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Date: September 2, 2015

To: Felicia Barnett, Director SCMTSC, EPA

From: Anita Singh, Ph.D., SERAS Statistician

Through: Richard, Leuser, SERAS Deputy Program Manager

SUBJECT: STATISTICAL EVALUATION OF GOLD KING MINE SPILL EVENT SURFACE WATER DATA, SILVERTON, COLORADO, SERAS-106, WO-64

On August 5, 2015, Environmental Protection Agency (EPA) personnel along with personnel from Environmental Restoration LLC, a company located in Fenton, Missouri and under EPA contract to mitigate pollutants from the closed mine, attempted to add a tap to the mine tailing pond resulting in a waste spill. Their actions accidentally destroyed the dam holding back the pond, spilling three million gallons of polluted mustard color mine waste water and tailings (Figures 1) into the Cement Creek tributary of the Animas River in Colorado (Figure 2). The mine waste water and tailings contained metals such as aluminum (Al), arsenic (As), iron (Fe), and lead (Pb). The spill affected San Juan River (SJR) waterways of municipalities in the states of Colorado, New Mexico, Utah and the Navajo Nation. Since the spill, EPA has been working closely with local, state and Navajo Nation officials to ensure the safety of citizens impacted by water contaminated by the spill. EPA activated its Emergency Operations Center to ensure coordination among its regions, laboratories and national program offices in Washington DC. EPA deployed federal On-Scene Coordinators (OSCs) and other technicians in Colorado, New Mexico and the Navajo Nation.

To assess the impacts of the release at the Gold King Mine, surface water and sediment samples were collected at several sampling stations (Figures 3 and 3a) from the northern border of New Mexico to the Navajo Nation. Sampling began on August 7, 2015 with analytical results, sampling stations, and latitudes and longitudes of the sampling locations posted on the EPA website. On August 18, 2105, Region 9 personnel asked the EPA Office of Research and Development (ORD) Site Characterization and Monitoring Technical Support Center (SCMTSC) for technical assistance in evaluating surface water and sediment data collected from the sampling stations installed in New Mexico, the Four-Corners, and Utah (Figures 3 and 3a). On August 19, Lockheed Martin personnel attended a scoping conference call with EPA personnel from Region 4 (R4), Region 9 (R9), and ORD's Las Vegas National Exposure Research Laboratory (NERL). Initially, only data collected up to August 12 was provided. Subsequently data collected up to August 18, 2015 for total and dissolved metals in surface waters was also provided.

This technical memorandum (TM) has been prepared by Lockheed Martin under the EPA Scientific, Engineering, Response and Analytical Services (SERAS) Contract. SERAS personnel were in constant

communication with R9 personnel (Mr. H. Allen, Chief OSC) exchanging updated data and statistical findings, to be shared with state and Navajo Nation officials. At this time, R9 personnel wanted statistical evaluation of surface water data. To address immediate needs of R9 personnel assigned to the Gold King Mine Site, several draft reports summarizing intermediate results (e.g., summary statistics by sampled dates, sampled stations, time series plots, background threshold values [BTVs], and other graphical displays) have been shared with them on daily basis from August 21 through August 27, 2015. Results summarized in those reports (and in this TM) have already been discussed with R9 personnel via conference calls held during the time period listed above.

Figure 1. Contaminated wastewater is seen at the entrance to the Gold King Mine in San Juan County, Colorado; the plume of contaminated water slowly continued to work its way downstream to the river.

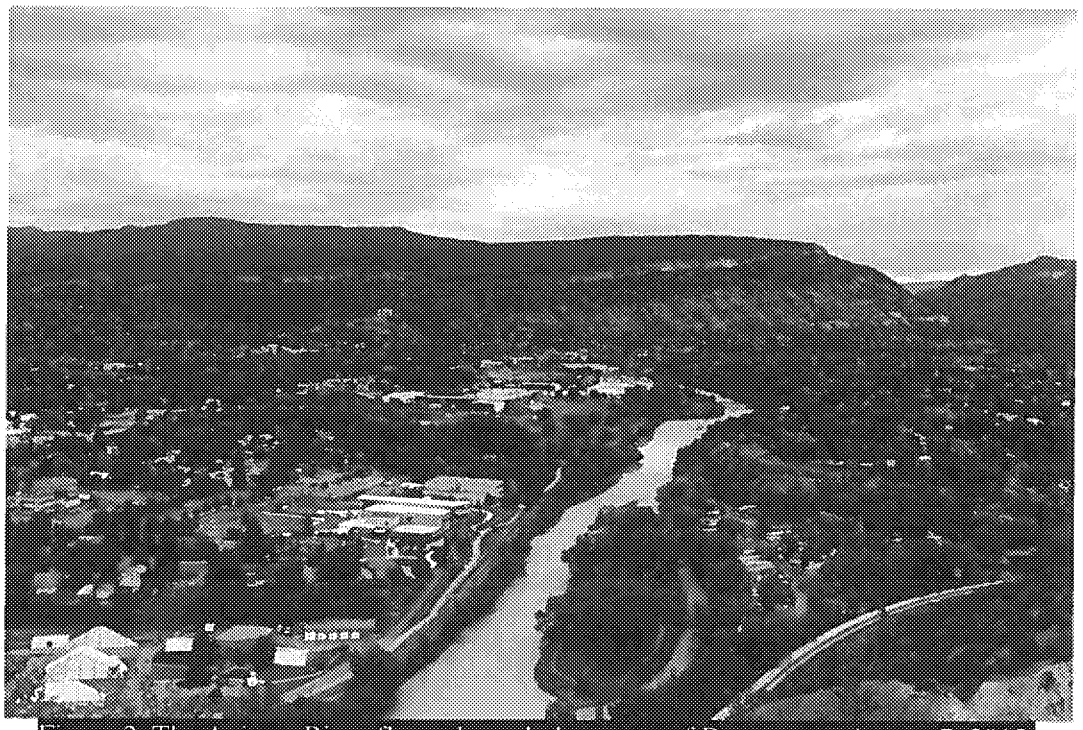


Figure 2. The Animas River flows through the center of Durango on August 7, 2015.

This TM summarizes results (using data collected up to August 18) described in the intermediate draft reports shared with R9 personnel. Several summary statistics tables and intermediate graphical displays such as Quantile-Quantile (Q-Q) plots and box plots have been retained in this TM as they provided useful information about plume status at various sampling stations across the SJR. ProUCL 5.0 was used to generate graphical displays and perform statistical evaluations summarized in this TM.

Significantly elevated levels of dissolved Al and dissolved Fe have been observed at several sampling stations following the Gold King Mine Spill Event. On August 19-20, an Excel file summarizing Pre-Spill Event data for total and dissolved metals collected from routine SJR sampling stations was also provided. The pre-Spill Event data collected during 2011-2104 has been used as background data to compute 95 percent (%) upper prediction limits (UPL95s) to determine background threshold values (BTVs) for several metals including Al, As, copper (Cu), Fe, Pb, and Zinc (Zn).

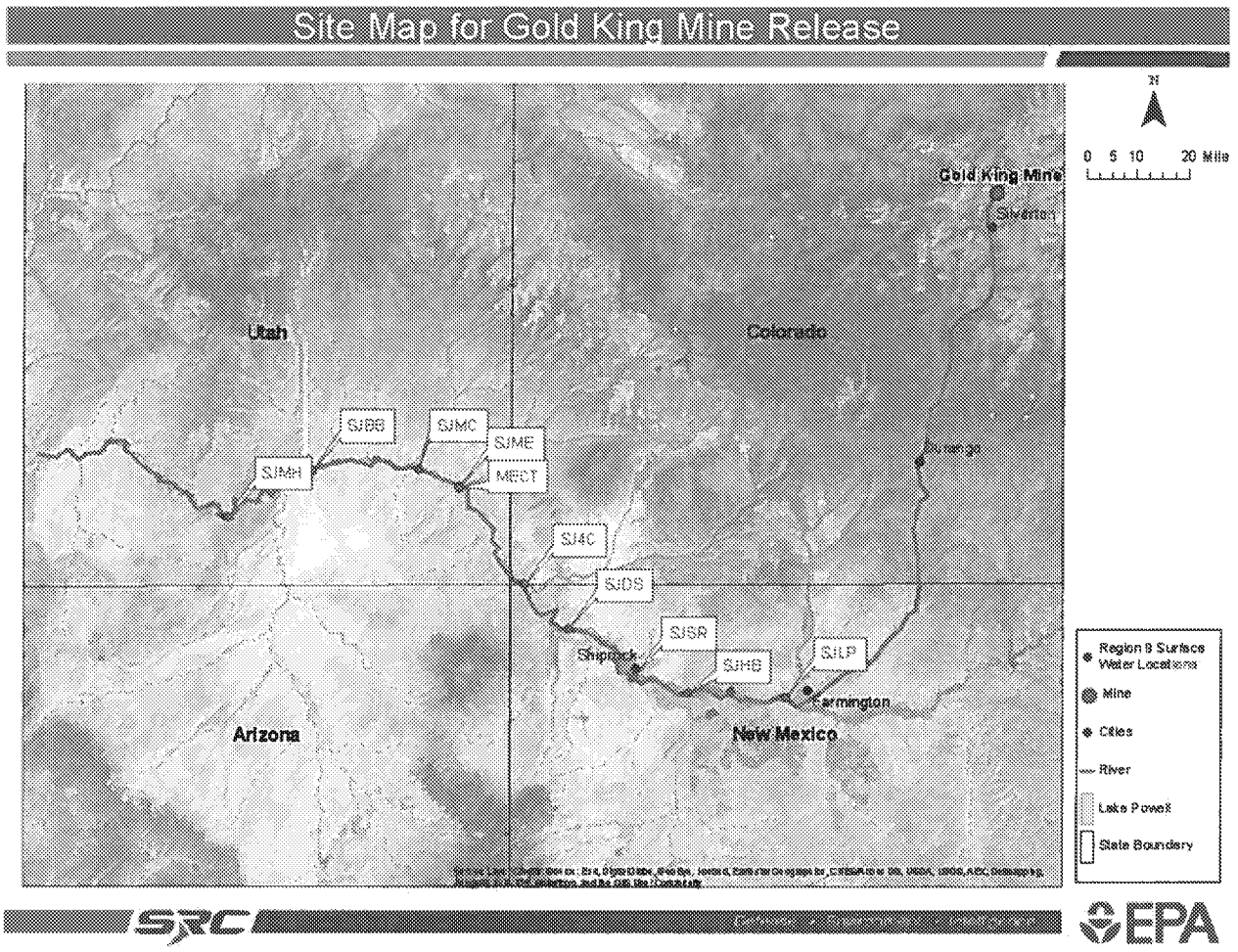


Figure 3. Map Showing the Sampling Stations

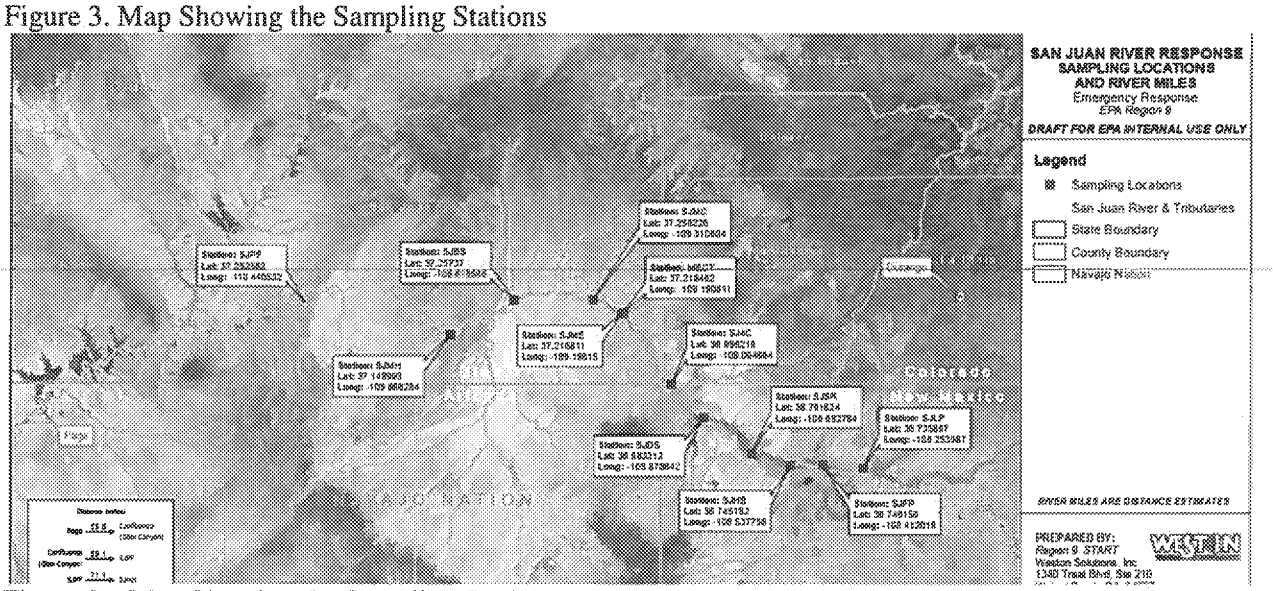
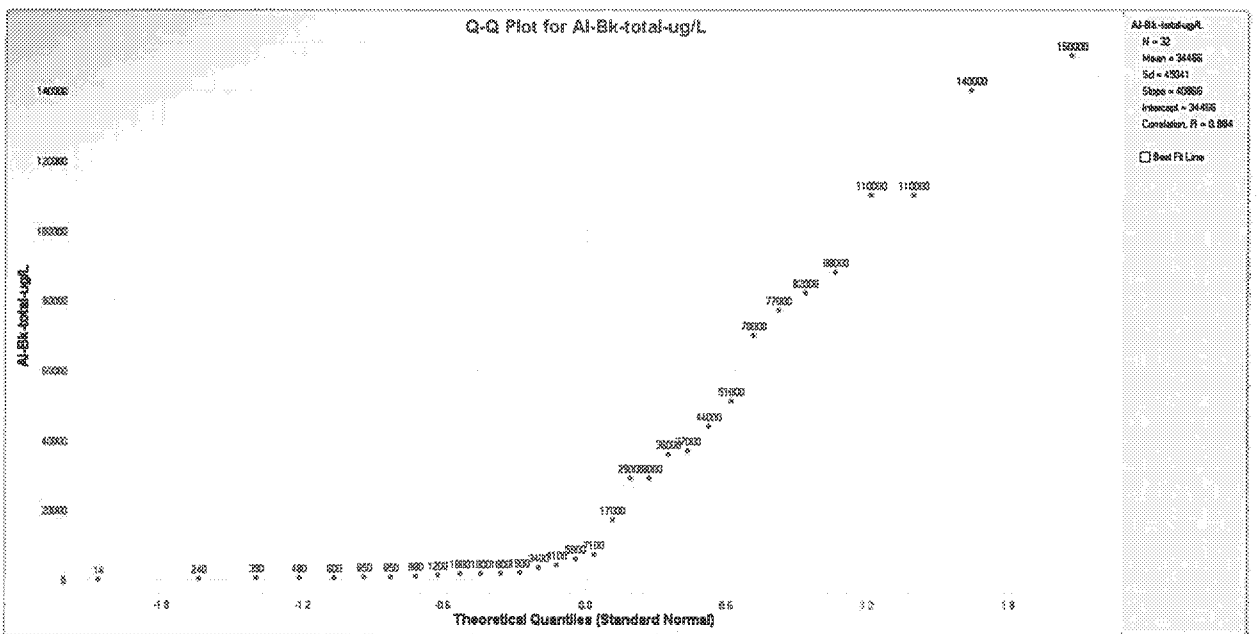


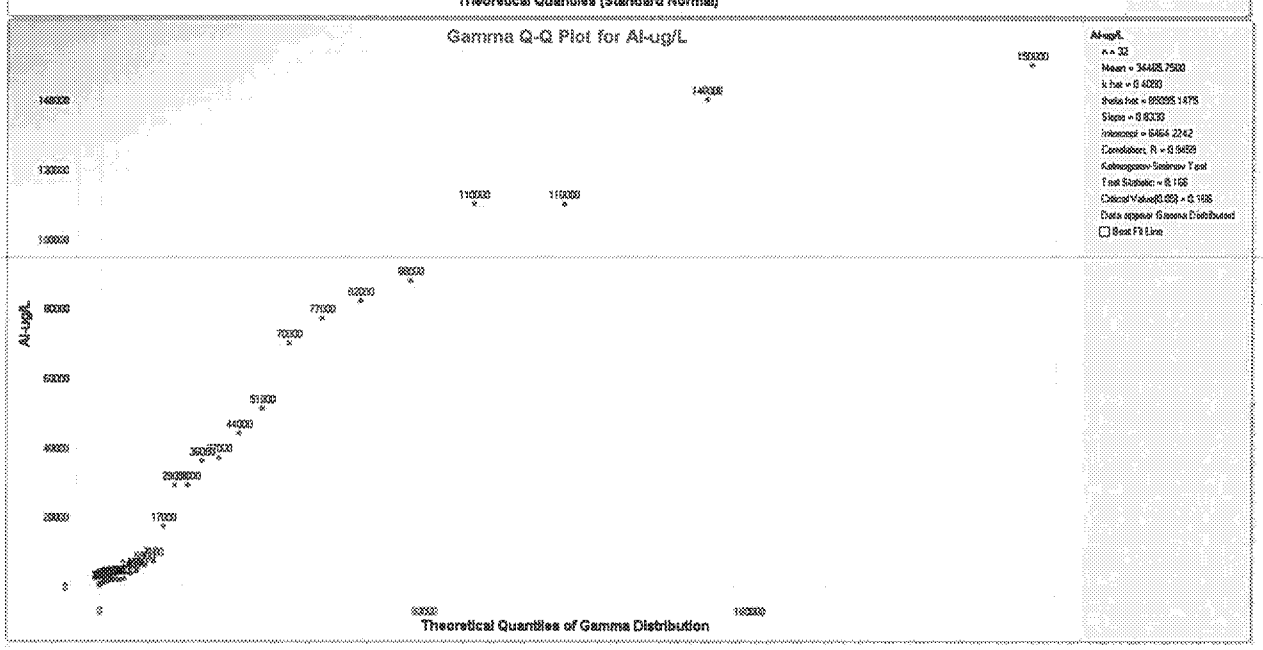
Figure 3a. Map Showing the Sampling Stations

1.0 95% Upper Prediction Limits (95% UPL, UPL95) to Determine BTVs

As requested by R9, 95% UPLs were computed for total and dissolved Al, Cu, Zn, Pb, and As based upon data collected prior to the Spill Event from several sampling stations (e.g., 02-06 [6], 02-07[7], 02-08[8], 10-25, 10-26, 10-30, and 10-31) of SJR. Most samples represent routine samples collected from 2011 through 2014 and can be considered to represent natural background conditions prior to the Spill Event. The data set consists of about 34 data points; and for several analytes (Al, As, Zn) stations: 6, 7, and 8 exhibit higher (with outliers) concentrations.

<u>UPL95 for Total Al (no nondetects are present) - SJR Background Data</u>

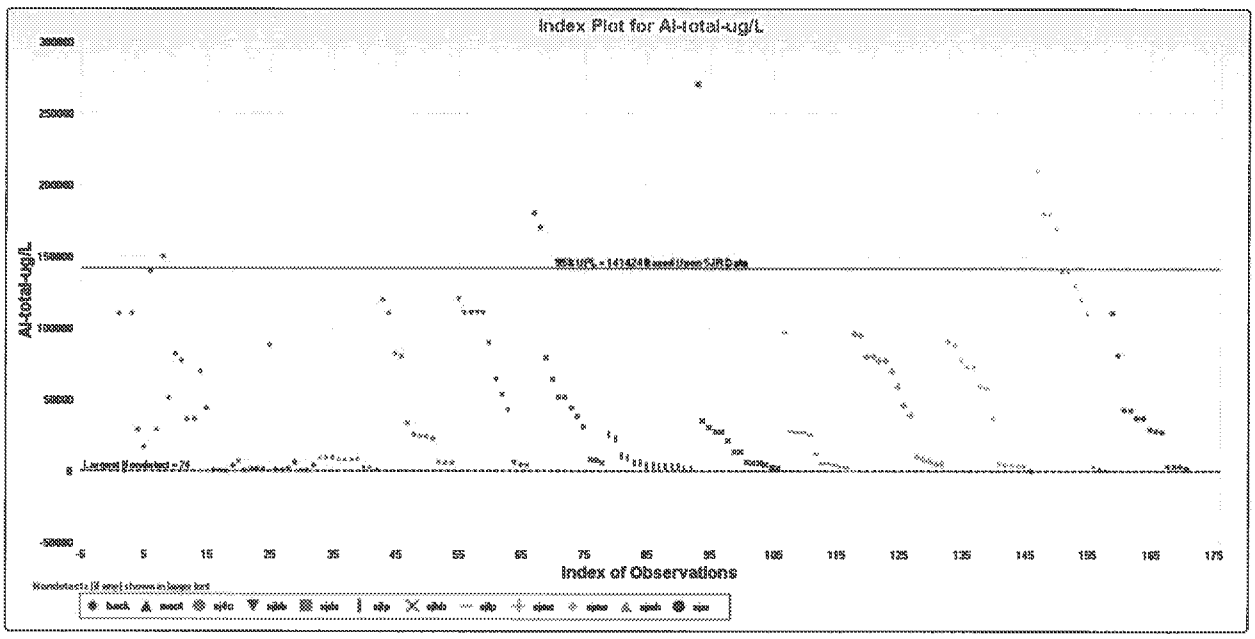




- Based upon the Rosner outlier test and from the above Q-Q plots, it was determined that the data set does not contain any outliers; and the total Al background data set follows an approximate gamma distribution. For gamma distribution, two methods are used to compute UPL95s (ProUCL Technical Guide); both UPLs have been reported in this TM.

