBL-301I	07/25/2018	yes	196.0000					
Sulfate	mg/L	CBL-301I	01/17/2019	yes	104.0000		yes			*
Sulfate	mg/L	CBL-301I	05/02/2019	yes	398.0000					
Sulfate	mg/L	CBL-301I	07/31/2019	yes	332.0000					
Sulfate	mg/L	CBL-301I	01/28/2020	yes	349.0000					
Sulfate	mg/L	CBL-301I	09/17/2020	yes	350.0000					
Sulfate	mg/L	CBL-301I	01/26/2021	yes	374.0000					
Sulfate	mg/L	CBL-301I	07/20/2021	yes	419.0000					
Sulfate	mg/L	CBL-301I	01/26/2022	yes	406.0000					
Sulfate	mg/L	CBL-301I	07/27/2022	yes	285.0000					
Sulfate	mg/L	CBL-302I	01/22/2016	yes	1020.0000					
Sulfate	mg/L	CBL-302I	05/04/2016	yes	993.0000					
Sulfate	mg/L	CBL-302I	07/27/2016	yes	1090.0000					
Sulfate	mg/L	CBL-302I	10/24/2016	yes	1180.0000					
Sulfate	mg/L	CBL-302I	01/23/2017	yes	1150.0000					
Sulfate	mg/L	CBL-302I	03/22/2017	yes	1120.0000					
Sulfate	mg/L	CBL-302I	05/16/2017	yes	1230.0000					
Sulfate	mg/L	CBL-302I	07/27/2017	yes	1180.0000					
Sulfate	mg/L	CBL-302I	02/08/2018	yes	1240.0000					
Sulfate	mg/L	CBL-302I	07/27/2018	yes	1390.0000					

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Table 2

Analytical Data and CUSUM Summary

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Sulfate	mg/L	CBL-302I	01/22/2019	yes	1250.0000					
Sulfate	mg/L	CBL-302I	07/31/2019	yes	1260.0000					
Sulfate	mg/L	CBL-302I	01/30/2020	yes	1350.0000					
Sulfate	mg/L	CBL-302I	09/17/2020	yes	1280.0000					
Sulfate	mg/L	CBL-302I	01/28/2021	yes	1290.0000					
Sulfate	mg/L	CBL-302I	07/21/2021	yes	1350.0000					
Sulfate	mg/L	CBL-302I	01/27/2022	yes	1340.0000					
Sulfate	mg/L	CBL-302I	07/28/2022	yes	1300.0000					
Sulfate	mg/L	CBL-306I	01/21/2016	yes	266.0000					
Sulfate	mg/L	CBL-306I	05/04/2016	yes	29.5000		yes			*
Sulfate	mg/L	CBL-306I	07/26/2016	yes	139.0000					
Sulfate	mg/L	CBL-306I	10/24/2016	yes	432.0000					
Sulfate	mg/L	CBL-306I	01/19/2017	yes	270.0000					
Sulfate	mg/L	CBL-306I	03/22/2017	yes	340.0000					
Sulfate	mg/L	CBL-306I	05/18/2017	yes	412.0000					
Sulfate	mg/L	CBL-306I	07/27/2017	yes	513.0000					
Sulfate	mg/L	CBL-306I	02/08/2018	yes	493.0000					
Sulfate	mg/L	CBL-306I	07/27/2018	yes	406.0000					
Sulfate	mg/L	CBL-306I	01/16/2019	yes	292.0000					
Sulfate	mg/L	CBL-306I	07/31/2019	yes	816.0000		yes			*
Sulfate	mg/L	CBL-306I	08/23/2019	yes	387.0000					
Sulfate	mg/L	CBL-306I	01/29/2020	yes	561.0000					
Sulfate	mg/L	CBL-306I	09/19/2020	yes	506.0000					
Sulfate	mg/L	CBL-306I	01/28/2021	yes	388.0000					
Sulfate	mg/L	CBL-306I	07/21/2021	yes	336.0000					
Sulfate	mg/L	CBL-306I	01/27/2022	yes	510.0000					
Sulfate	mg/L	CBL-306I	07/28/2022	yes	348.0000					
Sulfate	mg/L	CBL-308I	01/22/2016	yes	1490.0000					
Sulfate	mg/L	CBL-308I	05/04/2016	yes	1410.0000					
Sulfate	mg/L	CBL-308I	07/26/2016	yes	1490.0000					
Sulfate	mg/L	CBL-308I	10/24/2016	yes	1550.0000					
Sulfate	mg/L	CBL-308I	01/19/2017	yes	1320.0000					
Sulfate	mg/L	CBL-308I	03/22/2017	yes	1470.0000					
Sulfate	mg/L	CBL-308I	05/16/2017	yes	1580.0000					
Sulfate	mg/L	CBL-308I	07/26/2017	yes	1550.0000					
Sulfate	mg/L	CBL-308I	02/06/2018	yes	1570.0000					
Sulfate	mg/L	CBL-308I	07/25/2018	yes	1540.0000					
Sulfate	mg/L	CBL-308I	01/18/2019	yes	1520.0000					
Sulfate	mg/L	CBL-308I	07/31/2019	yes	1420.0000					
Sulfate	mg/L	CBL-308I	01/29/2020	yes	1340.0000					
Sulfate	mg/L	CBL-308I	09/18/2020	yes	1310.0000					
Sulfate	mg/L	CBL-308I	01/28/2021	yes	1340.0000					
Sulfate	mg/L	CBL-308I	07/21/2021	yes	1240.0000					
Sulfate	mg/L	CBL-308I	01/27/2022	yes	1310.0000					
Sulfate	mg/L	CBL-308I	07/27/2022	yes	1190.0000					
Sulfate	mg/L	CBL-341I	01/23/2017	yes	307.0000					
Sulfate	mg/L	CBL-341I	02/23/2017	yes	404.0000					
Sulfate	mg/L	CBL-341I	03/22/2017	yes	346.0000					
Sulfate	mg/L	CBL-341I	04/20/2017	yes	336.0000					
Sulfate	mg/L	CBL-341I	05/16/2017	yes	369.0000					

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Analytical Data and CUSUM Summary

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Sulfate	mg/L	CBL-341I	06/20/2017	yes	363.0000					
Sulfate	mg/L	CBL-341I	07/27/2017	yes	419.0000					
Sulfate	mg/L	CBL-341I	09/11/2017	yes	354.0000					
Sulfate	mg/L	CBL-341I	02/08/2018	yes	383.0000					
Sulfate	mg/L	CBL-341I	08/24/2018	yes	376.0000					
Sulfate	mg/L	CBL-341I	01/22/2019	yes	358.0000					
Sulfate	mg/L	CBL-341I	07/31/2019	yes	329.0000					
Sulfate	mg/L	CBL-341I	01/30/2020	yes	351.0000					
Sulfate	mg/L	CBL-341I	09/17/2020	yes	336.0000					
Sulfate	mg/L	CBL-341I	01/27/2021	yes	324.0000					
Sulfate	mg/L	CBL-341I	07/22/2021	yes	316.0000					
Sulfate	mg/L	CBL-341I	01/27/2022	yes	320.0000					
Sulfate	mg/L	CBL-341I	07/28/2022	yes	296.0000					
Total Dissolved Solids	mg/L	CBL-301I	01/21/2016	yes	4380.0000					
Total Dissolved Solids	mg/L	CBL-301I	05/04/2016	yes	5050.0000					
Total Dissolved Solids	mg/L	CBL-301I	07/27/2016	yes	6020.0000					
Total Dissolved Solids	mg/L	CBL-301I	10/24/2016	yes	4570.0000					
Total Dissolved Solids	mg/L	CBL-301I	01/23/2017	yes	6140.0000					
Total Dissolved Solids	mg/L	CBL-301I	03/22/2017	yes	6570.0000					
Total Dissolved Solids	mg/L	CBL-301I	05/18/2017	yes	6430.0000					
Total Dissolved Solids	mg/L	CBL-301I	07/26/2017	yes	4290.0000					
Total Dissolved Solids	mg/L	CBL-301I	02/08/2018	yes	5120.0000					
Total Dissolved Solids	mg/L	CBL-301I	07/25/2018	yes	5390.0000					
Total Dissolved Solids	mg/L	CBL-301I	01/17/2019	yes	1460.0000		yes			*
Total Dissolved Solids	mg/L	CBL-301I	05/02/2019	yes	5650.0000					
Total Dissolved Solids	mg/L	CBL-301I	07/31/2019	yes	6040.0000					
Total Dissolved Solids	mg/L	CBL-301I	01/28/2020	yes	4790.0000					
Total Dissolved Solids	mg/L	CBL-301I	09/17/2020	yes	6340.0000					
Total Dissolved Solids	mg/L	CBL-301I	01/26/2021	yes	6060.0000					
Total Dissolved Solids	mg/L	CBL-301I	07/20/2021	yes	5870.0000					
Total Dissolved Solids	mg/L	CBL-301I	01/26/2022	yes	4700.0000					
Total Dissolved Solids	mg/L	CBL-301I	07/27/2022	yes	4590.0000					
Total Dissolved Solids	mg/L	CBL-302I	01/22/2016	yes	5500.0000					
Total Dissolved Solids	mg/L	CBL-302I	05/04/2016	yes	5390.0000					
Total Dissolved Solids	mg/L	CBL-302I	07/27/2016	yes	6850.0000					
Total Dissolved Solids	mg/L	CBL-302I	10/24/2016	yes	4210.0000					
Total Dissolved Solids	mg/L	CBL-302I	01/23/2017	yes	6430.0000					
Total Dissolved Solids	mg/L	CBL-302I	03/22/2017	yes	6460.0000					
Total Dissolved Solids	mg/L	CBL-302I	05/16/2017	yes	5860.0000					
Total Dissolved Solids	mg/L	CBL-302I	07/27/2017	yes	5120.0000					
Total Dissolved Solids	mg/L	CBL-302I	02/08/2018	yes	6010.0000					
Total Dissolved Solids	mg/L	CBL-302I	07/27/2018	yes	5510.0000					
Total Dissolved Solids	mg/L	CBL-302I	01/22/2019	yes	5060.0000					
Total Dissolved Solids	mg/L	CBL-302I	07/31/2019	yes	4190.0000					
Total Dissolved Solids	mg/L	CBL-302I	01/30/2020	yes	4790.0000					
Total Dissolved Solids	mg/L	CBL-302I	09/17/2020	yes	4990.0000					
Total Dissolved Solids	mg/L	CBL-302I	01/28/2021	yes	4800.0000					
Total Dissolved Solids	mg/L	CBL-302I	07/21/2021	yes	4810.0000					
Total Dissolved Solids	mg/L	CBL-302I	01/27/2022	yes	4510.0000					
Total Dissolved Solids	mg/L	CBL-302I	07/28/2022	yes	5120.0000					

* - Outlier for that well and constituent.
** - Non-outlier detected sample Result and / or CUSUM value exceeds limit.
*** - ND value replaced with median RL.
**** - ND value replaced with manual RL.
ND = Not detected, Result = detection limit.

