Department of Energy

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JAN 10 2017

Mr. Allan Shingleton
Division of Waste Management
Kentucky Department for Environmental Protection
625 Hospital Drive
Madisonville, Kentucky 42431

PPPO-02-3944604-17

Ms. April Webb
Division of Waste Management
Kentucky Department for Environmental Protection
300 Sower Blvd, 2nd Floor
Frankfort, Kentucky 40601

Dear Mr. Shingleton and Ms. Webb:

TRANSMITTAL OF ERRATA PAGE FOR THE C-404 HAZARDOUS WASTE LANDFILL NOVEMBER 2016 SEMIANNUAL GROUNDWATER REPORT (APRIL 2016–SEPTEMBER 2016), PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY, FPDP-RPT-0024/V2, PERMIT NUMBER KY8-890-008-982

Enclosed is an errata page for the *C-404 Hazardous Waste Landfill November 2016 Semiannual Groundwater Report (April 2016–September 2016), Paducah Gaseous Diffusion Plant, Paducah, Kentucky*. The enclosed errata page has been prepared to correct an error associated with the arsenic concentration units noted in the subject document. Specifically, units for arsenic concentrations noted in Section 2, Statistical Synopsis, on page 6, were changed from 0.00243 µg/L to 0.00243 mg/L and from 0.0137 µg/L to 0.0137 mg/L. An errata sheet that summarizes the conforming changes and clean and redline versions of the changed page are enclosed.

If you have any questions or require additional information, please contact David Dollins at (270) 441-6819.

Sincerely,

Jennifer Woodard

Jennifer Woodard
Paducah Site Lead
Portsmouth/Paducah Project Office

Enclosures:

1. Errata sheet
2. Errata page for *C-404 Hazardous Waste Landfill November 2016 Semiannual Groundwater Report (April 2016–September 2016), Paducah Gaseous Diffusion Plant, Paducah, Kentucky* FPDP-RPT-0024/V2—Clean
3. Errata page for *C-404 Hazardous Waste Landfill November 2016 Semiannual Groundwater Report (April 2016–September 2016), Paducah Gaseous Diffusion Plant, Paducah, Kentucky* FPDP-RPT-0024/V2—Redline

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ERRATA SHEET

C-404 Hazardous Waste Landfill November 2016 Semiannual Groundwater Report (April 2016–September 2016), Paducah Gaseous Diffusion Plant, Paducah, Kentucky, FPDP-RPT-0024/V2, issued November 2016

The following 2 corrections should be incorporated into the document.

1. Section 2, page 6, 8th line, changed text from "0.00243 µg/L" to "0.00243 mg/L."
2. Section 2, page 6, 8th line, changed text from "0.0137 µg/L" to "0.0137 mg/L."

concentrations between compliance well MW84 and background wells (see Appendix B, Attachment B2). Both arsenic and dissolved arsenic are permit-required analyses. The mechanism of transport for arsenic from the landfill would have to be via a groundwater/dissolved pathway, because particulate-associated arsenic would not migrate through the subsurface. Finally, most of the leachate samples collected over the years have had no detectable arsenic (dissolved arsenic is not required by the permit for leachate) and do not contain arsenic concentrations that could be the source of the concentrations recently detected in RGA groundwater at MW84. Of the 26% (13 of 50) of leachate samples that do contain arsenic, the maximum concentration of 0.00243 mg/L in leachate is below the arsenic concentration of 0.0137 mg/L found in MW84; thus, the C-404 Landfill cannot be the source of the arsenic found in that well.

FPDP-RPT-0024/V2

C-404 Hazardous Waste Landfill November 2016 Semiannual Groundwater Report (April 2016–September 2016), Paducah Gaseous Diffusion Plant, Paducah, Kentucky

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This document is approved for public release per review by:

David Hayden — 11-18-16

FPDP Classification Support — Date

FPDP-RPT-0024/V2

C-404 Hazardous Waste Landfill November 2016 Semiannual Groundwater Report (April 2016–September 2016), Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Date Issued—November 2016

U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Prepared by
FLUOR FEDERAL SERVICES, INC.,
Paducah Deactivation Project
managing the
Deactivation Project at the
Paducah Gaseous Diffusion Plant
under Task Order DE-DT0007774

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CONTENTS

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TABLES

FIGURE

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ACRONYMS

AKGWA	Assembled Kentucky Groundwater
MW	monitoring well
PGDP	Paducah Gaseous Diffusion Plant
RCRA	Resource Conservation and Recovery Act
RGA	Regional Gravel Aquifer
UCRS	Upper Continental Recharge System
URGA	Upper Regional Gravel Aquifer
UTL	upper tolerance limit

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EXECUTIVE SUMMARY

This report, *C-404 Hazardous Waste Landfill November 2016 Semiannual Groundwater Report (April 2016–September 2016), Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* FPDP-RPT-0024/V2, is being submitted by the U.S. Department of Energy in accordance with requirements in Kentucky Division of Waste Management Hazardous Waste Facility Permit, KY8-890-008-982. The reporting period covers April through September 2016 and includes analytical data from the July 2016 sampling of monitoring wells (MWs) located in the vicinity of the closed C-404 Hazardous Waste Landfill (C-404 Landfill). In 1986, disposal of waste at C-404 Landfill was halted and a portion of the disposed-of waste was found to be Resource Conservation and Recovery Act (RCRA) hazardous. The landfill was covered with a RCRA multilayered cap and certified closed in 1987.

The groundwater monitoring analytical data were subjected to statistical analyses. The analyses were conducted in accordance with the Hazardous Waste Facility Permit. Only the arsenic concentration in compliance well MW84 was different from concentrations in the background wells. The MW84 arsenic exceedance is consistent with the 2007 Alternate Source Demonstration (PRS 2007), which demonstrates that the C-404 Landfill is not the source of the statistically significant exceedance of background, based on the results of the paired (parametric) Analysis of Variance (ANOVA) statistical analysis. This determination fulfills Section II.K.8 of the Hazardous Waste Facility Permit, which allows for demonstrating that the exceedance is consistent with the findings in the 2007 Alternate Source Demonstration and also allows for the demonstration to be submitted within the semiannual report.

For the remaining parameters, concentrations in the downgradient (compliance) wells are not statistically different from the concentrations in upgradient (background) wells.

On September 7, 2016, the leachate level was measured at 35 inches and 1,000 gal were removed and sampled on September 19, 2016. Analytical data were not available for inclusion in this report by the regulatory deadline. The leachate analytical data for the September 19, 2016, leachate sample will be included in the next semiannual report. Leachate analytical data from the sample collected during the previous reporting period (March 2016) are provided in this report because the laboratory results were not available by the regulatory deadline of the previous report.

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1. INTRODUCTION

This report contains the statistical evaluation of data from groundwater sampling and analysis for the C-404 Hazardous Waste Landfill (C-404 Landfill) at the Paducah Gaseous Diffusion Plant (PGDP), Paducah, Kentucky. This semiannual report is required by the Kentucky Division of Waste Management Hazardous Waste Facility Permit, KY8-890-008-982 (the permit) (KDWM 2015), Specific Condition II.K.6.d—Recordkeeping, Reporting, and Response. The period covered by this report is April through September 2016.

Groundwater analytical results are provided in Appendix A. The statistical analyses and qualification statement are provided in Appendix B. Landfill leachate analytical results are provided in Appendix C. The groundwater flow direction determination is provided in Appendix D.

1.1 BACKGROUND

The C-404 Landfill is located in the west-central portion of the PGDP secured area. The 1.2-acre facility operated as a surface impoundment from approximately 1952 until early 1957. During this time, influents to the impoundment originated from the C-400 Cleaning Building. In 1957, the impoundment was converted to a solid waste disposal facility for uranium-contaminated solid waste. When the impoundment was converted into a disposal facility, a sump was installed at the former weir to collect the leachate from the facility. Leachate is pumped from the sump, as needed, into a mobile tank. Then the leachate is transferred to a permitted hazardous waste storage facility on-site prior to characterization and transfer off-site for treatment.

In 1986, the disposal of waste at C-404 Landfill was halted, and a portion of the disposed-of waste was found to be Resource Conservation and Recovery Act (RCRA)-hazardous. The landfill was covered with a RCRA multilayered cap and certified closed in 1987. It currently is regulated under RCRA as a land disposal unit and compliance is monitored under the current Hazardous Waste Facility Permit (KDWM 2015).

Previous groundwater monitoring documented that concentrations in compliance wells were statistically different from background wells for trichloroethene. The *C-404 Landfill Source Demonstration, Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (PRS 2007) documented that the source of the differences from background concentrations in compliance wells is not from the C-404 Landfill, but rather, the source is located upgradient/crossgradient of the C-404 Landfill.

1.2 MONITORING PERIOD ACTIVITIES

1.2.1 Groundwater Monitoring

Groundwater sampling was conducted in July 2016 using Fluor Federal Services, Inc., procedure CP4-ES-2101, *Groundwater Sampling*. Appropriate sample containers and preservatives were used. The laboratory that performed analyses used U.S. Environmental Protection Agency-approved methods, as applicable. There are nine MWs sampled under this permit for the C-404 Landfill: four Upper Continental Recharge System (UCRS) wells and five Upper Regional Gravel Aquifer (URGA) wells. Table 1 presents the well numbers for URGA wells located upgradient and downgradient of the C-404 Landfill. Table 1 also presents the well numbers for the UCRS wells located in proximity to the URGA wells. This table refers to these UCRS wells as being adjacent to an "upgradient" or "downgradient" URGA well location, identified relative to the URGA groundwater flow direction (see Figure 1).

Table 1. Monitoring Well Locations

UCRS	
Located south of C-404, adjacent to upgradient URGA background well MW93	MW94
Located north of C-404, adjacent to downgradient URGA compliance wells	MW85, MW88, MW91
URGA	
Upgradient background wells	MW93, MW420
Downgradient compliance wells	MW84, MW87, MW90A*

*MW90 was abandoned in 2001 and replaced with MW90A.

The conceptual model for the site indicates that groundwater in the UCRS wells flows vertically until it reaches the URGA; therefore, UCRS wells are not considered "upgradient" or "downgradient" of other wells in the area.

Table 2 presents the Assembled Kentucky Groundwater (AKGWA) numbers for each MW. A map of the MW locations is provided in Figure 1. All of the MWs listed in Tables 1 and 2 were sampled during this reporting period, and the samples were analyzed for parameters required by Attachment E of the Hazardous Waste Facility Permit.

Appendix A of this report contains the analytical results from the wells that were sampled during the July 2016 semiannual sampling event. Appendix B of this report contains the statistical analyses.

Per Permit Specific Condition II.K.4.a, the groundwater flow rate and direction are evaluated annually and reported in each November report. For this report, a potentiometric map has been included in Appendix D using data from sampling performed in January and July 2016. Depth-to-water was measured on January 26, 2016, and July 26, 2016, from several wells at the perimeter of the C-404 Landfill. Water level measurements in 11 vicinity well locations define the potentiometric surface for the URGA (see Tables D.3 and D.4). Groundwater flow direction beneath the C-404 Landfill generally trends northeastward, but commonly varies from northeast to north. On January 26, 2016, and July 26, 2016, groundwater flow was toward the north-northeast (see Figures D.1 and D.2).

1.2.2 Landfill Leachate

In accordance with Section 1.2 of the Hazardous Waste Facility Permit, the quantity of liquid in the leachate collection system is monitored (at least monthly) and, at a minimum, will be "removed when the quantity exceeds 3 ft in depth." The volume of leachate removed from the sump during this reporting period, April to September 2016, was 1,000 gal. Once the leachate depth reached 3 ft, the leachate was pumped into a mobile tank. Then the leachate was transferred to a permitted hazardous waste storage facility on-site prior to characterization and transfer off-site for treatment. Because analytical results from leachate sampling conducted on September 19, 2016, were not available for inclusion in this report by the regulatory deadline, they will be included in the next semiannual report.

Leachate sample data from the previous reporting period are provided in this report because the laboratory data were not available by the regulatory deadline of the previous report. Analytical results from leachate sampling on March 14, 2016, are included in Appendix C.

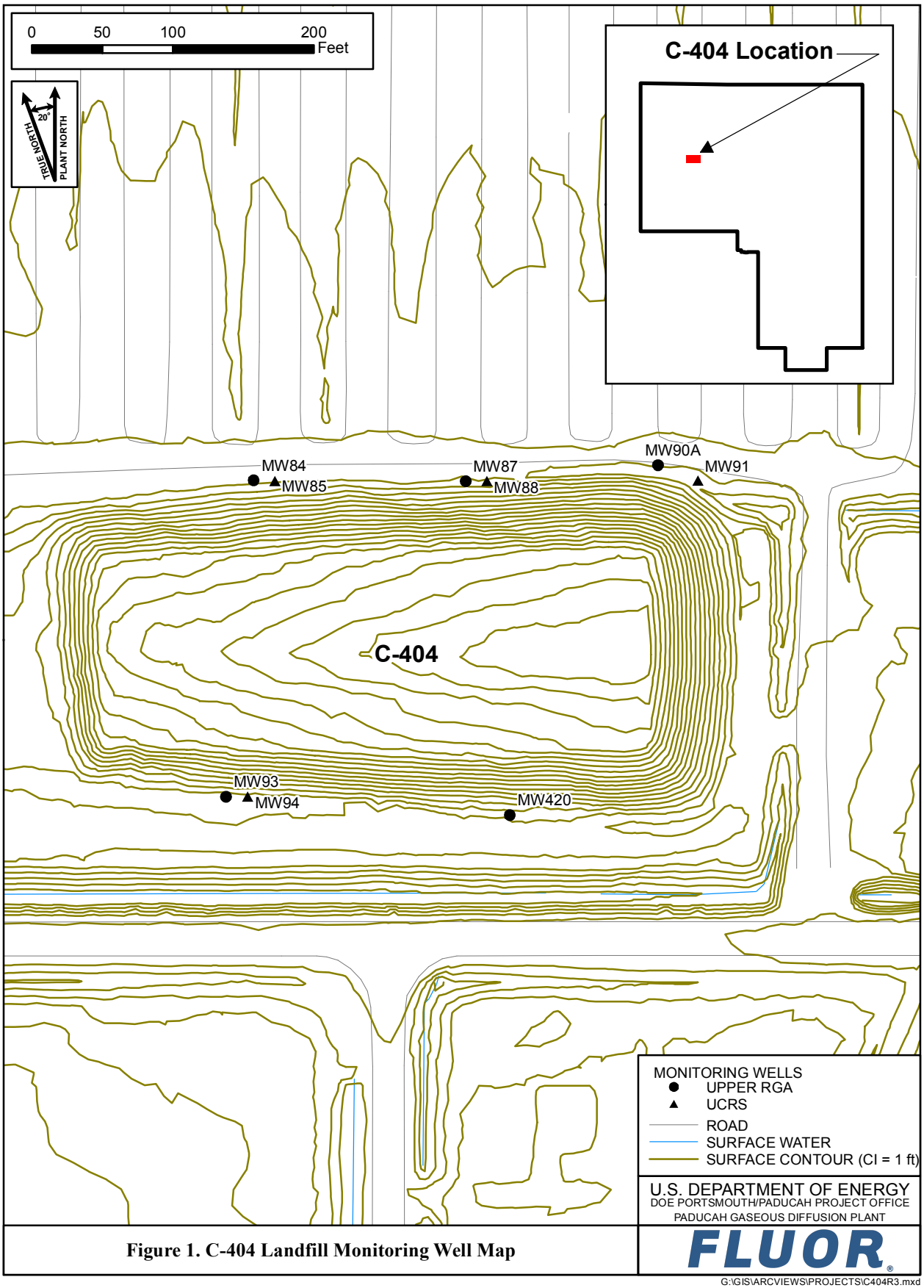

Figure 1. C-404 Landfill Monitoring Well Map

Table 2. Assembled Kentucky Groundwater Numbers

PGDP Well Number	AKGWA Number
MW84	8000-5233
MW85	8000-5234
MW87	8000-5236
MW88	8000-5237
MW90A	8004-0357
MW91	8000-5240
MW93	8000-5102
MW94	8000-5103
MW420	8005-3263

2. STATISTICAL SYNOPSIS

The statistical analyses conducted on the data collected from C-404 Landfill were performed in accordance with procedures in the Hazardous Waste Facility Permit, Attachment Part E, reissued in July 2015. Appendix B of this report contains the statistical analyses performed for this reporting period. Data utilized for statistical analyses included data from the URGA background wells, MW93 and MW420, and URGA compliance wells, MW84, MW87, and MW90A. For these statistical analyses, the reporting period data set includes data from July 2014, January 2015, July 2015, January 2016, and July 2016.