- BTV= 95% Gamma UPL: 141,424 (or 58,008) micrograms per Liter (µg/L).

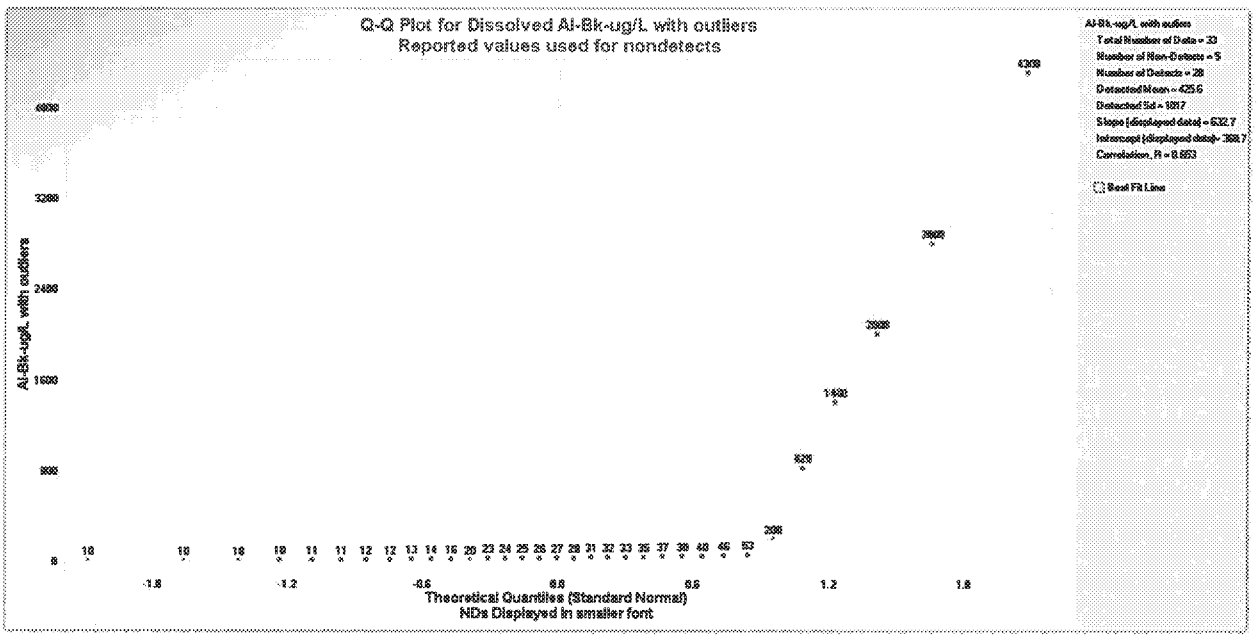
An index plot comparing Post-Spill Event onsite-stations data (collected after August 7) with the computed 95% UPL for total Al is shown below.



From the above index plot, it is noted that some onsite total Al concentrations from stations: SJMH, SJDS, and SJHB exceed the 95% UPL.

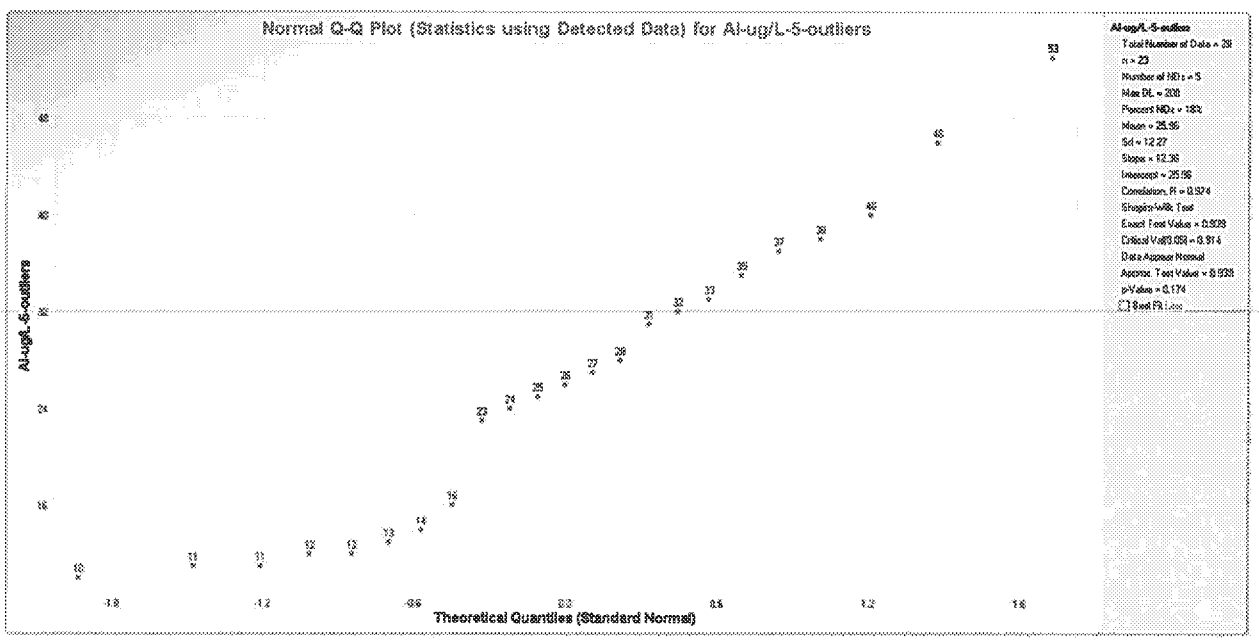
ED_004888_00033764-00006

UPL95 for Dissolved Al (nondetects are present) - SJR Background Data

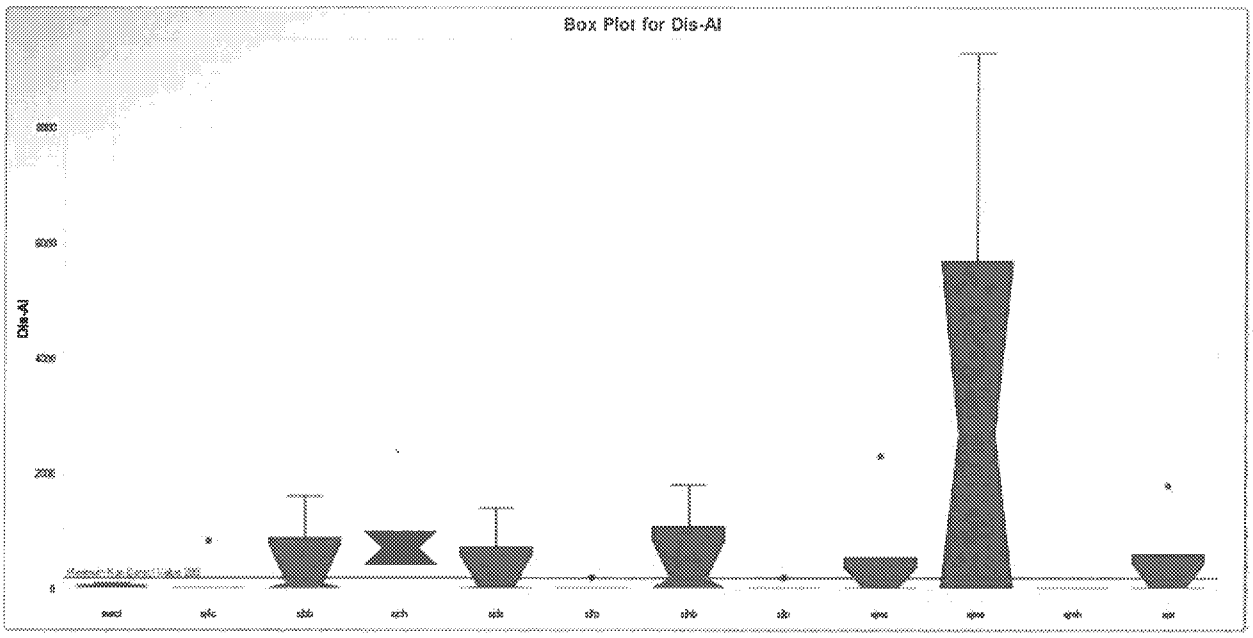


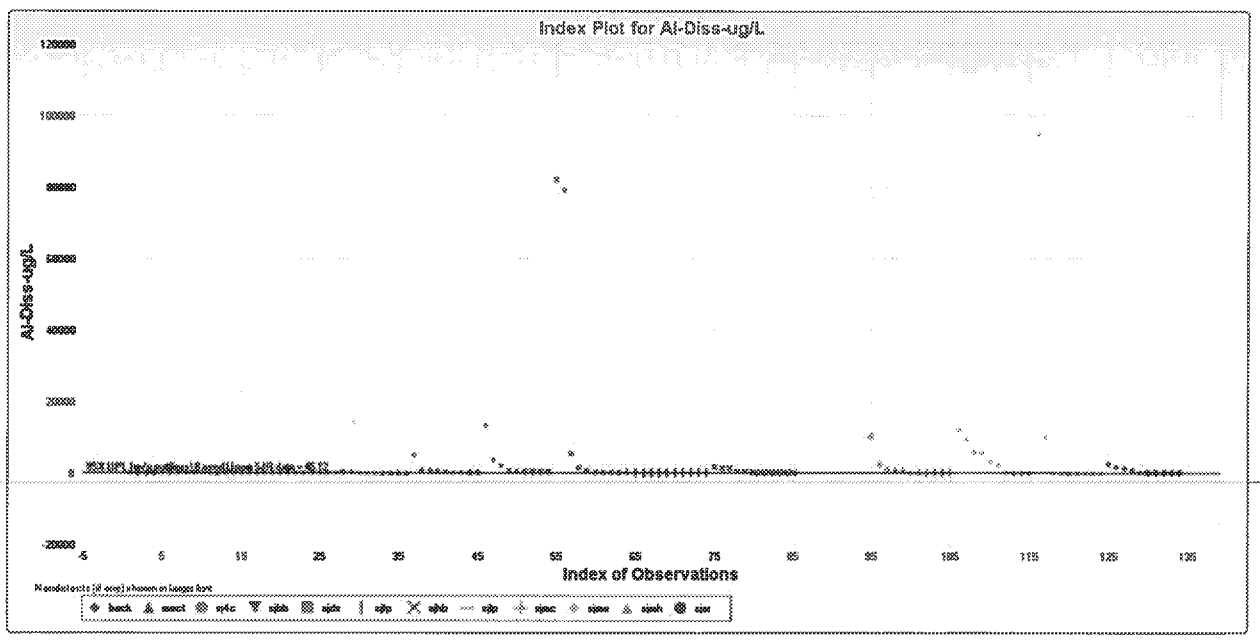
- The data set does not follow a discernible distribution, and 5 data points: 4300, 2800, 2000, 1400, and 820 are identified as outliers (Rosner test). Outliers are identified at stations 6 & 8.

- The detected data set without the 5 outliers appears to follow a normal distribution. The 95% UPL (KM-t-normal) accounting for nondetect observations = 45.12 µg/L



Box plots and an index plot comparing dissolved Al from onsite stations with the UPL95 are shown below. It is noted that dissolved Al from several onsite stations exceeded the BTV estimate (UPL95).

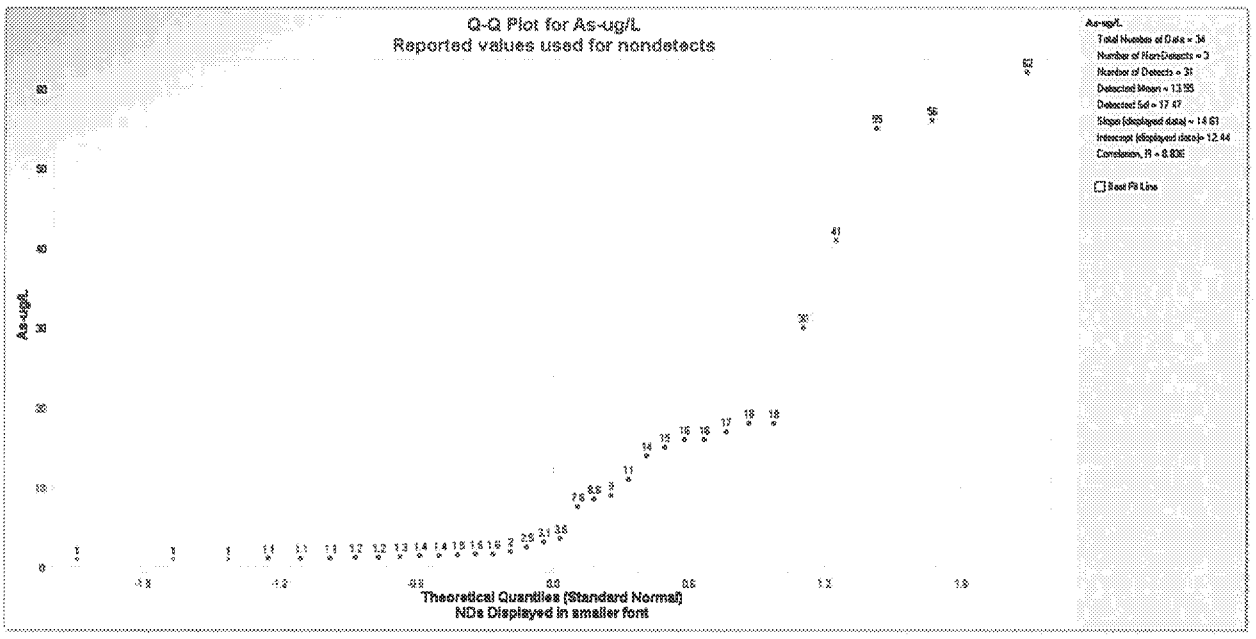




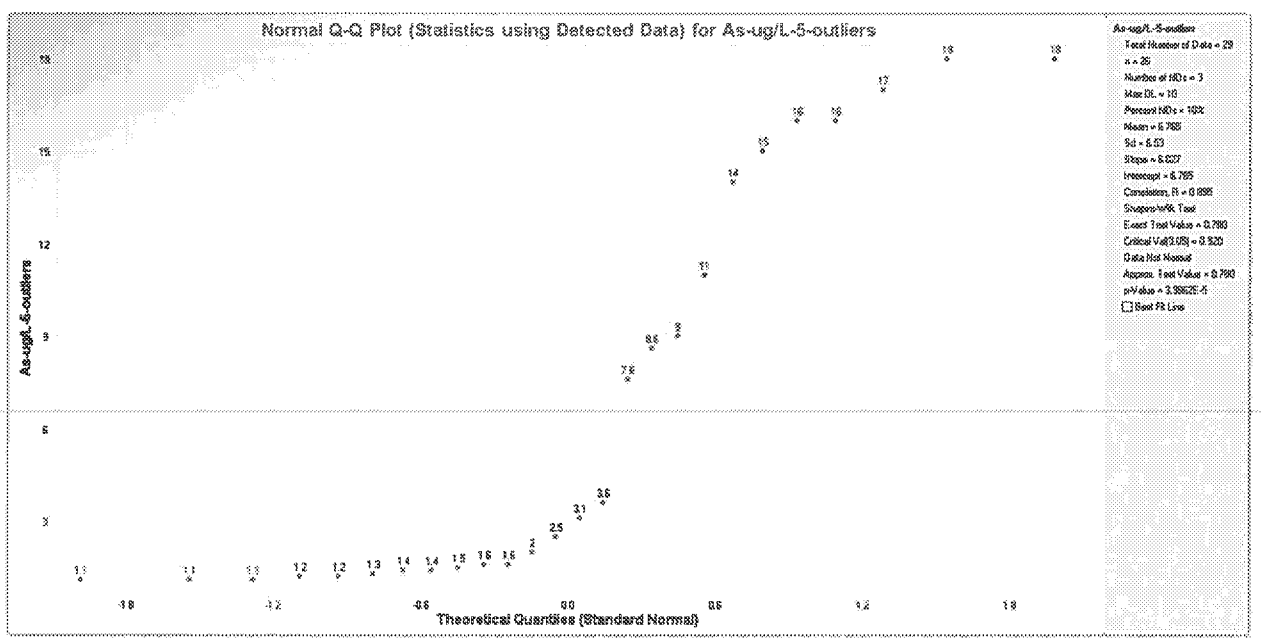
- From above box plots and index plot, it is noted that many dissolved Al concentrations from several sampled onsite stations exceed background the 95% UPL of 45.12 µg/L.

UPL95 for Arsenic (nondetects are present) - SJR Background Data

- Five potential outliers (30, 41, 55, 56, 62) shown below are from stations 6, 7 and 8.



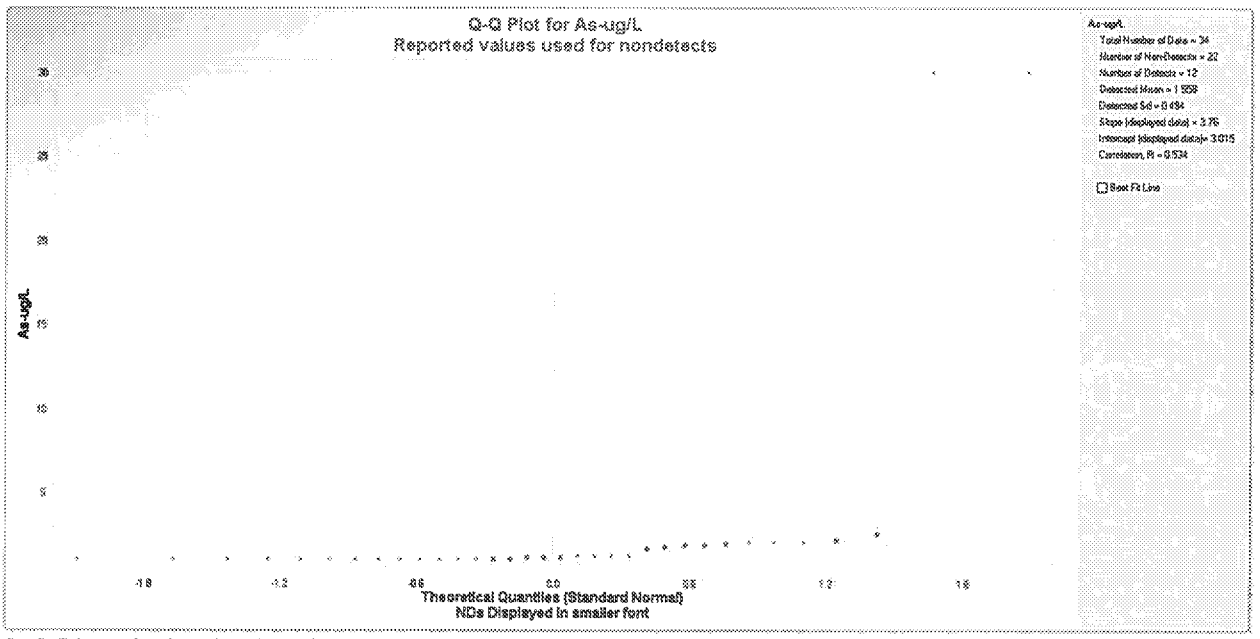
Q-Q Plot of Total As in Background Pre-Spill Event Data Set



