FRNP-RPT-0086/V2

C-404 Hazardous Waste Landfill November 2019 Semiannual Groundwater Report (April 2019–September 2019), Paducah Gaseous Diffusion Plant, Paducah, Kentucky

FOUR RIVERS NUCLEAR PARTNERSHIP, LLC

This document is approved for public release per review by:

Daniel Hayden — 11-13-19

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C-404 Hazardous Waste Landfill November 2019 Semiannual Groundwater Report (April 2019–September 2019), Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Date Issued—November 2019

U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Prepared by
FOUR RIVERS NUCLEAR PARTNERSHIP, LLC,
managing the
Deactivation and Remediation Project at the
Paducah Gaseous Diffusion Plant
under Contract DE-EM0004895

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ACRONYMS

AKGWA	Assembled Kentucky Groundwater
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
KDWM	Kentucky Division of Waste Management
MW	monitoring well
RCRA	Resource Conservation and Recovery Act
RGA	Regional Gravel Aquifer
UCRS	Upper Continental Recharge System
URGA	Upper Regional Gravel Aquifer

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EXECUTIVE SUMMARY

This report, *C-404 Hazardous Waste Landfill November 2019 Semiannual Groundwater Report (April 2019–September 2019), Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, FRNP-RPT-0086/V2, is being submitted by the U.S. Department of Energy in accordance with requirements in Kentucky Division of Waste Management Hazardous Waste Management Facility Permit, KY8-890-008-982 (Permit). This second reporting period 2019 covers April through September 2019 and includes analytical data from the July 2019 sampling of monitoring wells (MWs) located in the vicinity of the closed C-404 Hazardous Waste Landfill (C-404 Landfill).

During this reporting period, Regional Gravel Aquifer (RGA) compliance wells MW84, MW87, and MW93 were abandoned and replaced with MW84A, MW87A, and MW93A. The integrity of MW87 had deteriorated to a point that it no longer was suitable for its intended purpose (FRNP 2019). RGA compliance wells MW84 and MW93 were abandoned and replaced because they were the same age (installed in 1988) as MW87. Compliance wells MW84A, MW87A, and MW93A were sampled during this reporting period, and analytical data for these replacement wells are included in this report.

The groundwater monitoring analytical data were subjected to statistical analyses. The analyses were conducted in accordance with the Hazardous Waste Management Facility Permit. Trichloroethene (TCE) concentrations in compliance well MW84A were statistically different from concentrations in the background wells. The 2007 *C-404 Landfill Source Demonstration, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, PRS-ENM-0031/R2 (PRS 2007a) demonstrated that the C-404 Landfill was not the source of the historical, statistically significant background exceedance of TCE in MW84.

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

The leachate in the C-404 Landfill leachate collection system is monitored (at least monthly) and, at a minimum, is removed and sampled when the level exceeds 3 ft in depth. The volume of leachate removed from the sump during this reporting period, April through September 2019, was 1,000 gal. The leachate was sampled on June 20, 2019. Analytical results for the June 2019 leachate samples are provided in this report. Analytical results from the sample collected during the previous reporting period (March 2019) 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 closed C-404 Hazardous Waste Landfill (C-404 Landfill) at the U.S. Department of Energy Paducah Site (Paducah Site), Paducah, Kentucky. This semiannual report is required by the Kentucky Division of Waste Management Hazardous Waste Management Facility Permit, KY8-890-008-982 (Permit) (KDWM 2017), Specific Condition II.K.6.d—Recordkeeping, Reporting, and Response. The period covered by this report is April through September 2019.

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 annual groundwater flow rate and direction determination is provided in Appendix D.

1.1 BACKGROUND

The closed C-404 Landfill is located in the west-central portion of the Paducah Site 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 transferred off-site for treatment.

In 1986, the disposal of waste at the 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 Management Facility Permit (KDWM 2017).

Previous groundwater monitoring documented that concentrations in compliance wells were statistically different from background wells for trichloroethene (TCE). The *C-404 Landfill Source Demonstration, Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (PRS 2007a) 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.

Regional Gravel Aquifer (RGA) compliance monitoring well (MW) 90A was abandoned and replaced in 2001. RGA compliance well MW420 was installed in 2007 to assess groundwater quality at the C-404 Landfill better (PRS 2007b). The Burial Grounds Operable Unit evaluated the MW network at the C-404 Landfill relative to the prevailing groundwater flow direction and concluded that the additional RGA well was needed to assess upgradient groundwater quality.