Table 2

Analytical Data and CUSUM Summary

Constituent	Units	Well	Date	Background	Result		Outlier	CUSUM	Adjusted	
Total Dissolved Solids	mg/L	CBL-306I	01/21/2016	yes	1280.0000					
Total Dissolved Solids	mg/L	CBL-306I	05/04/2016	yes	431.0000		yes			*
Total Dissolved Solids	mg/L	CBL-306I	07/26/2016	yes	790.0000					
Total Dissolved Solids	mg/L	CBL-306I	10/24/2016	yes	1150.0000					
Total Dissolved Solids	mg/L	CBL-306I	01/19/2017	yes	1320.0000					
Total Dissolved Solids	mg/L	CBL-306I	03/22/2017	yes	1460.0000					
Total Dissolved Solids	mg/L	CBL-306I	05/18/2017	yes	1440.0000					
Total Dissolved Solids	mg/L	CBL-306I	07/27/2017	yes	1280.0000					
Total Dissolved Solids	mg/L	CBL-306I	02/08/2018	yes	1760.0000					
Total Dissolved Solids	mg/L	CBL-306I	07/27/2018	yes	1450.0000					
Total Dissolved Solids	mg/L	CBL-306I	01/16/2019	yes	1220.0000					
Total Dissolved Solids	mg/L	CBL-306I	07/31/2019	yes	676.0000		yes			*
Total Dissolved Solids	mg/L	CBL-306I	08/23/2019	yes	1710.0000					
Total Dissolved Solids	mg/L	CBL-306I	01/29/2020	yes	1830.0000					
Total Dissolved Solids	mg/L	CBL-306I	09/19/2020	yes	1730.0000					
Total Dissolved Solids	mg/L	CBL-306I	01/28/2021	yes	1420.0000					
Total Dissolved Solids	mg/L	CBL-306I	07/21/2021	yes	1320.0000					
Total Dissolved Solids	mg/L	CBL-306I	01/27/2022	yes	1730.0000					
Total Dissolved Solids	mg/L	CBL-306I	07/28/2022	yes	1540.0000					
Total Dissolved Solids	mg/L	CBL-308I	01/22/2016	yes	6820.0000					
Total Dissolved Solids	mg/L	CBL-308I	05/04/2016	yes	6120.0000					
Total Dissolved Solids	mg/L	CBL-308I	07/26/2016	yes	7890.0000					
Total Dissolved Solids	mg/L	CBL-308I	10/24/2016	yes	10200.0000					
Total Dissolved Solids	mg/L	CBL-308I	01/19/2017	yes	9620.0000					
Total Dissolved Solids	mg/L	CBL-308I	03/22/2017	yes	7260.0000					
Total Dissolved Solids	mg/L	CBL-308I	05/16/2017	yes	6590.0000					
Total Dissolved Solids	mg/L	CBL-308I	07/26/2017	yes	6480.0000					
Total Dissolved Solids	mg/L	CBL-308I	02/06/2018	yes	6200.0000					
Total Dissolved Solids	mg/L	CBL-308I	07/25/2018	yes	6320.0000					
Total Dissolved Solids	mg/L	CBL-308I	01/18/2019	yes	4760.0000					
Total Dissolved Solids	mg/L	CBL-308I	07/31/2019	yes	5820.0000					
Total Dissolved Solids	mg/L	CBL-308I	01/29/2020	yes	5980.0000					
Total Dissolved Solids	mg/L	CBL-308I	09/18/2020	yes	6860.0000					
Total Dissolved Solids	mg/L	CBL-308I	01/28/2021	yes	6190.0000					
Total Dissolved Solids	mg/L	CBL-308I	07/21/2021	yes	5270.0000					
Total Dissolved Solids	mg/L	CBL-308I	01/27/2022	yes	5320.0000					
Total Dissolved Solids	mg/L	CBL-308I	07/27/2022	yes	6840.0000					
Total Dissolved Solids	mg/L	CBL-341I	01/23/2017	yes	5000.0000					
Total Dissolved Solids	mg/L	CBL-341I	02/23/2017	yes	4520.0000					
Total Dissolved Solids	mg/L	CBL-341I	03/22/2017	yes	5110.0000					
Total Dissolved Solids	mg/L	CBL-341I	04/20/2017	yes	4240.0000					
Total Dissolved Solids	mg/L	CBL-341I	05/16/2017	yes	4840.0000					
Total Dissolved Solids	mg/L	CBL-341I	06/20/2017	yes	5940.0000					
Total Dissolved Solids	mg/L	CBL-341I	07/27/2017	yes	4150.0000					
Total Dissolved Solids	mg/L	CBL-341I	09/11/2017	yes	4860.0000					
Total Dissolved Solids	mg/L	CBL-341I	02/08/2018	yes	4320.0000					
Total Dissolved Solids	mg/L	CBL-341I	08/24/2018	yes	4800.0000					
Total Dissolved Solids	mg/L	CBL-341I	01/22/2019	yes	3870.0000					
Total Dissolved Solids	mg/L	CBL-341I	07/31/2019	yes	5370.0000					
Total Dissolved Solids	mg/L	CBL-341I	01/30/2020	yes	4900.0000					

* - Outlier for that well and constituent.
** - Non-outlier detected sample Result and / or CUSUM value exceeds limit.
*** - ND value replaced with median RL.
**** - ND value replaced with manual RL.
ND = Not detected, Result = detection limit.

Table 2

Analytical Data and CUSUM Summary

Constituent	Units	Well	Date	Background	Result		Outlier	CUSUM	Adjusted	
Total Dissolved Solids	mg/L	CBL-341I	09/17/2020	yes	4930.0000					
Total Dissolved Solids	mg/L	CBL-341I	01/27/2021	yes	3940.0000					
Total Dissolved Solids	mg/L	CBL-341I	07/22/2021	yes	4520.0000					
Total Dissolved Solids	mg/L	CBL-341I	01/27/2022	yes	3800.0000					
Total Dissolved Solids	mg/L	CBL-341I	07/28/2022	yes	4910.0000					

* - Outlier for that well and constituent.
** - Non-outlier detected sample Result and / or CUSUM value exceeds limit.
*** - ND value replaced with median RL.
**** - ND value replaced with manual RL.
ND = Not detected, Result = detection limit.

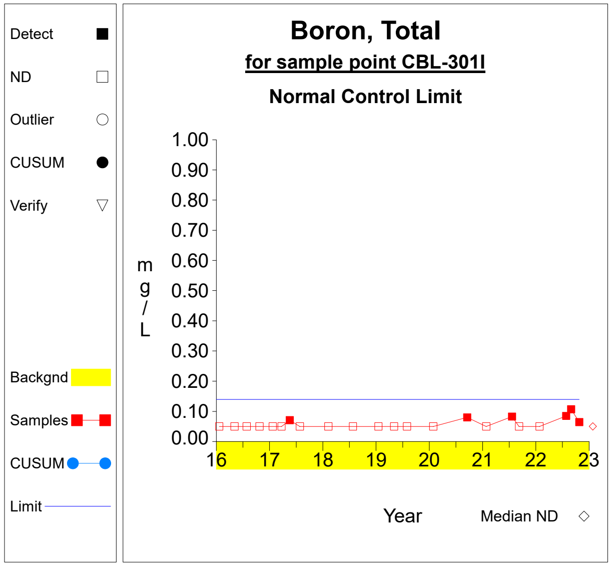
Table 4

Dixon's Test Outliers
1% Significance Level

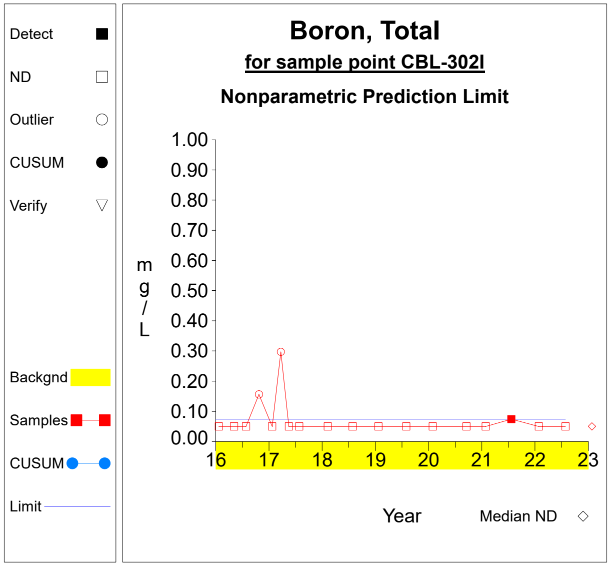
Constituent	Units	Well	Date	Result	ND Qualifier	Date Range	N	Critical Value
Boron, Total	mg/L	CBL-302I	10/24/2016	0.1560		01/22/2016-07/28/2022	18	0.5798
Boron, Total	mg/L	CBL-302I	03/22/2017	0.2970		01/22/2016-07/28/2022	18	0.5798
Calcium, Total	mg/L	CBL-301I	01/17/2019	156.0000		01/21/2016-07/27/2022	19	0.5503
Chloride	mg/L	CBL-301I	01/17/2019	619.0000		01/21/2016-07/27/2022	19	0.5503
Chloride	mg/L	CBL-306I	05/04/2016	20.0000		01/21/2016-07/28/2022	17	0.5798
Fluoride	mg/L	CBL-306I	03/22/2017	12.6000		01/21/2016-07/28/2022	18	0.5643
Fluoride	mg/L	CBL-308I	03/22/2017	9.0500		01/22/2016-07/27/2022	18	0.5643
Sulfate	mg/L	CBL-301I	01/17/2019	104.0000		01/21/2016-07/27/2022	19	0.5503
Sulfate	mg/L	CBL-306I	05/04/2016	29.5000		01/21/2016-07/28/2022	18	0.5643
Total Dissolved Solids	mg/L	CBL-301I	01/17/2019	1460.0000		01/21/2016-07/27/2022	19	0.5503
Total Dissolved Solids	mg/L	CBL-306I	05/04/2016	431.0000		01/21/2016-07/28/2022	18	0.5643

N = Total number of independent measurements in background at each well.
Date Range = Dates of the first and last measurements included in background at each well.
Critical Value depends on the significance level and on N-1 when the two most extreme values are tested or N for the most extreme value.

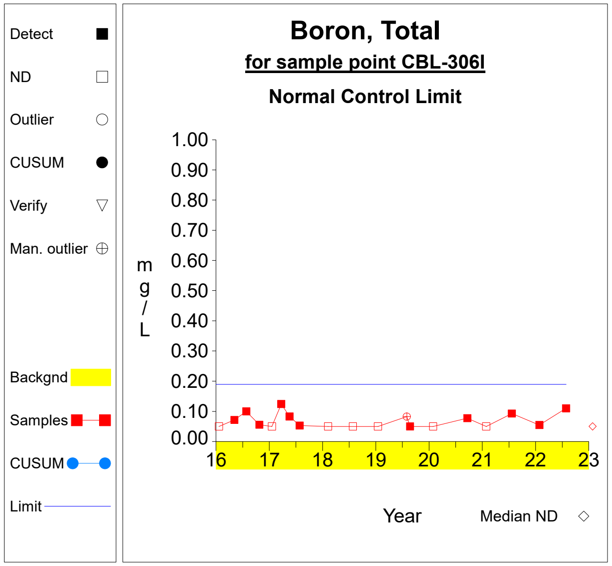
Intra-Well Control Charts / Prediction Limits