Q-Q Plot of Total As in Background Data - Less 5 Outliers

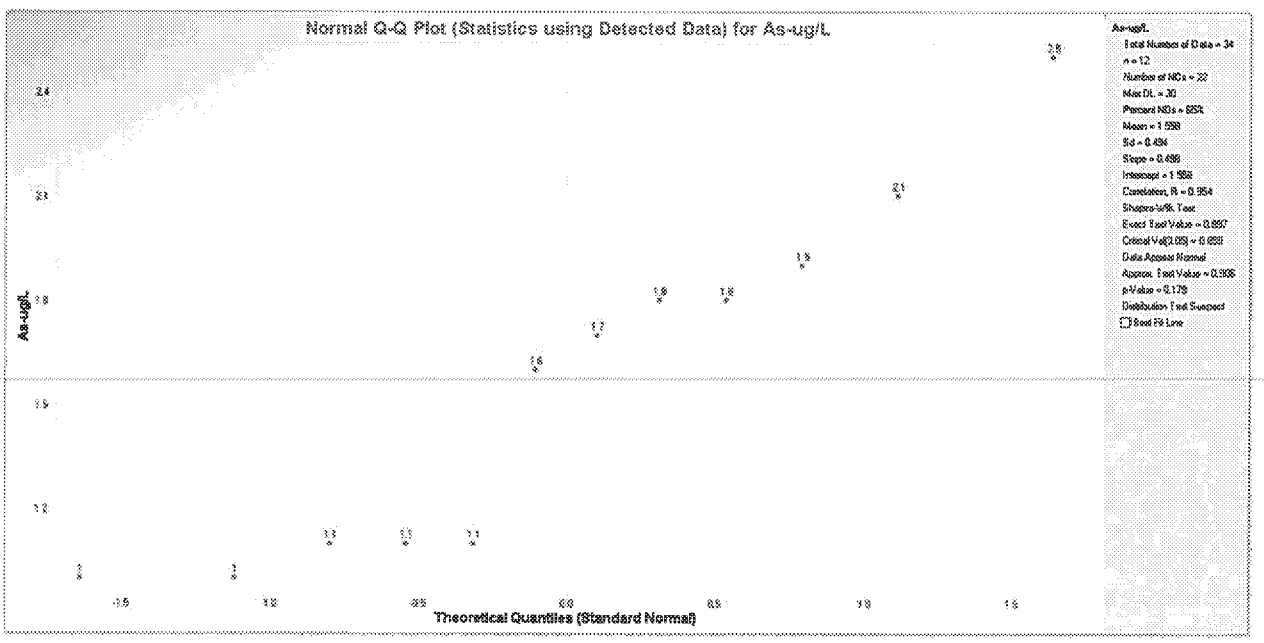
- Detected data with and without outliers do not follow a discernible distribution.
- UPL95 (with 5 outliers) = 57.5 µg/L, and
- UPL95 (without 5 outliers) = 18 µg/L

UPL95 for Dissolved As (nondetects are present) - SJR Background Data



Q-Q Plot of Dissolved As in SJR Background Data Set

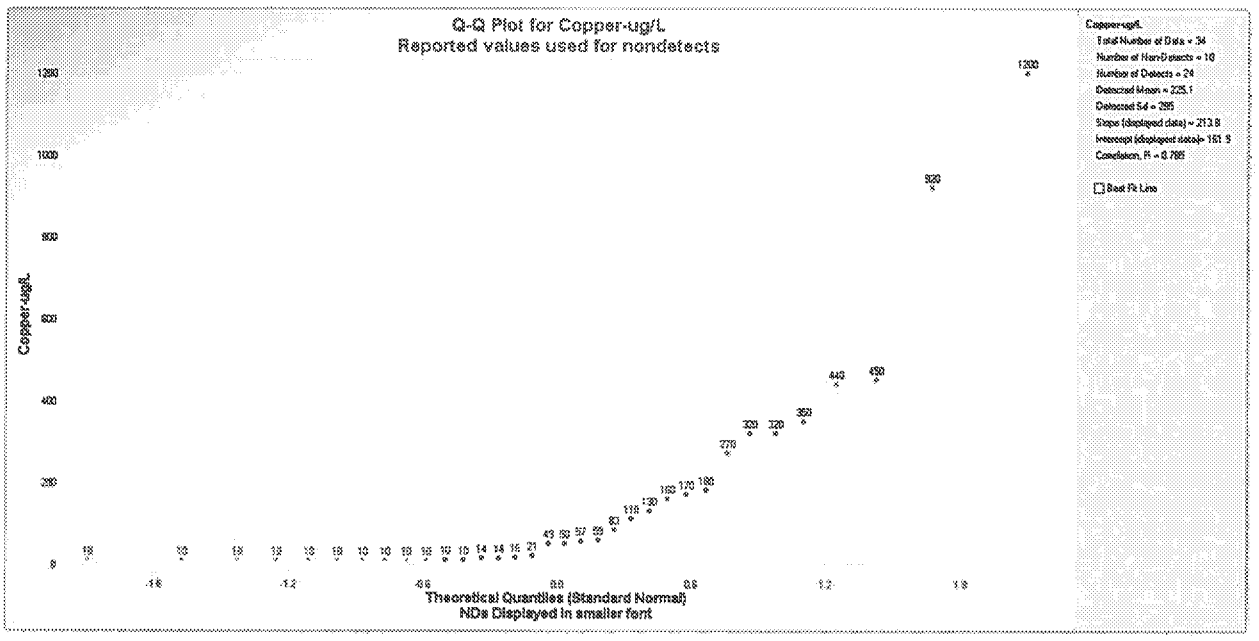
The higher 2 values are nondetects with a reporting limit of 30 µg/L; detected data shown below follow an approximate normal distribution.



- 95% UPL = UPL95 (KM-t-normal) = 1.914 µg/L

95% UPL for Total Cu (nondetects are present) - SJR Background Data

The total Cu data set has 10 NDs (out of 34 data points) in the SJR background data set. The Q-Q plot shown below and the outlier test suggest that 2 outliers: 920 (Station 7) and 1200 (Station 6) are present.



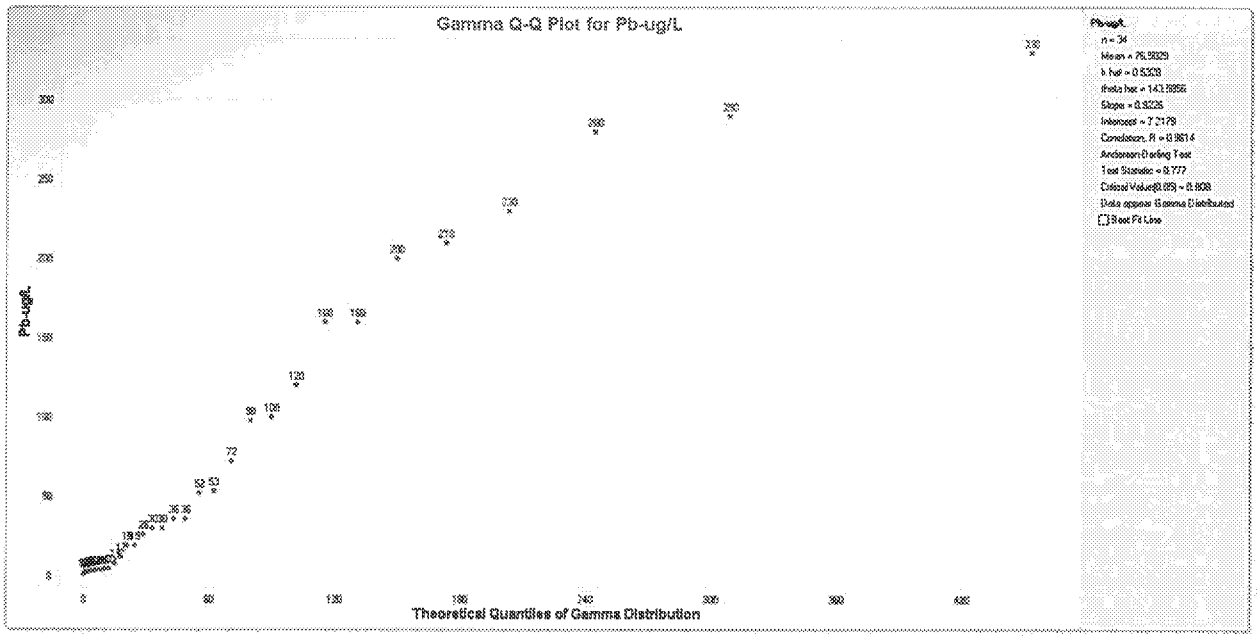
- Data with and without outliers follow a gamma distribution.
- BTV estimates are summarized as follows:
    - 95% UPL (Gamma KM) - all data with outliers = 577.7 (or 595.2) µg/L
    - 95% UPL (Gamma KM) - without 2 outliers = 368.5 (or 383.6) µg/L

95% UPL for Dissolved Cu (nondetects are present) - SJR Background Data

Dissolved copper has 32 NDs (out of 34 data points). Since the majority of background copper concentrations have been reported as NDs, a detection of dissolved copper in post-event data may be considered due to the Spill Event. At best, the largest detected value may be considered to represent an estimate of the BTV for dissolved Cu (a biased high estimate).

95% UPL for Total Pb - SJR Background Data

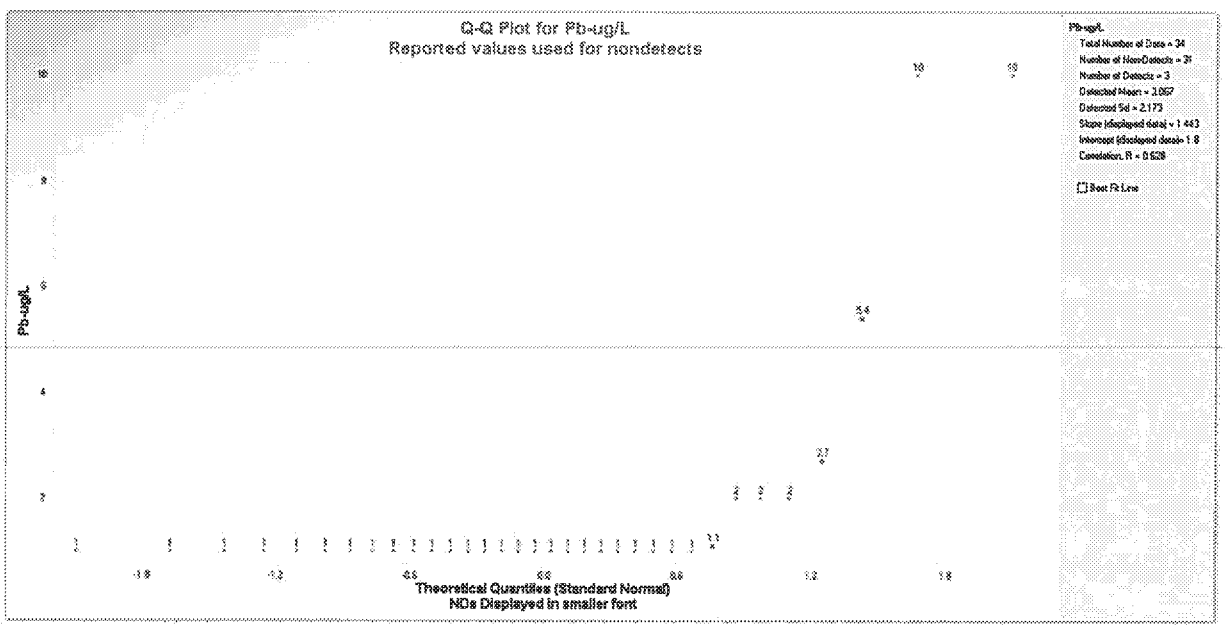
Only one nondetect (out of 34 data points) is present in the data set. The data set does not have outliers and the total Pb data set follows a gamma distribution as shown in the following figure.



- BTV estimate for total Pb=95% UPL is 284 (or 307) µg/L

<u>95% UPL for Dissolved Pb (31 nondetects are present out of 34 data points) - SJR Background Data</u>

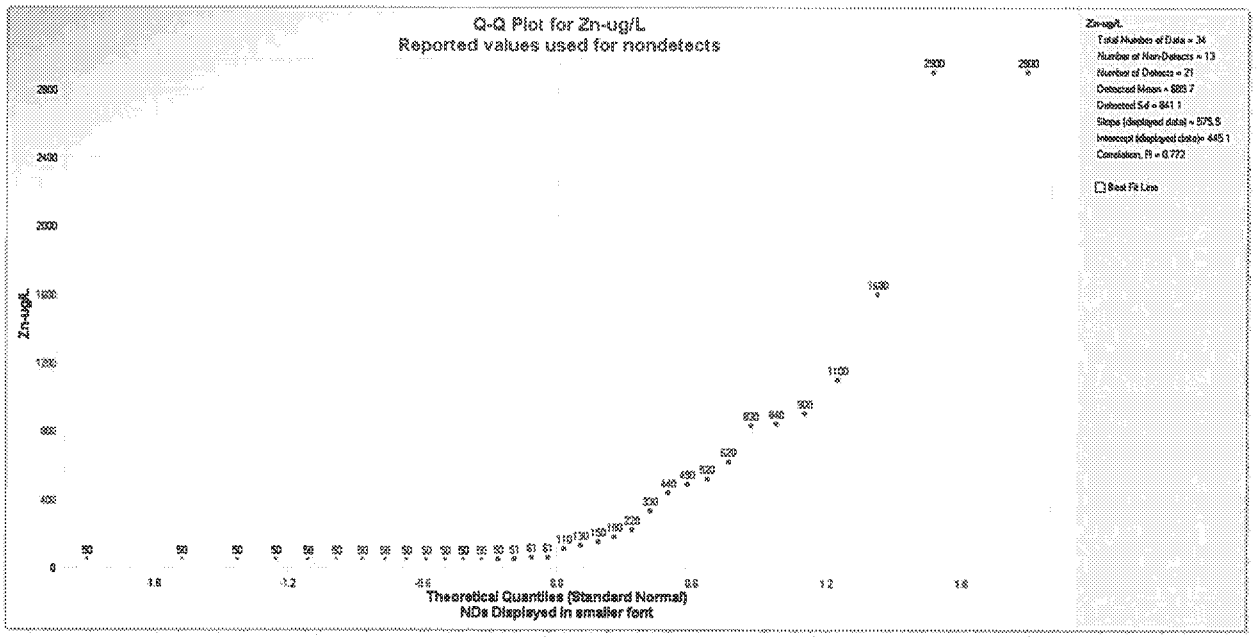
Most (31/34) of the dissolved Pb concentrations collected prior to the Spill Event are reported as nondetects.



- The number (3 out of 34) of detected concentrations is not sufficient to establish a BTV. At best, 5.4 (the largest reported value) or a 95% UPL of 2.59 (95% UPL KM(t)) based upon a normal

distribution may be considered to represent a BTV estimate for dissolved Pb in surface water. The project team should make this determination.

95% UPL for Total Zn - SJR Background Data



Q-Q plot of total Zn shown above and outlier test identified 3 outliers: intermediate outlier, 1600, is from Station 6, and extreme outliers 2900 and 2900 are from Station 7. Total Zn data sets: with outliers, without 2 extreme outliers and without 3 outliers follow gamma distributions.

- 95% UPL (Gamma KM): 1518 µg/L - influenced/ elevated by outliers
- 95% UPL without 2 outliers and accounting for nondetects (Gamma KM) = 950 µg/L
- 95% UPL without 3 outliers and accounting for nondetects (Gamma KM) = 793 µg/L

95% UPL for Dissolved Zn (all values reported as nondetects) - SJR Background Data

Dissolved Zn was not detected in pre-Spill Event routine samples collected from surface waters of the SJR. A detection of dissolved Zn in a post-event sample may potentially be considered due to the Spill Event.

2.0 Evaluation of Dissolved Al and Dissolved Fe

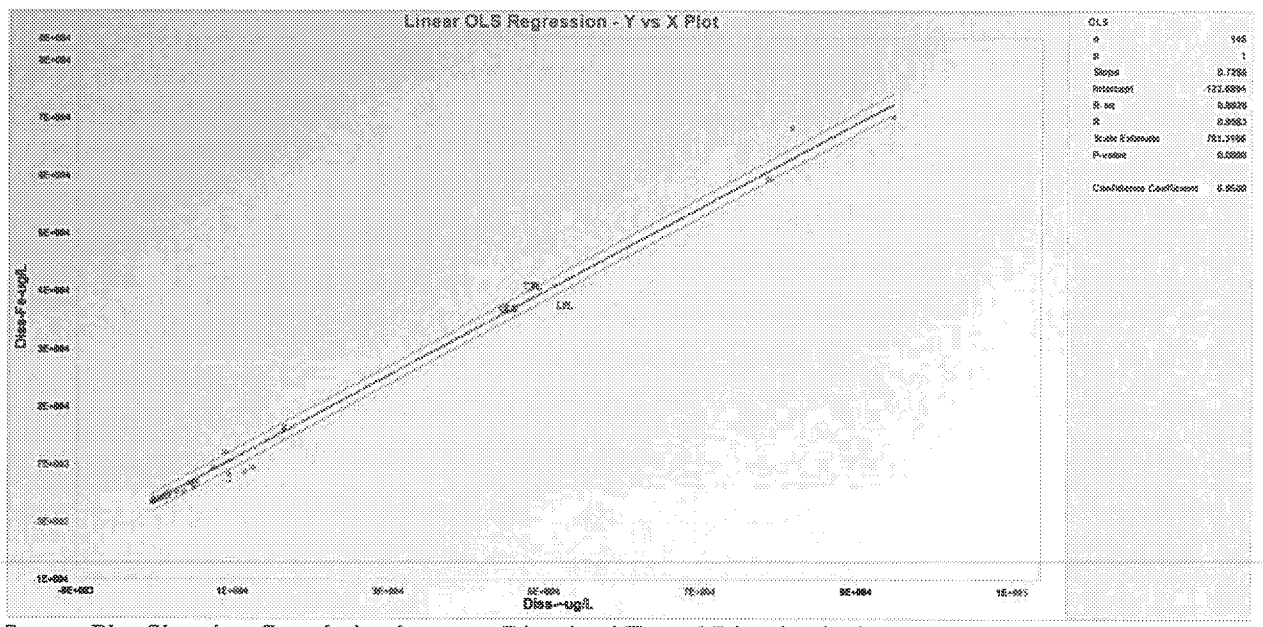
Post-event dissolved Al and Fe concentrations are significantly higher than BTVs at several SJR sampling stations. It is believed that higher levels of dissolved Al and Fe were present in samples collected from some SJR sampling stations (Figures 3, 3a) on days prior to the day(s) when the mine plume could have reached at those stations; and some of those elevated levels could be naturally occurring and may not be attributable to the August 5 Spill Event. The plume was moving downstream and reached the station at Four-Corners on August 11, 2015. However, at some of the Utah stations, elevated levels of Fe and Al are noted on earlier dates (e.g., prior to August 12) when the plume was far (could not have reached those

stations) from those stations. It is believed that concentrations of dissolved Fe and Al are naturally higher and were high even before the plume reached those Utah stations.

During a conference call held on August 25, 2105, Mr. Allen requested to closely look at dissolved Al and Fe data collected from Utah stations. He wanted to determine if concentrations of dissolved Fe and dissolved Al were naturally higher at sampling stations (e.g., SJBB, SJME, SJMC, SJMH) further down the Spill Event La Plata area (Figures 3 and 3a) during the earlier sampling events (e.g., during August 7-11.) before the plume reached those sampling stations. Several time-series plots were generated to determine if the Utah stations did indeed exhibit naturally higher levels of dissolved Fe and Al. Supplemented with expert regional knowledge, R9 personnel used (or plan to use) time series plots (Section 3.0) and the stations' data variability (Section 4.0) to determine if some Utah sampling stations exhibited high levels of dissolved Fe and Al.

2.1 Dissolved Fe and Dissolved Al are Highly Correlated

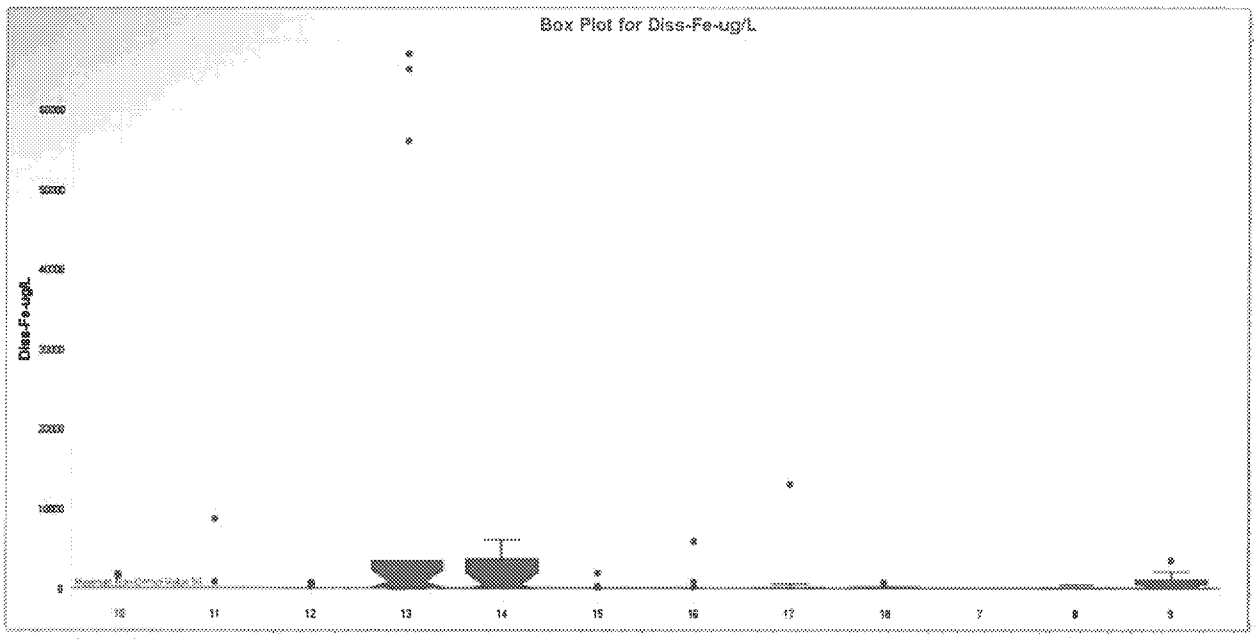
It is also noted that Al and Fe are highly correlated, suggesting that conclusions for one of them can be applied to the other analyte. Based upon the available data (as of August 18, 2015), a scatter plot (with regression line) of dissolved Fe versus dissolved Al is shown in the following figure. It is seen that the correlation between dissolved Fe and Al is almost 1 (=0.996).