Upper Continental Recharge System (UCRS) well MW91 was abandoned and replaced with MW91A in 2017. Downhole camera inspections of MW91, conducted in 2017 as part of the site well maintenance program, revealed significant corrosion and some biofouling and a hole in the well riser (FRNP 2017). The integrity of the well riser had deteriorated to a point that it no longer was suitable for its intended purpose. MW91A was placed 10 ft north of MW91 and screened at the same depth interval.

Previous groundwater monitoring of RGA compliance well MW87 documented that concentrations in the compliance well were statistically different from background wells for lead and uranium (FRNP 2018). The *C-404 Hazardous Waste Landfill Alternate Source Demonstration—Source of Lead and Uranium in MW87 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, (FRNP 2019) concluded that the statistical differences were a result of infiltration of UCRS groundwater into the RGA well due to compromised integrity of the well. The integrity of the well had deteriorated to a point that it no longer was suitable for its intended purpose. RGA compliance wells MW84, MW87, and MW93 were abandoned and replaced with MW84A, MW87A, and MW93A in 2019. RGA wells MW84 and MW93 were abandoned and replaced because they were the same age (installed in 1988) as MW87. MW84A and MW87A were placed 10 ft north of MW84 and MW87, respectively, and screened at the same depth intervals. MW93A was placed 6 ft west of MW91 and screened at the same depth interval.

1.2 MONITORING PERIOD ACTIVITIES

1.2.1 Groundwater Monitoring

There are nine MWs sampled under the Permit for the C-404 Landfill: four UCRS wells and five Upper Regional Gravel Aquifer (URGA) wells. A map of the MW locations is provided in Figure 1.

Table 1 presents the well number 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 the UCRS wells as being adjacent to an upgradient or downgradient URGA well location identified relative to these URGA groundwater flow direction. The conceptual model for the C-404 Landfill indicates that groundwater in the UCRS wells flows primarily vertically downward until it reaches the URGA; therefore, UCRS wells are not considered "upgradient" or "downgradient" of other wells in the area.

Table 1. Monitoring Well Locations

UCRS	
Located south of C-404 Landfill, adjacent to upgradient URGA background well MW93A	MW94
Located north of C-404 Landfill, adjacent to downgradient URGA compliance wells	MW85, MW88, MW91A*
URGA	
Upgradient background wells	MW93A*, MW420
Downgradient compliance wells	MW84A*, MW87A*, MW90A*

*MW90 was abandoned in 2001 and replaced with MW90A. MW91 was abandoned in 2017 and replaced with MW91A. MW84, MW87, and MW93 were abandoned in 2019 and replaced with MW84A, MW87A, and MW93A.