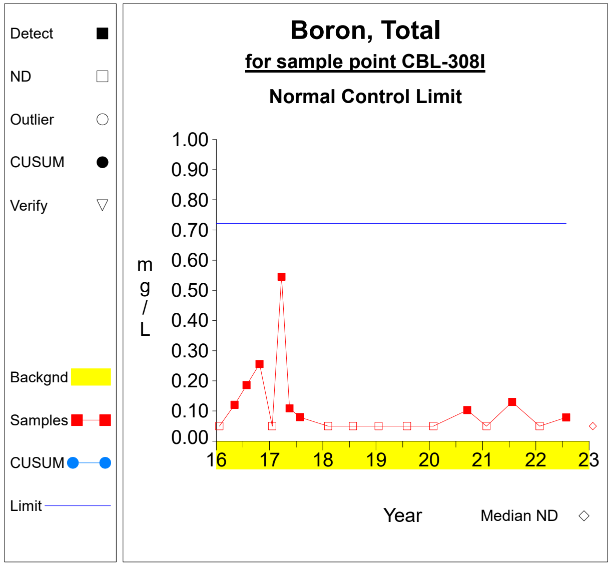
Graph 1



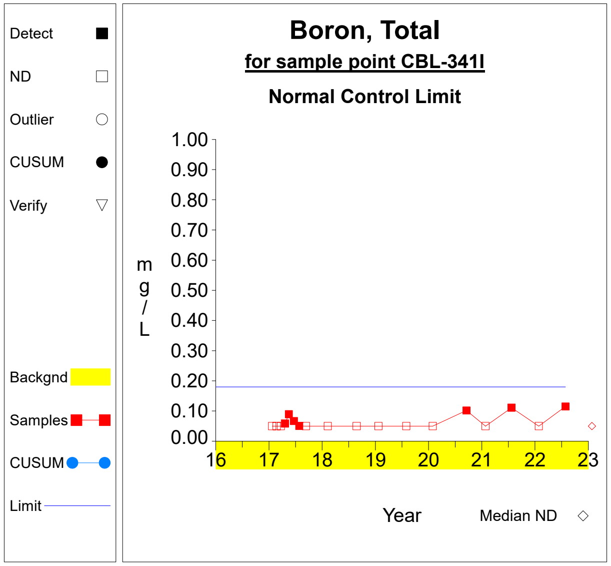
Graph 2



Graph 3

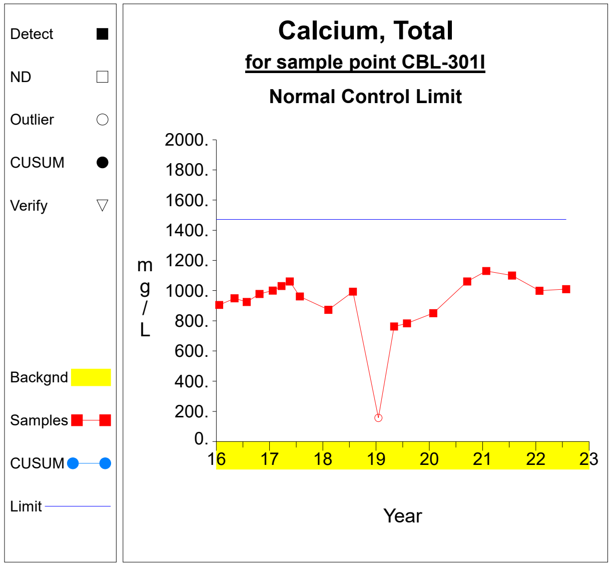


Graph 4

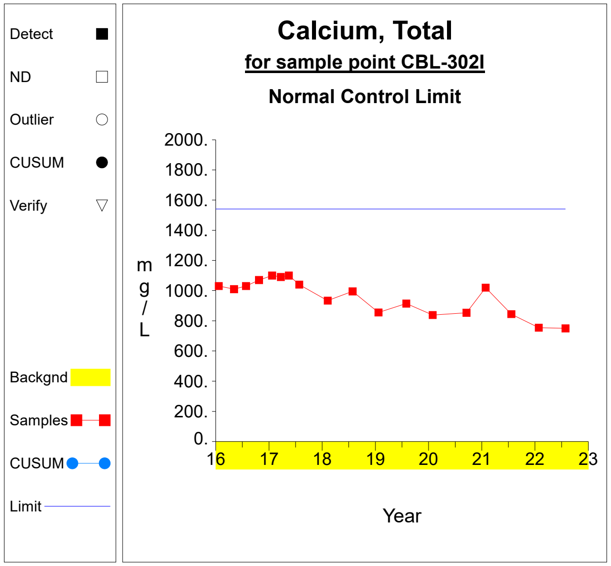


Graph 5

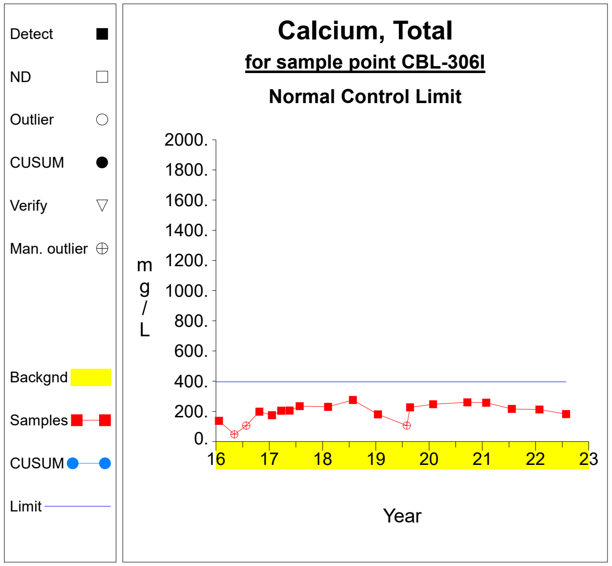
Intra-Well Control Charts / Prediction Limits



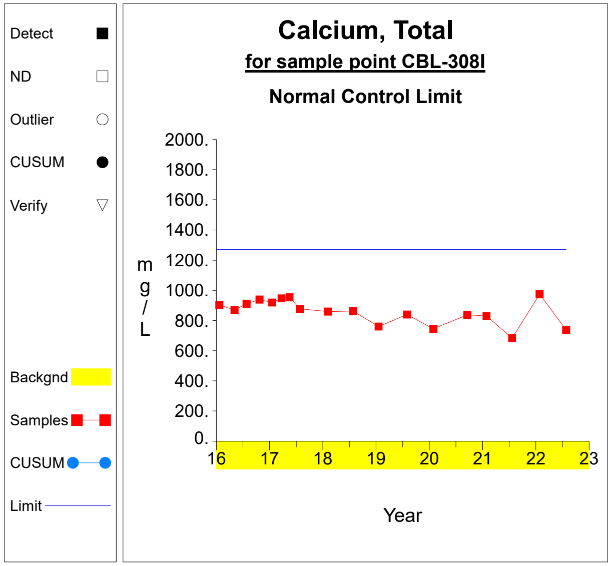
Graph 6



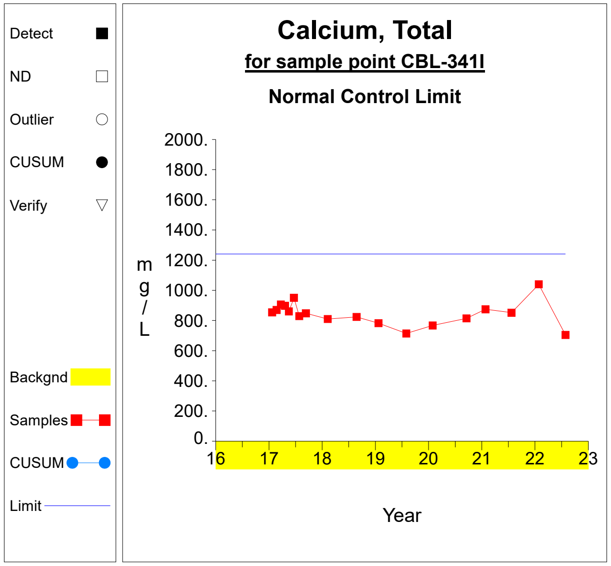
Graph 7



Graph 8

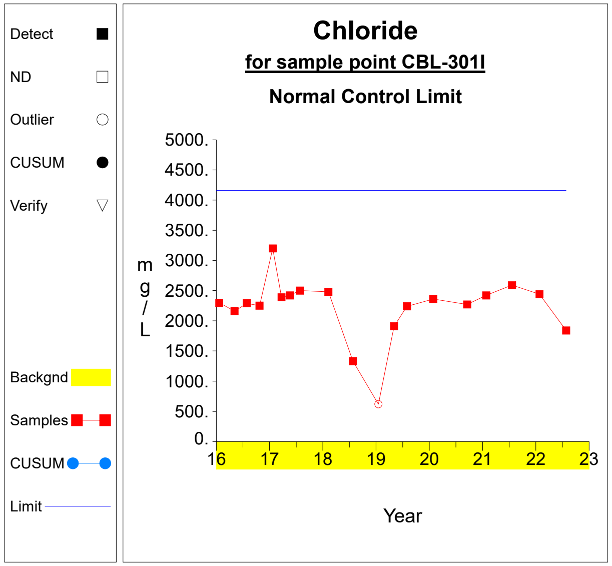


Graph 9

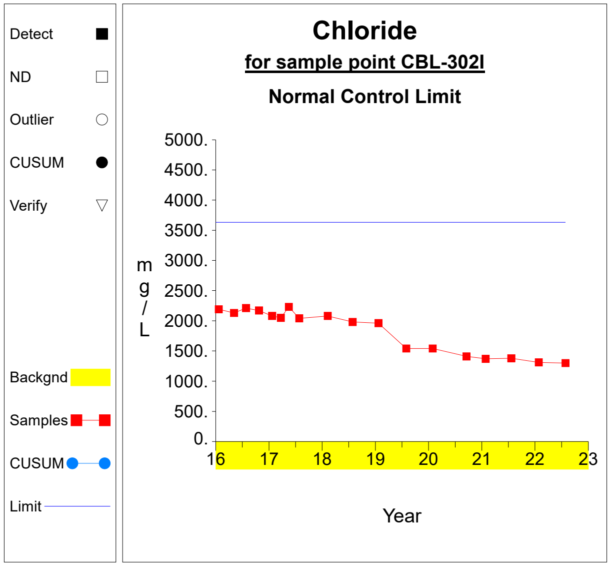


Graph 10

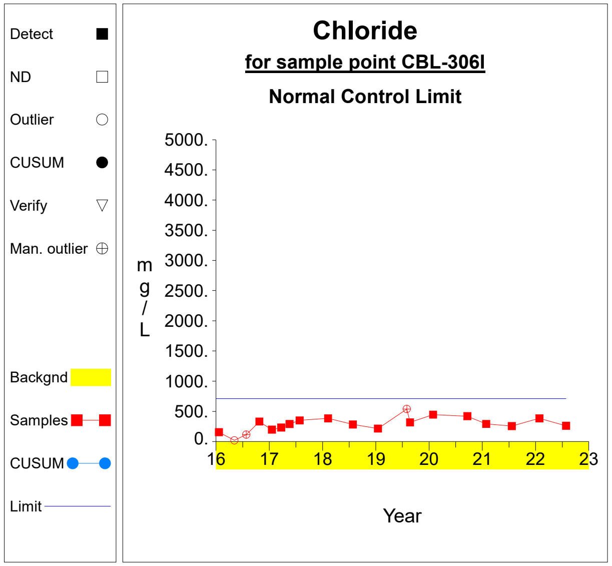
Intra-Well Control Charts / Prediction Limits