Scatter Plot Showing Correlation between Dissolved Fe and Dissolved Al

Box plots shown in Section 2.2 compare post-event dissolved Fe and Al by dates (all stations combined). Box plots for dissolved Fe and Al exhibit very similar/comparable patterns.

2.2 *Summary Statistics and Box Plots Comparing Post-event Dissolved Fe by Date - August 7 through August 18, 2015*



Box Plots Comparing Post Event Dissolved Fe Concentrations from August 7 through 18

Note: Labels along the x-axis in the above box plots represent actual dates (e.g. 10 represents August 10). Due to high variability (e.g., the highest value observed on August 13 was 67000 ug/L [at SJDS] and the highest value observed on August 10 was 1800 [at SJMC]), the scale of the box plots could be somewhat misleading. For example, a dot shown on the August 10 box plot represents a value of 1800 µg/L and not close to '0' as it appears to be. The details can be found in the following tables of summary statistics.

Summary Statistics for Dissolved Fe by Date

General Statistics for Censored Data Set (with NDs) using Kaplan Meier Method

Variable	NumObs	# Missing	Num Ds	NumNDs	% NDs	Min ND	Max ND	KM Mean	KM Var	KM SD	KM CV
Diss-Fe-ug/L (10)	13	0	4	9	69.23%	17	17	285.3	365905	604.9	2.12
Diss-Fe-ug/L (11)	13	0	4	9	69.23%	17	17	812.8	5270432	2296	2.824
Diss-Fe-ug/L (12)	13	0	4	9	69.23%	17	17	130.1	47979	219	1.684
Diss-Fe-ug/L (13)	13	0	12	1	7.69%	17	17	15264	6.806E+8	26089	1.709
Diss-Fe-ug/L (14)	14	0	9	5	35.71%	10	10	1712	4667704	2160	1.262
Diss-Fe-ug/L (15)	21	0	10	11	52.38%	10	22	146.4	161186	401.5	2.742
Diss-Fe-ug/L (16)	19	0	9	10	52.63%	17	22	377.8	1723298	1313	3.474
Diss-Fe-ug/L (17)	12	0	8	4	33.33%	10	17	1171	12739336	3569	3.049
Diss-Fe-ug/L (18)	10	0	10	0	0.00%	N/A	N/A	218.8	36402	190.8	0.872
Diss-Fe-ug/L (7)	1	0	0	1	100.00%	50	50	N/A	N/A	N/A	N/A
Diss-Fe-ug/L (8)	4	0	2	2	50.00%	50	50	103.5	21931	148.1	1.431
Diss-Fe-ug/L (9)	12	0	6	6	50.00%	17	17	678.3	1122512	1059	1.562

General Statistics for Raw Data Sets using Detected Data Only

Variable	NumObs	# Missing	Minimum	Maximum	Mean	Median	Var	SD	MAD/0.675	Skewness	CV
Diss-Fe-ug/L (10)	4	0	68	1800	889	844	883695	940.1	1136	0.0387	1.057
Diss-Fe-ug/L (11)	4	0	34	8700	2604	840	16663169	4082	597.5	1.947	1.568
Diss-Fe-ug/L (12)	4	0	28	710	384.5	400	83241	288.5	296.5	-0.279	0.75
Diss-Fe-ug/L (13)	12	0	30	67000	16534	1325	7.815E+8	27955	1853	1.35	1.691
Diss-Fe-ug/L (14)	9	0	99	6000	2658	2500	5351909	2313	3262	0.228	0.87
Diss-Fe-ug/L (15)	10	0	14	1900	295.6	116	328974	573.5	150.5	2.957	1.94
Diss-Fe-ug/L (16)	9	0	11	5900	765.1	65	3738288	1933	71.16	2.914	2.463
Diss-Fe-ug/L (17)	8	0	20	13000	1751	88.5	20684164	4548	98.59	2.822	2.597
Diss-Fe-ug/L (18)	10	0	44	710	218.8	200	36402	190.8	74.13	2.106	0.872
Diss-Fe-ug/L (7)	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Fe-ug/L (8)	2	0	18	360	189	189	58482	241.8	253.5	N/A	1.28
Diss-Fe-ug/L (9)	6	0	17	3500	1340	1150	1644626	1282	1319	0.941	0.957

2.3 Summary Statistics and Box Plots Comparing Post-event Dissolved Al by Date - August 7 through August 18, 2015

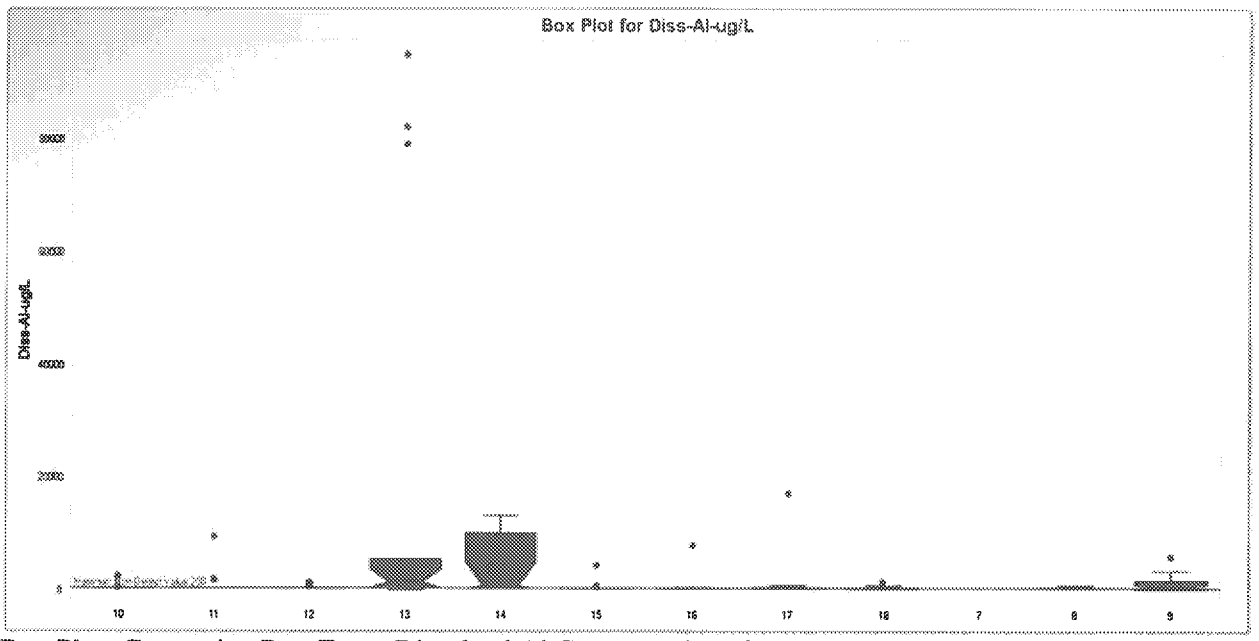
Summary Statistics for Dissolved Al by Date

General Statistics for Censored Data Set (with NDs) using Kaplan Meier Method

Variable	NumObs	# Missing	Num Ds	NumNDs	% NDs	Min ND	Max ND	KM Mean	KM Var	KM SD	KM CV
Diss-Al-ug/L (10)	13	0	6	7	53.85%	24	24	381.2	637490	798.4	2.094
Diss-Al-ug/L (11)	13	0	7	6	46.15%	24	24	999.5	6100957	2470	2.471
Diss-Al-ug/L (12)	13	0	5	8	61.54%	24	24	215.5	125988	354.9	1.647
Diss-Al-ug/L (13)	13	0	12	1	7.69%	24	24	20978	1.257E+9	35450	1.69
Diss-Al-ug/L (14)	14	0	9	5	35.71%	25	25	3893	24041274	4903	1.26
Diss-Al-ug/L (15)	21	0	10	11	52.38%	18	25	313.1	787917	887.6	2.835
Diss-Al-ug/L (16)	19	0	8	11	57.89%	18	24	463.5	2994494	1730	3.733
Diss-Al-ug/L (17)	12	0	8	4	33.33%	24	25	1571	21687582	4657	2.965
Diss-Al-ug/L (18)	10	0	10	0	0.00%	N/A	N/A	371.2	137713	371.1	1
Diss-Al-ug/L (7)	1	0	0	1	100.00%	200	200	N/A	N/A	N/A	N/A
Diss-Al-ug/L (8)	4	0	1	3	75.00%	200	200	302.5	31519	177.5	0.587
Diss-Al-ug/L (9)	12	0	7	5	41.67%	24	24	1053	2894356	1701	1.615

General Statistics for Raw Data Sets using Detected Data Only

Variable	NumObs	# Missing	Minimum	Maximum	Mean	Median	Var	SD	MAD/0.675	Skewness	CV
Diss-Al-ug/L (10)	6	0	28	2300	799	115.5	1270352	1127	129	0.957	1.412
Diss-Al-ug/L (11)	7	0	24	9300	1836	69	11451343	3384	66.72	2.364	1.843
Diss-Al-ug/L (12)	5	0	24	1100	522	560	218688	467.6	702.7	0.0771	0.896
Diss-Al-ug/L (13)	12	0	45	95000	22725	2300	1.442E+9	37973	3258	1.355	1.671
Diss-Al-ug/L (14)	9	0	230	13000	6041	5400	27530161	5247	6820	0.133	0.869
Diss-Al-ug/L (15)	10	0	26	4200	637.8	231.5	1614891	1271	301.7	2.989	1.992
Diss-Al-ug/L (16)	8	0	28	7800	1076	140	7387104	2718	137.9	2.824	2.526
Diss-Al-ug/L (17)	8	0	48	17000	2344	169	35128716	5927	174.9	2.819	2.529
Diss-Al-ug/L (18)	10	0	25	1300	371.2	315	137713	371.1	274.3	1.923	1
Diss-Al-ug/L (7)	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Al-ug/L (8)	1	0	610	610	610	610	N/A	N/A	0	N/A	N/A
Diss-Al-ug/L (9)	7	0	28	5700	1789	1400	4275102	2068	1984	1.291	1.156



Box Plots Comparing Post Event Dissolved Al Concentrations from August 7 through 18

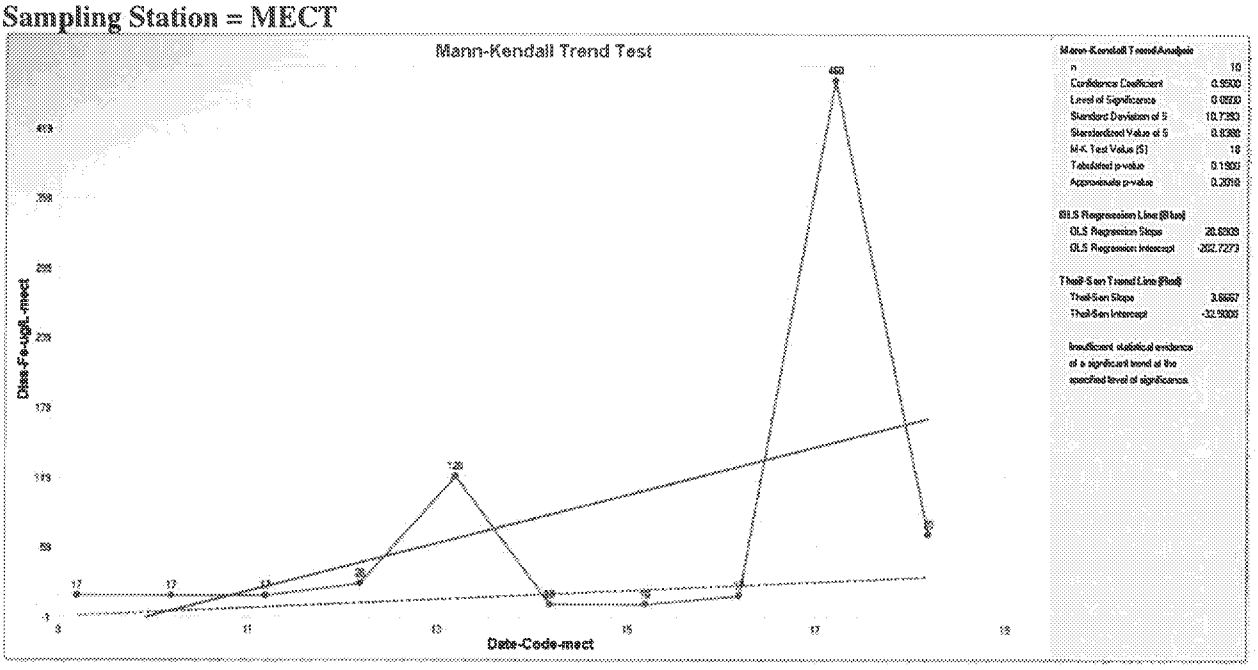
As mentioned earlier, labels along the x-axis in the above box plots represent actual dates (e.g. 10 represents August 10). The program (ProUCL) used to generate the box plots automatically arranges the group categories (e.g., dates coded as numbers) along the x-axis.

3.0 Post - Spill - Event Time Series Plots for Dissolved Iron and Dissolved Aluminum

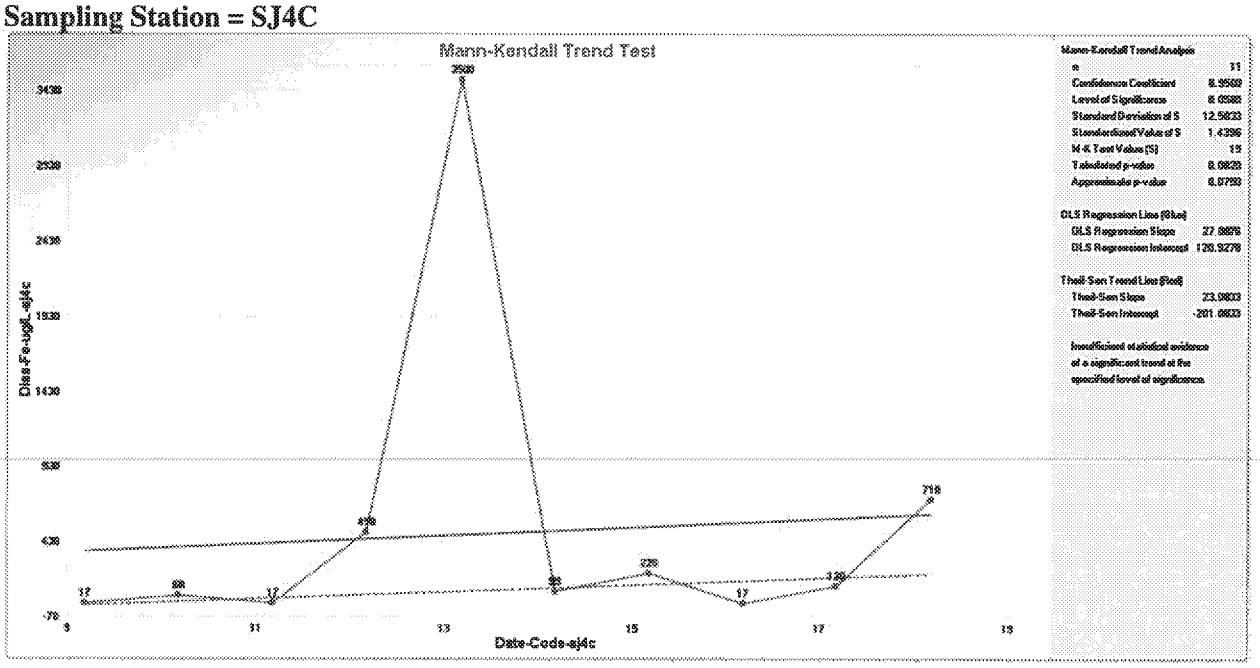
Time series plots for dissolved Fe and Al for each station are displayed below. Self explanatory Station IDs are shown along the y-axis and date-station IDs (August 7- 8) are displayed along the x-axis. From the following time series graphs, it is noted that data for Fe and Al do not exhibit any significant (increasing or decreasing) trends from August 8 through August 18, 2015. For both dissolved Al and Fe, several stations: SJ4C, SJBB, SJDS, SJMC, SJME, SJMH exhibit a peak (maximum concentration) during the time interval August 13-14.