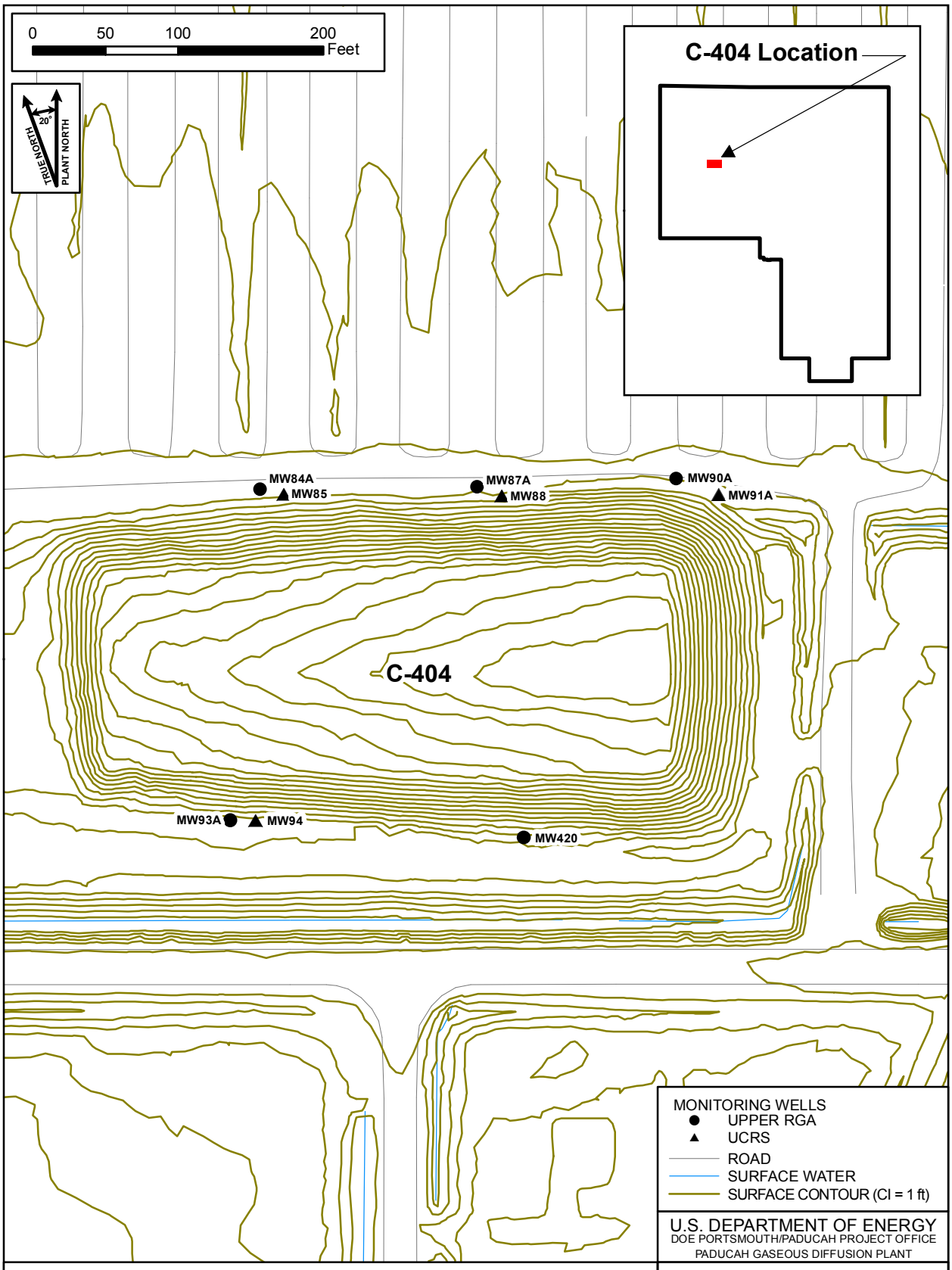

Figure 1. C-404 Landfill Monitoring Well Map

Table 2 presents the Assembled Kentucky Groundwater (AKGWA) numbers for each MW.

Table 2. Assembled Kentucky Groundwater Numbers

Paducah Site Well Number	AKGWA Number
MW84A	8007-4849
MW85	8000-5234
MW87A	8007-4850
MW88	8000-5237
MW90A	8004-0357
MW91A	8007-2917
MW93A	8007-4851
MW94	8000-5103
MW420	8005-3263

All nine MWs were sampled in July 2019 during this reporting period, and the samples were analyzed for parameters required by Part VIII.E of the Permit. Groundwater sampling was conducted using procedure CP4-ES-2101, *Groundwater Sampling*. Appropriate sample containers and preservatives were used. The laboratory that performed the analyses used U.S. Environmental Protection Agency-approved methods, as applicable. Appendix A of this report contains the analytical results. Appendix B of this report contains the statistical analyses.

1.2.2 Landfill Leachate

In accordance with Section 1.2 of the 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." Once the leachate depth reaches 3 ft, the leachate is pumped into a mobile tank. The leachate then is transferred to a permitted hazardous waste storage facility on-site prior to characterization and transferred off-site for treatment. The volume of leachate removed from the sump during this reporting period, April through September 2019, was 1,000 gal. The leachate was sampled on June 20, 2019. Analytical results for the June 2019 leachate samples are included in Appendix C. Analytical data from the sample collected during the previous reporting period (March 2019) are provided in this report because the laboratory results were not available by the regulatory deadline of the previous report.