Only the arsenic (see Appendix B) concentration in compliance well MW84 was different from concentrations in the background wells. The statistical tests on all other parameters, including dissolved arsenic, showed no statistical difference between concentrations in the compliance (downgradient) and background (upgradient) wells.

Since the nonparametric ANOVA test for arsenic identified a statistically significant difference between concentrations in the compliance well, MW84, and concentrations in background wells, in accordance with the permit provisions, the data were evaluated further by comparing the most recent compliance analytical data to a 95% upper tolerance limit (UTL) using the five most recent sets of data for each background well. Results of the comparison showed concentrations in compliance MW84 were higher than the UTL for the paired background concentrations. Analytical data were then evaluated using parametric ANOVA of wells in the same direction relative to the landfill (e.g., compare upgradient westernmost well MW93 analytical data to downgradient westernmost well MW84 analytical data). Results show the compliance (downgradient) well, MW84, does not have statistically significant higher concentrations than the background (upgradient) well, MW93; therefore, the results are consistent with the historical 2007 Alternate Source Demonstration (PRS 2007). Additional intra-well evaluation of trend was then performed for arsenic in MW84 using the Mann-Kendall statistical test. The Mann-Kendall statistical test identified a positive trend in MW84 over the past eight semiannual events.

STATISTICALLY SIGNIFICANT EXCEEDANCE OF BACKGROUND

The exceedance in arsenic concentration over background concentrations is consistent with the findings in the 2007 Alternate Source Demonstration (PRS 2007), as determined by the parametric ANOVA statistical test (see Appendix B, Attachment B1). The 2007 demonstration found that the statistically significant increase of trichloroethene (TCE) in the downgradient well, MW84, appeared to be due to an upgradient source whose TCE is migrating through the C-404 area. This determination fulfills Section II.K.8 of the Hazardous Waste Facility Permit, which allows for demonstrating that the exceedance is consistent with the findings in the 2007 Alternate Source Demonstration and allows for the demonstration to be submitted within the semiannual report.

Additional information that reinforces the alternate source demonstration is as follows. First, until the January 2015 sampling event, the westernmost upgradient well (MW93) had higher arsenic concentrations than the downgradient well MW84.Since then, the MW84 arsenic concentrations have increased steadily. This condition is similar to the pattern of TCE concentrations historically seen in these same wells and are attributed to a source upgradient/crossgradient of C-404 in the 2007 Alternate Source Demonstration. Second, groundwater flow directions are to the northeast (see Figures D.1 and D.2)—similarly indicating an upgradient, non-C-404 source of MW84 impacts. This condition is consistent with flow patterns found in 2007 during the Alternate Source Demonstration. Third, although there are significant differences in arsenic concentrations, there is no significant difference in dissolved arsenic

concentrations between compliance well MW84 and background wells (see Appendix B, Attachment B2). Both arsenic and dissolved arsenic are permit-required analyses. The mechanism of transport for arsenic from the landfill would have to be via a groundwater/dissolved pathway, because particulate-associated arsenic would not migrate through the subsurface. Finally, most of the leachate samples collected over the years have had no detectable arsenic (dissolved arsenic is not required by the permit for leachate) and do not contain arsenic concentrations that could be the source of the concentrations recently detected in RGA groundwater at MW84. Of the 26% (13 of 50) of leachate samples that do contain arsenic, the maximum concentration of 0.00243 µg/L in leachate is below the arsenic concentration of 0.0137 µg/L found in MW84; thus, the C-404 Landfill cannot be the source of the arsenic found in that well.

3. DATA VALIDATION AND QA/QC SUMMARY

The data and the data validation qualifiers for the July 2016 data set are provided in Appendix A. All data for this data set were considered useable as reported.

Data validation was performed on the analytical data by an independent, third-party validator.

Field quality control samples are collected semiannually during each sampling event. Equipment rinseate blanks, field blanks, and trip blanks are obtained to ensure quality control and are reported in the Analytical Results in Appendix A. No contamination was detected in these samples. Laboratory quality control samples, such as matrix spikes, matrix spike duplicates, and method blanks, are performed by the laboratory and reported in the laboratory report. Both field and laboratory quality control sample results are reviewed as part of the data validation process.

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4. PROFESSIONAL GEOLOGIST AUTHORIZATION

DOCUMENT IDENTIFICATION: *C-404 Hazardous Waste Landfill*
November 2016 Semiannual Groundwater Report
(April 2016–September 2016),
Paducah Gaseous Diffusion Plant, Paducah, Kentucky
(FPDP-RPT-0024/V2)

Stamped and signed pursuant to my authority as a duly registered geologist under the provisions of *KRS* Chapter 322A.

KRD
11-21-16

Kenneth R. Davis
Kenneth R. Davis

PG113927

November 21, 2016
Date

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5. REFERENCES

KDWM (Kentucky Division of Waste Management) 2015. Hazardous Waste Facility Permit for the U.S. Department of Energy, Paducah Gaseous Diffusion Plant, KY8-890-008-982, effective July 26.

PRS (Paducah Remediation Services, LLC) 2007. *C-404 Landfill Source Demonstration, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, PRS-ENM-0031/R2, Paducah Remediation Services, LLC, Kevil, KY.

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APPENDIX A

C-404 HAZARDOUS WASTE LANDFILL GROUNDWATER ANALYTICAL RESULTS

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Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Sampling Point: MW84 REG Downgradient URGA **Period:** Semiannual Report

AKGWA Well Tag #: 8000-5233

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-)	TPU	Method	Validation
Arsenic		0.0137	mg/L	0.005	7/12/2016			SW846-6020	=
Arsenic, Dissolved		0.0074	mg/L	0.005	7/12/2016			SW846-6020	=
Barometric Pressure Reading		30.01	Inches/Hg		7/12/2016				X
Cadmium	J	0.0003	mg/L	0.001	7/12/2016			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/12/2016			SW846-6020	=
Chromium		0.0206	mg/L	0.01	7/12/2016			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	7/12/2016			SW846-6020	=
Conductivity		368	umho/cm		7/12/2016				X
Depth to Water		47.75	ft		7/12/2016				X
Dissolved Oxygen		2.75	mg/L		7/12/2016				X
Lead		0.0024	mg/L	0.002	7/12/2016			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	7/12/2016			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/12/2016			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/12/2016			SW846-7470A	=
pH		5.34	Std Unit		7/12/2016				X
Redox		533	mV		7/12/2016				X
Selenium	U	0.005	mg/L	0.005	7/12/2016			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/12/2016			SW846-6020	=
Technetium-99	U	1.19	pCi/L	17.3	7/12/2016	10.1	10.1	HASL 300, Tc-02-RC M	=
Temperature		83.7	deg F		7/12/2016				X
Trichloroethene		1820	ug/L	20	7/12/2016			SW846-8260B	=
Turbidity		117	NTU		7/12/2016				X
Uranium		0.0003	mg/L	0.0002	7/12/2016			SW846-6020	=
Uranium-234	U	2.28	pCi/L	5.72	7/12/2016	3.7	3.71	HASL 300, U-02-RC M	=
Uranium-235	U	1.01	pCi/L	3.03	7/12/2016	2.84	2.84	HASL 300, U-02-RC M	=
Uranium-238	U	2.28	pCi/L	5.72	7/12/2016	3.7	3.71	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Sampling Point: MW85 REG Downgradient UCRS **Period:** Semiannual Report

AKGWA Well Tag #: 8000-5234

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-)	TPU	Method	Validation
Arsenic		0.0103	mg/L	0.005	7/12/2016			SW846-6020	=
Arsenic, Dissolved		0.0074	mg/L	0.005	7/12/2016			SW846-6020	=
Barometric Pressure Reading		30.01	Inches/Hg		7/12/2016				X
Cadmium	J	0.0002	mg/L	0.001	7/12/2016			SW846-6020	=
Cadmium, Dissolved	J	0.0002	mg/L	0.001	7/12/2016			SW846-6020	=
Chromium	J	0.007	mg/L	0.01	7/12/2016			SW846-6020	=
Chromium, Dissolved	J	0.0027	mg/L	0.01	7/12/2016			SW846-6020	=
Conductivity		382	umho/cm		7/12/2016				X
Depth to Water		9.71	ft		7/12/2016				X
Dissolved Oxygen		2.43	mg/L		7/12/2016				X
Lead	U	0.002	mg/L	0.002	7/12/2016			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	7/12/2016			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/12/2016			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/12/2016			SW846-7470A	=
pH		5.92	Std Unit		7/12/2016				X
Redox		516	mV		7/12/2016				X
Selenium	U	0.005	mg/L	0.005	7/12/2016			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/12/2016			SW846-6020	=
Technetium-99		71	pCi/L	18.2	7/12/2016	12.5	14.8	HASL 300, Tc-02-RC M	=
Temperature		83.6	deg F		7/12/2016				X
Trichloroethene		15.5	ug/L	1	7/12/2016			SW846-8260B	=
Turbidity		27.3	NTU		7/12/2016				X
Uranium		0.0003	mg/L	0.0002	7/12/2016			SW846-6020	=
Uranium-234	U	0.835	pCi/L	5.29	7/12/2016	2.86	2.86	HASL 300, U-02-RC M	=
Uranium-235	U	1.99	pCi/L	2.98	7/12/2016	3.4	3.41	HASL 300, U-02-RC M	=
Uranium-238	U	0.611	pCi/L	3.85	7/12/2016	2.29	2.29	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Sampling Point: MW85 FR Downgradient UCRS **Period:** Semiannual Report

AKGWA Well Tag #: 8000-5234

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-)	TPU	Method	Validation
Arsenic		0.0106	mg/L	0.005	7/12/2016			SW846-6020	=
Arsenic, Dissolved		0.0067	mg/L	0.005	7/12/2016			SW846-6020	=
Barometric Pressure Reading		30.01	Inches/Hg		7/12/2016				X
Cadmium	J	0.0002	mg/L	0.001	7/12/2016			SW846-6020	=
Cadmium, Dissolved	J	0.0002	mg/L	0.001	7/12/2016			SW846-6020	=
Chromium	J	0.0057	mg/L	0.01	7/12/2016			SW846-6020	=
Chromium, Dissolved	J	0.0029	mg/L	0.01	7/12/2016			SW846-6020	=
Conductivity		382	umho/cm		7/12/2016				X
Depth to Water		9.71	ft		7/12/2016				X
Dissolved Oxygen		2.43	mg/L		7/12/2016				X
Lead	U	0.002	mg/L	0.002	7/12/2016			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	7/12/2016			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/12/2016			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/12/2016			SW846-7470A	=
pH		5.92	Std Unit		7/12/2016				X
Redox		516	mV		7/12/2016				X
Selenium	U	0.005	mg/L	0.005	7/12/2016			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/12/2016			SW846-6020	=
Technetium-99		59.6	pCi/L	18.7	7/12/2016	12.5	14.2	HASL 300, Tc-02-RC M	=
Temperature		83.6	deg F		7/12/2016				X
Trichloroethene		15.3	ug/L	1	7/12/2016			SW846-8260B	=
Turbidity		27.3	NTU		7/12/2016				X
Uranium		0.0003	mg/L	0.0002	7/12/2016			SW846-6020	=
Uranium-234	U	2.27	pCi/L	4.98	7/12/2016	3.6	3.62	HASL 300, U-02-RC M	=
Uranium-235	U	0.845	pCi/L	5.33	7/12/2016	3.17	3.17	HASL 300, U-02-RC M	=
Uranium-238	U	-0.828	pCi/L	7.26	7/12/2016	2.8	2.8	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Sampling Point: MW87 REG Downgradient URGA **Period:** Semiannual Report

AKGWA Well Tag #: 8000-5236

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-)	TPU	Method	Validation
Arsenic		0.007	mg/L	0.005	7/12/2016			SW846-6020	=
Arsenic, Dissolved	J	0.0028	mg/L	0.005	7/12/2016			SW846-6020	=
Barometric Pressure Reading		30	Inches/Hg		7/12/2016				X
Cadmium	J	0.0005	mg/L	0.001	7/12/2016			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/12/2016			SW846-6020	=
Chromium		0.165	mg/L	0.01	7/12/2016			SW846-6020	=
Chromium, Dissolved	J	0.0044	mg/L	0.01	7/12/2016			SW846-6020	=
Conductivity		316	umho/cm		7/12/2016				X
Depth to Water		47.65	ft		7/12/2016				X
Dissolved Oxygen		2.48	mg/L		7/12/2016				X
Lead		0.0056	mg/L	0.002	7/12/2016			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	7/12/2016			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/12/2016			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/12/2016			SW846-7470A	=
pH		5.32	Std Unit		7/12/2016				X
Redox		544	mV		7/12/2016				X
Selenium	J	0.0016	mg/L	0.005	7/12/2016			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/12/2016			SW846-6020	=
Technetium-99	U	1.07	pCi/L	18	7/12/2016	10.5	10.5	HASL 300, Tc-02-RC M	=
Temperature		76.8	deg F		7/12/2016				X
Trichloroethene		1090	ug/L	20	7/12/2016			SW846-8260B	=
Turbidity		198	NTU		7/12/2016				X
Uranium		0.0006	mg/L	0.0002	7/12/2016			SW846-6020	=
Uranium-234	U	1.54	pCi/L	4.2	7/12/2016	3.03	3.04	HASL 300, U-02-RC M	=
Uranium-235	U	4.07	pCi/L	5.2	7/12/2016	4.8	4.84	HASL 300, U-02-RC M	=
Uranium-238	U	-0.175	pCi/L	6.15	7/12/2016	2.63	2.63	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Sampling Point: MW88 REG Downgradient UCRS **Period:** Semiannual Report

AKGWA Well Tag #: 8000-5237

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-)	TPU	Method	Validation
Arsenic		0.0106	mg/L	0.005	7/13/2016			SW846-6020	=
Arsenic, Dissolved	J	0.0042	mg/L	0.005	7/13/2016			SW846-6020	=
Barometric Pressure Reading		30.05	Inches/Hg		7/13/2016				X
Cadmium	U	0.001	mg/L	0.001	7/13/2016			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/13/2016			SW846-6020	=
Chromium		0.0166	mg/L	0.01	7/13/2016			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	7/13/2016			SW846-6020	=
Conductivity		669	umho/cm		7/13/2016				X
Depth to Water		9.57	ft		7/13/2016				X
Dissolved Oxygen		1.17	mg/L		7/13/2016				X
Lead		0.0049	mg/L	0.002	7/13/2016			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	7/13/2016			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/13/2016			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/13/2016			SW846-7470A	=
pH		5.44	Std Unit		7/13/2016				X
Redox		504	mV		7/13/2016				X
Selenium	U	0.005	mg/L	0.005	7/13/2016			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/13/2016			SW846-6020	=
Technetium-99		24.4	pCi/L	17.6	7/13/2016	10.9	11.2	HASL 300, Tc-02-RC M	=
Temperature		74.2	deg F		7/13/2016				X
Trichloroethene		9.5	ug/L	1	7/13/2016			SW846-8260B	=
Turbidity		556	NTU		7/13/2016				X
Uranium		0.0009	mg/L	0.0002	7/13/2016			SW846-6020	=
Uranium-234	U	1.44	pCi/L	1.77	7/13/2016	1.38	1.39	HASL 300, U-02-RC M	=
Uranium-235	U	0.565	pCi/L	0.848	7/13/2016	0.968	0.972	HASL 300, U-02-RC M	=
Uranium-238	U	0.804	pCi/L	1.27	7/13/2016	1.02	1.03	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Sampling Point: MW90A REG Downgradient URGA **Period:** Semiannual Report