3.1 *Post-Spill Event Time Series Graphs for Dissolved Fe by Sampling Station*

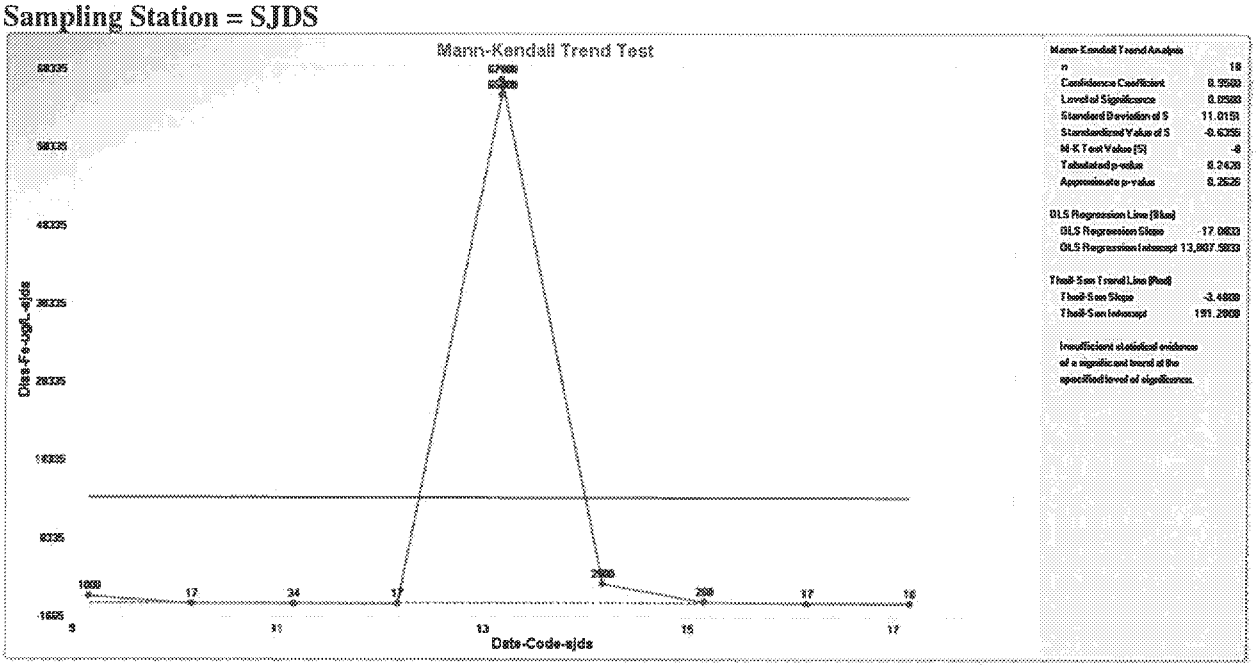
Sampling Station = MECT



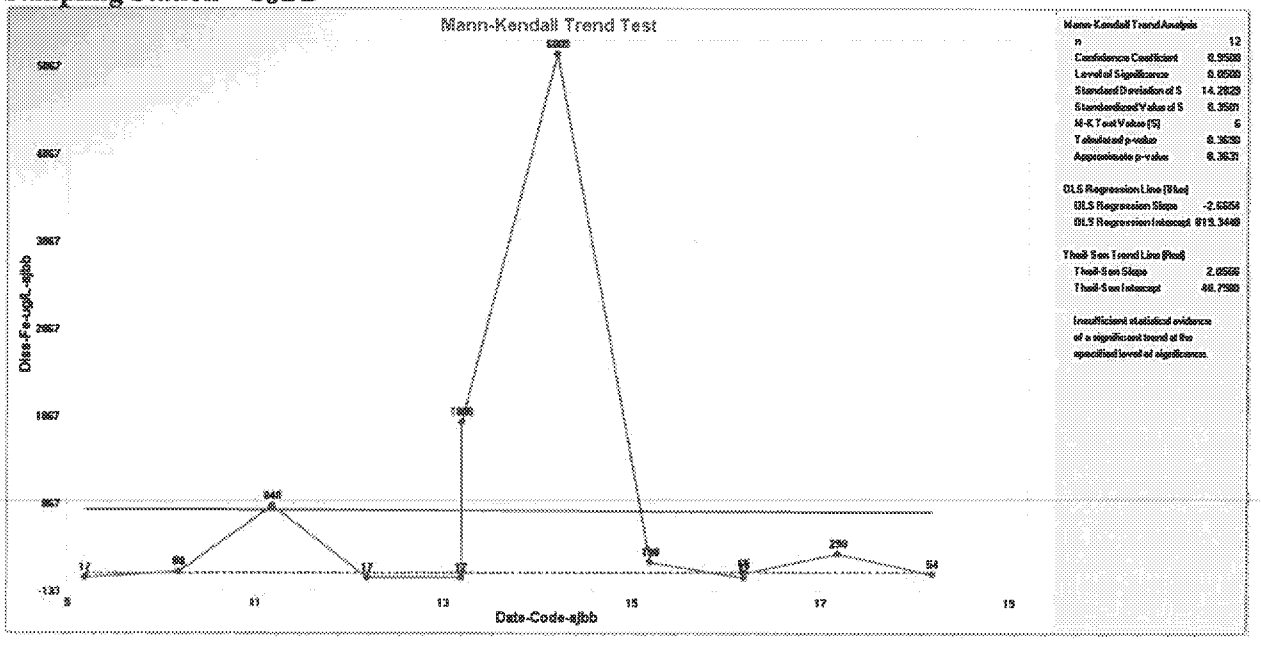
Sampling Station = SJ4C



Sampling Station = SJDS

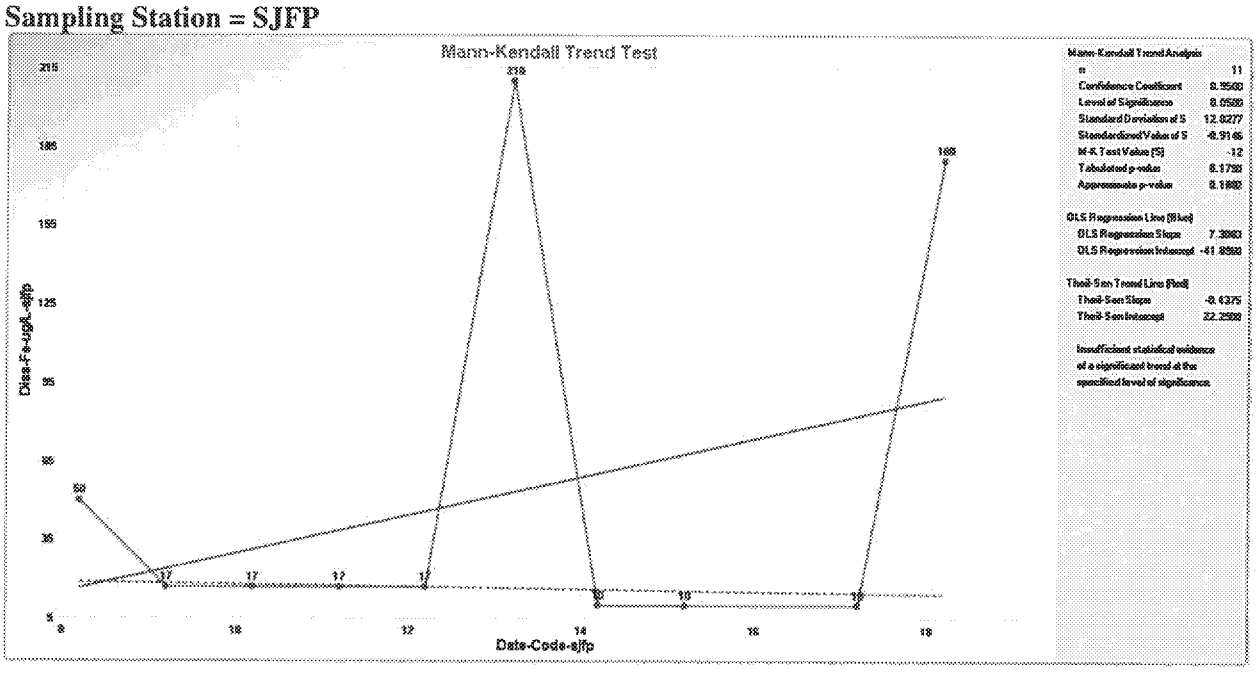


Sampling Station = SJBB

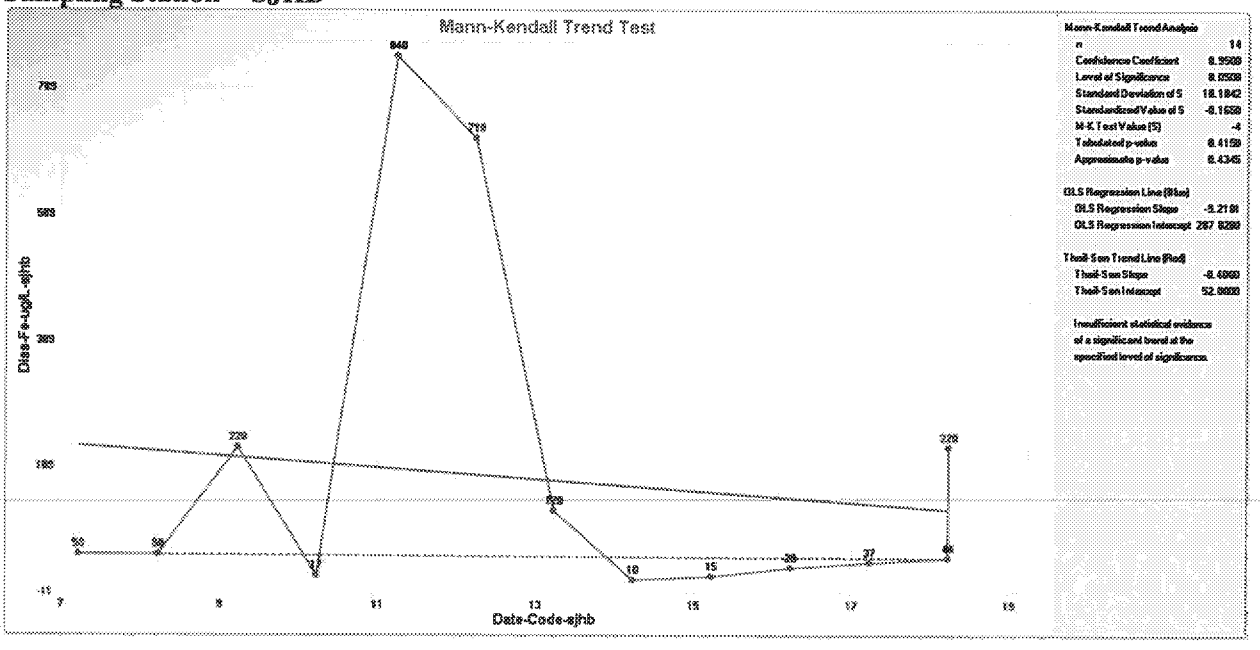


Note: Dissolved Fe at Station SJBB was elevated (=840) on August 11, even though it is believed that the plume reached this Utah station after August 12-13, 2015.

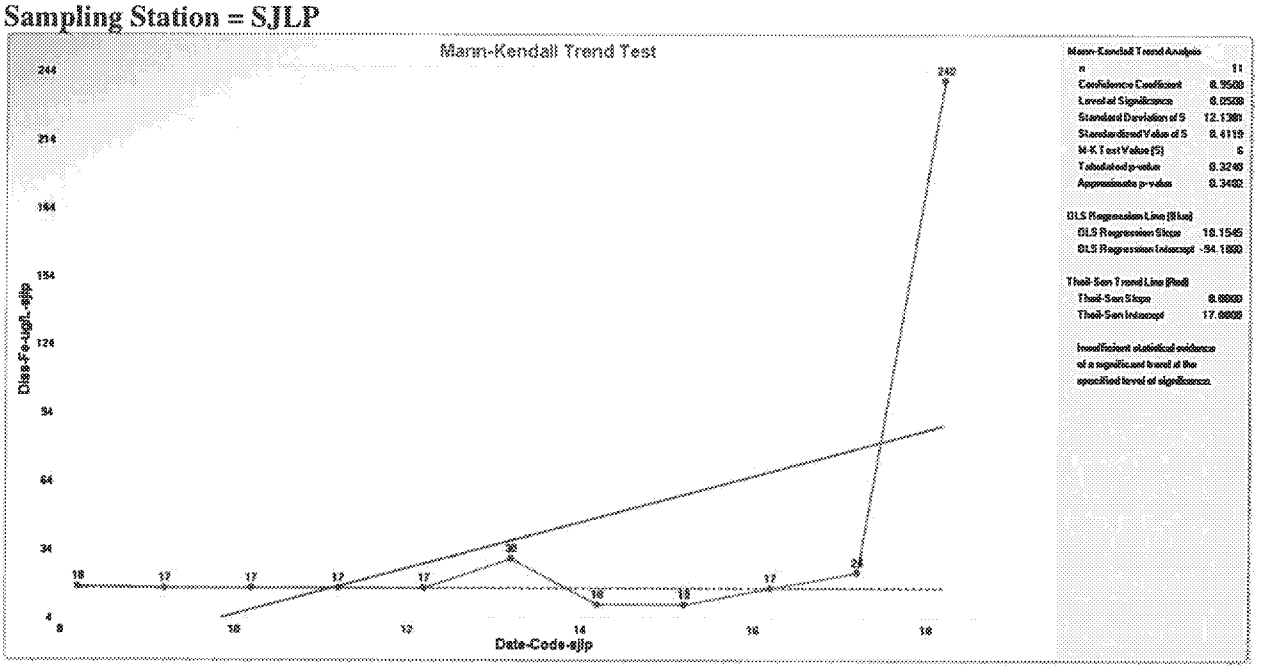
Sampling Station = SJFP



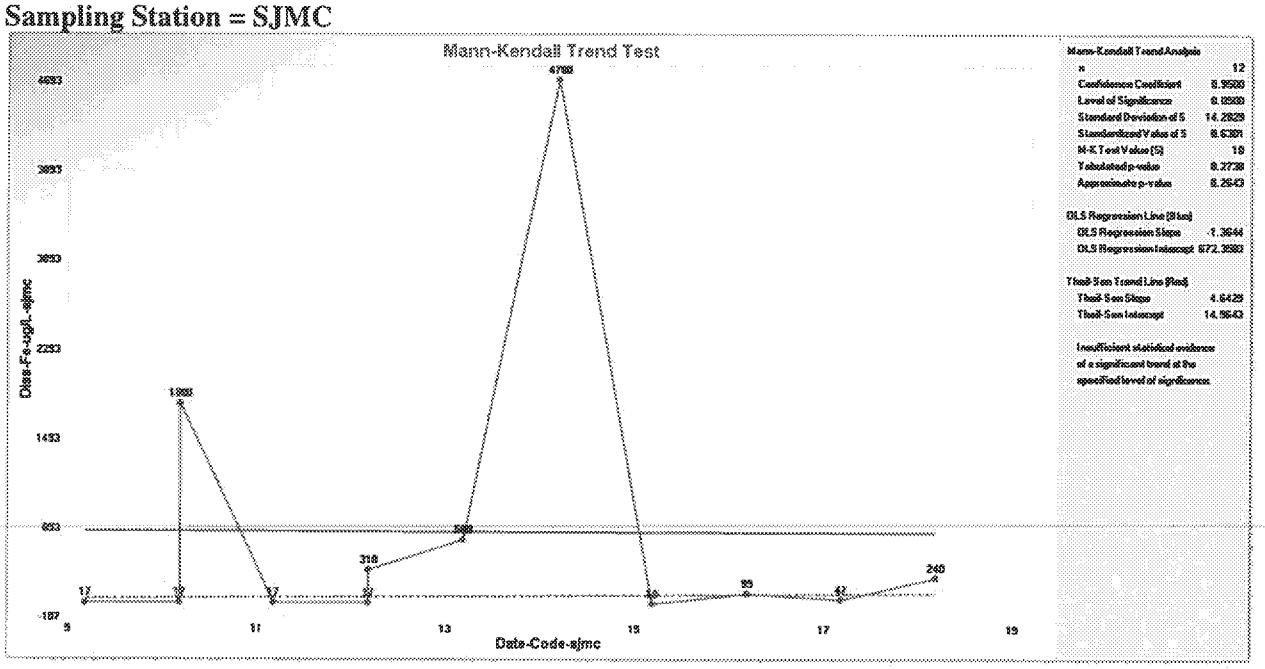
Sampling Station = SJHB



Sampling Station = SJLP

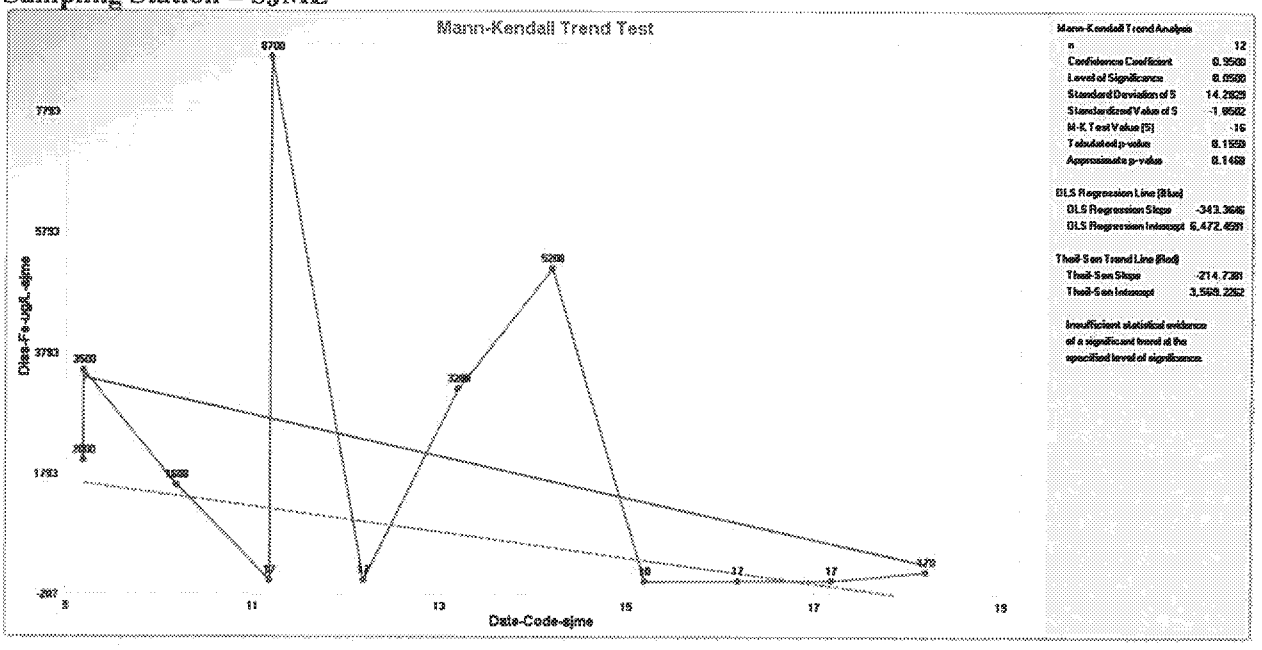


Sampling Station = SJMC



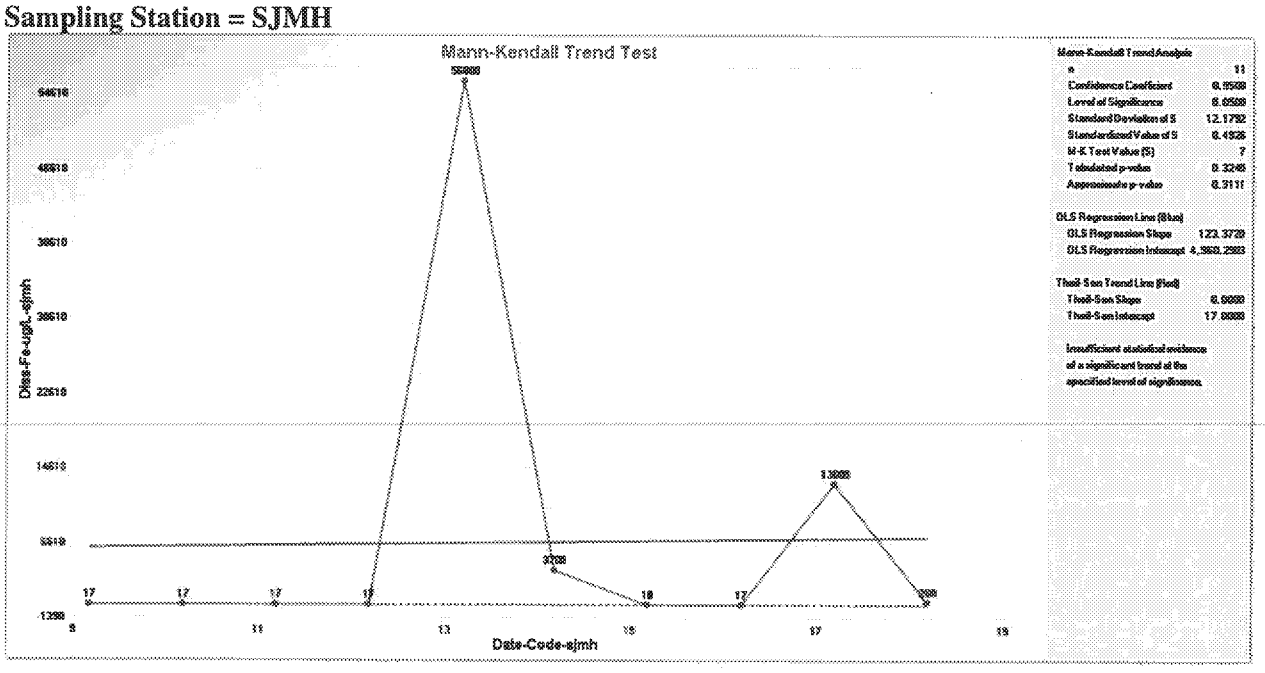
Note: Dissolved Fe at Station SJMC was elevated (=1800 ug/L) on August 10, even though it is believed that the plume reached this Utah station after August 11-12.

Sampling Station = SJME

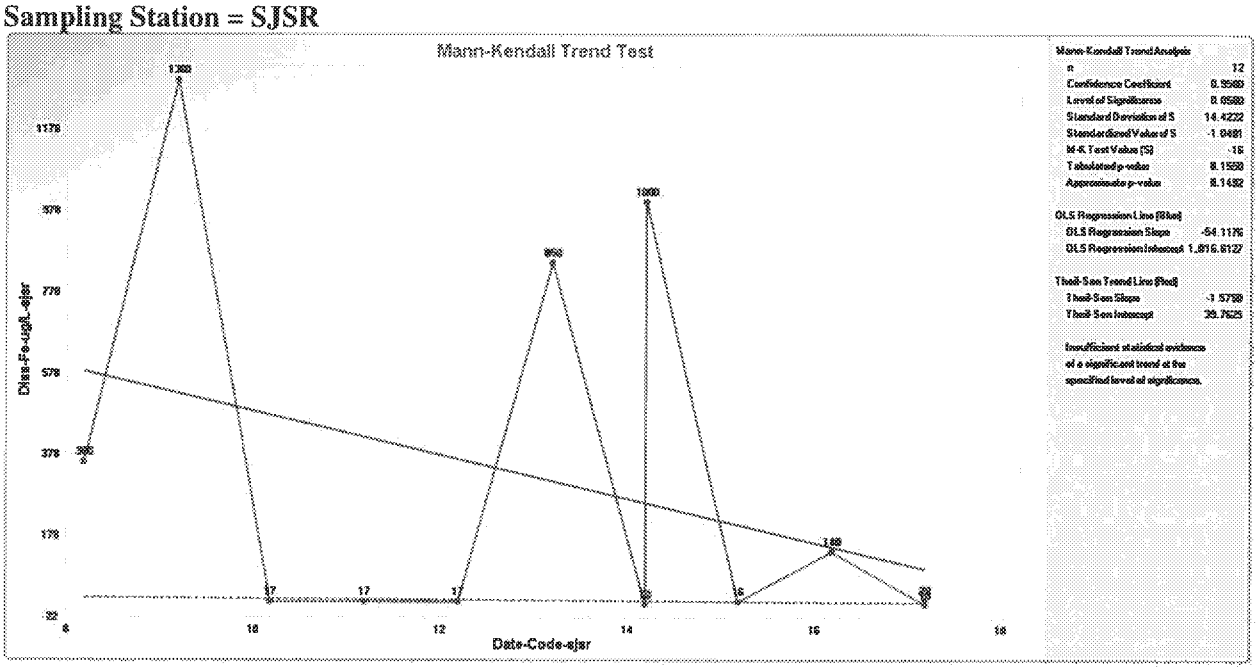


Note: Dissolved Fe at Station SJME was elevated on August 9-10 and on August 11, even though it is believed that the plume reached this station on or after August 12.