2. STATISTICAL SYNOPSIS

The statistical analyses conducted on the data collected from the C-404 Landfill were performed in accordance with procedures in the Permit, Part VIII.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, MW93A and MW420, and URGA compliance wells, MW84A, MW87A, and MW90A. For these statistical analyses, the reporting period data set includes data from July 2017, January 2018, August 2018, January 2019, and July 2019.

TCE concentrations in compliance well MW84A were statistically different from concentrations in the background wells. An alternate source demonstration previously was conducted for TCE in MW84. The 2007 *C-404 Landfill Source Demonstration, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, PRS-ENM-0031/R2, (PRS 2007a) demonstrated that the C-404 Landfill was not the source of the historical, statistically significant background exceedance of TCE in MW84. The 2007 demonstration found that the statistically significant increase of TCE in downgradient well MW84 appeared to be due to an upgradient source from which dissolved TCE is migrating through the C-404 Landfill area.

The statistical tests on all other parameters showed no statistical difference between concentrations in the compliance (downgradient) and background (upgradient) wells.

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3. DATA VALIDATION AND QA/QC SUMMARY

The data and the data validation qualifiers for the July 2019 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 during each semiannual sampling event. Equipment rinseate blanks, field blanks, field duplicates, and trip blanks are obtained to ensure quality control and are reported in the Analytical Results in Appendix A. 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.

FIELD DUPLICATE SAMPLE

During a May 23, 2018, teleconference, the U.S. Department of Energy discussed with Kentucky Division of Waste Management (KDWM) the method used to collect duplicate samples from MWs at the C-404 Landfill. The collection method being used is defined in SW-846 as a collocated duplicate and differs from a definition in the Permit Part VIII.E, Appendix E3. In the teleconference, KDWM agreed that the collocated duplicate collection method was appropriate for precision monitoring at the C-404 Landfill. Additionally, there was a discussion about how this collection method is an acceptable practice under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and it is the type of duplicate sampling utilized in CERCLA sampling events at the Paducah Site.

Permit Part VIII.E, Appendix E3, Monitoring Well Requirements, Section 1.4, Field Quality Control, states that field duplicates consist of two aliquots of a sample (i.e., the primary sample and its duplicate) that are aliquoted into two containers from a single sample collection container or sample mixing container. Additionally, the Permit defines a duplicate sample as two or more separate samples taken from the same source during the same sampling event.

Procedure CP4-ES-2704, *Trip, Equipment, and Field Blank Preparation*, describes a field duplicate sample (collocated duplicate) as being collected at the same time, using the same procedures, the same type of equipment, and in the same types of containers as the original sample. The samples are placed in separate, but identical sample containers as the original sample. This is consistent with the Permit's definition of a duplicate sample (i.e., separate samples taken from the same source during the same sampling event).

The Permit's description for collection of a field duplicate sample is similar to the field replicate sample identified in CP4-ES-2704. Field replicate samples also are referred to as split samples in the procedure. The field replicate sample is described as being collected by initially collecting twice as much volume as is normally collected, homogenizing the material by mixing, and distributing into two sets of sample containers. Additionally, the procedure states that samples for volatile organic compounds are not mixed prior to subsampling. A field replicate sample is not commonly used in groundwater sampling due to volatile organic compounds being a contaminant of concern at the Paducah Site.

In order to comply with the current Permit requirement until a Permit modification can be established, two field duplicates were collected during this reporting period. Both samples were collected from the same MW. A groundwater sample was collected from a MW along with a field duplicate sample (MW85 REP) prescribed by the Permit. A separate groundwater sample was collected from the same MW along with a field duplicate sample (MW85 FR) prescribed by CP4-ES-2704. See Appendix A for data.

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4. PROFESSIONAL GEOLOGIST AUTHORIZATION

DOCUMENT IDENTIFICATION: *C-404 Hazardous Waste Landfill*
November 2019 Semiannual Groundwater Report
(April 2019–September 2019),
Paducah Gaseous Diffusion Plant, Paducah, Kentucky
(FRNP-RPT-0086/V2)

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

PG 113927
KDavis 11-7-19

Kenneth R. Davis
Kenneth R. Davis

PG113927

November 7, 2019
Date

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5. REFERENCES

FRNP (Four Rivers Nuclear Partnership, LLC) 2017. *Abandonment of MW91 and Replacement with MW91A*, U.S. Department of Energy, Paducah, KY, December.