AKGWA Well Tag #: 8004-0357

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-)	TPU	Method	Validation
Arsenic	U	0.005	mg/L	0.005	7/13/2016			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	7/13/2016			SW846-6020	=
Barometric Pressure Reading		30.03	Inches/Hg		7/13/2016				X
Cadmium	U	0.001	mg/L	0.001	7/13/2016			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/13/2016			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	7/13/2016			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	7/13/2016			SW846-6020	=
Conductivity		200	umho/cm		7/13/2016				X
Depth to Water		46.29	ft		7/13/2016				X
Dissolved Oxygen		4.06	mg/L		7/13/2016				X
Lead	U	0.002	mg/L	0.002	7/13/2016			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	7/13/2016			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/13/2016			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/13/2016			SW846-7470A	=
pH		5.54	Std Unit		7/13/2016				X
Redox		516	mV		7/13/2016				X
Selenium	J	0.0017	mg/L	0.005	7/13/2016			SW846-6020	=
Selenium, Dissolved	J	0.0016	mg/L	0.005	7/13/2016			SW846-6020	=
Technetium-99	U	-4.16	pCi/L	18.3	7/13/2016	10.5	10.5	HASL 300, Tc-02-RC M	=
Temperature		76.9	deg F		7/13/2016				X
Trichloroethene		35.3	ug/L	1	7/13/2016			SW846-8260B	=
Turbidity		5.5	NTU		7/13/2016				X
Uranium	U	0.0002	mg/L	0.0002	7/13/2016			SW846-6020	=
Uranium-234	U	1.02	pCi/L	1.49	7/13/2016	1.13	1.14	HASL 300, U-02-RC M	=
Uranium-235	U	0.2	pCi/L	1.26	7/13/2016	0.75	0.751	HASL 300, U-02-RC M	=
Uranium-238	U	0.341	pCi/L	1.85	7/13/2016	0.991	0.992	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Sampling Point: MW91 REG Downgradient UCRS **Period:** Semiannual Report

AKGWA Well Tag #: 8000-5240

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-)	TPU	Method	Validation
Arsenic		0.0071	mg/L	0.005	7/11/2016			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	7/11/2016			SW846-6020	=
Barometric Pressure Reading		30.03	Inches/Hg		7/11/2016				X
Cadmium	J	0.0002	mg/L	0.001	7/11/2016			SW846-6020	=
Cadmium, Dissolved	J	0.0001	mg/L	0.001	7/11/2016			SW846-6020	=
Chromium		1.26	mg/L	0.2	7/11/2016			SW846-6020	=
Chromium, Dissolved		0.029	mg/L	0.01	7/11/2016			SW846-6020	=
Conductivity		516	umho/cm		7/11/2016				X
Depth to Water		10.9	ft		7/11/2016				X
Dissolved Oxygen		2.49	mg/L		7/11/2016				X
Lead		0.0084	mg/L	0.002	7/11/2016			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	7/11/2016			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/11/2016			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/11/2016			SW846-7470A	=
pH		5.36	Std Unit		7/11/2016				X
Redox		511	mV		7/11/2016				X
Selenium	J	0.0039	mg/L	0.005	7/11/2016			SW846-6020	=
Selenium, Dissolved	J	0.0031	mg/L	0.005	7/11/2016			SW846-6020	=
Technetium-99		1500	pCi/L	18.1	7/11/2016	32.8	170	HASL 300, Tc-02-RC M	=
Temperature		71.9	deg F		7/11/2016				X
Trichloroethene		106	ug/L	2	7/11/2016			SW846-8260B	=
Turbidity		574	NTU		7/11/2016				X
Uranium		0.0016	mg/L	0.0002	7/11/2016			SW846-6020	=
Uranium-234	U	-0.824	pCi/L	7.23	7/11/2016	2.79	2.79	HASL 300, U-02-RC M	=
Uranium-235	U	0.841	pCi/L	5.31	7/11/2016	3.16	3.16	HASL 300, U-02-RC M	=
Uranium-238	U	2.97	pCi/L	6.94	7/11/2016	4.46	4.48	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Sampling Point: MW93 REG Upgradient URGA **Period:** Semiannual Report

AKGWA Well Tag #: 8000-5102

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-)	TPU	Method	Validation
Arsenic		0.0071	mg/L	0.005	7/13/2016			SW846-6020	=
Arsenic, Dissolved	J	0.0043	mg/L	0.005	7/13/2016			SW846-6020	=
Barometric Pressure Reading		30	Inches/Hg		7/13/2016				X
Cadmium	J	0.0002	mg/L	0.001	7/13/2016			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/13/2016			SW846-6020	=
Chromium		0.207	mg/L	0.1	7/13/2016			SW846-6020	=
Chromium, Dissolved	J	0.0021	mg/L	0.01	7/13/2016			SW846-6020	=
Conductivity		367	umho/cm		7/13/2016				X
Depth to Water		49.22	ft		7/13/2016				X
Dissolved Oxygen		1.71	mg/L		7/13/2016				X
Lead	J	0.0018	mg/L	0.002	7/13/2016			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	7/13/2016			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/13/2016			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/13/2016			SW846-7470A	=
pH		6	Std Unit		7/13/2016				X
Redox		404	mV		7/13/2016				X
Selenium	U	0.005	mg/L	0.005	7/13/2016			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/13/2016			SW846-6020	=
Technetium-99	U	1.13	pCi/L	16.8	7/13/2016	9.78	9.78	HASL 300, Tc-02-RC M	=
Temperature		74.2	deg F		7/13/2016				X
Trichloroethene		2020	ug/L	50	7/13/2016			SW846-8260B	=
Turbidity		82.4	NTU		7/13/2016				X
Uranium	J	0.0002	mg/L	0.0002	7/13/2016			SW846-6020	=
Uranium-234	U	1.26	pCi/L	2.66	7/13/2016	1.84	1.86	HASL 300, U-02-RC M	=
Uranium-235	U	-0.062	pCi/L	2.16	7/13/2016	1.02	1.02	HASL 300, U-02-RC M	=
Uranium-238	U	0.265	pCi/L	2.11	7/13/2016	1.17	1.17	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Sampling Point: MW94 REG Upgradient UCRS **Period:** Semiannual Report

AKGWA Well Tag #: 8000-5103

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-)	TPU	Method	Validation
Arsenic	J	0.0035	mg/L	0.005	7/11/2016			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	7/11/2016			SW846-6020	=
Barometric Pressure Reading		30.03	Inches/Hg		7/11/2016				X
Cadmium	U	0.001	mg/L	0.001	7/11/2016			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/11/2016			SW846-6020	=
Chromium		0.0246	mg/L	0.01	7/11/2016			SW846-6020	=
Chromium, Dissolved	J	0.0041	mg/L	0.01	7/11/2016			SW846-6020	=
Conductivity		887	umho/cm		7/11/2016				X
Depth to Water		13.24	ft		7/11/2016				X
Dissolved Oxygen		1.08	mg/L		7/11/2016				X
Lead		0.0025	mg/L	0.002	7/11/2016			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	7/11/2016			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/11/2016			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/11/2016			SW846-7470A	=
pH		6.13	Std Unit		7/11/2016				X
Redox		478	mV		7/11/2016				X
Selenium	U	0.005	mg/L	0.005	7/11/2016			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/11/2016			SW846-6020	=
Technetium-99		532	pCi/L	16.8	7/11/2016	20.3	62.4	HASL 300, Tc-02-RC M	=
Temperature		71.6	deg F		7/11/2016				X
Trichloroethene		5.88	ug/L	1	7/11/2016			SW846-8260B	=
Turbidity		208	NTU		7/11/2016				X
Uranium		0.0025	mg/L	0.0002	7/11/2016			SW846-6020	=
Uranium-234	U	0.314	pCi/L	7.61	7/11/2016	3.58	3.58	HASL 300, U-02-RC M	=
Uranium-235	U	0	pCi/L	3.64	7/11/2016	2.45	2.45	HASL 300, U-02-RC M	=
Uranium-238	U	4.44	pCi/L	5.44	7/11/2016	4.78	4.83	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Sampling Point: MW420 REG Upgradient URGA **Period:** Semiannual Report

AKGWA Well Tag #: 8005-3263

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-)	TPU	Method	Validation
Arsenic	U	0.005	mg/L	0.005	7/13/2016			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	7/13/2016			SW846-6020	=
Barometric Pressure Reading		30.01	Inches/Hg		7/13/2016				X
Cadmium	U	0.001	mg/L	0.001	7/13/2016			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/13/2016			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	7/13/2016			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	7/13/2016			SW846-6020	=
Conductivity		308	umho/cm		7/13/2016				X
Depth to Water		49.41	ft		7/13/2016				X
Dissolved Oxygen		1.37	mg/L		7/13/2016				X
Lead	U	0.002	mg/L	0.002	7/13/2016			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	7/13/2016			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/13/2016			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/13/2016			SW846-7470A	=
pH		5.37	Std Unit		7/13/2016				X
Redox		534	mV		7/13/2016				X
Selenium	U	0.005	mg/L	0.005	7/13/2016			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/13/2016			SW846-6020	=
Technetium-99	U	8.3	pCi/L	17.4	7/13/2016	10.3	10.4	HASL 300, Tc-02-RC M	=
Temperature		72.8	deg F		7/13/2016				X
Trichloroethene		169	ug/L	2	7/13/2016			SW846-8260B	=
Turbidity		0.3	NTU		7/13/2016				X
Uranium	U	0.0002	mg/L	0.0002	7/13/2016			SW846-6020	=
Uranium-234	U	0.301	pCi/L	2.57	7/13/2016	1.31	1.31	HASL 300, U-02-RC M	UJ
Uranium-235	U	-0.056	pCi/L	1.96	7/13/2016	0.925	0.929	HASL 300, U-02-RC M	UJ
Uranium-238	U	0.708	pCi/L	1.58	7/13/2016	1.28	1.29	HASL 300, U-02-RC M	UJ

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Type of Sample: FB **Period:** Semiannual Report QC Samples

AKGWA Well Tag #: 0000-0000

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-)	TPU	Method	Validation
Arsenic	U	0.005	mg/L	0.005	7/11/2016			SW846-6020	=
Cadmium	U	0.001	mg/L	0.001	7/11/2016			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	7/11/2016			SW846-6020	=
Lead	U	0.002	mg/L	0.002	7/11/2016			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/11/2016			SW846-7470A	=
Selenium	U	0.005	mg/L	0.005	7/11/2016			SW846-6020	=
Technetium-99	U	-5.15	pCi/L	18.7	7/11/2016	10.6	10.6	HASL 300, Tc-02-RC M	=
Trichloroethene	U	1	ug/L	1	7/11/2016			SW846-8260B	=
Uranium	U	0.0002	mg/L	0.0002	7/11/2016			SW846-6020	=
Uranium-234	U	1.12	pCi/L	5.34	7/11/2016	3.08	3.09	HASL 300, U-02-RC M	=
Uranium-235	U	0.822	pCi/L	5.19	7/11/2016	3.08	3.09	HASL 300, U-02-RC M	=
Uranium-238	U	-0.21	pCi/L	4.19	7/11/2016	1.81	1.82	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Type of Sample: RI **Period:** Semiannual Report QC Samples

AKGWA Well Tag #: 0000-0000

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-)	TPU	Method	Validation
Arsenic	U	0.005	mg/L	0.005	7/11/2016			SW846-6020	=
Cadmium	U	0.001	mg/L	0.001	7/11/2016			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	7/11/2016			SW846-6020	=
Lead	U	0.002	mg/L	0.002	7/11/2016			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/11/2016			SW846-7470A	=
Selenium	U	0.005	mg/L	0.005	7/11/2016			SW846-6020	=
Technetium-99	U	5.27	pCi/L	19	7/11/2016	11.2	11.2	HASL 300, Tc-02-RC M	=
Trichloroethene	U	1	ug/L	1	7/11/2016			SW846-8260B	=
Uranium	U	0.0002	mg/L	0.0002	7/11/2016			SW846-6020	=
Uranium-234	U	1.45	pCi/L	7.28	7/11/2016	3.93	3.94	HASL 300, U-02-RC M	=
Uranium-235	U	1.67	pCi/L	4.56	7/11/2016	3.29	3.3	HASL 300, U-02-RC M	=
Uranium-238	U	0.461	pCi/L	6.67	7/11/2016	3.24	3.25	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Type of Sample: TB **Period:** Semiannual Report QC Samples

AKGWA Well Tag #: 0000-0000

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-)	TPU	Method	Validation
Trichloroethene	U	1	ug/L	1	7/13/2016			SW846-8260B	=
	U	1	ug/L	1	7/12/2016			SW846-8260B	=
	U	1	ug/L	1	7/11/2016			SW846-8260B	=

MEDIA Codes

WG Groundwater

QUALIFIER Codes

U Analyte analyzed for, but not detected at or below the lowest concentration reported.
J Estimated quantitation.

SAMPLE METHOD Codes

GR Grab

SAMPLING POINT Codes

UCRS Upper Continental Recharge System
URGA Upper Regional Gravel Aquifer

SAMPLE TYPE Codes

FB Field Blank
FR Field Replicate (Code used for Field Duplicate)
REG Regular
RI QC Equipment Rinseate/Decon
TB Trip Blank

VALIDATION Code

= Validated result, no qualifier is necessary.
J The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
U The analyte was analyzed for, but was not detected above the reported sample quantitation limit.
X Not validated.

APPENDIX B

C-404 HAZARDOUS WASTE LANDFILL STATISTICAL ANALYSES

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GROUNDWATER STATISTICAL SUMMARY

Introduction

The statistical analyses conducted on the data collected from C-404 Hazardous Waste Landfill (C-404 Landfill) were performed in accordance with procedures provided in Appendix E of the C-404 Hazardous Waste Management Permit, reissued by the Kentucky Division of Waste Management (KDWM) in July 2015. The percent of censored (nondetected) data points for individual parameters was calculated for the combined analytical data from the most recent five sampling events. The percent of censored data was used to select the types of statistical analyses to determine whether compliance well concentrations differed from background well concentrations. Data points were used in the statistical analysis for analyte results close to the sample quantitation limit that were judged to be below that limit by the data validator. For this report, the reporting period data set includes data from July 2014, January 2015, July 2015, January 2016, and July 2016.

Statistical Analysis Process

Utilizing the current data set and four previous data sets, the type of statistical test conducted for each chemical data set is a function of the number of samples and proportion of censored data (nondetects) to uncensored data (detects) in each group. The percent of censored (nondetected) data points for individual parameters was calculated for the combined analytical data. The statistical procedures applied to the data are summarized below.

- Determine the percentage of the censored data using the reporting period data set.

- Group by percentage of censored data where the following apply:

  — If censored data are greater than or equal to 90%, determine the limit of detection (LOD) and half of the LOD (1/2 LOD). This is Statistical Test 1.

  — If censored data are between 50% and 90%, perform a Test of Proportions. If the analysis indicates a significant proportional difference in compliance wells, further analyze through nonparametric Analysis of Variance (ANOVA) Test. This is Statistical Test 2.

  — If censored data are between 15% and 50%, perform nonparametric ANOVA Test. If results exceed the critical value, compute the critical difference used to identify individual well concentrations, which are significantly elevated compared with background. This is Statistical Test 3.

  — If censored data are less than 15%, actual data values are analyzed using parametric ANOVA procedures. If the wells exhibit equal variances, then the data are used as presented. If the wells do not exhibit equal variances, then the log of the data is taken and then used in the calculations. Where statistical testing indicates elevated compliance well concentrations, Bonferroni's Test of

Contrasts is performed. This is Statistical Test 4. If variances are found to be unequal even for log-transformed concentrations, Statistical Test 4 is abandoned and Statistical Test 3 is used to compare compliance wells with background wells. Statistical Test 4 is found in Section 5.2.1 of EPA guidance document, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance* (April 1989).