Sampling Station = SJMH

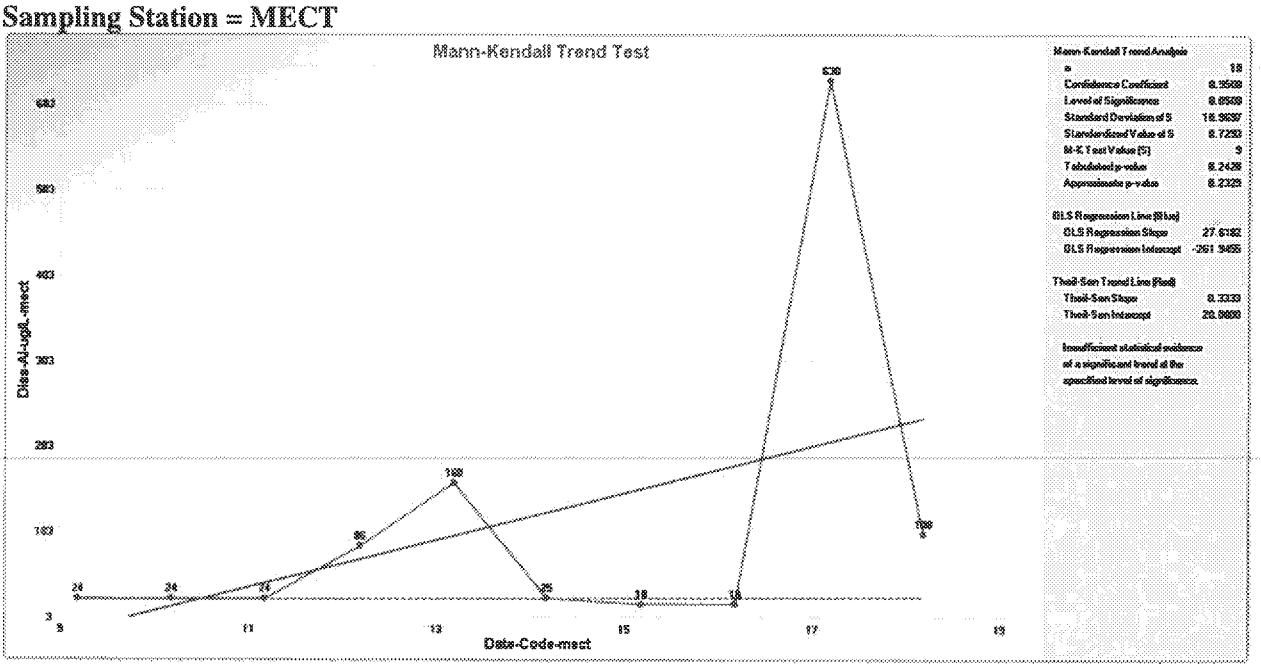


Sampling Station = SJSR

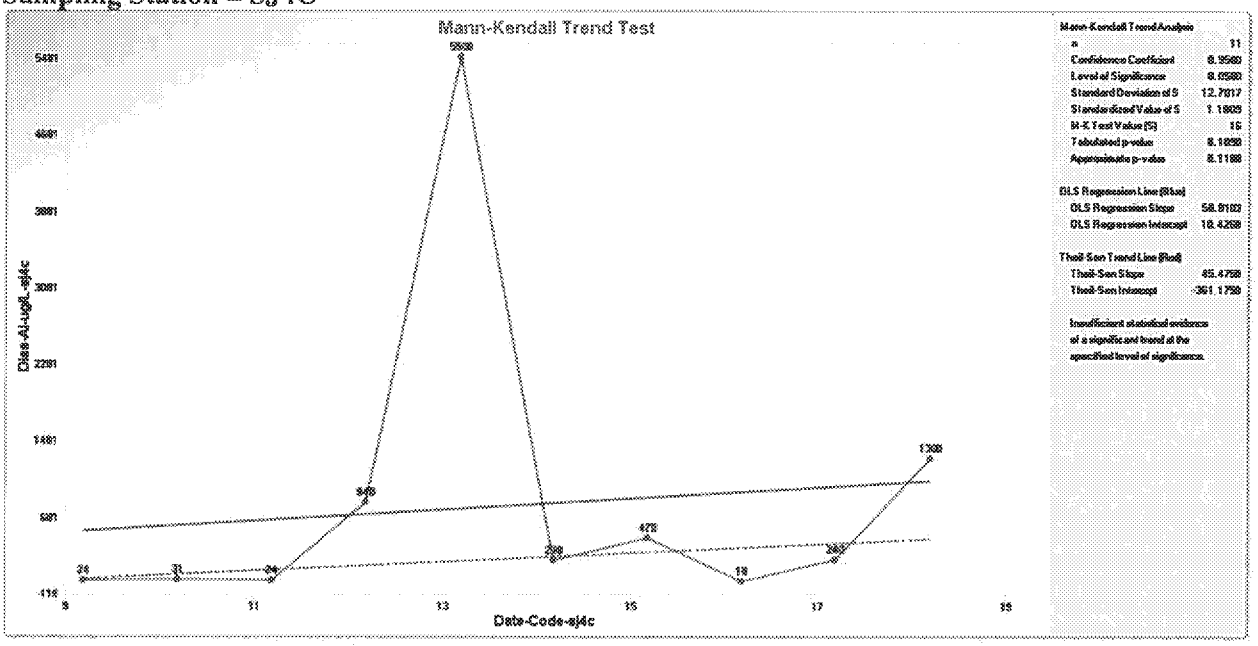


3.2 *Post-Spill Event Time Series Plots for Dissolved Al by Sampling Station*

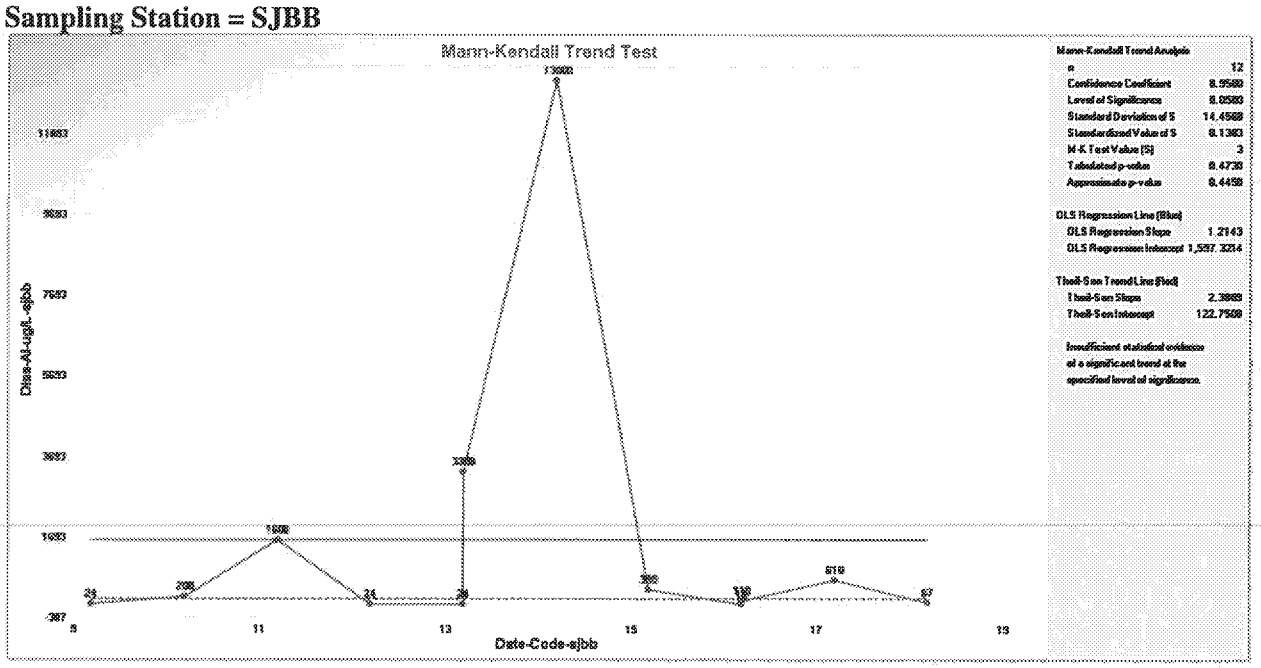
Sampling Station = MECT



Sampling Station = SJ4C

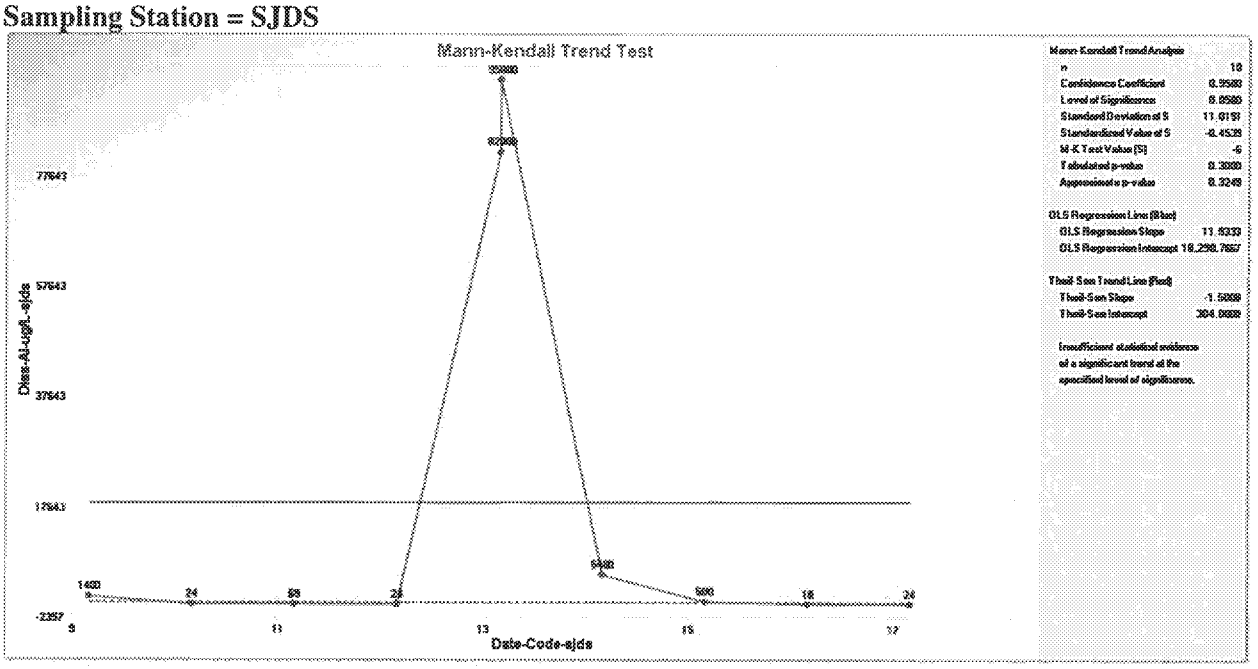


Sampling Station = SJBB

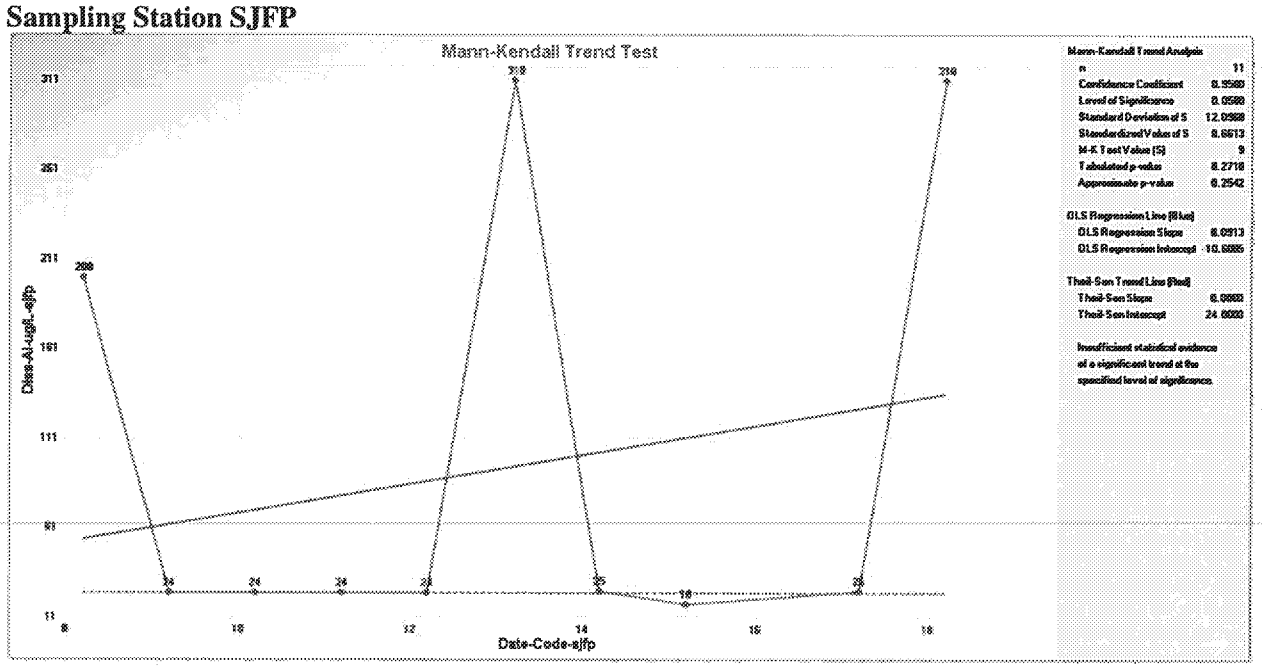


Note: Like dissolved Fe, dissolved Al at Station SJBB was elevated (1600 ug/L) on August 11, even though it is believed that the plume reached this Utah station after August 12.