FRNP 2018. *C-404 Hazardous Waste Landfill November 2018 Semiannual Groundwater Report (April 2019-September 2018), Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, FRNP-RPT-0026/V2, U.S. Department of Energy, Paducah, KY, November.

FRNP 2019. *C-404 Hazardous Waste Landfill Alternate Source Demonstration—Source of Lead and Uranium in MW87 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, FRNP-RPT-0078, Four Rivers Nuclear Partnership, LLC, Kevil, KY.

KDWM (Kentucky Division of Waste Management) 2017. Hazardous Waste Management Facility Permit for the U.S. Department of Energy, Paducah Gaseous Diffusion Plant, KY8-890-008-982, effective October 13.

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

PRS 2007b. *Well Plan for Addition of Wells for C-404 Monitoring Well Network, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, PRS/PROJ/0028, Paducah Remediation Services, LLC, Kevil, KY, July.

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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: MW84A REG Downgradient URGA **Period:** Semiannual Report

AKGWA Well Tag #: 8007-4849

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic		0.0168	mg/L	0.005	7/22/2019			SW846-6020	=
Arsenic, Dissolved	BJ	0.00207	mg/L	0.005	7/22/2019			SW846-6020	U
Barometric Pressure Reading		29.91	Inches/Hg		7/22/2019				X
Cadmium	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	7/22/2019			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	7/22/2019			SW846-6020	=
Conductivity		779	umho/cm		7/22/2019				X
Depth to Water		43.22	ft		7/22/2019				X
Dissolved Oxygen		0.56	mg/L		7/22/2019				X
Lead	U	0.002	mg/L	0.002	7/22/2019			SW846-6020	=
Lead, Dissolved	J	0.00072	mg/L	0.002	7/22/2019			SW846-6020	U
Mercury	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
pH		6.22	Std Unit		7/22/2019				X
Redox		348	mV		7/22/2019				X
Selenium	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Sulfate		155	mg/L	10	7/22/2019			SW846-9056	=
Technetium-99		126	pCi/L	22.1	7/22/2019	16.2	21.4	HASL 300, Tc-02-RC M	=
Temperature		64.1	deg F		7/22/2019				X
Trichloroethene	Y1	2000	ug/L	50	7/22/2019			SW846-8260B	J
Turbidity		27.6	NTU		7/22/2019				X
Uranium		0.00089	mg/L	0.0002	7/22/2019			SW846-6020	=
Uranium-234		1.77	pCi/L	1.12	7/22/2019	1.17	1.2	HASL 300, U-02-RC M	=
Uranium-235	U	0.971	pCi/L	0.978	7/22/2019	0.988	0.997	HASL 300, U-02-RC M	=
Uranium-238		1.12	pCi/L	0.791	7/22/2019	0.921	0.933	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		0.00879	mg/L	0.005	7/22/2019			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Barometric Pressure Reading		29.91	Inches/Hg		7/22/2019				X
Cadmium	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Chromium	J	0.00441	mg/L	0.01	7/22/2019			SW846-6020	=
Chromium, Dissolved	J	0.0042	mg/L	0.01	7/22/2019			SW846-6020	=
Conductivity		420	umho/cm		7/22/2019				X
Depth to Water		8.05	ft		7/22/2019				X
Dissolved Oxygen		2.47	mg/L		7/22/2019				X
Lead	U	0.002	mg/L	0.002	7/22/2019			SW846-6020	=
Lead, Dissolved	J	0.00077	mg/L	0.002	7/22/2019			SW846-6020	U
Mercury	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
pH		6.37	Std Unit		7/22/2019				X
Redox		395	mV		7/22/2019				X
Selenium	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Sulfate		9.29	mg/L	0.4	7/22/2019			SW846-9056	=
Technetium-99		53.6	pCi/L	20.9	7/22/2019	13.7	14.9	HASL 300, Tc-02-RC M	=
Temperature		66.4	deg F		7/22/2019				X
Trichloroethene	Y1	2.21	ug/L	1	7/22/2019			SW846-8260B	=
Turbidity		31.5	NTU		7/22/2019				X
Uranium		0.00027	mg/L	0.0002	7/22/2019			SW846-6020	=
Uranium-234	U	-0.0342	pCi/L	1.94	7/22/2019	0.854	0.855	HASL 300, U-02-RC M	=
Uranium-235	U	0.152	pCi/L	1.62	7/22/2019	0.844	0.845	HASL 300, U-02-RC M	=
Uranium-238	U	0.718	pCi/L	1.56	7/22/2019	1.06	1.07	HASL 300, U-02-RC M	=

* The field duplicate sample associated with this sample is Sampling Point MW85 FR.