If the statistical method above indicates no statistical difference between concentrations in downgradient wells and concentrations in background wells, then there are no indications of statistically significant impacts on the groundwater from the C-404 Landfill. If the tiered statistical method above identifies a statistically significant difference between concentrations in downgradient wells and concentrations in background wells, then the data will be evaluated further to determine if the concentrations in downgradient wells are within statistically developed upper tolerance limit (UTL) for background concentrations or are consistent with the findings of the 2007 Alternate Source Demonstration (ASD), as follows:

(1) Compare the most recent downgradient sample results to a 95% UTL using the five most recent sets of data for each upgradient well as described below. If downgradient concentrations are lower than the UTL for the paired upgradient concentrations, then there is no confirmed exceedance.

(2) Evaluate results using paired ANOVA of wells in the same direction relative to the landfill (e.g., compare upgradient westernmost well results to downgradient westernmost well results). If ANOVA does not identify a statistically significant difference between upgradient and downgradient wells, then the results are consistent with the historical ASD.

(3) If results show downgradient wells have statistically significant higher concentrations than upgradient wells, even when evaluated with respect to the ASD, additional intra-well evaluation of trend will be performed using the Mann-Kendall test for trend. If concentrations do not show an increasing trend, then there is no confirmed exceedance attributable to C-404.

(4) Review other RGA well results in vicinity to determine if they are consistent with ASD.

If the statistical analysis identifies downgradient well concentrations that are increasing, are higher than UTL, are higher than the upgradient well concentrations even when the ASD results are taken into account, this evaluation will identify a confirmed, statistically significant exceedance (in a compliance well) over background.

Data Analysis

Data from the upgradient background wells in the Upper Regional Gravel Aquifer (URGA) are included for comparison with three downgradient URGA wells. Figure 1 of this C-404 Landfill Groundwater Report provides a map of the well locations associated with the C-404 Landfill. Upper Continental Recharge System (UCRS) wells in Figure 1 are provided for reference only. Data from wells that are in the UCRS are not included in the statistical analyses.

Table B.1 presents the C-404 Landfill upgradient or background wells and downgradient or compliance wells from the URGA. Data from the URGA compliance wells were compared with data from the URGA background wells.

Table B.1. Monitoring Well Locations

URGA	
Upgradient background wells	MW93, MW420
Downgradient compliance wells	MW84, MW87, MW90A*

*MW90 was abandoned in 2001 and replaced with MW90A.

For this report, the reporting period data set from July 2014 through July 2016 consists of five sets of data.

Table B.2 lists the number of analyses (observations), nondetects (censored observations), detects (uncensored observations), and missing observations by parameter. When field duplicate data are available from a well, the higher of the two readings was retained for further evaluation.

Censoring Percentage and Statistical Analysis

The type of statistical test set applied to the data is a function of the number of nondetects (censored) versus detects (uncensored) in each of the parameter groups and among the wells. Table B.3 presents the percentage of censored and uncensored data and type of statistical test chosen for each of the parameters.

Table B.2. Summary of Missing, Censored, and Uncensored Data Collected

Parameters	Observations	Missing Observations*	Censored Observations (Nondetects)	Uncensored Observations (Detects)
URGA				
Arsenic	25	0	10	15
Arsenic, Dissolved	25	0	17	8
Cadmium	25	0	16	9
Cadmium, Dissolved	25	0	25	0
Chromium	25	0	8	17
Chromium, Dissolved	25	0	14	11
Lead	25	0	14	11
Lead, Dissolved	25	0	25	0
Mercury	25	0	25	0
Mercury, Dissolved	25	0	25	0
Selenium	25	0	19	6
Selenium, Dissolved	25	0	21	4
Technetium-99	25	0	24	1
Trichloroethene	25	0	0	25
Uranium (Metals)	25	0	11	14
Uranium-234	25	0	25	0
Uranium-235	25	0	25	0
Uranium-238	25	0	25	0

*Missing parameters that were dissolved metals were not analyzed when the parent total metals were not detected in prior sampling events.

Table B.3. Percent Censored Report and Statistical Test Set Selected

Parameter	Total Samples (Nonmissing)	Censored (Nondetects)	Uncensored (Detects)	Percent Censored	Statistical Test Set*
URGA					
Arsenic	25	10	15	40.00	3
Arsenic, Dissolved	25	17	8	68.00	2
Cadmium	25	16	9	64.00	2
Cadmium, Dissolved	25	25	0	100.00	1
Chromium	25	8	17	32.00	3
Chromium, Dissolved	25	14	11	56.00	2
Lead	25	14	11	56.00	2
Lead, Dissolved	25	25	0	100.00	1
Mercury	25	25	0	100.00	1
Mercury, Dissolved	25	25	0	100.00	1
Selenium	25	19	6	76.00	2
Selenium, Dissolved	25	21	4	84.00	2
Technetium-99	25	24	1	96.00	1
Trichloroethene	25	0	25	0.00	4/3**
Uranium (Metals)	25	11	14	44.00	3
Uranium-234	25	25	0	100.00	1
Uranium-235	25	25	0	100.00	1
Uranium-238	25	25	0	100.00	1

*A list of the constituents with greater than or equal to 90% censored data is included in Table B.4, which summarizes the results of Statistical Test 1.

**Because equality of variance could not be confirmed, Statistical Test 4, Parametric ANOVA, was abandoned, and Statistical Test 3, Nonparametric ANOVA, was performed.

SUMMARY OF CONCLUSIONS

The results for Statistical Test 1, LOD, are summarized in Table B.4. Table B.5 provides the summary of conclusions for the statistical analyses for the C-404 Landfill, including the statistical tests performed, the attachment number, well type, parameter, and results of each statistical test. Results of Statistical Test 2, Statistical Test 3, and Statistical Test 4 are presented in Attachments B1 through B10. The statistician qualification statement is presented in Attachment B11.

Table B.4. Statistical Test 1: Limit of Detection

Parameter	LOD Values	½ LOD Values
URGA		
Cadmium, Dissolved (mg/L)	0.001	0.0005
Lead, Dissolved (mg/L)	0.002	0.001
Mercury (mg/L)	0.0002	0.0001
Mercury, Dissolved (mg/L)	0.0002	0.0001
Technetium-99 (pCi/L)	18.3	9.15
Uranium-234 (pCi/L)	5.72	2.86
Uranium-235 (pCi/L)	5.2	2.6
Uranium-238 (pCi/L)	6.15	3.075

In summary, Statistical Test 2, Test of Proportions, for dissolved arsenic, cadmium, dissolved chromium, lead, selenium, and dissolved selenium in the URGA indicated no statistically significant difference between concentrations in downgradient wells and concentrations in background wells.

Statistical Test 3, Nonparametric ANOVA, for arsenic in the URGA identified a statistically significant difference between concentrations in downgradient wells and concentrations in background wells; therefore, the data were evaluated further by comparing results to the UTL. The 95% UTL indicated a statistically significant difference between concentrations in downgradient wells and concentrations in background wells. Based on these results, the data were evaluated using paired (parametric) ANOVA of wells in the same direction relative to the landfill [e.g., a comparison was performed of upgradient westernmost well results (MW84) to downgradient westernmost well (MW93) results]. Results of the ANOVA have not identified that there is a significant difference between upgradient and downgradient wells, and the results are consistent with the historical 2007 Alternate Source Demonstration. A Mann-Kendall test was performed to further evaluate the data, and it identified a positive trend in MW84.

Statistical Test 3, Nonparametric ANOVA, for chromium in the URGA identified a statistically significant difference between concentrations in downgradient wells and concentrations in background wells; therefore, the data were evaluated further by comparing results to the UTL. The 95% UTL indicated there was no statistically significant difference between concentrations in downgradient wells and concentrations in background wells.

Statistical Test 4, Parametric ANOVA, could not be used for trichloroethene in the URGA because there was no evidence of equality of variance. Thus, Statistical Test 4 was abandoned and Statistical Test 3, Nonparametric ANOVA, was performed. Statistical Test 3 showed there was no statistically significant

difference between concentrations in downgradient wells and concentrations in background wells for trichloroethene.

Statistical Test 3, Nonparametric ANOVA, for uranium in the URGA indicated no statistically significant difference between concentrations in downgradient wells and concentrations in background wells.

Table B.5. Summary of Conclusions from the Statistical Analyses for the C-404 Hazardous Waste Landfill for the July 2016 Data Set

Attachment	RGA Well Type	Parameter	Applied Statistical Test	Results
B1	URGA	Arsenic	Statistical Test 3, Nonparametric ANOVA with 95% UTL, paired ANOVA (MW84 vs. MW93), Mann-Kendall, and data review	Because Nonparametric ANOVA indicated a statistically significant difference between concentrations in downgradient wells and concentrations in background wells for compliance well MW84, a comparison to the 95% UTL, paired ANOVA, Mann-Kendall, and an attempt to review data were performed, as required by the Hazardous Waste Facility Permit. Results of the ANOVA have not identified significant difference between upgradient and downgradient wells, and the results are consistent with the historical 2007 Alternate Source Demonstration. The Mann-Kendall identified a positive trend in MW84.
B2	URGA	Arsenic, Dissolved	Statistical Test 2, Test of Proportions	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B3	URGA	Cadmium	Statistical Test 2, Test of Proportions	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B4	URGA	Chromium	Statistical Test 3, Nonparametric ANOVA/95% UTL	Because Nonparametric ANOVA indicated a statistically significant difference between concentrations in downgradient wells and concentrations in background wells for compliance well MW84, comparison to the 95% UTL was performed, as required by the Hazardous Waste Facility Permit. Results of the comparison showed no statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B5	URGA	Chromium, Dissolved	Statistical Test 2, Test of Proportions	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B6	URGA	Lead	Statistical Test 2, Test of Proportions	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.

Table B.5. Summary of Conclusions from the Statistical Analyses for the C-404 Hazardous Waste Landfill for the July 2016 Data Set (Continued)

Attachment	RGA Well Type	Parameter	Applied Statistical Test	Results
B7	URGA	Selenium	Statistical Test 2, Test of Proportions	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B8	URGA	Selenium, Dissolved	Statistical Test 2, Test of Proportions	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B9	URGA	Trichloroethene	Statistical Test 4, Parametric ANOVA/ Statistical Test 3, Nonparametric ANOVA	Because equality of variance could not be confirmed, Statistical Test 4 was abandoned and Statistical Test 3, Nonparametric ANOVA, was performed. Results of this analysis showed no statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B10	URGA	Uranium	Statistical Test 3, Nonparametric ANOVA	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.

ATTACHMENT B1

ARSENIC
STATISTICAL TEST 3

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Arsenic (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-14	**0.0058**	0.0025	**0.00511**	**0.00302**	0.0025
Jan-15	**0.00185**	0.0025	**0.0073**	**0.00174**	0.0025
Jul-15	**0.00702**	0.0025	**0.00922**	**0.00447**	0.0025
Jan-16	**0.00743**	0.0025	**0.0103**	**0.00481**	0.0025
Jul-16	**0.00709**	0.0025	**0.0137**	**0.00698**	0.0025
Sum	0.0417		0.04563	0.02102	0.0125
n_i	10		5	5	5
$(x_i)_{avg}$	0.00417		0.00913	0.00420	0.0025

mg/L = milligrams per liter
BG = background
DL = detection limit
All data sets represent 1/2 DL values for nondetects.
Bolded values indicate a detected result.

Overall mean x.. =	0.00483
N =	25
p =	4
x.. =	0.12

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	Arsenic (mg/L)	Adjusted Rank	Tie Number
1	0	5.5	Tie 1
2	0	5.5	
3	0	5.5	
4	0	5.5	
5	0	5.5	
6	0	5.5	
7	0	5.5	
8	0	5.5	
9	0	5.5	
10	0	5.5	
11	**0.00174**	11	
12	**0.00185**	12	
13	**0.00302**	13	
14	**0.00447**	14	
15	**0.00481**	15	
16	**0.00511**	16	
17	**0.0058**	17	
18	**0.00698**	18	
19	**0.00702**	19	
20	**0.00709**	20	
21	**0.0073**	21	
22	**0.00743**	22	
23	**0.00922**	23	
24	**0.0103**	24	
25	**0.0137**	25	

mg/L = milligrams per liter
BG = background
DL = detection limit
Bolded values indicate a detected result.
NOTE: For this method, observations below the detection limit are reported as a concentration of 0.

n_{tie}	Adjustment for Ties: $(n_{tie}^3 - n_{tie})$	
10	Tie 1 =	990
	$\sum T_i$ =	990

Sums of Ranks and Averages

Arsenic (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-14	**0.0058**	0	**0.00511**	**0.00302**	0
Jan-15	**0.00185**	0	**0.0073**	**0.00174**	0
Jul-15	**0.00702**	0	**0.00922**	**0.00447**	0
Jan-16	**0.00743**	0	**0.0103**	**0.00481**	0
Jul-16	**0.00709**	0	**0.0137**	**0.00698**	0

Observation Ranks for Arsenic					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-14	17	5.5	16	13	5.5
Jan-15	12	5.5	21	11	5.5
Jul-15	19	5.5	23	14	5.5
Jan-16	22	5.5	24	15	5.5
Jul-16	20	5.5	25	18	5.5
R_i	117.5		109	71	27.5
$(R_i)_{avg}$	11.8		21.8	14.2	5.5
R_i^2/n_i	1380.6		2376.2	1008.2	151.3

$\Sigma R_i^2/n_i$ = 4916.3

mg/L = milligrams per liter
BG = background
DL = detection limit
Bolded values indicate a detected result.

K = 4
N = 25

NOTE: For this method, observations below the detection limit are reported as a concentration of 0.

Calculation of Kruskal-Wallis Statistic

H =	12.762	Kruskal-Wallis Statistic	$H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$
H' =	13.627	Corrected Kruskal-Wallis	$H' = H/[1-(\sum T_i/N^3-N)]$
χ^2_{crit}* =	7.815	3	degrees of freedom at the 5% significance level

NOTE: $H' > \chi^2_{crit}$

If $H' \leq \chi^2_{crit}$, the data from each well come from the same continuous distribution and hence have the same median concentrations of a specific constituent.

If $H' > \chi^2_{crit}$, reject the null hypothesis and calculate the critical difference for well comparisons to the background.

K-1 =	3	α/(K-1) =	0.01667	Z(α/(K-1))** =	2.1280
α =	0.05	1-(α/K-1) =	0.983		

NOTE *Table 1, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).
**Table 4, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Calculate Critical Values

Average Background Ranking = 11.750

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93			
BG Well	MW420			
	MW84	8.578	10.05	evidence of contamination
	MW87	8.578	2.45	not contaminated
	MW90A	8.578	-6.25	not contaminated

mg/L = milligrams per liter
BG = background
DL = detection limit

CONCLUSION: If $(R_i)_{avg} - (R_b)_{avg} > C_i$, then there is evidence that the compliance well is contaminated.

If $(R_i)_{avg} - (R_b)_{avg} < C_i$ for wells, there is no evidence of a statistically significant difference between concentrations in downgradient compliance test wells and background wells.

Since $(R_i)_{avg} - (R_b)_{avg} > C_i$ for MW84, there is a statistically significant difference between downgradient compliance test wells and background wells in MW84 from C-404.

Because nonparametric ANOVA indicated a statistically significant difference between compliance test wells and background wells at the C-404 Landfill in compliance well MW84, the 95% UTL was performed.

Since $(R_i)_{avg} - (R_b)_{avg} < C_i$ for MW87 and MW90A, there is no statistically significant difference from C-404 in these downgradient compliance test wells.

Section 5.2.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

95% Upper Tolerance Limit (UTL)

Compare the most recent downgradient sample results to a calculated 95% UTL using the five most recent sets of data for each upgradient well, as described below. If downgradient concentration is less than the UTL for the paired upgradient concentrations, then there is no confirmed exceedance.