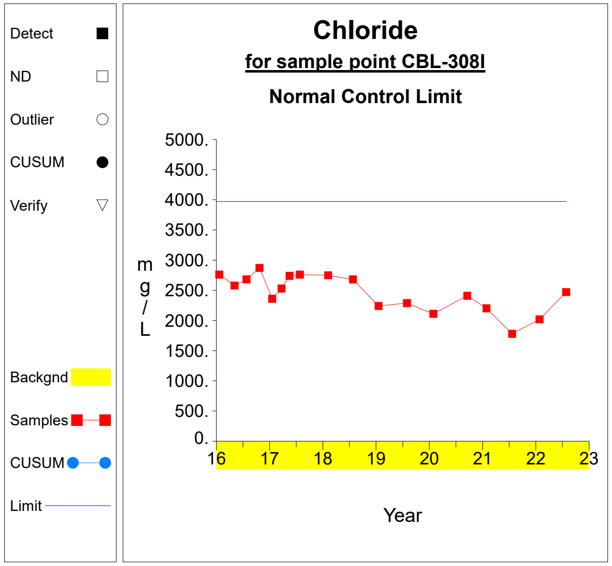
Graph 11



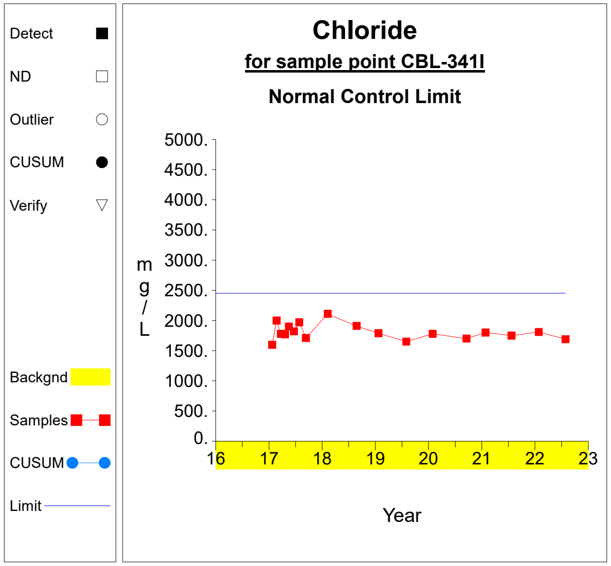
Graph 12



Graph 13

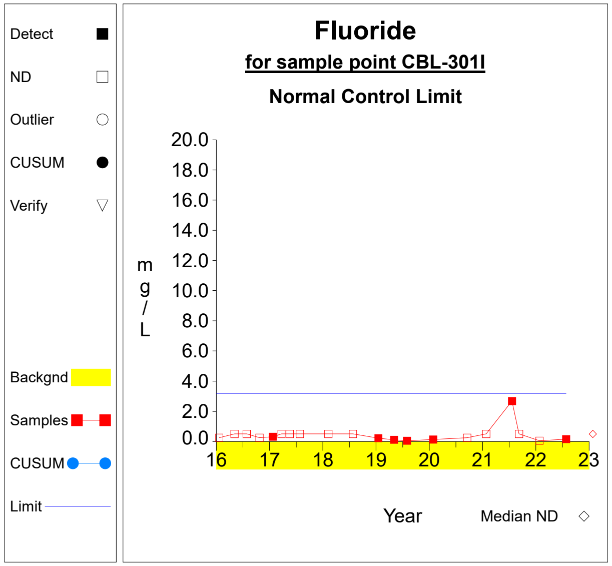


Graph 14

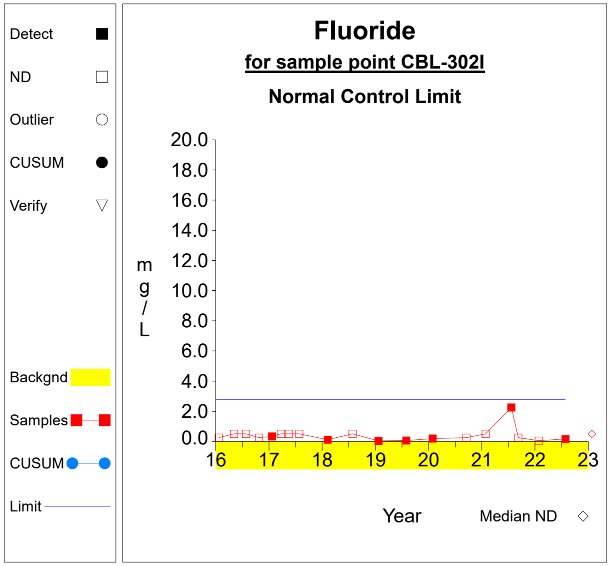


Graph 15

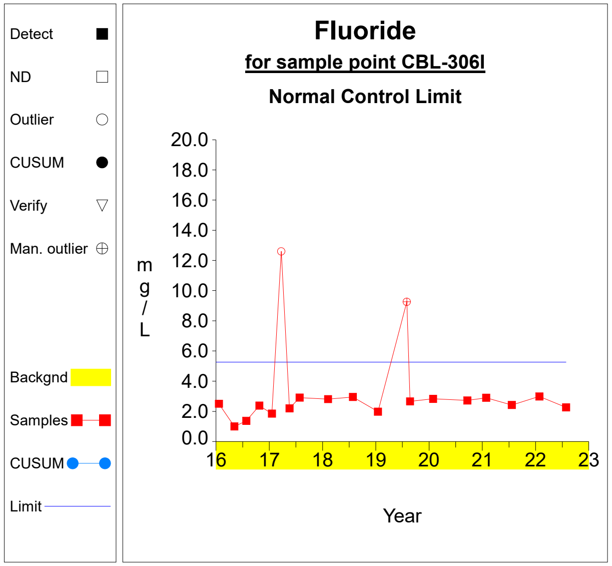
Intra-Well Control Charts / Prediction Limits



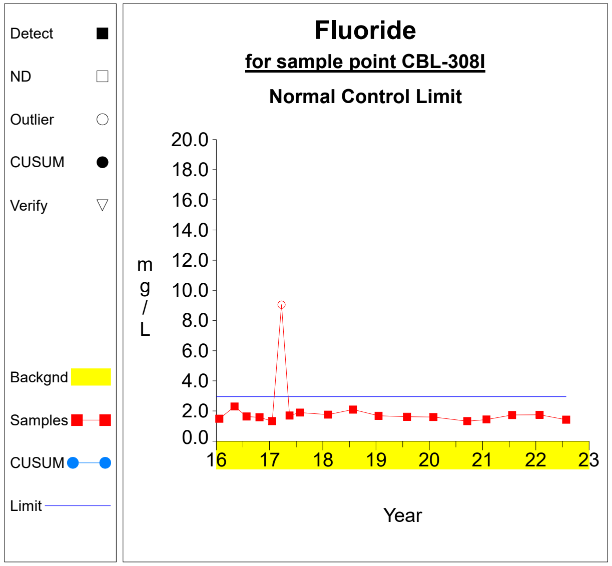
Graph 16



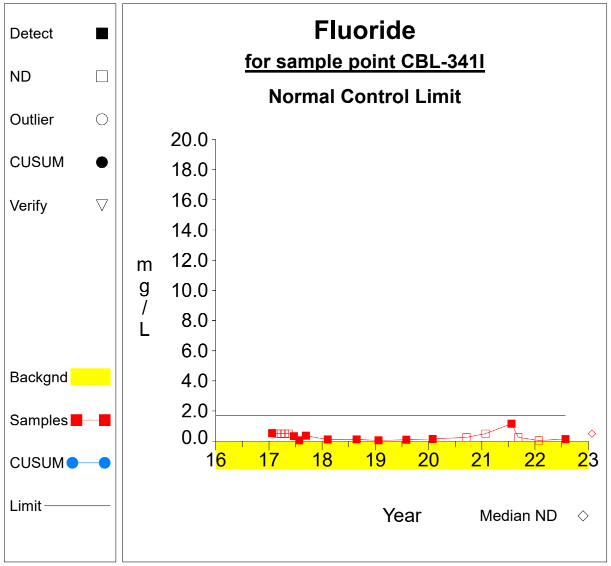
Graph 17



Graph 18

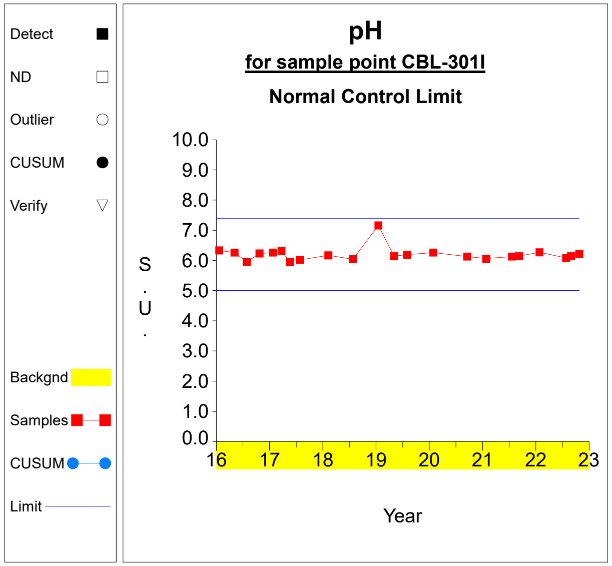


Graph 19

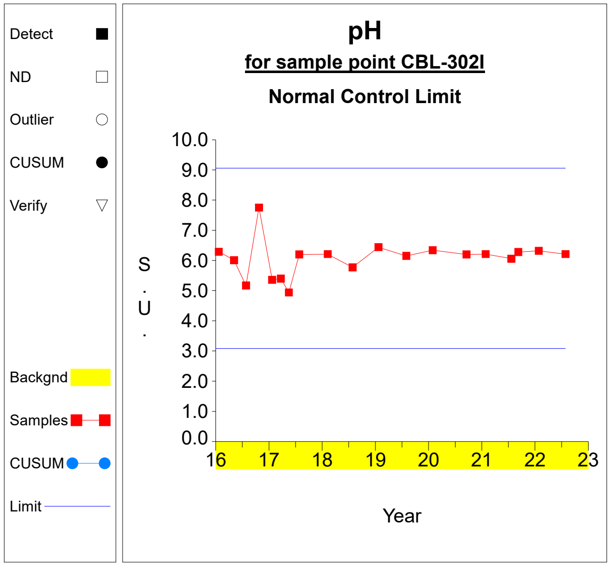


Graph 20

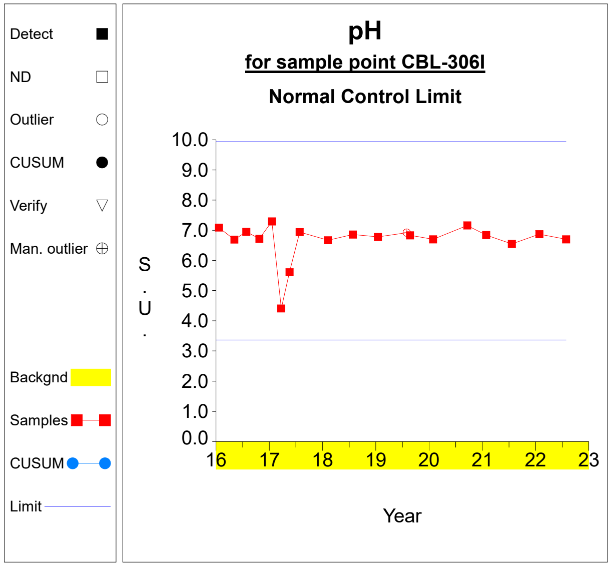
Intra-Well Control Charts / Prediction Limits



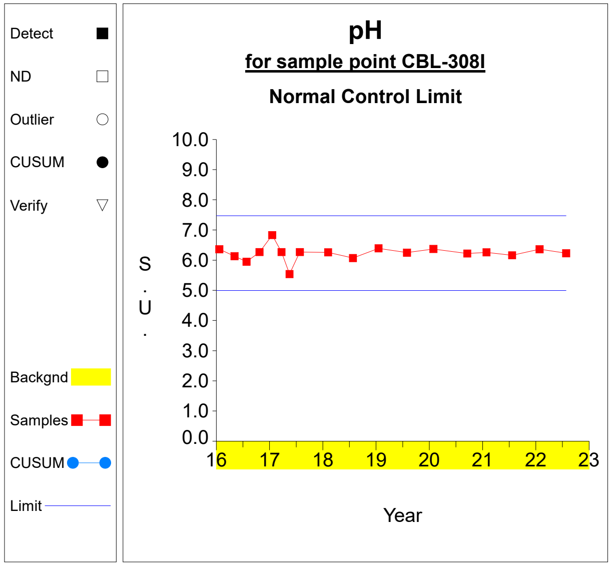
Graph 21



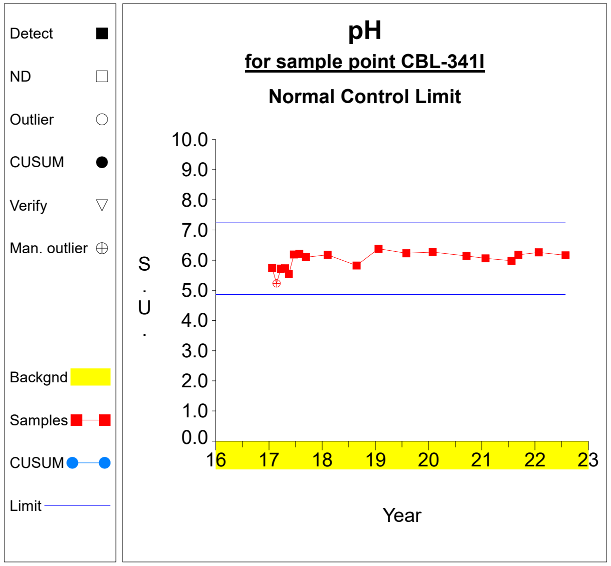
Graph 22



Graph 23

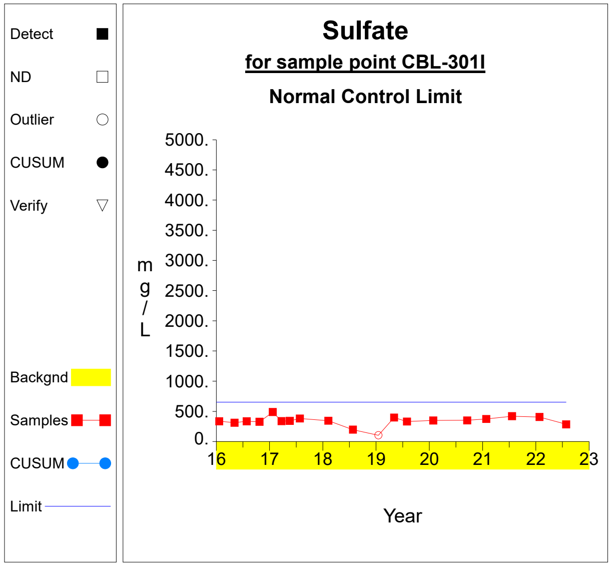


Graph 24

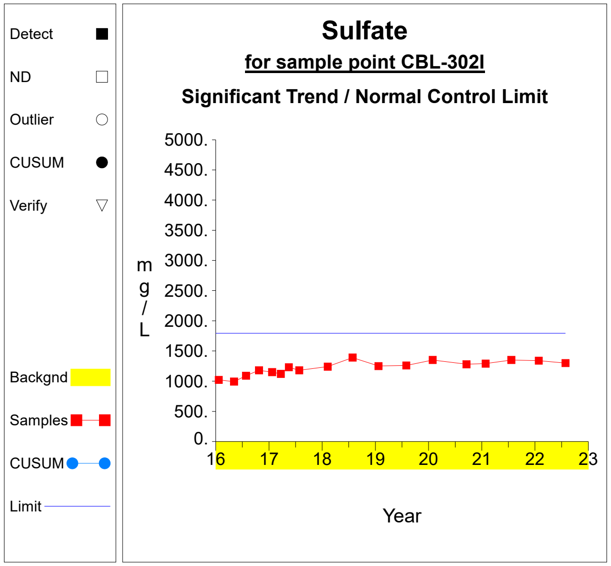


Graph 25

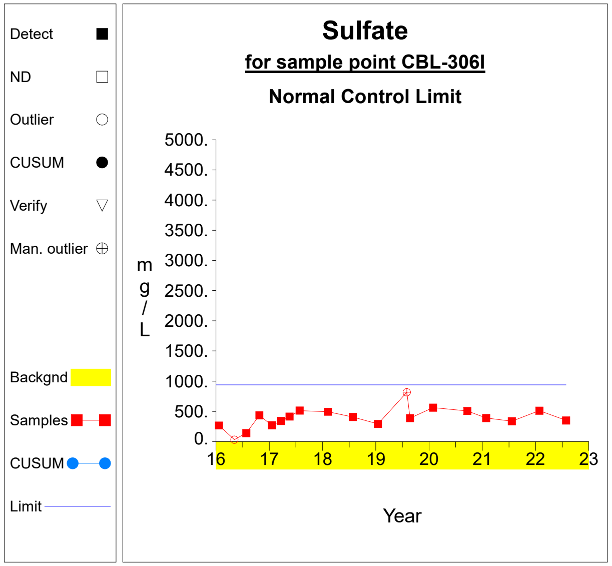
Intra-Well Control Charts / Prediction Limits