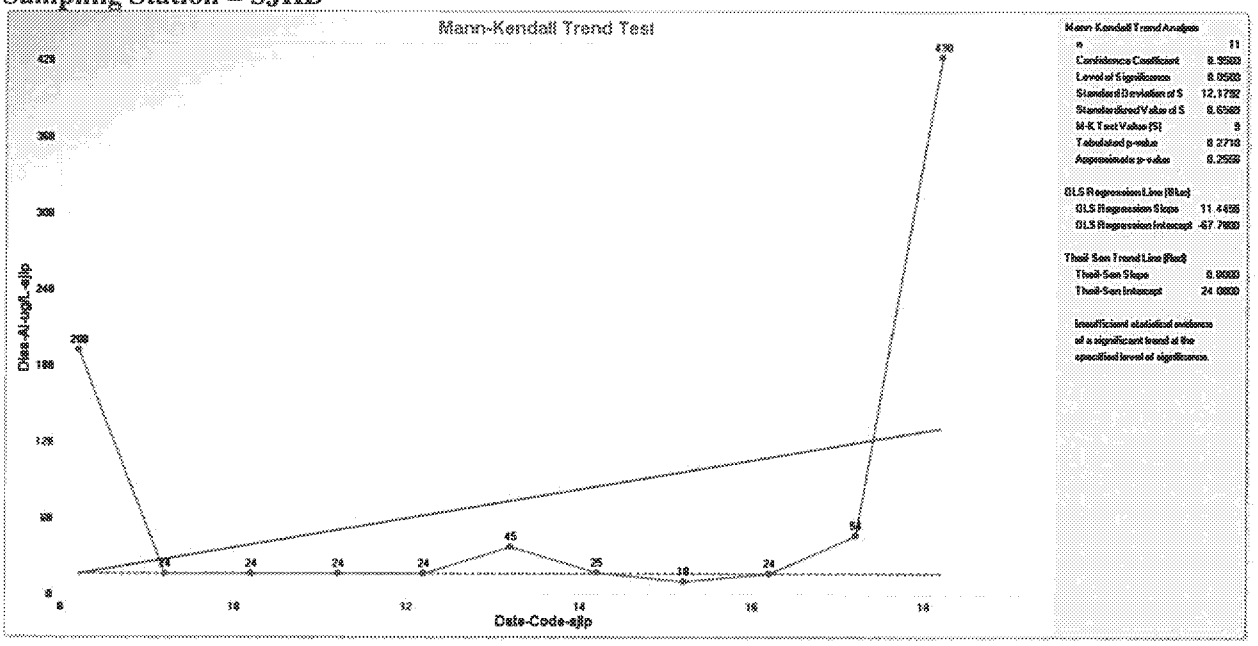
Sampling Station = SJDS



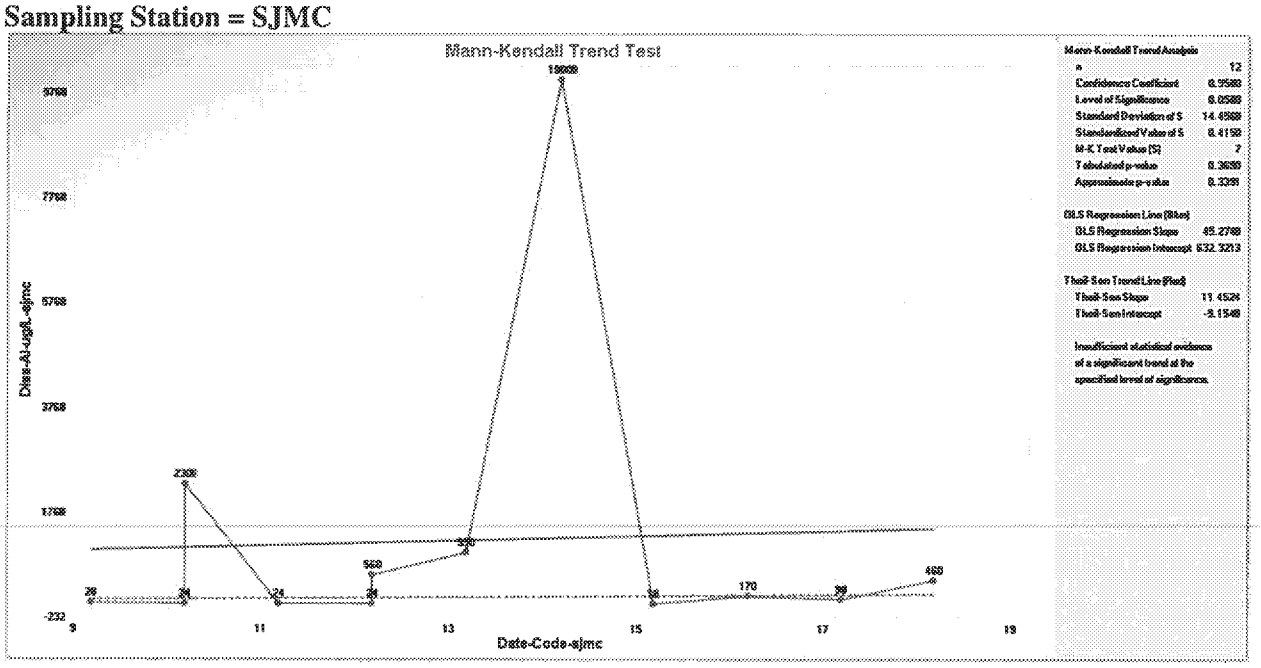
Sampling Station SJFP



Sampling Station = SJHB

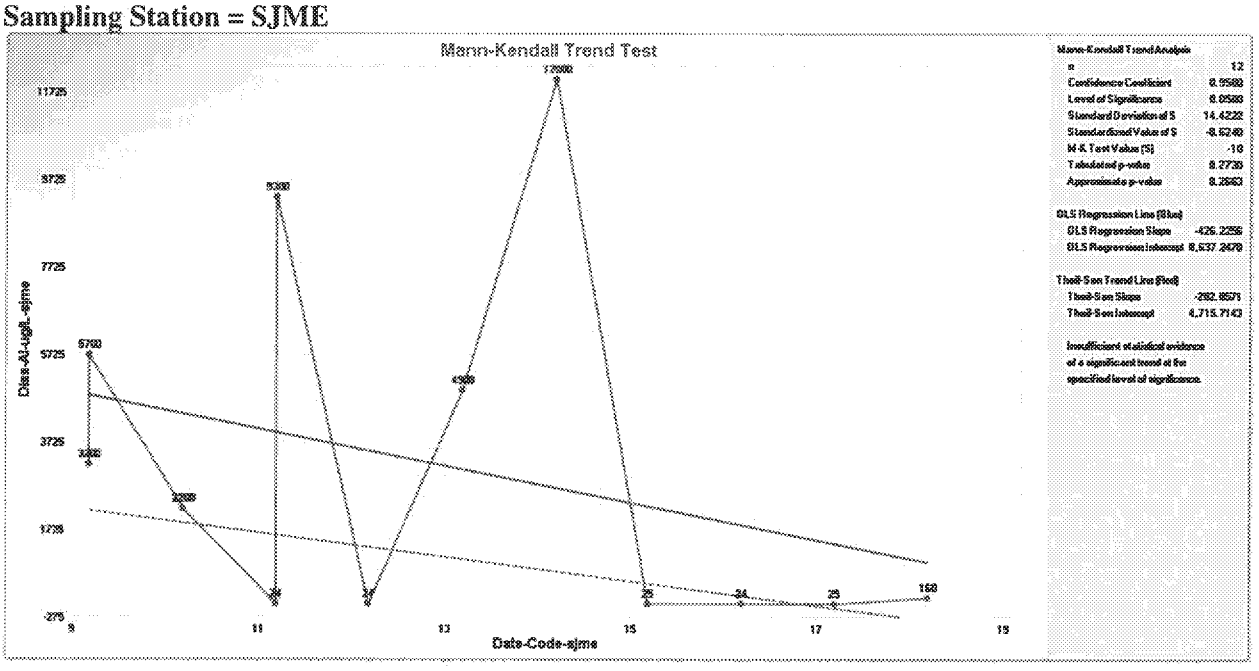


Sampling Station = SJMC



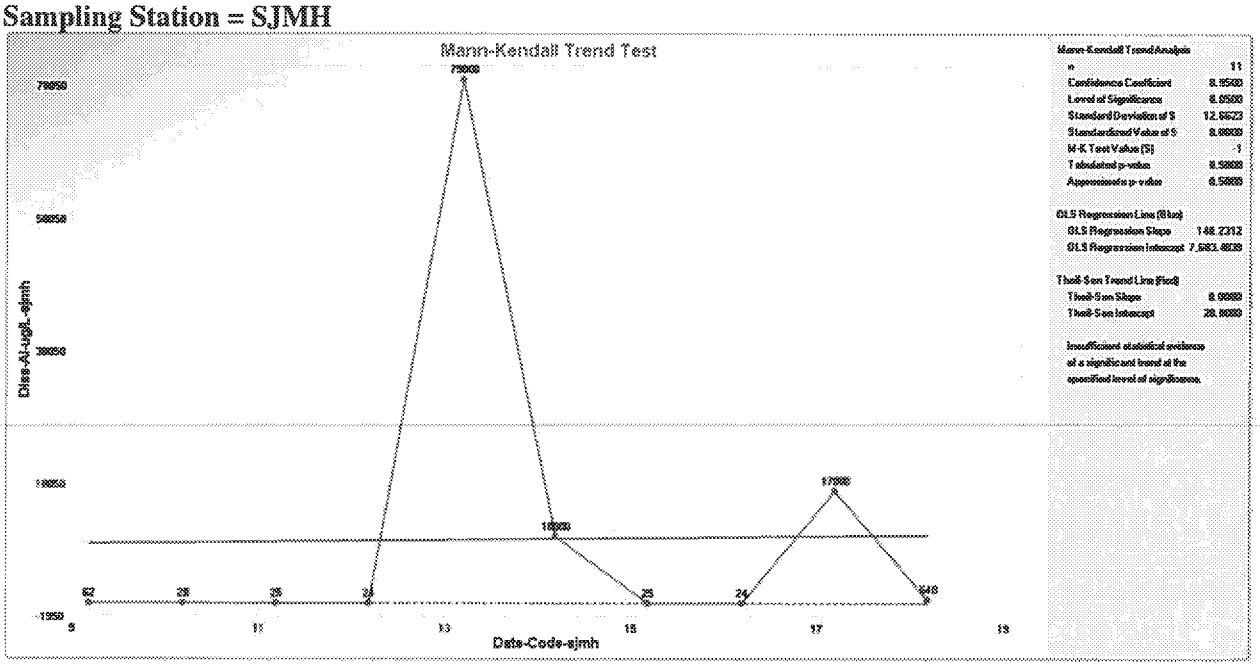
Note: Like dissolved Fe, dissolved Al at Station SJMC was elevated on August 10, even though it is believed that the plume reached this Utah station after August 12.

Sampling Station = SJME

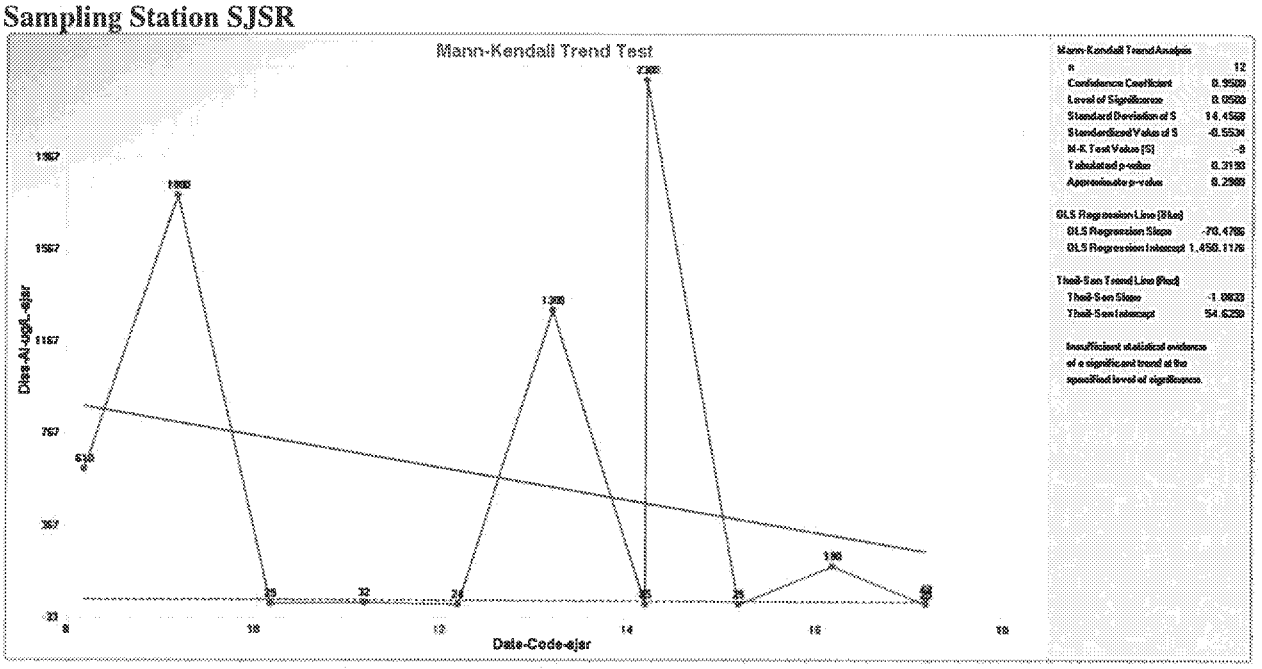


Note: Like dissolved Fe at Station SJME, dissolved Al was elevated on August 9-10 and on August 11, even though it is believed that the plume reached this station on or after August 12.

Sampling Station = SJMH



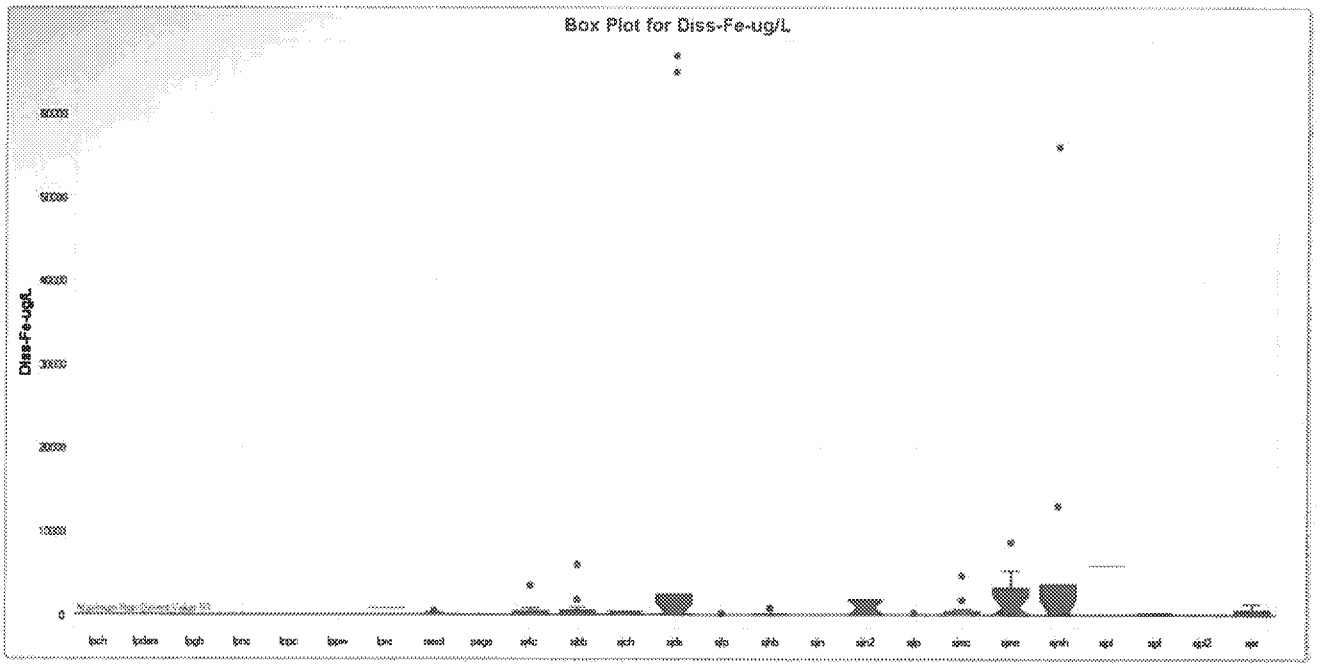
Sampling Station SJSR



4.0 Box Plots and Summary Statistics for Post-Spill Event Dissolved Fe and Al by Station

Several new sampling stations were included from Lake Powell (code starting with LP/lp) which did not have enough data at the time this TM was generated. It is of interest to know the main statistics (e.g., mean, median, variability) of Fe and Al by sampled stations. These are summarized below.

Box Plots Comparing Dissolved Fe by Sampled Station



Summary Statistics for Post-Spill Event Dissolved Fe by Station

From File: updated-Fe-Diss-onsite data.xls

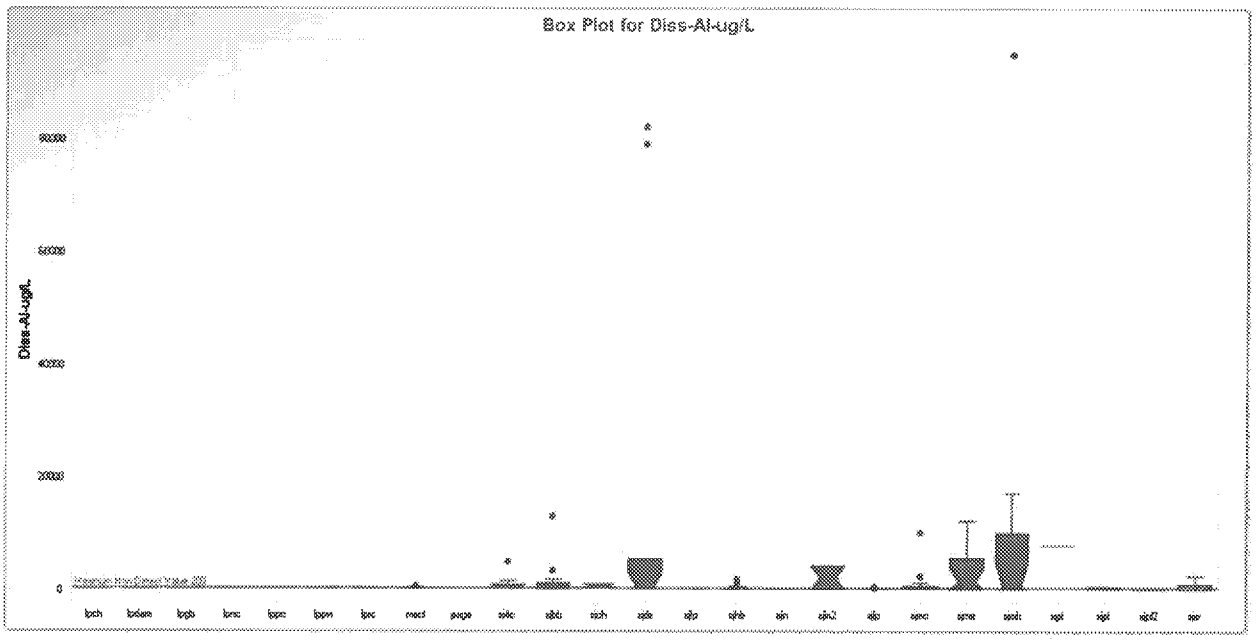
General Statistics for Censored Data Set (with NDs) using Kaplan Meier Method

Variable	NumObs	# Missing	Num Ds	NumNDs	% NDs	Min ND	Max ND	KM Mean	KM Var	KM SD	KM CV
Diss-Fe-ug/L (lpch)	1	0	0	1	100.00%	22	22	N/A	N/A	N/A	N/A
Diss-Fe-ug/L (lpdam)	1	0	0	1	100.00%	22	22	N/A	N/A	N/A	N/A
Diss-Fe-ug/L (lpgb)	1	0	1	0	0.00%	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Fe-ug/L (lpnc)	2	0	0	2	100.00%	22	22	N/A	N/A	N/A	N/A
Diss-Fe-ug/L (lppc)	1	0	0	1	100.00%	22	22	N/A	N/A	N/A	N/A
Diss-Fe-ug/L (lppw)	1	0	0	1	100.00%	22	22	N/A	N/A	N/A	N/A
Diss-Fe-ug/L (lprc)	1	0	1	0	0.00%	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Fe-ug/L (mect)	10	0	5	5	50.00%	10	17	74.5	17697	133	1.786
Diss-Fe-ug/L (page)	1	0	1	0	0.00%	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Fe-ug/L (sj4c)	11	0	7	4	36.36%	17	17	480.5	957807	978.7	2.037
Diss-Fe-ug/L (sjbb)	12	0	8	4	33.33%	17	17	782.9	2727195	1651	2.109
Diss-Fe-ug/L (sjch)	2	0	2	0	0.00%	N/A	N/A	360	45000	212.1	0.589
Diss-Fe-ug/L (sjds)	10	0	6	4	40.00%	10	17	13583	6.876E+8	26223	1.93
Diss-Fe-ug/L (sjfp)	11	0	2	9	81.82%	10	50	43.64	5132	71.64	1.642
Diss-Fe-ug/L (sjhb)	14	0	9	5	35.71%	10	50	165.4	67431	259.7	1.57
Diss-Fe-ug/L (sjin)	1	0	0	1	100.00%	22	22	N/A	N/A	N/A	N/A
Diss-Fe-ug/L (sjin2)	2	0	2	0	0.00%	N/A	N/A	971	1726082	1314	1.353
Diss-Fe-ug/L (sjlp)	11	0	5	6	54.55%	10	17	35.36	4230	65.04	1.839
Diss-Fe-ug/L (sjmc)	12	0	7	5	41.67%	10	17	652.2	1727396	1314	2.015
Diss-Fe-ug/L (sjme)	12	0	7	5	41.67%	10	17	2035	6842892	2616	1.285
Diss-Fe-ug/L (sjmh)	11	0	5	6	54.55%	10	17	6640	2.576E+8	16050	2.417
Diss-Fe-ug/L (sjpl)	1	0	1	0	0.00%	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Fe-ug/L (sjpl)	2	0	1	1	50.00%	22	22	141	14161	119	0.844
Diss-Fe-ug/L (sjpl2)	2	0	1	1	50.00%	22	22	30.5	72.25	8.5	0.279
Diss-Fe-ug/L (sjsr)	12	0	7	5	41.67%	10	17	311.8	199678	446.9	1.433

General Statistics for Raw Data Sets using Detected Data Only

Variable	NumObs	# Missing	Minimum	Maximum	Mean	Median	Var	SD	MAD/0.675	Skewness	CV
Diss-Fe-ug/L (pch)	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Fe-ug/L (pdam)	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Fe-ug/L (pgb)	1	0	25	25	25	25	N/A	N/A	0	N/A	N/A
Diss-Fe-ug/L (pnc)	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Fe-ug/L (ppc)	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Fe-ug/L (ppw)	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Fe-ug/L (prc)	1	0	780	780	780	780	N/A	N/A	0	N/A	N/A
Diss-Fe-ug/L (mect)	5	0	17	460	139	70	33842	184	74.13	1.978	1.323
Diss-Fe-ug/L (page)	1	0	11	11	11	11	N/A	N/A	0	N/A	N/A
Diss-Fe-ug/L (sj4c)	7	0	68	3500	745.3	220	1530862	1237	225.4	2.455	1.66
Diss-Fe-ug/L (sjbb)	8	0	54	6000	1166	240	4172367	2043	267.6	2.405	1.752
Diss-Fe-ug/L (sjch)	2	0	210	510	360	360	45000	212.1	222.4	N/A	0.589
Diss-Fe-ug/L (sjds)	6	0	34	67000	22632	1750	1.130E+9	33609	2377	0.967	1.485
Diss-Fe-ug/L (sjfp)	2	0	180	210	195	195	450	21.21	22.24	N/A	0.109
Diss-Fe-ug/L (sjhb)	9	0	15	840	248.3	120	96281	310.3	148.3	1.41	1.249
Diss-Fe-ug/L (sjin)	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Fe-ug/L (sjin2)	2	0	42	1900	971	971	1726082	1314	1377	N/A	1.353
Diss-Fe-ug/L (sjlb)	5	0	17	240	65.8	24	9510	97.52	8.895	2.22	1.482
Diss-Fe-ug/L (sjmc)	7	0	47	4700	1111	310	2865681	1693	389.9	2.068	1.524
Diss-Fe-ug/L (sjme)	7	0	170	8700	3481	3200	7827748	2798	2372	1.076	0.804
Diss-Fe-ug/L (sjmh)	5	0	14	56000	14595	3700	5.634E+8	23737	5465	1.983	1.626
Diss-Fe-ug/L (sjpf)	1	0	5900	5900	5900	5900	N/A	N/A	0	N/A	N/A
Diss-Fe-ug/L (sjpl)	1	0	260	260	260	260	N/A	N/A	0	N/A	N/A
Diss-Fe-ug/L (sjpl2)	1	0	39	39	39	39	N/A	N/A	0	N/A	N/A
Diss-Fe-ug/L (sjsr)	7	0	16	1300	526.6	360	270236	519.8	510	0.46	0.987