July 2016 Data, Second Reporting Period
Observations (mg/L)

Well No.						
MW93	**0.0058**	**0.00185**	**0.00702**	**0.00743**	**0.00709**	**Upgradient Well**[!]
MW420	0.0025	0.0025	0.0025	0.0025	0.0025	**Upgradient Well**[!]
MW84		X: Mean Value =	0.0042			**0.0137**
MW87		S: Standard Devi	0.0023			0.00698
MW90A		K* factor =	2.911	(for n = 10)		0.0025
		CV = S/X		0.5612 <1, assume normal distribution		
		Upper Tolerance Interval: TL = X +(KxS) =		**0.0110**	(mg/L)	

! = Data from previous 5 sampling events.
* = Table 5, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Result: **MW84 exceeded the UTL, which is statistically significant evidence that this compliance well has elevated concentration with respect to background data.**

Because the 95% UTL indicated a statistically significant difference between compliance test wells and background wells at the C-404 Landfill in compliance well MW84, the paired ANOVA was performed.

Paired (Parametric) ANOVA

Evaluate results using paired ANOVA of wells in the same direction relative to the landfill [e.g., compare upgradient westernmost well (i.e., MW93) results to downgradient westernmost well (i.e., MW84) results]. If ANOVA does not identify a statistically significant difference between upgradient and downgradient wells, then the results are consistent with the historical ASD.

Arsenic (mg/L)				
Date	Background	Compliance		
	MW93	MW84	n_i^2	
Jul-14	**0.0058**	**0.00511**	0.0000336	0.0000261
Jan-15	**0.00185**	**0.0073**	0.0000034	0.0000533
Jul-15	**0.00702**	**0.00922**	0.0000493	0.0000850
Jan-16	**0.00743**	**0.0103**	0.0000552	0.0001061
Jul-16	**0.00709**	**0.0137**	0.0000503	0.0001877
Sum (x_i)	0.0292	0.04563	0.0748	Total Sum (x..)
n_i	5	5		
$(x_i)_{avg}$	0.00584	0.00913		
$(x_i)^2$	0.00085	0.00208		

mg/L = milligrams per liter
Bolded values indicate a detected result.

Overall mean x.. = 0.00748
N = 10
p = 2
$x_{..}$ = 0.0748

Determine Normality of Dataset

Coefficient of Variability Test

Table of Residuals (x_i-$x_i$avg)

Date	Background	Compliance
	MW93	MW84
Jul-14	-0.00004	-0.00402
Jan-15	-0.00399	-0.00183
Jul-15	0.00118	0.00009
Jan-16	0.00159	0.00117
Jul-16	0.00125	0.00457

X: Mean Value = 0.00000
S: Standard Deviation = 0.00265
K* Factor = 2.911 (for n = 10)
CV = S/X = #ΔIç/0! †Unable to calculate due to the mean being zero.

†The Coefficient of Variability Test was not performed due to mean = 0 (i.e., division by 0 not possible).

*Table 5, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

If the coefficient of variation is < 1, the residuals appear to be normally distributed.
If the coefficient of variation is > or = 1, the residuals are not normally distributed.

Determine Equality of Variance of Dataset

p = number of wells	$x_{..} =$ 0.0748
n_i = number of data points per well	$(x_{avg})_{..} =$ 0.00748
N = total sample size	$n_i =$ 5
S^2 = the square of the standard deviation	p = 2
$\ln(S_i^2)$ = natural logarithm of each variance	N = 10
f = total sample size minus the number of wells (groups)	f_i = 4
$f_i = n_i - 1$	

Calculations for Equality of Variance: Bartlett's Test

S_i	S_i^2	$\ln(S_i^2)$	n_i	$f_i S_i^2$	$f_i \ln(S_i^2)$
0.00231	0.00001	-12.138	5	0.0000214	-48.6
0.00323	0.00001	-11.470	5	0.0000418	-45.9

$\sum(S_i^2) =$ 0.00002 $\quad\quad$ $\sum f_i \ln(S_i^2) =$ -94.43118

Equality of Variance: Bartlett's Test

f =	8	
Sp^2 =	0.0000079	
ln Sp^2 =	-11.749	
χ^2 =	0.439	(If calculated $\chi^2 \leq \chi^2_{crit}$, then variances are equal at the given significance level).
χ^2_{crit} * =	3.841	at a 5% significance level with 1 degrees of freedom (p-1)

Since calculated $\chi 2 \leq \chi 2_{crit}$, then the analysis can proceed as normal.

*Table 1, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Between Well Sum of Squares

Source of Variation	Sums of Squares		Degrees of Freedom	Mean Squares	Calculated F	F Statistic**
Between Wells	SS_{wells} =	0.00003	1	0.00003	3.42	5.32
Error	SS_{Error} =	0.00006	8	0.000008		
Total	SS_{Total} =	0.00009	9			

If calculated F > F statistic, then reject the hypothesis of equal well means. If calculated F is less than or equal to F statistic, it can be concluded that there is no significant difference between concentrations; therefore, there is no evidence of well contamination.

CONCLUSION: **Calculated F < F statistic; therefore, ANOVA has not identified there to be a significant difference between upgradient and downgradient wells and the results are consistent with the historical 2007 Alternate Source Demonstration.**

**Table 2, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989). F statistic taken at the 5% significance level.

MW84 Trend Summary Utilizing the Previous Eight Quarters

Location	Well ID	Parameter	Sample Size	Alpha[1]	p-Value[2]	S[3]	Var(S)[4]	Sen's Slope[5]	Kendall Correlation[6]	Decision[7]
C-404	MW84	Arsenic	8	0.05	0.007	20.00	0.000	0.001	0.714	**Positive Trend**

Footnotes:

[1]An alpha of 0.05 represents a 95% confidence interval.

[2]The p-value represents the risk of acceptance the H_a hypothesis of a trend, in terms of a percentage.

[3]The initial value of the Mann-Kendall statistic, S, is assumed to be 0 (e.g., no trend). If a data value from a later time period is higher than a data value from an earlier time period, S is incremented by 1. On the other hand, if the data value from a later time period is lower than a data value sampled earlier, S is decremented by 1. The net result of all such increments and decrements yields the final value of S. A very high positive value of S is an indicator of an increasing trend, and a very low negative value indicates a decreasing trend.

[4]VAR(S) represents the varience of S in the sample set and takes into account statistical ties.

[5]The magnitude of trend is predicted by the Sen's Slope. Here, the slope is described as the median of all $(x_j-x_k)/(j-k)$, where x is a data point, and j and k are values of time.

[6]Kendall's correlation is described as the difference of concordant pairs and discordant pairs, also taking sample size and statistical ties into account. When the Kendall's correlation is postive, it indicates an increasing trend, and when it is negative, it indicates a decreasing trend.

[7]The Mann-Kendall decision operates on two hypothesis, the H_0 and H_a. H_0 assumes there is no trend in the data, whereas H_a assumes either a positve or negative trend. Two different tests were run to test for positive or negative trends. This table reports the test with the lowest p-value.

Note: Statistics generated using XLSTAT Version 2016

ATTACHMENT B2

ARSENIC (DISSOLVED)
STATISTICAL TEST 2

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Attachment B2: Statistical Test 2, Test of Proportions, July 2016
Arsenic, Dissolved URGA

Arsenic, Dissolved (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-14	0.0025	0.0025	0.0025	0.0025	0.0025
Jan-15	**0.0035**	0.0025	**0.00245**	0.0025	0.0025
Jul-15	**0.00478**	0.0025	**0.00544**	**0.00273**	0.0025
Jan-16	0.0025	0.0025	0.0025	0.0025	0.0025
Jul-16	**0.00434**	0.0025	**0.00737**	**0.00282**	0.0025

mg/L = milligrams per liter
BG = background
DL = detection limit
All data sets represent 1/2 DL values for nondetects.
Bolded values indicate a detected result.

[!]Test of Proportions

Calculate the number of detections in background wells vs. compliance wells.

X =	3	X = number of samples above DL in background wells
Y =	5	Y = number of samples above DL in compliance wells
n_b =	10	n_b = count of background well results/samples analyzed
n_c =	15	n_c = count of compliance well results/samples analyzed
n =	25	n = total number of samples

P =	0.320	P = (x+y)/n
nP =	8	n = n_b+n_c
n(1-P) =	17	

NOTE: If nP and n(1-P) are both >= 5, then the normal approximation may be used.

P_b =	0.300	P_b = proportion of detects in background wells
P_c =	0.333	P_c = proportion of detects in compliance wells
S_D =	0.190	S_D = standard error of difference in proportions
Z =	-0.175	Z = (P_b-P_c)/S_D
absolute value of Z =	0.175	

If the absolute value of Z exceeds the 97.5th percentile value of 1.96 from the standard normal distribution, this provides statistically significant evidence at the 5% significance level that the proportion of detects in one group of data exceeds the proportion of detects in the other group.

CONCLUSION: Because the absolute value of Z is less than 1.96, there is no statistical evidence that the proportion of samples with detected results differs between the background well and compliance well samples.

[!] Section 8.1.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance* (EPA 1989).

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ATTACHMENT B3

CADMIUM
STATISTICAL TEST 2

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Attachment B3: Statistical Test 2, Test of Proportions, July 2016
Cadmium URGA

Cadmium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-14	0.0005	0.0005	0.0005	0.0005	0.0005
Jan-15	0.0005	0.0005	**0.00018**	**0.00014**	0.0005
Jul-15	0.0005	0.0005	**0.00012**	0.0005	0.0005
Jan-16	**0.000152**	0.0005	**0.000179**	**0.000121**	0.0005
Jul-16	**0.000199**	0.0005	**0.000292**	**0.000451**	0.0005

mg/L = milligrams per liter
BG = background
DL = detection limit
All data sets represent 1/2 DL values for nondetects.
Bolded values indicate a detected result.

[!] Test of Proportions

Calculate the number of detections in background wells vs. compliance wells.

X =	2	X = number of samples above DL in background wells
Y =	7	Y = number of samples above DL in compliance wells
n_b =	10	n_b = count of background well results/samples analyzed
n_c =	15	n_c = count of compliance well results/samples analyzed
n =	25	n = total number of samples

P =	0.360	P = (x+y)/n
nP =	9	$n = n_b+n_c$
n(1-P) =	16	

NOTE: If nP and n(1-P) are both >= 5, then the normal approximation may be used.

P_b =	0.200	P_b = proportion of detects in background wells
P_c =	0.467	P_c = proportion of detects in compliance wells
S_D =	0.196	S_D = standard error of difference in proportions
Z =	-1.361	$Z = (P_b-P_c)/S_D$
absolute value of Z =	1.361	

If the absolute value of Z exceeds the 97.5th percentile value of 1.96 from the standard normal distribution, this provides statistically significant evidence at the 5% significance level that the proportion of detects in one group of data exceeds the proportion of detects in the other group.

CONCLUSION: Because the absolute value of Z is less than 1.96, there is no statistical evidence that the proportion of samples with detected results differs between the background well and compliance well samples.

[!] Section 8.1.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance* (EPA 1989).

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ATTACHMENT B4

CHROMIUM
STATISTICAL TEST 3

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Attachment B4: Statistical Test 3, Nonparametric ANOVA, July 2016 Chromium URGA

Chromium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-14	**0.011**	0.005	**0.331**	**0.00903**	**0.00227**
Jan-15	**0.0273**	0.005	**0.442**	**0.031**	0.005
Jul-15	**0.00473**	0.005	**0.0347**	**0.00809**	0.005
Jan-16	**0.0401**	0.005	**0.0393**	**0.0266**	**0.00525**
Jul-16	**0.207**	0.005	**0.0206**	**0.165**	0.005
Sum	0.3151		0.86760	0.23972	0.0225
n_i	10		5	5	5
$(x_i)_{avg}$	0.03151		0.17352	0.04794	0.0045

mg/L = milligrams per liter
BG = background
DL = detection limit
All data sets represent 1/2 DL values for nondetects.
Bolded values indicate a detected result.

Overall mean x.. = 0.05780

N = 25
p = 4
x.. = 1.44

Attachment B4: Statistical Test 3, Nonparametric ANOVA, July 2016 Chromium URGA

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	Chromium (mg/L)	Adjusted Rank	Tie Number
1	0	0	Tie 1
2	0	0	
3	0	0	
4	0	0	
5	0	0	
6	0	0	
7	0	0	
8	0	0	
9	**0.00227**	9	
10	**0.00473**	10	
11	**0.00525**	11	
12	**0.00809**	12	
13	**0.00903**	13	
14	**0.011**	14	
15	**0.0206**	15	
16	**0.0266**	16	
17	**0.0273**	17	
18	**0.031**	18	
19	**0.0347**	19	
20	**0.0393**	20	
21	**0.0401**	21	
22	**0.165**	22	
23	**0.207**	23	
24	**0.331**	24	
25	**0.442**	25	

mg/L = milligrams per liter
BG = background
DL = detection limit
Bolded values indicate a detected result.
NOTE: For this method, observations below the detection limit are reported as a concentration of 0.

n_{tie}	Adjustment for Ties: $(n_{tie}^3 - n_{tie})$
8	Tie 1 = 504
	$\sum T_i$ = 504

Attachment B4: Statistical Test 3, Nonparametric ANOVA, July 2016 Chromium URGA

Sums of Ranks and Averages

Chromium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-14	**0.011**	0	**0.331**	**0.00903**	**0.00227**
Jan-15	**0.0273**	0	**0.442**	**0.031**	0
Jul-15	**0.00473**	0	**0.0347**	**0.00809**	0
Jan-16	**0.0401**	0	**0.0393**	**0.0266**	**0.00525**
Jul-16	**0.207**	0	**0.0206**	**0.165**	0

Observation Ranks for Chromium					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-14	**14**	4.5	**24**	**13**	**9**
Jan-15	**17**	4.5	**25**	**18**	4.5
Jul-15	**10**	4.5	**19**	**12**	4.5
Jan-16	**21**	4.5	**20**	**16**	**11**
Jul-16	**23**	4.5	**15**	**22**	4.5
R_i	107.5		103	81	33.5
$(R_i)_{avg}$	10.8		20.6	16.2	6.7
R_i^2/n_i	1155.6		2121.8	1312.2	224.5

$\Sigma R_i^2/n_i$ = 4814.1

K = 4

N = 25

mg/L = milligrams per liter

BG = background

DL = detection limit

Bolded values indicate a detected result.

NOTE: For this method, observations below the detection limit are reported as a concentration of 0.

Calculation of Kruskal-Wallis Statistic

H = 10.875 Kruskal-Wallis Statistic $H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$

H' = 11.238 Corrected Kruskal-Wallis $H' = H/[1-(\sum T_i/N^3-N)]$

χ^2_{crit}* = 7.815 3 degrees of freedom at the 5% significance level

NOTE: $H' > \chi^2_{crit}$

If $H' \leq \chi^2_{crit}$, the data from each well come from the same continuous distribution and hence have the same median concentrations of a specific constituent.

If $H' > \chi^2_{crit}$, reject the null hypothesis and calculate the critical difference for well comparisons to the background.

K-1 = 3 $\alpha/(K-1)$ = 0.01667 $Z(\alpha/(K-1))$** = 2.1280

α = 0.05 $1-(\alpha/K-1)$ = 0.983

NOTE *Table 1, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

**Table 4, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Attachment B4: Statistical Test 3, Nonparametric ANOVA, July 2016 Chromium URGA

Calculate Critical Values

Average Background Ranking = 10.750

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93			
BG Well	MW420			
	MW84	8.578	9.85	evidence of contamination
	MW87	8.578	5.45	not contaminated
	MW90A	8.578	-4.05	not contaminated

mg/L = milligrams per liter
BG = background
DL = detection limit

CONCLUSION: If $(R_i)_{avg} - (R_b)_{avg} > C_i$, then there is evidence that the compliance well is contaminated.

If $(R_i)_{avg} - (R_b)_{avg} < C_i$ for wells, there is no evidence of a statistically signficant difference between concentrations in downgradient compliance test wells and background wells.