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		0.00912	mg/L	0.005	7/22/2019			SW846-6020	=
Arsenic, Dissolved	BJ	0.00263	mg/L	0.005	7/22/2019			SW846-6020	U
Cadmium	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Chromium	J	0.00416	mg/L	0.01	7/22/2019			SW846-6020	=
Chromium, Dissolved	J	0.00408	mg/L	0.01	7/22/2019			SW846-6020	=
Lead	U	0.002	mg/L	0.002	7/22/2019			SW846-6020	=
Lead, Dissolved	J	0.0009	mg/L	0.002	7/22/2019			SW846-6020	U
Mercury	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
Selenium	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Sulfate		9.26	mg/L	0.4	7/22/2019			SW846-9056	=
Technetium-99		54	pCi/L	20	7/22/2019	13.1	14.4	HASL 300, Tc-02-RC M	=
Trichloroethene	Y1	2.55	ug/L	1	7/22/2019			SW846-8260B	=
Uranium		0.00027	mg/L	0.0002	7/22/2019			SW846-6020	=
Uranium-234		2.35	pCi/L	1.37	7/22/2019	1.52	1.56	HASL 300, U-02-RC M	=
Uranium-235	U	0.201	pCi/L	1.27	7/22/2019	0.754	0.755	HASL 300, U-02-RC M	=
Uranium-238	U	1.19	pCi/L	1.58	7/22/2019	1.22	1.23	HASL 300, U-02-RC M	=

* Field duplicate sample collected as prescribed by internal procedure.

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		0.00954	mg/L	0.005	7/22/2019			SW846-6020	=
Arsenic, Dissolved	BJ	0.00255	mg/L	0.005	7/22/2019			SW846-6020	U
Barometric Pressure Reading		29.92	Inches/Hg		7/22/2019				X
Cadmium	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Chromium	J	0.00338	mg/L	0.01	7/22/2019			SW846-6020	=
Chromium, Dissolved	J	0.00318	mg/L	0.01	7/22/2019			SW846-6020	=
Conductivity		343	umho/cm		7/22/2019				X
Depth to Water		9.86	ft		7/22/2019				X
Dissolved Oxygen		2.01	mg/L		7/22/2019				X
Lead	U	0.002	mg/L	0.002	7/22/2019			SW846-6020	=
Lead, Dissolved	J	0.00084	mg/L	0.002	7/22/2019			SW846-6020	U
Mercury	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
pH		5.98	Std Unit		7/22/2019				X
Redox		450	mV		7/22/2019				X
Selenium	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Sulfate		9.5	mg/L	0.4	7/22/2019			SW846-9056	=
Technetium-99		57.4	pCi/L	21.4	7/22/2019	14	15.4	HASL 300, Tc-02-RC M	=
Temperature		69.4	deg F		7/22/2019				X
Trichloroethene	Y1	1.06	ug/L	1	7/22/2019			SW846-8260B	=
Turbidity		8.1	NTU		7/22/2019				X
Uranium		0.00026	mg/L	0.0002	7/22/2019			SW846-6020	=
Uranium-234	U	0.382	pCi/L	1.4	7/22/2019	0.813	0.816	HASL 300, U-02-RC M	=
Uranium-235	U	0.339	pCi/L	1.23	7/22/2019	0.778	0.78	HASL 300, U-02-RC M	=
Uranium-238	U	0.411	pCi/L	1.1	7/22/2019	0.727	0.729	HASL 300, U-02-RC M	=

* The field duplicate sample associated with this sample is Sampling Point MW85 REP.