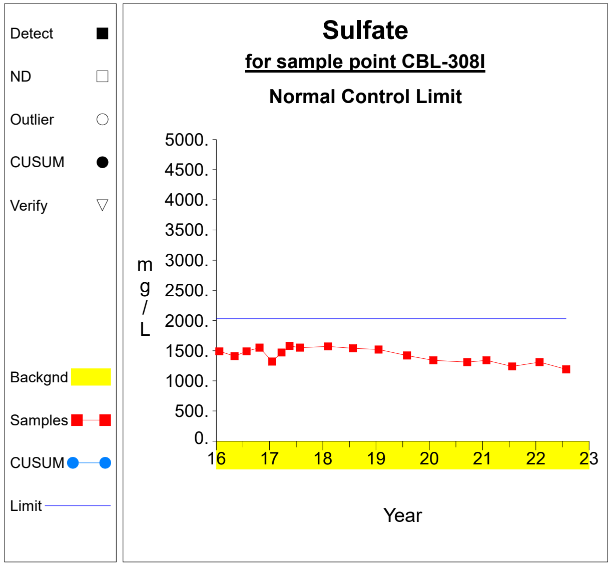
Graph 26



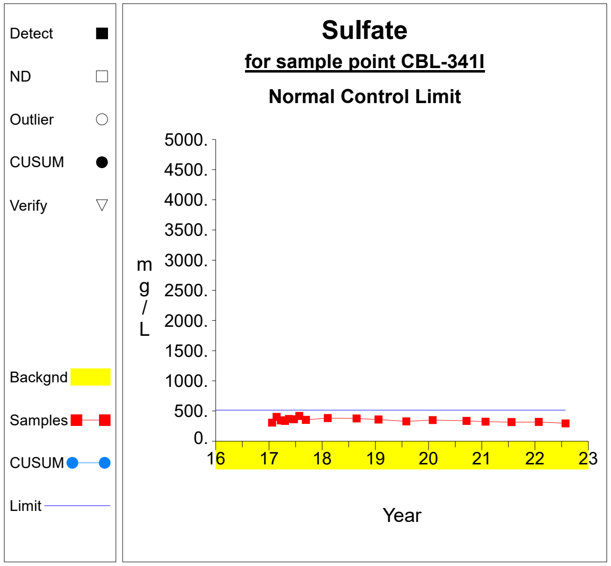
Graph 27



Graph 28

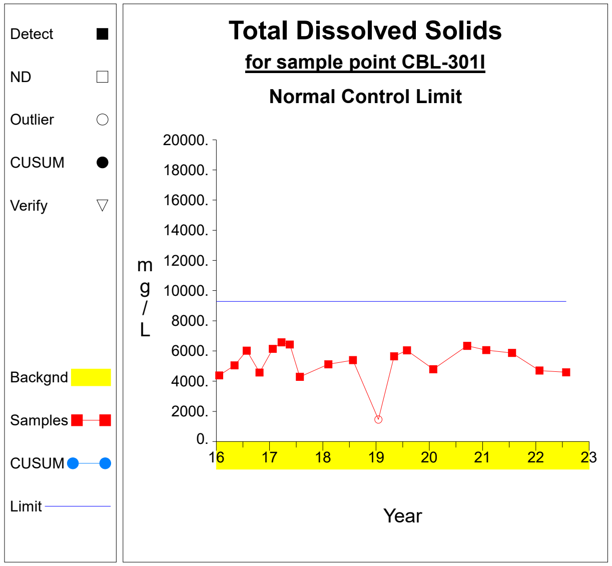


Graph 29

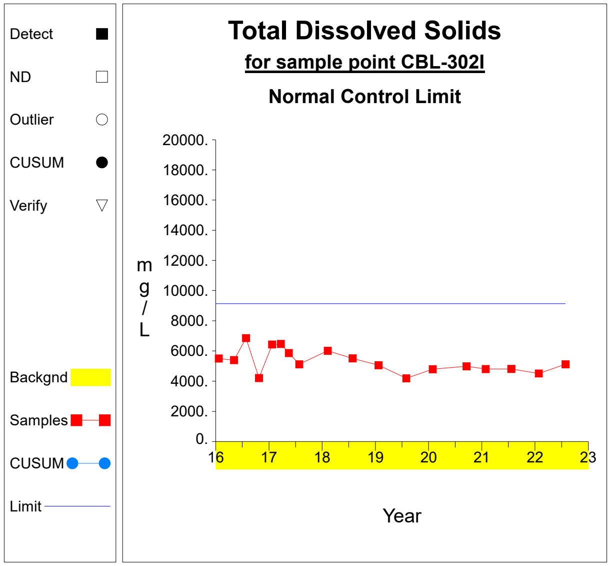


Graph 30

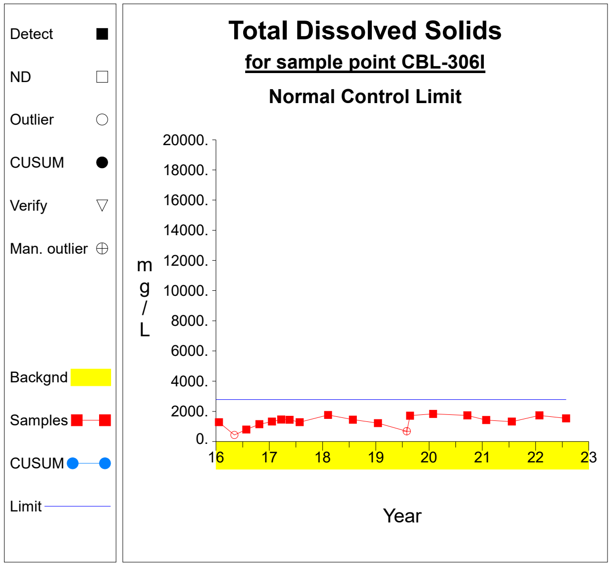
Intra-Well Control Charts / Prediction Limits



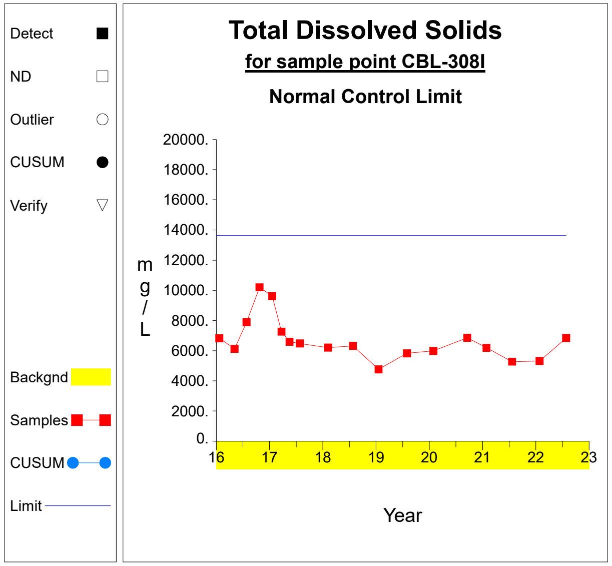
Graph 31



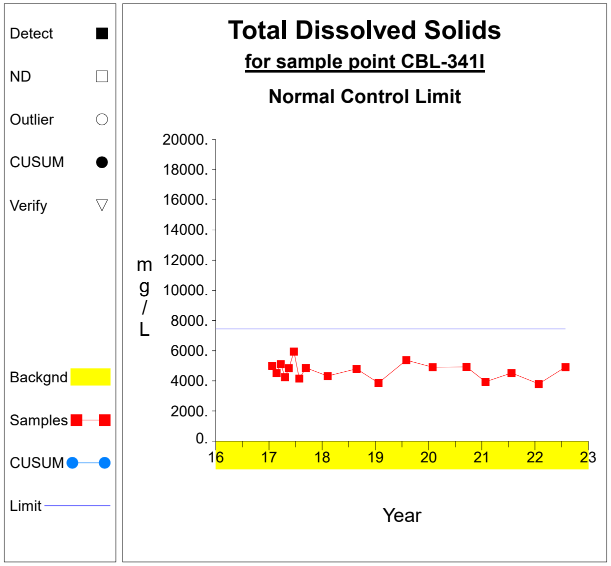
Graph 32



Graph 33

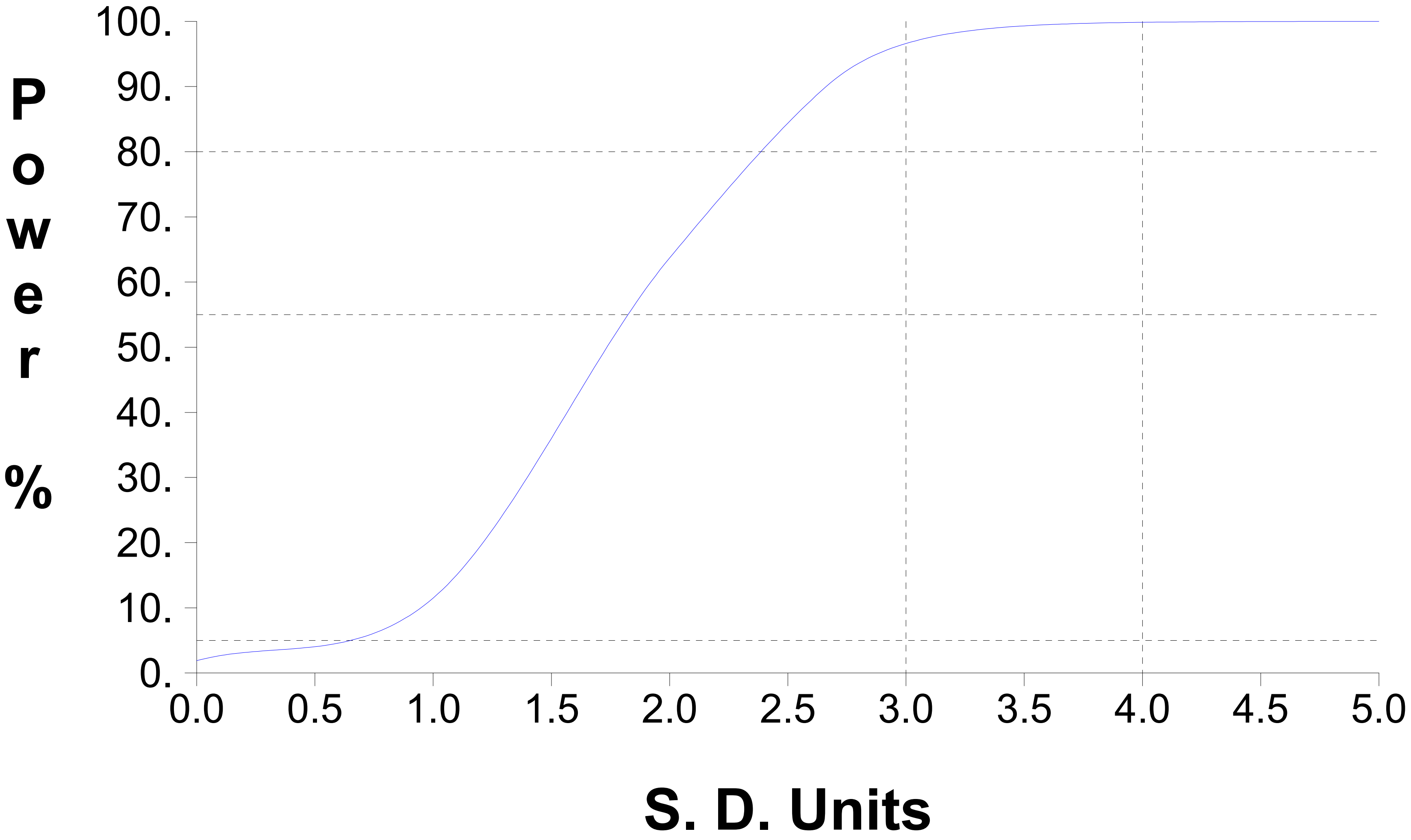


Graph 34



Graph 35

False Positive and False Negative Rates for Current Intra-Well Control Charts Monitoring Program



Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Boron, Total (mg/L) at CBL-301I
Normal Control Limit

Step	Equation	Description
1	$\bar{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{1.29} / \mathbf{22}$ $= \mathbf{0.059}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{\frac{1}{2}}$ $= ((\mathbf{0.081} - \mathbf{1.664}/\mathbf{22}) / (\mathbf{22}-1))^{\frac{1}{2}}$ $= \mathbf{0.016}$	Compute background sd.
3	$SCL = \bar{\mathbf{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{0.059} + \mathbf{5.0} * \mathbf{0.016}$ $= \mathbf{0.139}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{22} * (\mathbf{22}-1) / 2$ $= \mathbf{231}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{0.0}$	Sen's estimator of trend.
6	$var(S) = \mathbf{764.333}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{\frac{1}{2}}) / 2$ $= (\mathbf{231} - \mathbf{2.326} * \mathbf{764.333}^{\frac{1}{2}}) / 2$ $= \mathbf{83.347}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1th largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{0.0}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Boron, Total (mg/L) at CBL-302I
Nonparametric Prediction Limit

Step	Equation	Description
1	PL = max(X) = **0.074**	Compute nonparametric prediction limit as largest background measurement.
2	Conf = **0.99**	Confidence level is based on N, K and resampling strategy (see Gibbons 1994).

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Boron, Total (mg/L) at CBL-306I
Normal Control Limit

Step	Equation	Description
1	$\bar{X} = \text{sum}[X] / N$ $= 1.222 / 18$ $= 0.068$	Compute background mean.
2	$S = ((\text{sum}[X^2] - \text{sum}[X]^2/N) / (N-1))^{1/2}$ $= ((0.093 - 1.494/18) / (18-1))^{1/2}$ $= 0.024$	Compute background sd.
3	$SCL = \bar{X} + F * S$ $= 0.068 + 5.0 * 0.024$ $= 0.189$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = N * (N-1) / 2$ $= 18 * (18-1) / 2$ $= 153$	Number of sample pairs during trend detection period.
5	$S = 0.0$	Sen's estimator of trend.
6	$\text{var}(S) = 631.667$	Variance estimate for slope.
7	$M_1(S) = (N' - Z_{.99} * \text{var}(S)^{1/2}) / 2$ $= (153 - 2.326 * 631.667^{1/2}) / 2$ $= 47.27$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1th largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = -0.003$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Boron, Total (mg/L) at CBL-308I
Normal Control Limit

Step	Equation	Description
1	$\overline{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{2.059} / \mathbf{18}$ $= \mathbf{0.114}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{\frac{1}{2}}$ $= ((\mathbf{0.486} - \mathbf{4.239}/\mathbf{18}) / (\mathbf{18}-1))^{\frac{1}{2}}$ $= \mathbf{0.121}$	Compute background sd.
3	$SCL = \overline{\mathbf{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{0.114} + \mathbf{5.0} * \mathbf{0.121}$ $= \mathbf{0.722}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{18} * (\mathbf{18}-1) / 2$ $= \mathbf{153}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{0.0}$	Sen's estimator of trend.
6	$var(S) = \mathbf{605.0}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{\frac{1}{2}}) / 2$ $= (\mathbf{153} - \mathbf{2.326} * \mathbf{605.0}^{\frac{1}{2}}) / 2$ $= \mathbf{47.894}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1th largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-0.027}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Boron, Total (mg/L) at CBL-341I
Normal Control Limit

Step	Equation	Description
1	$\overline{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{1.144} / \mathbf{18}$ $= \mathbf{0.064}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2] - sum[X]^2/N}) / (\mathbf{N}-1))^{1/2}$ $= ((\mathbf{0.082} - \mathbf{1.308/18}) / (\mathbf{18}-1))^{1/2}$ $= \mathbf{0.023}$	Compute background sd.
3	$SCL = \overline{\mathbf{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{0.064} + \mathbf{5.0} * \mathbf{0.023}$ $= \mathbf{0.18}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{18} * (\mathbf{18}-1) / 2$ $= \mathbf{153}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{0.0}$	Sen's estimator of trend.
6	$\text{var}(S) = \mathbf{532.0}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{1/2}) / 2$ $= (\mathbf{153} - \mathbf{2.326} * \mathbf{532.0}^{1/2}) / 2$ $= \mathbf{49.675}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{0.0}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Calcium, Total (mg/L) at CBL-301I
Normal Control Limit

Step	Equation	Description
1	$\overline{X} = sum[X] / N$ $= 17369.0 / 18$ $= 964.944$	Compute background mean.
2	$S = ((sum[X^2] - sum[X]^2/N) / (N-1))^{1/2}$ $= ((1.69 \times 10^7 - 3.02 \times 10^8/18) / (18-1))^{1/2}$ $= 101.271$	Compute background sd.
3	$SCL = \overline{X} + F * S$ $= 964.944 + 5.0 * 101.271$ $= 1471.3$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = N * (N-1) / 2$ $= 18 * (18-1) / 2$ $= 153$	Number of sample pairs during trend detection period.
5	$S = 16.171$	Sen's estimator of trend.
6	$var(S) = 696.0$	Variance estimate for slope.
7	$M_1(S) = (N' - Z_{.99} * var(S)^{1/2}) / 2$ $= (153 - 2.326 * 696.0^{1/2}) / 2$ $= 45.818$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1th largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = -27.044$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Calcium, Total (mg/L) at CBL-302I
Normal Control Limit

Step	Equation	Description
1	$\bar{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{17227.0} / \mathbf{18}$ $= \mathbf{957.056}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{\frac{1}{2}}$ $= ((\mathbf{1.67 \times 10^7} - \mathbf{2.97 \times 10^8}/\mathbf{18}) / (\mathbf{18}-1))^{\frac{1}{2}}$ $= \mathbf{116.748}$	Compute background sd.
3	$SCL = \bar{\mathbf{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{957.056} + \mathbf{5.0} * \mathbf{116.748}$ $= \mathbf{1540.795}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{18} * (\mathbf{18}-1) / 2$ $= \mathbf{153}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{-46.655}$	Sen's estimator of trend.
6	$var(S) = \mathbf{695.0}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{\frac{1}{2}}) / 2$ $= (\mathbf{153} - \mathbf{2.326} * \mathbf{695.0}^{\frac{1}{2}}) / 2$ $= \mathbf{45.84}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1th largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-66.423}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Calcium, Total (mg/L) at CBL-306I
Normal Control Limit

Step	Equation	Description
1	$\bar{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{3437.0} / \mathbf{16}$ $= \mathbf{214.813}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{\frac{1}{2}}$ $= ((\mathbf{758029.0} - \mathbf{1.18}\times\mathbf{10^7}/\mathbf{16}) / (\mathbf{16}-1))^{\frac{1}{2}}$ $= \mathbf{36.257}$	Compute background sd.
3	$SCL = \bar{\mathbf{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{214.813} + \mathbf{5.0} * \mathbf{36.257}$ $= \mathbf{396.097}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{16} * (\mathbf{16}-1) / 2$ $= \mathbf{120}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{9.18}$	Sen's estimator of trend.
6	$var(S) = \mathbf{493.333}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{\frac{1}{2}}) / 2$ $= (\mathbf{120} - \mathbf{2.326} * \mathbf{493.333}^{\frac{1}{2}}) / 2$ $= \mathbf{34.168}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-4.826}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Calcium, Total (mg/L) at CBL-308I
Normal Control Limit

Step	Equation	Description
1	$\overline{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{15450.0} / \mathbf{18}$ $= \mathbf{858.333}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{\frac{1}{2}}$ $= ((\mathbf{1.34 \times 10^7} - \mathbf{2.39 \times 10^8}/\mathbf{18}) / (\mathbf{18}-1))^{\frac{1}{2}}$ $= \mathbf{82.361}$	Compute background sd.
3	$SCL = \overline{\mathbf{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{858.333} + \mathbf{5.0} * \mathbf{82.361}$ $= \mathbf{1270.141}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{18} * (\mathbf{18}-1) / 2$ $= \mathbf{153}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{-24.047}$	Sen's estimator of trend.
6	$var(S) = \mathbf{697.0}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{\frac{1}{2}}) / 2$ $= (\mathbf{153} - \mathbf{2.326} * \mathbf{697.0}^{\frac{1}{2}}) / 2$ $= \mathbf{45.796}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1th largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-45.396}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Calcium, Total (mg/L) at CBL-341I
Normal Control Limit

Step	Equation	Description
1	$\overline{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{15196.0} / \mathbf{18}$ $= \mathbf{844.222}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{1/2}$ $= ((\mathbf{1.29 \times 10^7} - \mathbf{2.31 \times 10^8}/\mathbf{18}) / (\mathbf{18}-1))^{1/2}$ $= \mathbf{79.475}$	Compute background sd.
3	$SCL = \overline{\mathbf{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{844.222} + \mathbf{5.0} * \mathbf{79.475}$ $= \mathbf{1241.598}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{18} * (\mathbf{18}-1) / 2$ $= \mathbf{153}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{-24.621}$	Sen's estimator of trend.
6	$var(S) = \mathbf{697.0}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{1/2}) / 2$ $= (\mathbf{153} - \mathbf{2.326} * \mathbf{697.0}^{1/2}) / 2$ $= \mathbf{45.796}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1th largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-46.4}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Chloride (mg/L) at CBL-301I
Normal Control Limit

Step	Equation	Description
1	$\overline{X} = \mathbf{sum[X]} / \mathbf{N}$	Compute background mean.
	$= \mathbf{41390.0} / \mathbf{18}$	
	$= \mathbf{2299.444}$	
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{\frac{1}{2}}$	Compute background sd.
	$= ((\mathbf{9.75{\times}10^7} - \mathbf{1.71{\times}10^9/18}) / (\mathbf{18}-1))^{\frac{1}{2}}$	
	$= \mathbf{372.424}$	
3	$SCL = \overline{\mathbf{X}} + \mathbf{F} * \mathbf{S}$	Compute combined Shewhart-CUSUM normal control limit.
	$= \mathbf{2299.444} + \mathbf{5.0} * \mathbf{372.424}$	
	$= \mathbf{4161.565}$	
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$	Number of sample pairs during trend detection period.
	$= \mathbf{18} * (\mathbf{18}-1) / 2$	
	$= \mathbf{153}$	
5	$S = \mathbf{10.311}$	Sen's estimator of trend.
6	$var(S) = \mathbf{696.0}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{\frac{1}{2}}) / 2$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
	$= (\mathbf{153} - \mathbf{2.326} * \mathbf{696.0}^{\frac{1}{2}}) / 2$	
	$= \mathbf{45.818}$	
8	$LCL(S) = \mathbf{-82.048}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Chloride (mg/L) at CBL-302I
Normal Control Limit