Since $(R_i)_{avg} - (R_b)_{avg} > C_i$ for MW84, there is a statistically significant difference between downgradient compliance test wells and background wells in MW84 from C-404.

Because nonparametric ANOVA indicated a statistically significant difference between compliance test wells and background wells at the C-404 Landfill in compliance well MW84, the 95% UTL was performed.

Since $(R_i)_{avg} - (R_b)_{avg} < C_i$ for MW87 and MW90A, there is no statistically significant difference from C-404 in these downgradient compliance test wells.

Section 5.2.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Attachment B4: Statistical Test 3, Nonparametric ANOVA, July 2016 Chromium URGA

95% Upper Tolerance Limit (UTL)

Compare the most recent downgradient sample results to a calculated 95% UTL using the five most recent sets of data for each upgradient well, as described below. If downgradient concentration is less than the UTL for the paired upgradient concentrations, then there is no confirmed exceedance.

July 2016 Data, Second Reporting Period
Observations (mg/L)

Well No.							
MW93	**0.011**	**0.0273**	**0.00473**	**0.0401**	**0.207**		**Upgradient Well[!]**
MW420	0.01	0.01	0.01	0.01	0.01		**Upgradient Well[!]**
MW84		X: Mean Value =		0.0340		0.0206	
MW87		S: Standard Deviation =		0.0617		0.165	
MW90A		K* factor =		2.911	(for n = 10)	0.01	
		CV = S/X	**1.8144**	≥1**			
		Upper Tolerance Interval: TL = X +(KxS)		**0.2137**	**(mg/L)**		

! = Data from previous 5 sampling events.
* = K Factor (from Table 5, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* , USEPA 1989.)

**** Redo the test using log-transformed data since the distributions were not normal.**

Observations (mg/L)

Well No.							
MW93	**0.011**	**0.0273**	**0.00473**	**0.0401**	**0.207**		**Upgradient Well[!]**
MW420	0.01	0.01	0.01	0.01	0.01		**Upgradient Well[!]**
		LOG TRANSFORMED DATA					
MW93	**-4.5099**	**-3.6009**	**-5.3538**	**-3.2164**	**-1.5750**		**Log transformed data[!]**
MW420	**-4.6052**	**-4.6052**	**-4.6052**	**-4.6052**	**-4.6052**		**Log transformed data[!]**
							Log Data
MW84		X: Mean Value =		-4.1282		0.0206	-3.8825
MW87		S: Standard Deviation =		1.0757		0.165	-1.8018
MW90A		K* factor =		2.911	(for n = 10)	0.01	-5.2495
		CV = S/X	**-0.2606**	<1, assume normal distribution			
		Upper Tolerance Interval: TL = X +(KxS)		**-0.9969**	**(mg/L)**		

! = Data from previous 5 sampling events.
* = K Factor (from Table 5, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* , USEPA 1989.)

Result: **None of the Test Wells had exceeded the UTL, which is statistically significant evidence that these wells have no elevated concentration with respect to background data.**

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ATTACHMENT B5

CHROMIUM, DISSOLVED
STATISTICAL TEST 2

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Attachment B5: Statistical Test 2, Test of Proportions, July 2016
Chromium, Dissolved URGA

Chromium, Dissolved (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-14	0.005	0.005	**0.00228**	**0.00205**	**0.00231**
Jan-15	0.005	0.005	**0.00405**	0.005	0.005
Jul-15	0.005	0.005	0.005	0.005	0.005
Jan-16	**0.00323**	**0.00252**	**0.00856**	**0.00370**	**0.00618**
Jul-16	**0.0021**	0.005	0.005	**0.00438**	0.005

mg/L = milligrams per liter
BG = background
DL = detection limit
All data sets represent 1/2 DL values for nondetects.
Bolded values indicate a detected result.

[!] **Test of Proportions**

Calculate the number of detections in background wells vs. compliance wells.

X =	3	X = number of samples above DL in background wells
Y =	8	Y = number of samples above DL in compliance wells
n_b =	10	n_b = count of background well results/samples analyzed
n_c =	15	n_c = count of compliance well results/samples analyzed
n =	25	n = total number of samples

P =	0.440	P = (x+y)/n
nP =	11	n = n_b+n_c
n(1-P) =	14	

NOTE: If nP and n(1-P) are both >= 5, then the normal approximation may be used.

P_b =	0.300	P_b = proportion of detects in background wells
P_c =	0.533	P_c = proportion of detects in compliance wells
S_D =	0.203	S_D = standard error of difference in proportions
Z =	-1.151	Z = (P_b-P_c)/S_D
absolute value of Z =	1.151	

If the absolute value of Z exceeds the 97.5th percentile value of 1.96 from the standard normal distribution, this provides statistically significant evidence at the 5% significance level that the proportion of detects in one group of data exceeds the proportion of detects in the other group.

CONCLUSION: Because the absolute value of Z is less than 1.96, there is no statistical evidence that the proportion of samples with detected results differs between the background well and compliance well samples.

[!] Section 8.1.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance* (EPA 1989).

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ATTACHMENT B6

LEAD
STATISTICAL TEST 2

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Attachment B6: Statistical Test 2, Test of Proportions, July 2016
Lead URGA

Lead (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-14	**0.00066**	0.001	0.001	0.001	0.001
Jan-15	**0.0024**	0.001	**0.00189**	**0.0009**	0.001
Jul-15	0.001	0.001	**0.00088**	0.001	0.001
Jan-16	**0.00144**	0.001	**0.00108**	**0.00107**	0.001
Jul-16	**0.00181**	0.001	**0.00239**	**0.0056**	0.001

mg/L = milligrams per liter
BG = background
DL = detection limit
Nondetect values are 1/2 DL.
Bolded values indicate a detected result.

[!] **Test of Proportions**

Calculate the number of detections in background wells vs. compliance wells.

X =	4	X = number of samples above DL in background wells
Y =	7	Y = number of samples above DL in compliance wells
n_b =	10	n_b = count of background well results/samples analyzed
n_c =	15	n_c = count of compliance well results/samples analyzed
n =	25	n = total number of samples

P =	0.440	P = (x+y)/n
nP =	11	$n = n_b+n_c$
n(1-P) =	14	

NOTE: If nP and n(1-P) are both >= 5, then the normal approximation may be used.

P_b =	0.400	P_b = proportion of detects in background wells
P_c =	0.467	P_c = proportion of detects in compliance wells
S_D =	0.203	S_D = standard error of difference in proportions
Z =	-0.329	$Z = (P_b-P_c)/S_D$
absolute value of Z =	0.329	

If the absolute value of Z exceeds the 97.5th percentile value of 1.96 from the standard normal distribution, this provides statistically significant evidence at the 5% significance level that the proportion of detects in one group of data exceeds the proportion of detects in the other group.

CONCLUSION: Because the absolute value of Z is less than 1.96, there is no statistical evidence that the proportion of samples with detected results differs between the background well and compliance well samples.

[!] Section 8.1.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance* (EPA 1989).

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ATTACHMENT B7

SELENIUM
STATISTICAL TEST 2

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Attachment B7: Statistical Test 2, Test of Proportions, July 2016
Selenium URGA

Selenium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-14	0.0025	0.0025	0.0025	0.0025	**0.00166**
Jan-15	0.0025	0.0025	0.0025	0.0025	**0.00182**
Jul-15	0.0025	0.0025	0.0025	0.0025	0.0025
Jan-16	**0.00165**	0.0025	0.0025	0.0025	**0.00231**
Jul-16	0.0025	0.0025	0.0025	**0.00159**	**0.0017**

mg/L = milligrams per liter
BG = background
DL = detection limit
Nondetect values are 1/2 DL.
Bolded values indicate a detected result.

[!]Test of Proportions

Calculate the number of detections in background wells vs. compliance wells.

X =	1	X = number of samples above DL in background wells
Y =	5	Y = number of samples above DL in compliance wells
n_b =	10	n_b = count of background well results/samples analyzed
n_c =	15	n_c = count of compliance well results/samples analyzed
n =	25	n = total number of samples

P =	0.240	P=(x+y)/n
nP =	6	$n=n_b+n_c$
n(1-P) =	19	

NOTE: If nP and n(1-P) are both >= 5, then the normal approximation may be used.

P_b =	0.100	P_b = proportion of detects in background wells
P_c =	0.333	P_c = proportion of detects in compliance wells
S_D =	0.174	S_D = standard error of difference in proportions
Z =	-1.338	$Z = (P_b-P_c)/S_D$
absolute value of Z =	1.338	

If the absolute value of Z exceeds the 97.5th percentile value of 1.96 from the standard normal distribution, this provides statistically significant evidence at the 5% significance level that the proportion of detects in one group of data exceeds the proportion of detects in the other group.

CONCLUSION: Because the absolute value of Z is less than 1.96, there is no statistical evidence that the proportion of samples with detected results differs between the background well and compliance well samples.

[!]Section 8.1.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance* (EPA 1989).

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ATTACHMENT B8

SELENIUM, DISSOLVED
STATISTICAL TEST 2

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Attachment B8: Statistical Test 2, Test of Proportions, July 2016
Selenium, Dissolved URGA

Selenium, Dissolved (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-14	0.0025	0.0025	0.0025	0.0025	0.0025
Jan-15	0.0025	0.0025	0.0025	0.0025	0.0025
Jul-15	0.0025	0.0025	0.0025	0.0025	0.0025
Jan-16	**0.00225**	0.0025	0.0025	**0.00199**	**0.00197**
Jul-16	0.0025	0.0025	0.0025	0.0025	**0.00157**

mg/L = milligrams per liter
BG = background
DL = detection limit
Nondetect values are 1/2 DL.
Bolded values indicate a detected result.

[!] **Test of Proportions**

Calculate the number of detections in background wells vs. compliance wells.

X =	1	X = number of samples above DL in background wells
Y =	3	Y = number of samples above DL in compliance wells
n_b =	10	n_b = count of background well results/samples analyzed
n_c =	15	n_c = count of compliance well results/samples analyzed
n =	25	n = total number of samples

P =	0.160	P = (x+y)/n
nP =	4	$n = n_b+n_c$
n(1-P) =	21	

NOTE: If nP and n(1-P) are both >= 5, then the normal approximation may be used; however, because nP < 5 and/or n(1-P) < 5, the test was continued to determine if the conclusion, along with a simple evaluation of the data would be similar.

P_b =	0.100	P_b = proportion of detects in background wells
P_c =	0.200	P_c = proportion of detects in compliance wells
S_D =	0.150	S_D = standard error of difference in proportions
Z =	-0.668	$Z = (P_b-P_c)/S_D$
absolute value of Z =	0.668	

If the absolute value of Z exceeds the 97.5th percentile value of 1.96 from the standard normal distribution, this provides statistically significant evidence at the 5% significance level that the proportion of detects in one group of data exceeds the proportion of detects in the other group.

CONCLUSION: Because the absolute value of Z is less than 1.96, there is no statistical evidence that the proportion of samples with detected results differs between the background well and compliance well samples.

[!] Section 8.1.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance* (EPA 1989).

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ATTACHMENT B9

TRICHLOROETHENE
STATISTICAL TESTS 4/3

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Attachment B9: Statistical Test 4, Parametric ANOVA, July 2016 Trichloroethene URGA

Trichloroethene (TCE, µg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-14	**2710**	**203**	**1270**	**1030**	**46.2**
Jan-15	**2970**	**208**	**1380**	**1010**	**37.3**
Jul-15	**2520**	**191**	**1530**	**1250**	**37.9**
Jan-16	**2490**	**222**	**1350**	**1230**	**39.8**
Jul-16	**2020**	**169**	**1820**	**1090**	**35.3**
n_i	10		5	5	5
Sum	13703		7350	5610	196.50
(x_i)avg	1370.30		1470.00	1122.00	39.30

µg/L = micrograms per liter
Bolded values indicate a detected result.

Overall mean x.. = 1074.38
N = 25
p = 4
x.. = 26859.50

Determine Normality of Dataset

Coefficient of Variability Test

Table of Residuals

Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-14	1339.70	-1167.30	-200.00	-92.00	6.90
Jan-15	1599.70	-1162.30	-90.00	-112.00	-2.00
Jul-15	1149.70	-1179.30	60.00	128.00	-1.40
Jan-16	1119.70	-1148.30	-120.00	108.00	0.50
Jul-16	649.70	-1201.30	350.00	-32.00	-4.00

X: Mean Value = 2.73E-14
S: Standard Deviation = 776.1
K* Factor = 2.292 (for n = 25)
CV = S/X = 2.84E+16 > or = 1, log-transformed data are not normally distributed

*K factor [from Table 5, Appendix B of *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989)].
If the coefficient of variation is < 1, the residuals appear to be normally distributed.
Because the coefficient of variation is > or = 1, log-transformed data are not normally distributed.

Attachment B9: Statistical Test 4, Parametric ANOVA, July 2016 Trichloroethene URGA

Determine Equality of Variance of Dataset

p = number of wells
n_i = number of data points per well
N = total sample size
S^2 = the square of the standard deviation
$\ln(S_i^2)$ = natural logarithm of each variance
f = total sample size minus the number of wells (groups)
$f_i = n_i - 1$

$x_{..} =$ 26859.50
$(x_{avg})_{..} =$ 1074.38

p = 4
N = 25

Calculations for Equality of Variance: Bartlett's Test

S_i	S_i^2	$\ln(S_i^2)$	n_i	$f_i S_i^2$	$f_i \ln(S_i^2)$
1256.869	1579719.79	14.273	10	14217478.1	128.5
217.141	47150.00	10.761	5	188600.000	43.0
111.893	12520.00	9.435	5	50080.000	37.7
4.178	17.46	2.860	5	69.820	11.4

$\sum(S_i^2) =$ 1639407.24 $\sum f_i \ln(S_i^2) =$ 220.7

Equality of Variance: Bartlett's Test

f = 21
$Sp^2 =$ 688391.806
$\ln Sp^2 =$ 13.442
$\chi^2 =$ 61.606 (If calculated $\chi^2 \leq \chi^2_{crit}$, then variances are equal at the given significance level).
χ^2_{crit} * = 7.815 at a 5% significance level with 3 degrees of freedom

Variances are not equal, transform the original data to lognormal (i.e., since calculated $\chi 2$ > tabulated $\chi 2$).

*Table 1, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Lognormal Data for TCE

ln[TCE (µg/L)]					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-14	7.90	5.31	7.15	6.94	3.83
Jan-15	8.00	5.34	7.23	6.92	3.62
Jul-15	7.83	5.25	7.33	7.13	3.63
Jan-16	7.82	5.40	7.21	7.11	3.68
Jul-16	7.61	5.13	7.51	6.99	3.56
x_i	65.60		36.42	35.09	18.33
(x_i)avg	6.56		7.28	7.02	3.67

µg/L = micrograms per liter

Determine Normality of Dataset

Coefficient of Variability Test

Table of Residuals

Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-14	1.34	-1.25	-0.14	-0.08	0.17
Jan-15	1.44	-1.22	-0.05	-0.10	-0.05
Jul-15	1.27	-1.31	0.05	0.11	-0.03
Jan-16	1.26	-1.16	-0.08	0.10	0.02
Jul-16	1.05	-1.43	0.22	-0.02	-0.10

X: Mean Value = 4.97E-16
S: Standard Deviation = 0.83
K* Factor = 2.292 (for n = 25)
CV = S/X = 1.67E+15 > or = 1, log-transformed data are not normally distributed

*K factor [from Table 5, Appendix B of *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989)].