Paducah OREIS
GROUNDWATER MONITORING REPORT

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

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

AKGWA Well Tag #: 8000-5234

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic		0.00929	mg/L	0.005	7/22/2019			SW846-6020	=
Arsenic, Dissolved	BJ	0.00313	mg/L	0.005	7/22/2019			SW846-6020	U
Cadmium	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Chromium	J	0.00326	mg/L	0.01	7/22/2019			SW846-6020	=
Chromium, Dissolved	J	0.00331	mg/L	0.01	7/22/2019			SW846-6020	=
Lead	U	0.002	mg/L	0.002	7/22/2019			SW846-6020	=
Lead, Dissolved	J	0.00092	mg/L	0.002	7/22/2019			SW846-6020	U
Mercury	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
Selenium	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Sulfate		9.53	mg/L	0.4	7/22/2019			SW846-9056	=
Technetium-99		55.1	pCi/L	20.3	7/22/2019	13.3	14.7	HASL 300, Tc-02-RC M	=
Trichloroethene	JY1	0.85	ug/L	1	7/22/2019			SW846-8260B	=
Uranium		0.00025	mg/L	0.0002	7/22/2019			SW846-6020	=
Uranium-234		2.12	pCi/L	1.96	7/22/2019	1.65	1.69	HASL 300, U-02-RC M	=
Uranium-235	U	1.26	pCi/L	1.8	7/22/2019	1.45	1.46	HASL 300, U-02-RC M	=
Uranium-238	U	0.363	pCi/L	1.32	7/22/2019	0.834	0.836	HASL 300, U-02-RC M	=

* Field duplicate sample collected as prescribed in the Permit.

Paducah OREIS
GROUNDWATER MONITORING REPORT

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

Sampling Point: MW87A REG Downgradient URGA **Period:** Semiannual Report

AKGWA Well Tag #: 8007-4850

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic		0.00723	mg/L	0.005	7/22/2019			SW846-6020	=
Arsenic, Dissolved	BJ	0.00237	mg/L	0.005	7/22/2019			SW846-6020	U
Barometric Pressure Reading		29.92	Inches/Hg		7/22/2019				X
Cadmium	J	0.0006	mg/L	0.001	7/22/2019			SW846-6020	U
Cadmium, Dissolved	J	0.00065	mg/L	0.001	7/22/2019			SW846-6020	U
Chromium	U	0.01	mg/L	0.01	7/22/2019			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	7/22/2019			SW846-6020	=
Conductivity		323	umho/cm		7/22/2019				X
Depth to Water		43.17	ft		7/22/2019				X
Dissolved Oxygen		2.29	mg/L		7/22/2019				X
Lead	U	0.002	mg/L	0.002	7/22/2019			SW846-6020	=
Lead, Dissolved	J	0.00083	mg/L	0.002	7/22/2019			SW846-6020	U
Mercury	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
pH		5.93	Std Unit		7/22/2019				X
Redox		429	mV		7/22/2019				X
Selenium	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Sulfate		7.44	mg/L	0.4	7/22/2019			SW846-9056	=
Technetium-99	U	1.22	pCi/L	19.9	7/22/2019	11.6	11.6	HASL 300, Tc-02-RC M	=
Temperature		64.9	deg F		7/22/2019				X
Trichloroethene	Y1	1850	ug/L	50	7/22/2019			SW846-8260B	=
Turbidity		9.2	NTU		7/22/2019				X
Uranium	U	0.0002	mg/L	0.0002	7/22/2019			SW846-6020	=
Uranium-234	U	0.463	pCi/L	2.02	7/22/2019	1.11	1.12	HASL 300, U-02-RC M	=
Uranium-235	U	0.69	pCi/L	1.52	7/22/2019	1.1	1.1	HASL 300, U-02-RC M	=
Uranium-238	U	0.346	pCi/L	1.64	7/22/2019	0.912	0.913	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		0.0077	mg/L	0.005	7/22/2019			SW846-6020	=
Arsenic, Dissolved	BJ	0.00263	mg/L	0.005	7/22/2019			SW846-6020	U
Barometric Pressure Reading		29.93	Inches/Hg		7/22/2019				X
Cadmium	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	7/22/2019			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	7/22/2019			SW846-6020	=
Conductivity		621	umho/cm		7/22/2019				X
Depth to Water		7.81	ft		7/22/2019				X
Dissolved Oxygen		3.74	mg/L		7/22/2019				X
Lead	U	0.002	mg/L	0.002	7/22/2019			SW846-6020	=
Lead, Dissolved	J	0.00082	mg/L	0.002	7/22/2019			SW846-6020	U
Mercury	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
pH		5.79	Std Unit		7/22/2019				X
Redox		450	mV		7/22/2019				X
Selenium	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Sulfate		124	mg/L	4	7/22/2019			SW846-9056	=
Technetium-99	U	19.2	pCi/L	19.5	7/22/2019	11.9	12	HASL 300, Tc-02-RC M	=
Temperature		66.5	deg F		7/22/2019				X
Trichloroethene	Y1	4.7	ug/L	1	7/22/2019			SW846-8260B	=
Turbidity		19.2	NTU		7/22/2019				X
Uranium	J	0.000083	mg/L	0.0002	7/22/2019			SW846-6020	=
Uranium-234	U	0.218	pCi/L	2.09	7/22/2019	1.06	1.06	HASL 300, U-02-RC M	=
Uranium-235	U	1.02	pCi/L	1.78	7/22/2019	1.48	1.49	HASL 300, U-02-RC M	=
Uranium-238	U	0.24	pCi/L	2.11	7/22/2019	1.08	1.08	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	7/22/2019			SW846-6020	=
Arsenic, Dissolved	BJ	0.00289	mg/L	0.005	7/22/2019			SW846-6020	U
Barometric Pressure Reading		29.93	Inches/Hg		7/22/2019				X
Cadmium	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	7/22/2019			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	7/22/2019			SW846-6020	=
Conductivity		203	umho/cm		7/22/2019				X
Depth to Water		42.39	ft		7/22/2019				X
Dissolved Oxygen		4.31	mg/L		7/22/2019				X
Lead	U	0.002	mg/L	0.002	7/22/2019			SW846-6020	=
Lead, Dissolved	J	0.00078	mg/L	0.002	7/22/2019			SW846-6020	U
Mercury	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
pH		5.94	Std Unit		7/22/2019				X
Redox		469	mV		7/22/2019				X
Selenium	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Sulfate		4.36	mg/L	0.4	7/22/2019			SW846-9056	=
Technetium-99	U	11.4	pCi/L	19.4	7/22/2019	11.6	11.7	HASL 300, Tc-02-RC M	=
Temperature		66.3	deg F		7/22/2019				X
Trichloroethene	Y1	55.7	ug/L	1	7/22/2019			SW846-8260B	=
Turbidity		4	NTU		7/22/2019				X
Uranium	U	0.0002	mg/L	0.0002	7/22/2019			SW846-6020	=
Uranium-234		1.67	pCi/L	1.34	7/22/2019	1.26	1.29	HASL 300, U-02-RC M	=
Uranium-235	U	1.26	pCi/L	1.45	7/22/2019	1.25	1.27	HASL 300, U-02-RC M	=
Uranium-238		2.31	pCi/L	0.578	7/22/2019	1.36	1.4	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