Step	Equation	Description
1	$\overline{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{32970.0} / \mathbf{18}$ $= \mathbf{1831.667}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{1/2}$ $= ((\mathbf{6.26 \times 10^7} - \mathbf{1.09 \times 10^9}/\mathbf{18}) / (\mathbf{18}-1))^{1/2}$ $= \mathbf{360.265}$	Compute background sd.
3	$SCL = \mathbf{\overline{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{1831.667} + \mathbf{5.0} * \mathbf{360.265}$ $= \mathbf{3632.994}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{18} * (\mathbf{18}-1) / 2$ $= \mathbf{153}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{-159.984}$	Sen's estimator of trend.
6	$var(S) = \mathbf{695.0}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{1/2}) / 2$ $= (\mathbf{153} - \mathbf{2.326} * \mathbf{695.0}^{1/2}) / 2$ $= \mathbf{45.84}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1th largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-190.868}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Chloride (mg/L) at CBL-306I
Normal Control Limit

Step	Equation	Description
1	$\overline{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{4810.0} / \mathbf{16}$ $= \mathbf{300.625}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{1/2}$ $= ((\mathbf{1.55 \times 10^6} - \mathbf{2.31 \times 10^7}/\mathbf{16}) / (\mathbf{16}-1))^{1/2}$ $= \mathbf{82.083}$	Compute background sd.
3	$SCL = \overline{\mathbf{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{300.625} + \mathbf{5.0} * \mathbf{82.083}$ $= \mathbf{711.039}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{16} * (\mathbf{16}-1) / 2$ $= \mathbf{120}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{16.104}$	Sen's estimator of trend.
6	$var(S) = \mathbf{493.333}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{1/2}) / 2$ $= (\mathbf{120} - \mathbf{2.326} * \mathbf{493.333}^{1/2}) / 2$ $= \mathbf{34.168}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-15.759}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Chloride (mg/L) at CBL-308I
Normal Control Limit

Step	Equation	Description
1	$\bar{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{44230.0} / \mathbf{18}$ $= \mathbf{2457.222}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{1/2}$ $= ((\mathbf{1.10 \times 10^8} - \mathbf{1.96 \times 10^9}/\mathbf{18}) / (\mathbf{18}-1))^{1/2}$ $= \mathbf{303.175}$	Compute background sd.
3	$SCL = \bar{\mathbf{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{2457.222} + \mathbf{5.0} * \mathbf{303.175}$ $= \mathbf{3973.1}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{18} * (\mathbf{18}-1) / 2$ $= \mathbf{153}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{-106.468}$	Sen's estimator of trend.
6	$\mathrm{var}(S) = \mathbf{695.0}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{1/2}) / 2$ $= (\mathbf{153} - \mathbf{2.326} * \mathbf{695.0}^{1/2}) / 2$ $= \mathbf{45.84}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-174.502}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Chloride (mg/L) at CBL-341I
Normal Control Limit

Step	Equation	Description
1	$\overline{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{32540.0} / \mathbf{18}$ $= \mathbf{1807.778}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}\text{-}1))^{1/2}$ $= ((\mathbf{5.91{\times}10^7} - \mathbf{1.06{\times}10^9}/\mathbf{18}) / (\mathbf{18}\text{-}1))^{1/2}$ $= \mathbf{129.14}$	Compute background sd.
3	$SCL = \overline{\mathbf{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{1807.778} + \mathbf{5.0} * \mathbf{129.14}$ $= \mathbf{2453.477}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}\text{-}1) / 2$ $= \mathbf{18} * (\mathbf{18}\text{-}1) / 2$ $= \mathbf{153}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{-16.82}$	Sen's estimator of trend.
6	$var(S) = \mathbf{696.0}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{1/2}) / 2$ $= (\mathbf{153} - \mathbf{2.326} * \mathbf{696.0}^{1/2}) / 2$ $= \mathbf{45.818}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1th largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-57.489}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Fluoride (mg/L) at CBL-301I
Normal Control Limit

Step	Equation	Description
1	$\overline{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{10.16} / \mathbf{20}$ $= \mathbf{0.508}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{1/2}$ $= ((\mathbf{10.634} - \mathbf{103.226/20}) / (\mathbf{20}-1))^{1/2}$ $= \mathbf{0.537}$	Compute background sd.
3	$SCL = \mathbf{\overline{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{0.508} + \mathbf{5.0} * \mathbf{0.537}$ $= \mathbf{3.191}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{20} * (\mathbf{20}-1) / 2$ $= \mathbf{190}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{0.0}$	Sen's estimator of trend.
6	$var(S) = \mathbf{681.333}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{1/2}) / 2$ $= (\mathbf{190} - \mathbf{2.326} * \mathbf{681.333}^{1/2}) / 2$ $= \mathbf{64.643}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-0.035}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Fluoride (mg/L) at CBL-302I
Normal Control Limit

Step	Equation	Description
1	$\overline{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{9.153} / \mathbf{19}$ $= \mathbf{0.482}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{1/2}$ $= ((\mathbf{8.255} - \mathbf{83.772}/\mathbf{19}) / (\mathbf{19}-1))^{1/2}$ $= \mathbf{0.462}$	Compute background sd.
3	$SCL = \overline{\mathbf{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{0.482} + \mathbf{5.0} * \mathbf{0.462}$ $= \mathbf{2.793}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{19} * (\mathbf{19}-1) / 2$ $= \mathbf{171}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{0.0}$	Sen's estimator of trend.
6	$\mathrm{var}(S) = \mathbf{604.333}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{1/2}) / 2$ $= (\mathbf{171} - \mathbf{2.326} * \mathbf{604.333}^{1/2}) / 2$ $= \mathbf{56.91}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-0.031}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Fluoride (mg/L) at CBL-306I
Normal Control Limit

Step	Equation	Description
1	$\bar{X} = \text{sum}[X] / N$ $= 40.73 / 17$ $= 2.396$	Compute background mean.
2	$S = ((\text{sum}[X^2] - \text{sum}[X]^2/N) / (N-1))^{1/2}$ $= ((102.838 - 1658.933/17) / (17-1))^{1/2}$ $= 0.573$	Compute background sd.
3	$SCL = \bar{X} + F * S$ $= 2.396 + 5.0 * 0.573$ $= 5.261$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = N * (N-1) / 2$ $= 17 * (17-1) / 2$ $= 136$	Number of sample pairs during trend detection period.
5	$S = 0.119$	Sen's estimator of trend.
6	$\text{var}(S) = 589.333$	Variance estimate for slope.
7	$M_1(S) = (N' - Z_{.99} * \text{var}(S)^{1/2}) / 2$ $= (136 - 2.326 * 589.333^{1/2}) / 2$ $= 39.767$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = -0.032$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Fluoride (mg/L) at CBL-308I
Normal Control Limit

Step	Equation	Description
1	$\overline{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{28.4} / \mathbf{17}$ $= \mathbf{1.671}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{\frac{1}{2}}$ $= ((\mathbf{48.489} - \mathbf{806.56}/\mathbf{17}) / (\mathbf{17}-1))^{\frac{1}{2}}$ $= \mathbf{0.255}$	Compute background sd.
3	$SCL = \overline{\mathbf{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{1.671} + \mathbf{5.0} * \mathbf{0.255}$ $= \mathbf{2.948}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{17} * (\mathbf{17}-1) / 2$ $= \mathbf{136}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{-0.02}$	Sen's estimator of trend.
6	$var(S) = \mathbf{588.333}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{\frac{1}{2}}) / 2$ $= (\mathbf{136} - \mathbf{2.326} * \mathbf{588.333}^{\frac{1}{2}}) / 2$ $= \mathbf{39.791}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-0.111}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Fluoride (mg/L) at CBL-341I
Normal Control Limit

Step	Equation	Description
1	$\bar{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{7.116} / \mathbf{19}$ $= \mathbf{0.375}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{1/2}$ $= ((\mathbf{3.957} - \mathbf{50.632}/\mathbf{19}) / (\mathbf{19}-1))^{1/2}$ $= \mathbf{0.268}$	Compute background sd.
3	$SCL = \bar{\mathbf{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{0.375} + \mathbf{5.0} * \mathbf{0.268}$ $= \mathbf{1.714}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{19} * (\mathbf{19}-1) / 2$ $= \mathbf{171}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{0.0}$	Sen's estimator of trend.
6	$var(S) = \mathbf{751.667}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{1/2}) / 2$ $= (\mathbf{171} - \mathbf{2.326} * \mathbf{751.667}^{1/2}) / 2$ $= \mathbf{53.615}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-0.133}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
pH (S.U.) at CBL-301I
Normal Control Limit

Step	Equation	Description
1	$\bar{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{136.43} / \mathbf{22}$ $= \mathbf{6.201}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{\frac{1}{2}}$ $= ((\mathbf{847.258} - \mathbf{18613.145/22}) / (\mathbf{22}-1))^{\frac{1}{2}}$ $= \mathbf{0.24}$	Compute background sd.
3	$SCL = \bar{\mathbf{X}} \pm \mathbf{F} * \mathbf{S}$ $= \mathbf{6.201} \pm \mathbf{5.0} * \mathbf{0.24}$ $= \mathbf{5.003}, \mathbf{7.4}$	Compute combined Shewhart-CUSUM normal control interval.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{22} * (\mathbf{22}-1) / 2$ $= \mathbf{231}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{-0.007}$	Sen's estimator of trend.
6	$var(S) = \mathbf{1248.333}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{\frac{1}{2}}) / 2$ $= (\mathbf{231} - \mathbf{2.326} * \mathbf{1248.333}^{\frac{1}{2}}) / 2$ $= \mathbf{74.409}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1th largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-0.036}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
pH (S.U.) at CBL-302I
Normal Control Limit

Step	Equation	Description
1	$\bar{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{115.31} / \mathbf{19}$ $= \mathbf{6.069}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{\frac{1}{2}}$ $= ((\mathbf{706.23} - \mathbf{13296.396}/\mathbf{19}) / (\mathbf{19}-1))^{\frac{1}{2}}$ $= \mathbf{0.597}$	Compute background sd.
3	$SCL = \bar{\mathbf{X}} \pm \mathbf{F} * \mathbf{S}$ $= \mathbf{6.069} \pm \mathbf{5.0} * \mathbf{0.597}$ $= \mathbf{3.083}, \mathbf{9.055}$	Compute combined Shewhart-CUSUM normal control interval.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{19} * (\mathbf{19}-1) / 2$ $= \mathbf{171}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{0.044}$	Sen's estimator of trend.
6	$\mathrm{var}(S) = \mathbf{812.333}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{\frac{1}{2}}) / 2$ $= (\mathbf{171} - \mathbf{2.326} * \mathbf{812.333}^{\frac{1}{2}}) / 2$ $= \mathbf{52.353}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-0.04}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
pH (S.U.) at CBL-306I
Normal Control Limit

Step	Equation	Description
1	$\bar{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{119.66} / \mathbf{18}$ $= \mathbf{6.648}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{\frac{1}{2}}$ $= ((\mathbf{802.809} - \mathbf{14318.516}/\mathbf{18}) / (\mathbf{18}-1))^{\frac{1}{2}}$ $= \mathbf{0.657}$	Compute background sd.
3	$SCL = \bar{\mathbf{X}} \pm \mathbf{F} * \mathbf{S}$ $= \mathbf{6.648} \pm \mathbf{5.0} * \mathbf{0.657}$ $= \mathbf{3.363}, \mathbf{9.932}$	Compute combined Shewhart-CUSUM normal control interval.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{18} * (\mathbf{18}-1) / 2$ $= \mathbf{153}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{-0.011}$	Sen's estimator of trend.
6	$var(S) = \mathbf{696.0}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{\frac{1}{2}}) / 2$ $= (\mathbf{153} - \mathbf{2.326} * \mathbf{696.0}^{\frac{1}{2}}) / 2$ $= \mathbf{45.818}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-0.094}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
pH (S.U.) at CBL-308I
Normal Control Limit

Step	Equation	Description
1	$\bar{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{112.19} / \mathbf{18}$ $= \mathbf{6.233}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{\frac{1}{2}}$ $= ((\mathbf{700.296} - \mathbf{12586.596}/\mathbf{18}) / (\mathbf{18}-1))^{\frac{1}{2}}$ $= \mathbf{0.247}$	Compute background sd.
3	$SCL = \bar{\mathbf{X}} \pm \mathbf{F} * \mathbf{S}$ $= \mathbf{6.233} \pm \mathbf{5.0} * \mathbf{0.247}$ $= \mathbf{4.996}, \mathbf{7.47}$	Compute combined Shewhart-CUSUM normal control interval.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{18} * (\mathbf{18}-1) / 2$ $= \mathbf{153}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{-0.002}$	Sen's estimator of trend.
6	$var(S) = \mathbf{691.333}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{\frac{1}{2}}) / 2$ $= (\mathbf{153} - \mathbf{2.326} * \mathbf{691.333}^{\frac{1}{2}}) / 2$ $= \mathbf{45.921}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-0.03}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
pH (S.U.) at CBL-341I
Normal Control Limit