Determine Equality of Variance of Dataset

p = number of wells (background wells considered as one group)
n_i = number of data points per well
N = total sample size
S^2 = the square of the standard deviation
$\ln(S_i^2)$ = natural logarithm of each variance
f = total sample size minus the number of wells (groups)
$f_i = n_i - 1$

$x_{..} = 155.45$
$(x_{avg})_{..} = 6.22$
p = 4
N = 25

Calculations for Equality of Variance: Bartlett's Test

S_i	S_i^2	$\ln(S_i^2)$	ni	$f_iS_i^2$	$f_i\ln(S_i^2)$
1.347	1.814	0.595	10	16.325	5.4
0.141	0.020	-3.918	5	0.080	-15.7
0.099	0.010	-4.624	5	0.039	-18.5
0.102	0.010	-4.561	5	0.042	-18.2

$\sum(S_i^2) =$ 1.85 $\sum f_i\ln(S_i^2) =$ -47.1

Equality of Variance: Bartlett's Test

f = 21
$Sp^2 =$ 0.785
$\ln Sp^2 =$ -0.242
$\chi^2 =$ 41.971 (If calculated $\chi^2 \leq$ tabulated χ^2, then variances are equal at the given significance level).
tabulated χ^2 * = 7.815 at a 5% significance level with 3 degrees of freedom

Variances are not equal (i.e., calculated $\chi 2 >$ tabulated $\chi 2$).

*Table 1, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989)].

Because variances are not equal, Statistical Test 3 - Nonparametric ANOVA is performed.

Attachment B9: Statistical Test 3, Nonparametric ANOVA, July 2016 Trichloroethene URGA

Statistical Test 3, Nonparametric ANOVA

TCE (µg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-14	**2710**	**203**	**1270**	**1030**	**46.2**
Jan-15	**2970**	**208**	**1380**	**1010**	**37.3**
Jul-15	**2520**	**191**	**1530**	**1250**	**37.9**
Jan-16	**2490**	**222**	**1350**	**1230**	**39.8**
Jul-16	**2020**	**169**	**1820**	**1090**	**35.3**
n_i	10		5	5	5
x_i	13703		7350	5610	196.50
(x_i)avg	1370.30		1470.00	1122.00	39.30

µg/L = micrograms per liter
BG=background
DL=detection limit
All data sets represent 1/2 DL values for nondetects.
Bolded values indicate a detected result.

Overall mean x.. = 1074.38

N = 25
p = 4
x.. = 26859.50

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	TCE (µg/L)	Adjusted Rank	Tie Number
1	**35.3**	1	
2	**37.3**	2	
3	**37.9**	3	
4	**39.8**	4	
5	**46.2**	5	
6	**169**	6	
7	**191**	7	
8	**203**	8	
9	**208**	9	
10	**222**	10	
11	**1010**	11	
12	**1030**	12	
13	**1090**	13	
14	**1230**	14	
15	**1250**	15	
16	**1270**	16	
17	**1350**	17	
18	**1380**	18	
19	**1530**	19	
20	**1820**	20	
21	**2020**	21	
22	**2490**	22	
23	**2520**	23	
24	**2710**	24	
25	**2970**	25	

µg/L = micrograms per liter
BG = background
DL = detection limit
Bolded values indicate a detected result.
NOTE: For this method, observations below the detection limit are reported as a concentration of 0.

Adjustment for Ties: $(ntie^3-ntie)$

n_{tie} Tie 1 = 0
0

$\sum T_i$ = 0

Attachment B9: Statistical Test 3, Nonparametric ANOVA, July 2016 Trichloroethene URGA

Sums of Ranks and Averages

TCE (µg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-14	**2710**	**203**	**1270**	**1030**	**46.2**
Jan-15	**2970**	**208**	**1380**	**1010**	**37.3**
Jul-15	**2520**	**191**	**1530**	**1250**	**37.9**
Jan-16	**2490**	**222**	**1350**	**1230**	**39.8**
Jul-16	**2020**	**169**	**1820**	**1090**	**35.3**

Observation Ranks for TCE					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-14	**24**	**8**	**16**	**12**	**5**
Jan-15	**25**	**9**	**18**	**11**	**2**
Jul-15	**23**	**7**	**19**	**15**	**3**
Jan-16	**22**	**10**	**17**	**14**	**4**
Jul-16	**21**	**6**	**20**	**13**	**1**
R_i	155		90	65	15
$(R_i)_{avg}$	15.5		18.0	13.0	3
R_i^2/n_i	2402.5		1620.0	845.0	45

$\Sigma R_i^2/n_i$ = 4912.5

K = 4

N = 25

µg/L = micrograms per liter
BG=background
DL=detection limit
Bolded values indicate a detected result.
NOTE: For this method, observations below the detection limit are reported as a concentration of 0.

Calculation of Kruskal-Wallis Statistic

H =	12.692	Kruskal-Wallis Statistic	$H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$
H' =	12.692	Corrected Kruskal-Wallis	$H' = H/[1-(\sum T_i/N^3-N)]$
χ^2_{crit}* =	7.815	3	degrees of freedom at the 5% significance level

NOTE: $H' > \chi^2_{crit}$

If $H' \leq \chi^2_{crit}$, the data from each well come from the same continuous distribution and hence have the same median concentrations of a specific constituent.
If $H' > \chi^2_{crit}$, reject the null hypothesis and calculate the critical difference for well comparisons to the background.

K-1 =	3	α/(K-1) =	0.01667	Z(α/(K-1))** =	2.128
α =	0.05	1-(α/K-1) =	0.983		

NOTE *Table 1, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (USEPA 1989).
**Table 4, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (USEPA 1989).

Calculate Critical Values

Average Background Ranking = 15.5

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93			
BG Well	MW420			
	MW84	8.578	2.50	not contaminated
	MW87	8.578	-2.50	not contaminated
	MW90A	8.578	-12.50	not contaminated

µg/L = micrograms per liter
BG = background
DL = detection limit

CONCLUSION: If $(R_i)_{avg} - (R_b)_{avg} > C_i$, then there is evidence that the compliance well is contaminated.

If $(R_i)_{avg} - (R_b)_{avg} < C_i$ for wells, there is no evidence of a statistically significant difference between downgradient compliance test wells and background wells.

Since $(R_i)_{avg} - (R_b)_{avg} < C_i$ for MW84, MW87, and MW90A, there is no statistically significant difference between compliance test wells and background wells at the C-404 Landfill; however, the negative values indicate that background wells have elevated concentrations.

Section 5.2.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

ATTACHMENT B10

URANIUM
STATISTICAL TEST 3

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Attachment B10: Statistical Test 3, Nonparametric ANOVA, July 2016 Uranium URGA

Uranium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-14	**0.000093**	0.0001	**0.00011**	**0.000085**	0.0001
Jan-15	**0.00214**	0.0001	**0.00043**	**0.00019**	0.0001
Jul-15	**0.0001**	0.0001	**0.00018**	**0.000087**	0.0001
Jan-16	**0.000203**	0.0001	**0.000226**	**0.000273**	0.0001
Jul-16	**0.000165**	0.0001	**0.000345**	**0.000559**	0.0001
Sum	0.0032		0.00129	0.00119	0.0005
n_i	10		5	5	5
$(x_i)_{avg}$	0.00032		0.00026	0.00024	0.0001

mg/L = milligrams per liter
BG = background
DL = detection limit
All data sets represent 1/2 DL values for nondetects.
Bolded values indicate a detected result.

Overall mean x.. = 0.00025

N = 25
p = 4
x.. = 0.01

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	Uranium (mg/L)	Adjusted Rank	Tie Number
1	0	5.5	Tie 1
2	0	5.5	
3	0	5.5	
4	0	5.5	
5	0	5.5	
6	0	5.5	
7	0	5.5	
8	0	5.5	
9	0	5.5	
10	0	5.5	
11	**0.000085**	11	
12	**0.000087**	12	
13	**0.000093**	13	
14	**0.0001**	14	
15	**0.00011**	15	
16	**0.000165**	16	
17	**0.00018**	17	
18	**0.00019**	18	
19	**0.000203**	19	
20	**0.000226**	20	
21	**0.000273**	21	
22	**0.000345**	22	
23	**0.00043**	23	
24	**0.000559**	24	
25	**0.00214**	25	

mg/L = milligrams per liter
BG = background
DL = detection limit
Bolded values indicate a detected result.
NOTE: For this method, observations below the detection limit are reported as a concentration of 0.

n_{tie}	Adjustment for Ties: $(n_{tie}^3 - n_{tie})$	
10	Tie 1 =	990
	$\sum T_i$ =	990

Attachment B10: Statistical Test 3, Nonparametric ANOVA, July 2016 Uranium URGA

Sums of Ranks and Averages

Uranium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-14	**0.000093**	0	**0.00011**	**0.000085**	0
Jan-15	**0.00214**	0	**0.00043**	**0.00019**	0
Jul-15	**0.0001**	0	**0.00018**	**0.000087**	0
Jan-16	**0.000203**	0	**0.000226**	**0.000273**	0
Jul-16	**0.000165**	0	**0.000345**	**0.000559**	0

Observation Ranks for Uranium					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-14	13	5.5	15	11	5.5
Jan-15	25	5.5	23	18	5.5
Jul-15	14	5.5	17	12	5.5
Jan-16	19	5.5	20	21	5.5
Jul-16	16	5.5	22	24	5.5
R_i	114.5		97	86	27.5
$(R_i)_{avg}$	11.5		19.4	17.2	5.5
R_i^2/n_i	1311.0		1881.8	1479.2	151.3

$\Sigma R_i^2/n_i$ = 4823.3

mg/L = milligrams per liter
BG = background
DL = detection limit
Bolded values indicate a detected result.

K = 4
N = 25

NOTE: For this method, observations below the detection limit are reported as a concentration of 0.

Calculation of Kruskal-Wallis Statistic

H = 11.045 Kruskal-Wallis Statistic $H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$

H' = 11.794 Corrected Kruskal-Wallis $H' = H/[1-(\sum T_i/N^3-N)]$

χ^2_{crit}* = 7.815 3 degrees of freedom at the 5% significance level

NOTE: $H' > \chi^2_{crit}$

If $H' \leq \chi^2_{crit}$, the data from each well come from the same continuous distribution and hence have the same median concentrations of a specific constituent.

If $H' > \chi^2_{crit}$, reject the null hypothesis and calculate the critical difference for well comparisons to the background.

K-1= 3 $\alpha/(K-1)$ = 0.01667 $Z(\alpha/(K-1))$** = 2.1280

α = 0.05 $1-(\alpha/K-1)$ = 0.983

NOTE *Table 1, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).
**Table 4, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Attachment B10: Statistical Test 3, Nonparametric ANOVA, July 2016 Uranium URGA

Calculate Critical Values

Average Background Ranking = 11.450

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93			
BG Well	MW420			
	MW84	8.578	7.95	not contaminated
	MW87	8.578	5.75	not contaminated
	MW90A	8.578	-5.95	not contaminated

mg/L = milligrams per liter
BG = background
DL = detection limit

CONCLUSION: If $(R_i)_{avg} - (R_b)_{avg} > C_i$, then there is evidence that the compliance well is contaminated.

If $(R_i)_{avg} - (R_b)_{avg} < C_i$ for wells, there is no evidence of a statistically significant difference between downgradient compliance test wells and background wells.

Since $(R_i)_{avg} - (R_b)_{avg} < C_i$ for MW84, MW87, and MW90A, there is no statistically significant difference between compliance test wells and background wells at the C-404 Landfill; however, the negative value indicates that the background well has elevated concentrations.

Section 5.2.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

ATTACHMENT B11

STATISTICIAN STATEMENT

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FLUOR®

October 10, 2016

Ms. Myrna Redfield
Fluor Federal Services, Inc.
5511 Hobbs Road
Kevil, KY 42053

Dear Ms. Redfield:

I am submitting this statement as a supplementary document to the completed statistical analysis I performed on the groundwater data for the C-404 Landfill at the Paducah Gaseous Diffusion Plant.

As a Chemist, with a Bachelor of Science degree in chemistry and a minor in biology, I have over 20 years of experience in reviewing and assessing laboratory analytical results associated with environmental sampling and investigation activities. For the generation of these statistical analyses, my work was observed and reviewed by a senior chemist and geologist with Fluor Federal Services, Inc.

For this project, the statistical analyses on groundwater data from July 2014 through July 2016 were performed in accordance with the C-404 Hazardous Waste Landfill Permit, Appendix E using Microsoft Excel 2010. The spreadsheets include the results for the following statistical tests:

- Test of Proportions
- Parametric Analysis of Variance (ANOVA)
- Nonparametric ANOVA

The statistical analyses procedures were based on the U.S. Environmental Protection Agency (USEPA) *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Interim Final Guidance* (1989).

Sincerely,

Jennifer R. Blewett

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APPENDIX C

C-404 HAZARDOUS WASTE LANDFILL LEACHATE ANALYTICAL RESULTS

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Paducah OREIS Report for 404L16-02

L1404L2-16 from: C404L on 3/14/2016 Media: WW SmpMethod: GR

Comments:

Analysis	Results	Counting Error	Units	Result Qual	Foot Note	Reporting Limit	TPU	Method	V/V/A*
ANION									
Fluoride	7.42		mg/L			0.2		SW846-9056	I / X /
FS									
Conductivity	633		umho/cm					FS	/ /
Dissolved Oxygen	6.25		mg/L					FS	/ /
pH	7.73		Std Unit					FS	/ /
Redox	43		mV					FS	/ /
Temperature	55.6		deg F					FS	/ /
METAL									
Arsenic	0.00243		mg/L	BJ		0.005		SW846-6020	/ X /
Barium	0.0987		mg/L			0.002		SW846-6020	S / X /
Cadmium	0.001		mg/L	U		0.001		SW846-6020	/ X /
Chromium	0.01		mg/L	U		0.01		SW846-6020	/ X /
Copper	0.00821		mg/L			0.001		SW846-6020	/ X /
Iron	0.1		mg/L	U		0.1		SW846-6020	/ X /
Lead	0.002		mg/L	U		0.002		SW846-6020	/ X /
Mercury	0.0002		mg/L	U		0.0002		SW846-7470A	/ X /
Nickel	0.00374		mg/L			0.002		SW846-6020	/ X /
Selenium	0.005		mg/L	U		0.005		SW846-6020	/ X /
Silver	0.001		mg/L	U		0.001		SW846-6020	/ X /
Uranium	90.6		mg/L	B		0.2		SW846-6020	I / X /
Zinc	0.00787		mg/L	J		0.01		SW846-6020	S / X /
PPCB									
PCB-1016	0.0952		ug/L	U		0.0952		SW846-8082	/ X /
PCB-1221	0.0952		ug/L	U		0.0952		SW846-8082	/ X /
PCB-1232	0.0952		ug/L	U		0.0952		SW846-8082	/ X /
PCB-1242	0.0952		ug/L	U		0.0952		SW846-8082	/ X /

*Verification/Validation/Assessment

PCB-1248	1		ug/L		0.0952		SW846-8082	/ X /
PCB-1254	0.0952		ug/L	U	0.0952		SW846-8082	/ X /
PCB-1260	0.0952		ug/L	U	0.0952		SW846-8082	/ X /
PCB-1268	0.0952		ug/L	U	0.0952		SW846-8082	/ X /
Polychlorinated biphenyl	1		ug/L		0.0952		SW846-8082	I / X /
RADS								
Cesium-137	-0.732	5.95	pCi/L	U	11.2	5.96	EPA-901.1	/ X /
Neptunium-237	1.49	0.987	pCi/L		0.967	1	ASTM C 1476-00 Mod	/ X /
Plutonium-239/240	-0.0688	0.475	pCi/L	U	1.16	0.476	HASL 300, Pu-11-RC M	/ X /
Technetium-99	300	16.2	pCi/L		19.9	37	HASL 300, Tc-02-RC M	/ X /
Thorium-230	0.564	1.3	pCi/L	U	2.22	1.32	HASL 300, Th-01-RC M	/ X /
Uranium-234	4520	5170	pCi/L	U	6450	5220	HASL 300, U-02-RC M	/ X /
Uranium-235	992	3720	pCi/L	U	6260	3730	HASL 300, U-02-RC M	/ X /
Uranium-238	29300	11200	pCi/L		5060	12200	HASL 300, U-02-RC M	/ X /
VOA								
Trichloroethene	1		ug/L	U	1		SW846-8260B	/ X /
WETCHEM								
Ammonia as Nitrogen	0.0648		mg/L	B	0.05		EPA-350.1	S / X /

TB404L2-16 from: QC on 3/14/2016 Media: WQ SmpMethod:

Comments:

Analysis	Results	Counting Error	Units	Result Qual	Foot Note	Reporting Limit	TPU	Method	V/V/A*
VOA									
Trichloroethene	1		ug/L	U		1		SW846-8260B	/ X /

*Verification/Validation/Assessment

APPENDIX D

C-404 HAZARDOUS WASTE LANDFILL GROUNDWATER FLOW RATE AND DIRECTION

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2016 ANNUAL REPORT OF THE C-404 LANDFILL HYDRAULIC FLOW RATE AND DIRECTION

The C-404 Hazardous Waste Landfill (C-404 Landfill) Permit requires annual determination of average hydraulic flow rate and direction of flow in the uppermost aquifer. The uppermost aquifer below C-404 Landfill is the Regional Gravel Aquifer (RGA). Water level measurements currently are taken from several wells at the perimeter of the C-404 Landfill on a semiannual basis. The water levels used for this analysis (taken on January 26 and July 26, 2016) were measured as closely as possible and within a 24-hour period to ensure the comparability of the data. These measurements were used to plot the potentiometric surface of the upper RGA for the January and July 2016 sampling events.