Box Plots Comparing Dissolved Al by Sampled Station



Summary Statistics for Dissolved Al by Sampling Station

General Statistics for Censored Data Set (with NDs) using Kaplan Meier Method

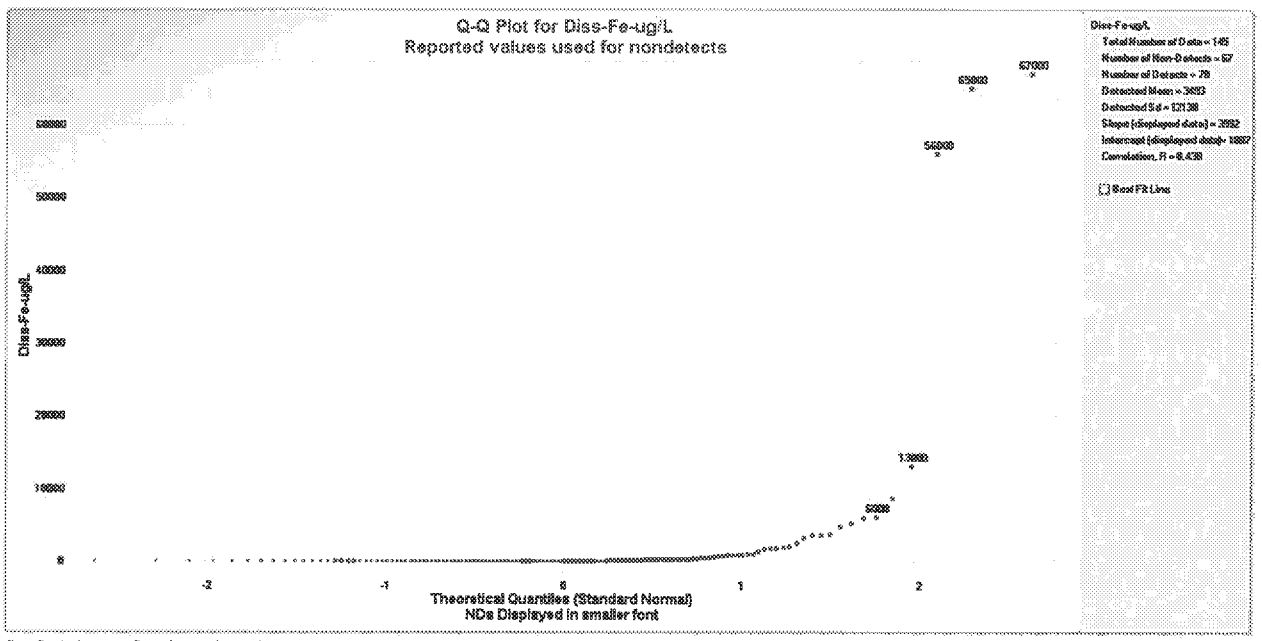
Variable	NumObs	# Missing	Num Ds	NumNDs	% NDs	Min ND	Max ND	KM Mean	KM Var	KM SD	KM CV
Diss-Al-ug/L (lpch)	1	0	0	1	100.00%	25	25	N/A	N/A	N/A	N/A
Diss-Al-ug/L (lpdam)	1	0	0	1	100.00%	24	24	N/A	N/A	N/A	N/A
Diss-Al-ug/L (lpgb)	1	0	1	0	0.00%	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Al-ug/L (lpnc)	2	0	0	2	100.00%	24	24	N/A	N/A	N/A	N/A
Diss-Al-ug/L (lppc)	1	0	1	0	0.00%	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Al-ug/L (lppw)	1	0	0	1	100.00%	25	25	N/A	N/A	N/A	N/A
Diss-Al-ug/L (lprc)	1	0	1	0	0.00%	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Al-ug/L (mect)	10	0	4	6	60.00%	18	25	108.4	32433	180.1	1.661
Diss-Al-ug/L (page)	1	0	0	1	100.00%	18	18	N/A	N/A	N/A	N/A
Diss-Al-ug/L (sj4c)	11	0	7	4	36.36%	18	24	789.4	2375019	1541	1.952
Diss-Al-ug/L (sjbb)	12	0	8	4	33.33%	18	24	1612	12652786	3557	2.206
Diss-Al-ug/L (sjch)	2	0	2	0	0.00%	N/A	N/A	720	156800	396	0.55
Diss-Al-ug/L (sjds)	10	0	7	3	30.00%	18	24	18445	1.238E+9	35183	1.907
Diss-Al-ug/L (sjfp)	11	0	2	9	81.82%	18	200	71.09	12684	112.6	1.584
Diss-Al-ug/L (sjhb)	14	0	8	6	42.86%	24	200	291.5	252062	502.1	1.722
Diss-Al-ug/L (sjin)	1	0	1	0	0.00%	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Al-ug/L (sjin2)	2	0	2	0	0.00%	N/A	N/A	2137	8516065	2918	1.366
Diss-Al-ug/L (sjjp)	11	0	3	8	72.73%	18	200	61.82	13716	117.1	1.894
Diss-Al-ug/L (sjmc)	12	0	9	3	25.00%	18	24	1224	7405651	2721	2.224
Diss-Al-ug/L (sjme)	12	0	7	5	41.67%	24	25	3132	15367537	3920	1.252
Diss-Al-ug/L (sjmh)	11	0	7	4	36.36%	24	25	9705	5.086E+8	22552	2.324
Diss-Al-ug/L (sjpf)	1	0	1	0	0.00%	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Al-ug/L (sjpl)	2	0	2	0	0.00%	N/A	N/A	300	145800	381.8	1.273
Diss-Al-ug/L (sjpl2)	2	0	2	0	0.00%	N/A	N/A	59.5	24.5	4.95	0.0832
Diss-Al-ug/L (sjsr)	12	0	8	4	33.33%	24	25	533.8	601334	775.5	1.453

General Statistics for Raw Data Sets using Detected Data Only

Variable	NumObs	# Missing	Minimum	Maximum	Mean	Median	Var	SD	MAD/0.675	Skewness	CV
Diss-Al-ug/L (pch)	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Al-ug/L (pdam)	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Al-ug/L (pgb)	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Al-ug/L (pnc)	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Al-ug/L (ppc)	1	0	37	37	37	37	N/A	N/A	0	N/A	N/A
Diss-Al-ug/L (ppw)	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Al-ug/L (prc)	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Al-ug/L (mect)	5	0	62	610	221.6	160	49877	223.3	109.7	1.936	1.008
Diss-Al-ug/L (page)	1	0	230	230	230	230	N/A	N/A	0	N/A	N/A
Diss-Al-ug/L (sj4c)	8	0	25	4900	1004	355	2667468	1633	487	2.458	1.627
Diss-Al-ug/L (sjbb)	8	0	100	13000	2416	510	19479284	4414	600.4	2.517	1.827
Diss-Al-ug/L (sjch)	2	0	440	1000	720	720	156800	396	415.1	N/A	0.55
Diss-Al-ug/L (sjds)	8	0	24	82000	21062	985	1.350E+9	36738	1421	1.432	1.744
Diss-Al-ug/L (sjfp)	2	0	310	320	315	315	50	7.071	7.413	N/A	0.0224
Diss-Al-ug/L (sjhb)	8	0	25	1800	449.5	115	425721	652.5	119.3	1.686	1.452
Diss-Al-ug/L (sjin)	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diss-Al-ug/L (sjin2)	2	0	73	4200	2137	2137	8516065	2918	3059	N/A	1.366
Diss-Al-ug/L (sjlp)	5	0	28	430	117.8	45	30566	174.8	19.27	2.217	1.484
Diss-Al-ug/L (sjmc)	8	0	28	10000	1826	510	11452526	3384	661.2	2.583	1.854
Diss-Al-ug/L (sjme)	7	0	310	12000	5459	5500	16639014	4079	4893	0.529	0.747
Diss-Al-ug/L (sjmh)	7	0	24	95000	17522	540	1.211E+9	34798	765	2.457	1.986
Diss-Al-ug/L (sjpf)	1	0	7800	7800	7800	7800	N/A	N/A	0	N/A	N/A
Diss-Al-ug/L (sjpl)	2	0	30	500	265	265	110450	332.3	348.4	N/A	1.254
Diss-Al-ug/L (sjpl2)	1	0	63	63	63	63	N/A	N/A	0	N/A	N/A
Diss-Al-ug/L (sjsr)	7	0	26	2300	896.3	610	834647	913.6	865.8	0.589	1.019

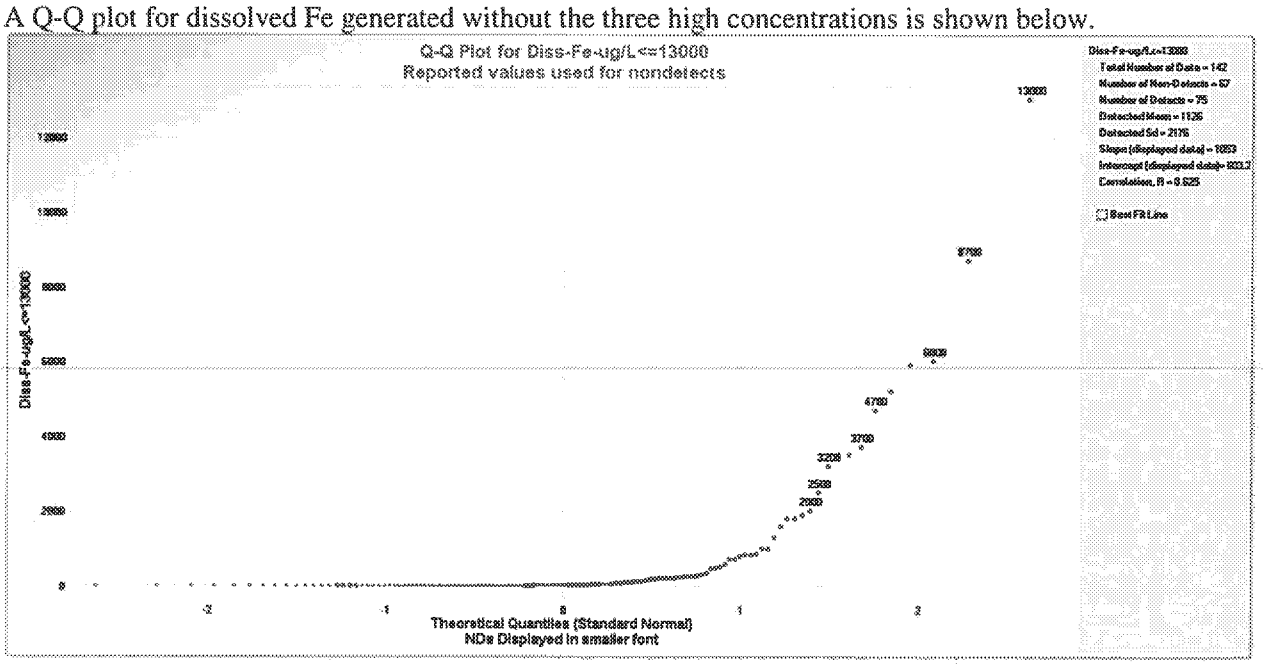
The following Q-Q plots for dissolved Fe and Al were provided in an intermediate draft report and are included in this TM for the purpose of completeness.

Q-Q Plots for Post-Spill Event Dissolved Fe

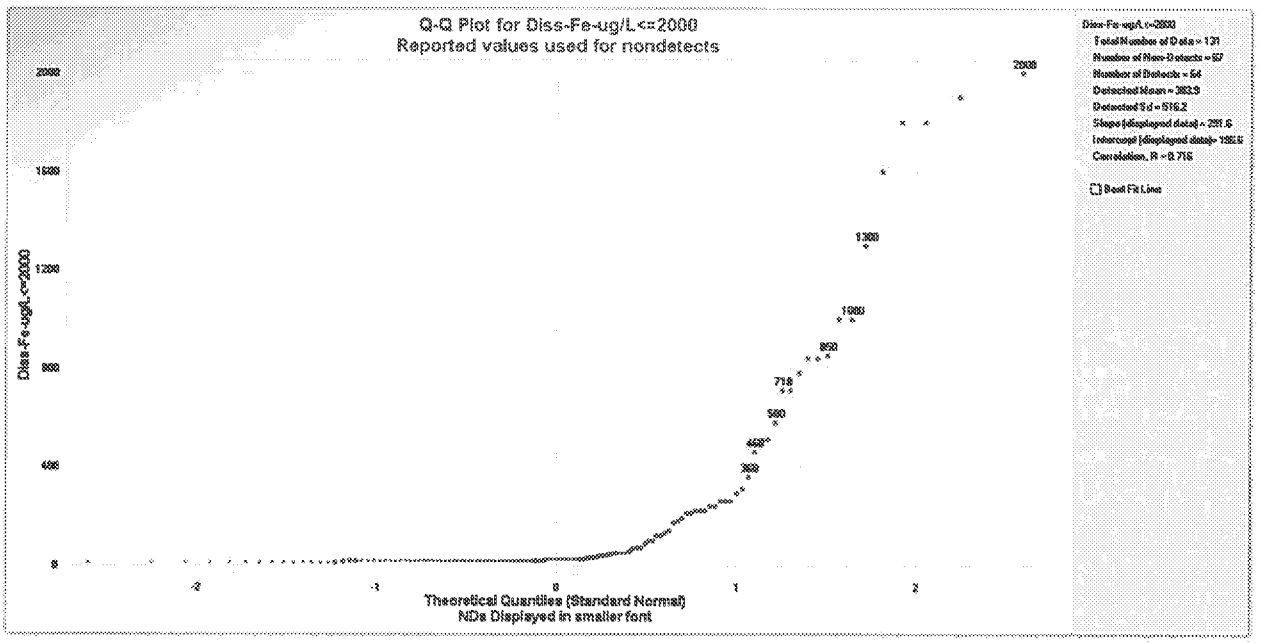


Q-Q Plot of Dissolved Fe Based upon All Data

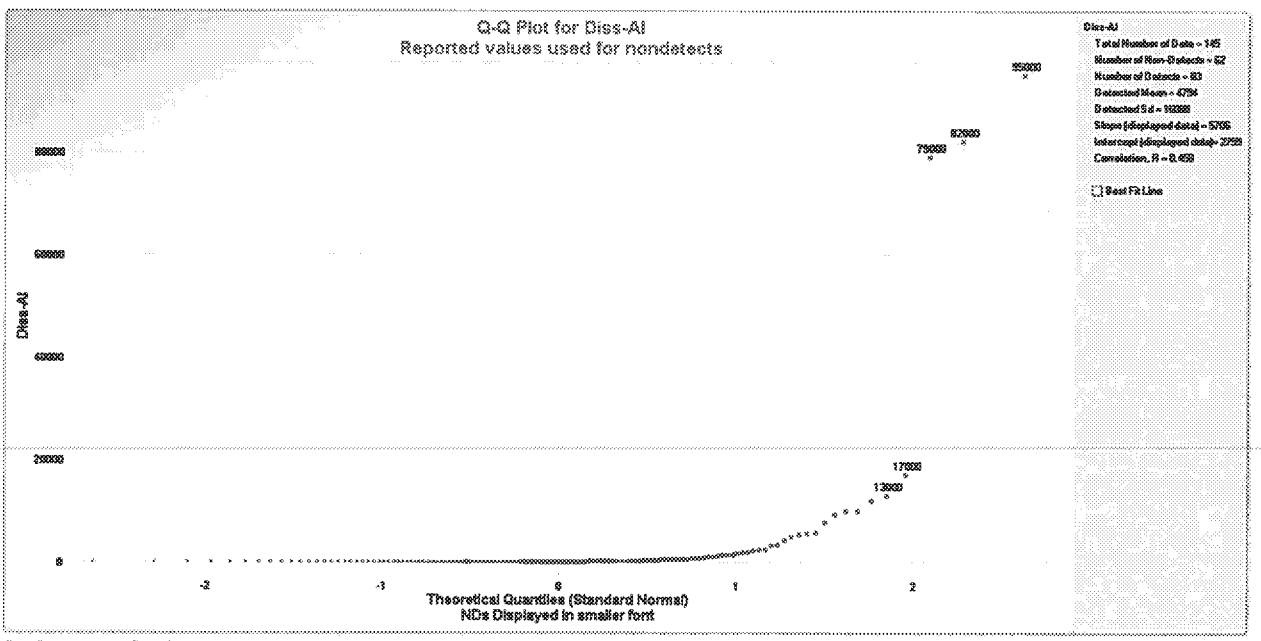
A Q-Q plot for dissolved Fe generated without the three high concentrations is shown below.



Another Q-Q plot generated using all dissolved Fe concentrations <=2000 µg/L is shown as follows.



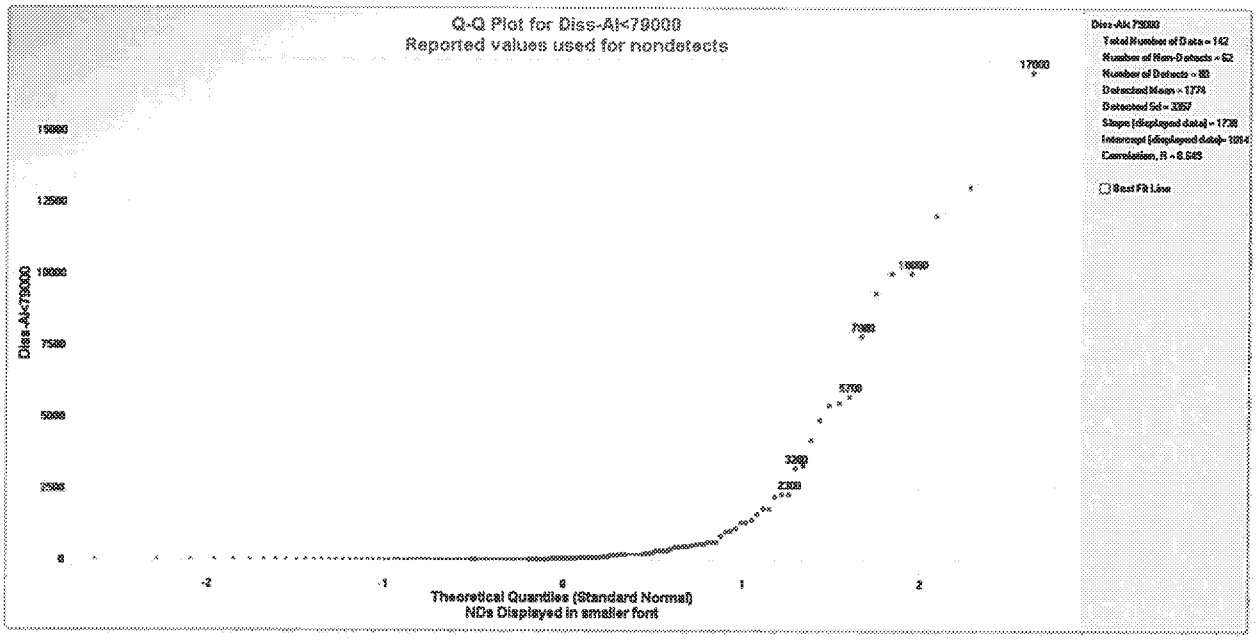
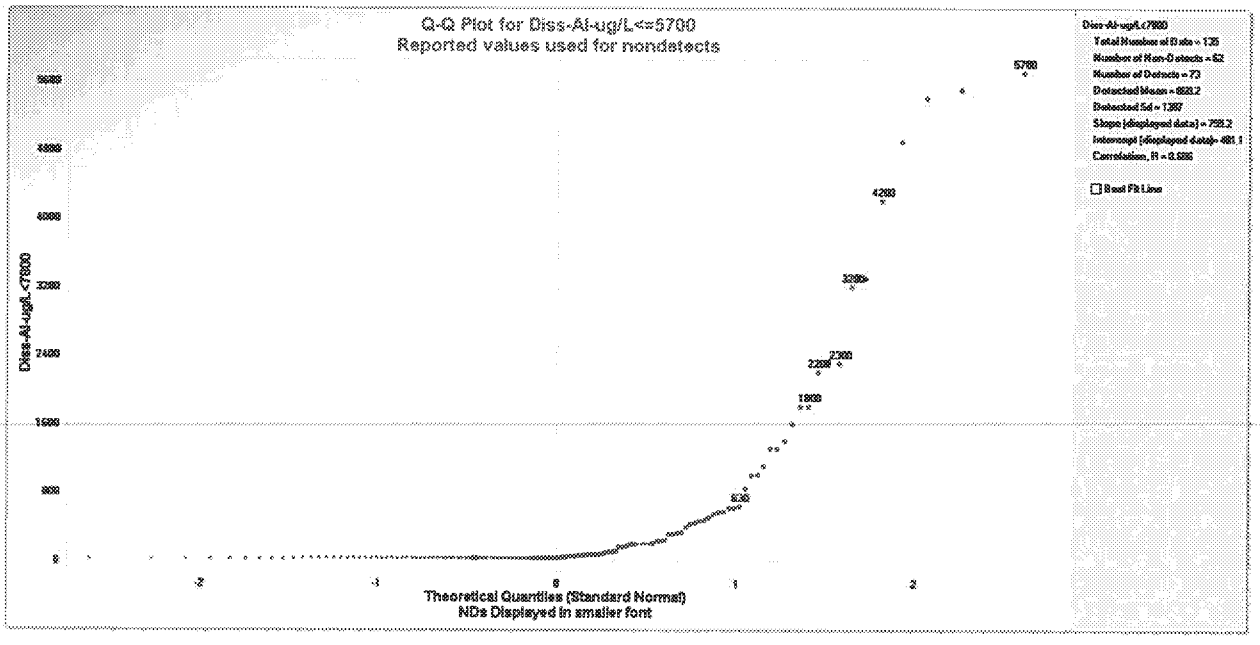
Q-Q Plots for Post-Spill Event Dissolved Al



Q-Q Plot of Dissolved Al Based upon All Data

Note: The three elevated values were noted on August 13 at stations SJDH and SJMH (highest value).

A Q-Q plot for dissolved Al generated without three high concentrations is shown below.



Next, a Q-Q plot generated using all dissolved Al concentrations <=5700 µg/L is shown as follows.