Step	Equation	Description
1	$\bar{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{108.89} / \mathbf{18}$ $= \mathbf{6.049}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{\frac{1}{2}}$ $= ((\mathbf{659.685} - \mathbf{11857.032}/\mathbf{18}) / (\mathbf{18}-1))^{\frac{1}{2}}$ $= \mathbf{0.238}$	Compute background sd.
3	$SCL = \bar{\mathbf{X}} \pm \mathbf{F} * \mathbf{S}$ $= \mathbf{6.049} \pm \mathbf{5.0} * \mathbf{0.238}$ $= \mathbf{4.861}, \mathbf{7.238}$	Compute combined Shewhart-CUSUM normal control interval.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{18} * (\mathbf{18}-1) / 2$ $= \mathbf{153}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{0.067}$	Sen's estimator of trend.
6	$var(S) = \mathbf{696.0}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{\frac{1}{2}}) / 2$ $= (\mathbf{153} - \mathbf{2.326} * \mathbf{696.0}^{\frac{1}{2}}) / 2$ $= \mathbf{45.818}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-0.015}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Sulfate (mg/L) at CBL-301I
Normal Control Limit

Step	Equation	Description
1	$\overline{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{6310.0} / \mathbf{18}$ $= \mathbf{350.556}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{1/2}$ $= ((\mathbf{2.27} \times \mathbf{10^6} - \mathbf{3.98} \times \mathbf{10^7}/\mathbf{18}) / (\mathbf{18}-1))^{1/2}$ $= \mathbf{60.294}$	Compute background sd.
3	$SCL = \overline{\mathbf{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{350.556} + \mathbf{5.0} * \mathbf{60.294}$ $= \mathbf{652.024}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{18} * (\mathbf{18}-1) / 2$ $= \mathbf{153}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{6.483}$	Sen's estimator of trend.
6	$\text{var}(S) = \mathbf{696.0}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{1/2}) / 2$ $= (\mathbf{153} - \mathbf{2.326} * \mathbf{696.0}^{1/2}) / 2$ $= \mathbf{45.818}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-8.207}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Sulfate (mg/L) at CBL-302I
Normal Control Limit

Step	Equation	Description
1	$\overline{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{22013.0} / \mathbf{18}$ $= \mathbf{1222.944}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{\frac{1}{2}}$ $= ((\mathbf{2.71}\times\mathbf{10^7} - \mathbf{4.85}\times\mathbf{10^8}/\mathbf{18}) / (\mathbf{18}-1))^{\frac{1}{2}}$ $= \mathbf{114.114}$	Compute background sd.
3	$SCL = \overline{\mathbf{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{1222.944} + \mathbf{5.0} * \mathbf{114.114}$ $= \mathbf{1793.513}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{18} * (\mathbf{18}-1) / 2$ $= \mathbf{153}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{45.342}$	Sen's estimator of trend.
6	$var(S) = \mathbf{695.0}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{\frac{1}{2}}) / 2$ $= (\mathbf{153} - \mathbf{2.326} * \mathbf{695.0}^{\frac{1}{2}}) / 2$ $= \mathbf{45.84}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{25.012}$	One-sided lower confidence limit for slope.
9	$LCL(S) > 0$	**Significant increasing trend.**

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Sulfate (mg/L) at CBL-306I
Normal Control Limit

Step	Equation	Description
1	$\bar{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{6599.0} / \mathbf{17}$ $= \mathbf{388.176}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{1/2}$ $= ((\mathbf{2.76}\times\mathbf{10^6} - \mathbf{4.35}\times\mathbf{10^7}/\mathbf{17}) / (\mathbf{17}-1))^{1/2}$ $= \mathbf{110.356}$	Compute background sd.
3	$SCL = \bar{\mathbf{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{388.176} + \mathbf{5.0} * \mathbf{110.356}$ $= \mathbf{939.958}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{17} * (\mathbf{17}-1) / 2$ $= \mathbf{136}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{18.243}$	Sen's estimator of trend.
6	$var(S) = \mathbf{589.333}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{1/2}) / 2$ $= (\mathbf{136} - \mathbf{2.326} * \mathbf{589.333}^{1/2}) / 2$ $= \mathbf{39.767}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-14.639}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits

Sulfate (mg/L) at CBL-308I

Normal Control Limit

Step	Equation	Description
1	$\bar{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{25640.0} / \mathbf{18}$ $= \mathbf{1424.444}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{\frac{1}{2}}$ $= ((\mathbf{3.68} \times \mathbf{10^7} - \mathbf{6.57} \times \mathbf{10^8}/\mathbf{18}) / (\mathbf{18}-1))^{\frac{1}{2}}$ $= \mathbf{121.424}$	Compute background sd.
3	$SCL = \bar{\mathbf{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{1424.444} + \mathbf{5.0} * \mathbf{121.424}$ $= \mathbf{2031.565}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{18} * (\mathbf{18}-1) / 2$ $= \mathbf{153}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{-41.243}$	Sen's estimator of trend.
6	$var(S) = \mathbf{693.0}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{\frac{1}{2}}) / 2$ $= (\mathbf{153} - \mathbf{2.326} * \mathbf{693.0}^{\frac{1}{2}}) / 2$ $= \mathbf{45.884}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-65.458}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Sulfate (mg/L) at CBL-341I
Normal Control Limit

Step	Equation	Description
1	$\overline{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{6287.0} / \mathbf{18}$ $= \mathbf{349.278}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{1/2}$ $= ((\mathbf{2.21}\times\mathbf{10^6} - \mathbf{3.95}\times\mathbf{10^7}/\mathbf{18}) / (\mathbf{18}-1))^{1/2}$ $= \mathbf{32.89}$	Compute background sd.
3	$SCL = \overline{\mathbf{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{349.278} + \mathbf{5.0} * \mathbf{32.89}$ $= \mathbf{513.727}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{18} * (\mathbf{18}-1) / 2$ $= \mathbf{153}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{-10.817}$	Sen's estimator of trend.
6	$var(S) = \mathbf{696.0}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{1/2}) / 2$ $= (\mathbf{153} - \mathbf{2.326} * \mathbf{696.0}^{1/2}) / 2$ $= \mathbf{45.818}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-19.435}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Total Dissolved Solids (mg/L) at CBL-301I
Normal Control Limit

Step	Equation	Description
1	$\bar{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{98000.0} / \mathbf{18}$ $= \mathbf{5444.444}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{\frac{1}{2}}$ $= ((\mathbf{5.44}\times\mathbf{10^8} - \mathbf{9.60}\times\mathbf{10^9}/\mathbf{18}) / (\mathbf{18}-1))^{\frac{1}{2}}$ $= \mathbf{767.695}$	Compute background sd.
3	$SCL = \mathbf{\bar{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{5444.444} + \mathbf{5.0} * \mathbf{767.695}$ $= \mathbf{9282.919}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{18} * (\mathbf{18}-1) / 2$ $= \mathbf{153}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{8.889}$	Sen's estimator of trend.
6	$var(S) = \mathbf{697.0}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{\frac{1}{2}}) / 2$ $= (\mathbf{153} - \mathbf{2.326} * \mathbf{697.0}^{\frac{1}{2}}) / 2$ $= \mathbf{45.796}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-248.456}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Total Dissolved Solids (mg/L) at CBL-302I
Normal Control Limit

Step	Equation	Description
1	$\overline{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{95610.0} / \mathbf{18}$ $= \mathbf{5311.667}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{1/2}$ $= ((\mathbf{5.18\times10^8} - \mathbf{9.14\times10^9}/\mathbf{18}) / (\mathbf{18}-1))^{1/2}$ $= \mathbf{764.87}$	Compute background sd.
3	$SCL = \mathbf{\overline{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{5311.667} + \mathbf{5.0} * \mathbf{764.87}$ $= \mathbf{9136.018}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{18} * (\mathbf{18}-1) / 2$ $= \mathbf{153}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{-219.811}$	Sen's estimator of trend.
6	$var(S) = \mathbf{696.0}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{1/2}) / 2$ $= (\mathbf{153} - \mathbf{2.326} * \mathbf{696.0}^{1/2}) / 2$ $= \mathbf{45.818}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-407.793}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Total Dissolved Solids (mg/L) at CBL-306I
Normal Control Limit

Step	Equation	Description
1	$\overline{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{24430.0} / \mathbf{17}$ $= \mathbf{1437.059}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{\frac{1}{2}}$ $= ((\mathbf{3.62}\times\mathbf{10^7} - \mathbf{5.97}\times\mathbf{10^8}/\mathbf{17}) / (\mathbf{17}-1))^{\frac{1}{2}}$ $= \mathbf{267.085}$	Compute background sd.
3	$SCL = \overline{\mathbf{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{1437.059} + \mathbf{5.0} * \mathbf{267.085}$ $= \mathbf{2772.485}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{17} * (\mathbf{17}-1) / 2$ $= \mathbf{136}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{76.005}$	Sen's estimator of trend.
6	$var(S) = \mathbf{586.333}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{\frac{1}{2}}) / 2$ $= (\mathbf{136} - \mathbf{2.326} * \mathbf{586.333}^{\frac{1}{2}}) / 2$ $= \mathbf{39.839}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-5.732}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Total Dissolved Solids (mg/L) at CBL-308I
Normal Control Limit

Step	Equation	Description
1	$\bar{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{120540.0} / \mathbf{18}$ $= \mathbf{6696.667}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{\frac{1}{2}}$ $= ((\mathbf{8.40 \times 10^8} - \mathbf{1.45 \times 10^{10}}/\mathbf{18}) / (\mathbf{18}-1))^{\frac{1}{2}}$ $= \mathbf{1385.271}$	Compute background sd.
3	$SCL = \bar{\mathbf{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{6696.667} + \mathbf{5.0} * \mathbf{1385.271}$ $= \mathbf{13623.023}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{18} * (\mathbf{18}-1) / 2$ $= \mathbf{153}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{-270.134}$	Sen's estimator of trend.
6	$var(S) = \mathbf{697.0}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{\frac{1}{2}}) / 2$ $= (\mathbf{153} - \mathbf{2.326} * \mathbf{697.0}^{\frac{1}{2}}) / 2$ $= \mathbf{45.796}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-711.043}$	One-sided lower confidence limit for slope.

Worksheet 2 - Intra-Well Control Charts / Prediction Limits
Total Dissolved Solids (mg/L) at CBL-341I
Normal Control Limit

Step	Equation	Description
1	$\overline{X} = \mathbf{sum[X]} / \mathbf{N}$ $= \mathbf{84020.0} / \mathbf{18}$ $= \mathbf{4667.778}$	Compute background mean.
2	$S = ((\mathbf{sum[X^2]} - \mathbf{sum[X]}^2/\mathbf{N}) / (\mathbf{N}-1))^{1/2}$ $= ((\mathbf{3.97} \times \mathbf{10^8} - \mathbf{7.06} \times \mathbf{10^9}/\mathbf{18}) / (\mathbf{18}-1))^{1/2}$ $= \mathbf{554.018}$	Compute background sd.
3	$SCL = \overline{\mathbf{X}} + \mathbf{F} * \mathbf{S}$ $= \mathbf{4667.778} + \mathbf{5.0} * \mathbf{554.018}$ $= \mathbf{7437.868}$	Compute combined Shewhart-CUSUM normal control limit.
4	$N' = \mathbf{N} * (\mathbf{N}-1) / 2$ $= \mathbf{18} * (\mathbf{18}-1) / 2$ $= \mathbf{153}$	Number of sample pairs during trend detection period.
5	$S = \mathbf{-76.49}$	Sen's estimator of trend.
6	$\text{var}(S) = \mathbf{696.0}$	Variance estimate for slope.
7	$M_1(S) = (\mathbf{N'} - \mathbf{Z}_{.99} * \mathbf{var(S)}^{1/2}) / 2$ $= (\mathbf{153} - \mathbf{2.326} * \mathbf{696.0}^{1/2}) / 2$ $= \mathbf{45.818}$	Ordinal position for one-sided lower confidence limit for slope. The LCL is the M_1^{th} largest slope estimate. When M_1 is not an integer, interpolation is used.
8	$LCL(S) = \mathbf{-305.108}$	One-sided lower confidence limit for slope.