Contours for each potentiometric surface were drawn after water-level data were corrected for barometric pressure; groundwater hydraulic gradients then are calculated from the contours. The average of the gradients measured during this reporting period is the annual average groundwater hydraulic gradient for the upper RGA and is calculated at 1.10×10^{-3} ft/ft.

The hydraulic conductivity (K) values reported in the *Resource Conservation and Recovery Act (RCRA) Part B Permit Modification for Inclusion of C-404 Low-Level Radioactive/Hazardous Waste Landfill* (Clausen et al., 1992) were determined by multi-well testing and range from 21 to 140 ft/day (7.41×10^{-3} to 4.94×10^{-2} cm/s).

Multiplication of the hydraulic gradient (i) and the hydraulic conductivity (K) yields the specific discharge (q) for a unit area of the RGA. Annual average linear-flow velocity (v) is calculated by multiplying the hydraulic conductivity by the gradient and dividing by the porosity (n). It is assumed that (n) equals 25 percent in the RGA beneath the C-404 Landfill.

Table D.1 summarizes the annual average results of the calculations. Table D.2 presents the calculation information for the annual groundwater flow rate. The January and July potentiometric surface data of the upper RGA are presented in Tables D.3 and D.4, and potentiometric surface maps are presented in Figures D.1 and D.2.

Table D.1. C-404 Landfill Annual Average Groundwater Flow Rate for 2016

Hydraulic Conductivity (K) Range	Annual Average Specific Discharge (q) ft/day (cm/s)	Annual Average Linear Flow Velocity (v) ft/day cm/s)
High K	0.15 (5.4×10^{-5})	0.61 (2.2×10^{-4})
Low K	0.02 (8.1×10^{-6})	0.09 (3.2×10^{-5})

The potentiometric contours depict the directions of hydraulic flow during each sampling event. Hydraulic flow direction beneath the C-404 Landfill generally trends northeastward, but commonly varies from northeast to north.

Table D.2. Calculation Information for the C-404 Landfill Annual Groundwater Flow Rate 2016

Upper RGA K = 21 ft/d					
	i (ft/ft)	q (ft/d)	q (cm/s)	v (ft/d)	v (cm/s)
January 2016	-8.72E-04	0.02	6.5E-06	0.07	2.6E-05
July 2016	-1.32E-03	0.03	9.8E-06	0.11	3.9E-05
Annual Average	**-1.10E-03**	**0.02**	**8.1E-06**	**0.09**	**3.2E-05**
Upper RGA K = 140 ft/d					
	i (ft/ft)	q (ft/d)	q (cm/s)	v (ft/d)	v (cm/s)
January 2016	-8.72E-04	0.12	4.3E-05	0.49	1.7E-04
July 2016	-1.32E-03	0.18	6.5E-05	0.74	2.6E-04
Annual Average	**-1.10E-03**	**0.15**	**5.4E-05**	**0.61**	**2.2E-04**

q = K*i

where:
q = specific discharge (per unit area)
K = hydraulic conductivity
i = hydraulic gradient (from potentiometric map)

v = q/n

where:
v = average linear velocity
q = specific discharge
n_e = porosity (assumed to be 25%)

ft/ft = foot per foot
ft/d = foot per day
cm/s = centimeter/second

Table D.3. Barometric Pressure Corrections

C-404 Landfill (January 2016) Water Levels									
						Raw Data		Corrected Data*	
Date	Time	Well	Datum Elev (ft amsl)	BP (in Hg)	Delta BP (ft H_2O)	DTW (ft)	Elev (ft amsl)	DTW (ft)	Elev (ft amsl)
1/26/2016	8:28	MW67	374.95	30.17	0.00	48.53	326.42	48.53	326.42
1/26/2016	8:40	MW76	376.77	30.17	0.00	50.31	326.46	50.31	326.46
1/26/2016	8:14	MW84	376.01	30.17	0.00	49.50	326.51	49.50	326.51
1/26/2016	13:03	MW87	375.79	30.21	-0.05	49.44	326.35	49.39	326.40
1/26/2016	7:57	MW90A	374.20	30.17	0.00	47.88	326.32	47.88	326.32
1/26/2016	8:36	MW93	377.67	30.17	0.00	51.19	326.48	51.19	326.48
1/26/2016	8:45	MW227	378.81	30.17	0.00	52.35	326.46	52.35	326.46
1/26/2016	8:38	MW333	377.35	30.17	0.00	50.84	326.51	50.84	326.51
1/26/2016	8:10	MW337	374.67	30.17	0.00	48.16	326.51	48.16	326.51
1/26/2016	8:12	MW338	374.86	30.17	0.00	48.42	326.44	48.42	326.44
1/26/2016	8:31	MW420	377.70	30.17	0.00	51.21	326.49	51.21	326.49

Initial Barometric Pressure **30.17**
Elev = elevation
amsl = above mean sea level
BP = barometric pressure
DTW = depth to water in feet below datum
URGA = Upper Regional Gravel Aquifer
LRGA = Lower Regional Gravel Aquifer
UCRS = Upper Continental Recharge System
*Assumes a barometric efficiency of 1.0

Table D.4. Barometric Pressure Corrections

C-404 Landfill (July 2016) Water Levels									
						Raw Data		Corrected Data*	
Date	Time	Well	Datum Elev (ft amsl)	BP (in Hg)	Delta BP (ft H_2O)	DTW (ft)	Elev (ft amsl)	DTW (ft)	Elev (ft amsl)
7/26/2016	8:11	MW67	374.95	30.02	0.00	47.08	327.87	47.08	327.87
7/26/2016	8:26	MW76	376.77	30.02	0.00	48.76	328.01	48.76	328.01
7/26/2016	7:51	MW84	376.01	30.01	0.01	48.01	328.00	48.02	327.99
7/26/2016	8:09	MW87	375.79	30.02	0.00	47.94	327.85	47.94	327.85
7/26/2016	8:03	MW90A	374.20	30.02	0.00	46.49	327.71	46.49	327.71
7/26/2016	8:20	MW93	377.67	30.02	0.00	49.45	328.22	49.45	328.22
7/26/2016	7:24	MW227	378.81	30.01	0.01	50.52	328.29	50.53	328.28
7/26/2016	8:23	MW333	377.35	30.02	0.00	49.06	328.29	49.06	328.29
7/26/2016	7:45	MW337	374.67	30.01	0.01	46.57	328.10	46.58	328.09
7/26/2016	7:48	MW338	374.86	30.01	0.01	46.82	328.04	46.83	328.03
7/26/2016	8:14	MW420	377.70	30.02	0.00	49.64	328.06	49.64	328.06

Initial Barometric Pressure **30.02**
Elev = elevation
amsl = above mean sea level
BP = barometric pressure
DTW = depth to water in feet below datum
URGA = Upper Regional Gravel Aquifer
LRGA = Lower Regional Gravel Aquifer
UCRS = Upper Continental Recharge System
*Assumes a barometric efficiency of 1.0

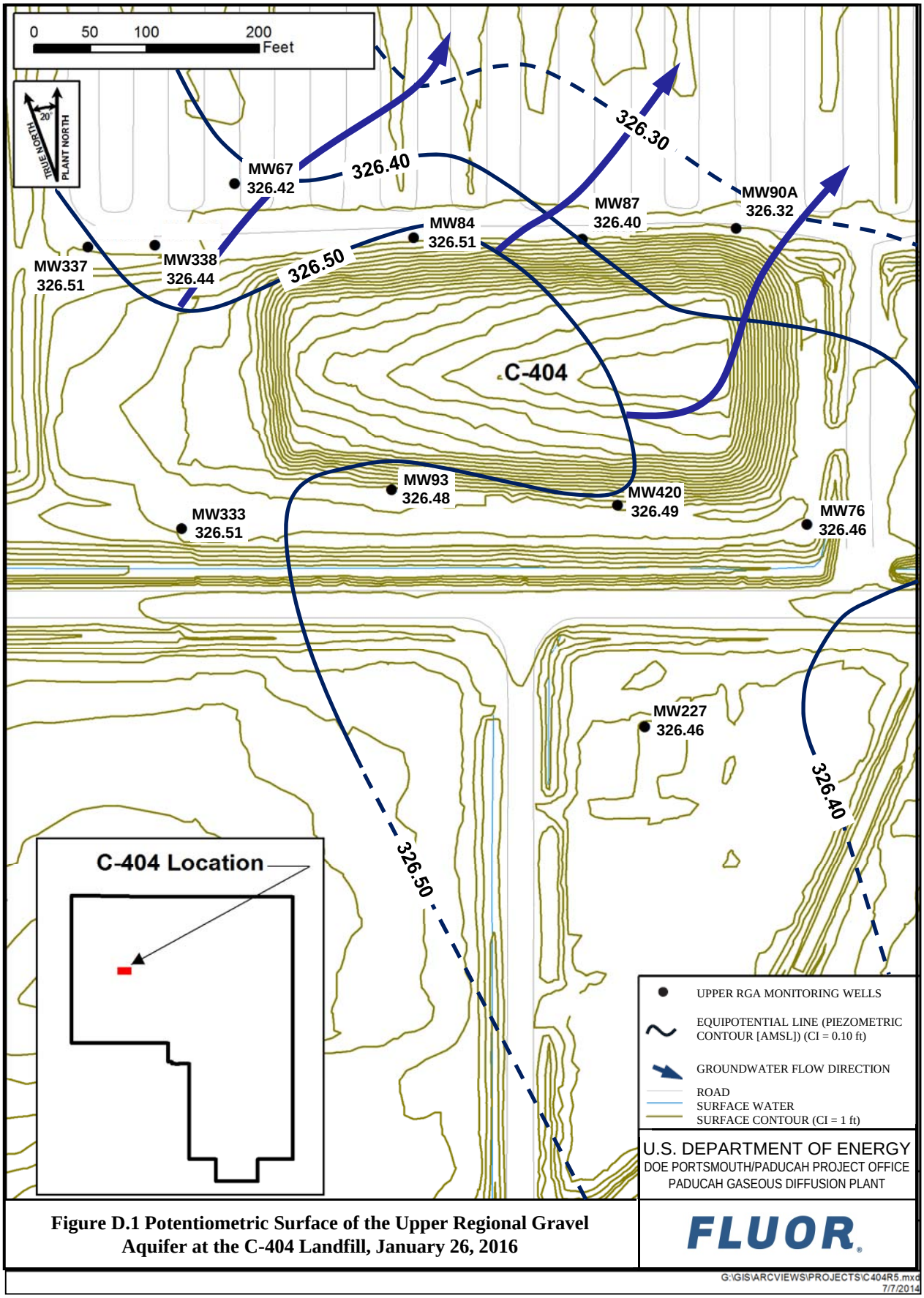

Figure D.1 Potentiometric Surface of the Upper Regional Gravel Aquifer at the C-404 Landfill, January 26, 2016

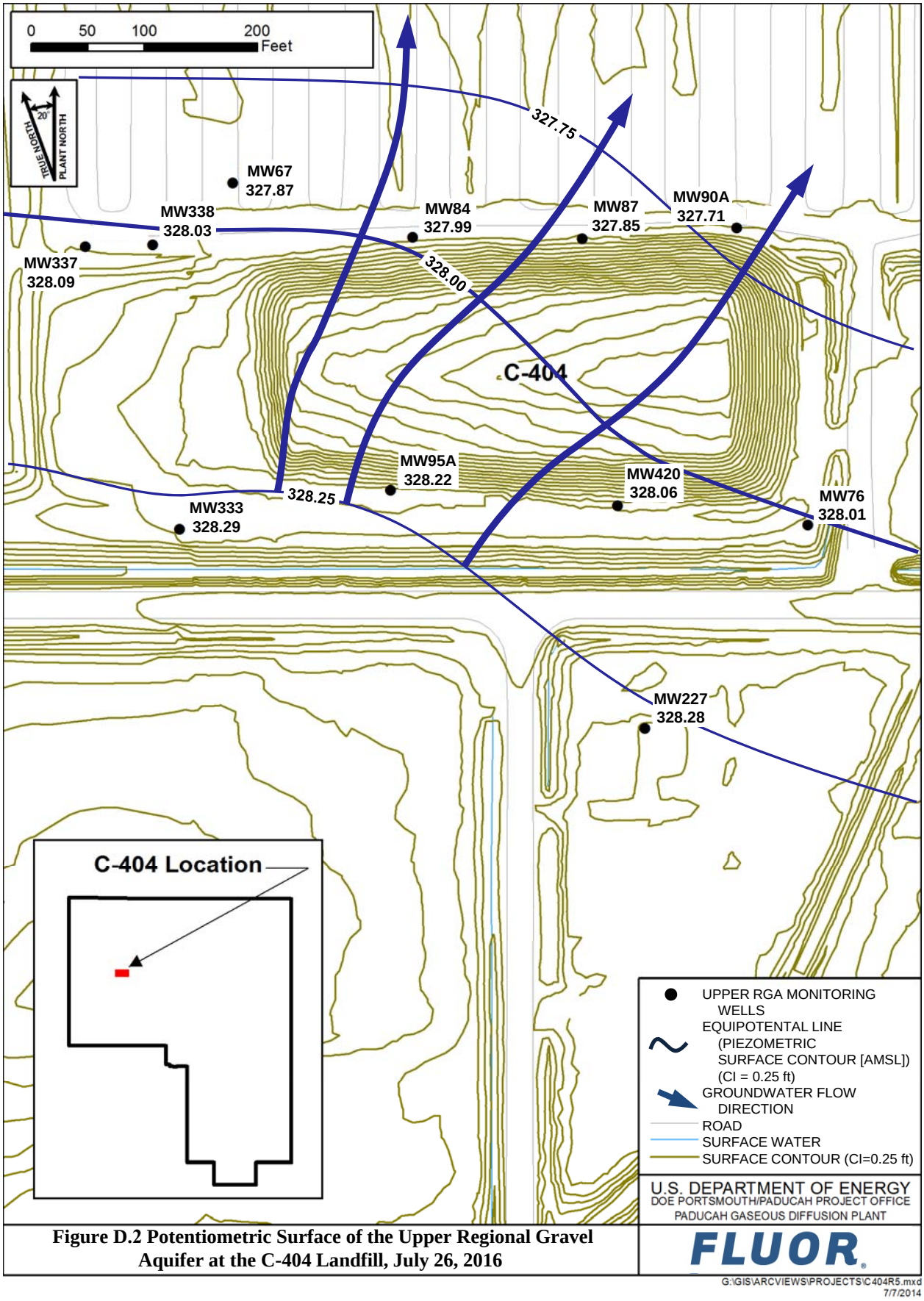

Figure D.2 Potentiometric Surface of the Upper Regional Gravel Aquifer at the C-404 Landfill, July 26, 2016