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

Sampling Point: MW91A REG Downgradient UCRS **Period:** Semiannual Report

AKGWA Well Tag #: 8007-2917

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic		0.0233	mg/L	0.005	7/22/2019			SW846-6020	=
Arsenic, Dissolved	B	0.0151	mg/L	0.005	7/22/2019			SW846-6020	J
Barometric Pressure Reading		29.92	Inches/Hg		7/22/2019				X
Cadmium	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Chromium	J	0.00348	mg/L	0.01	7/22/2019			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	7/22/2019			SW846-6020	=
Conductivity		1092	umho/cm		7/22/2019				X
Depth to Water		12.14	ft		7/22/2019				X
Dissolved Oxygen		2.77	mg/L		7/22/2019				X
Lead	U	0.002	mg/L	0.002	7/22/2019			SW846-6020	=
Lead, Dissolved	J	0.00075	mg/L	0.002	7/22/2019			SW846-6020	U
Mercury	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
pH		6.27	Std Unit		7/22/2019				X
Redox		96	mV		7/22/2019				X
Selenium	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Sulfate		163	mg/L	10	7/22/2019			SW846-9056	=
Technetium-99	U	13.4	pCi/L	19.9	7/22/2019	11.9	12	HASL 300, Tc-02-RC M	=
Temperature		66.3	deg F		7/22/2019				X
Trichloroethene	Y1	25.7	ug/L	1	7/22/2019			SW846-8260B	=
Turbidity		17.1	NTU		7/22/2019				X
Uranium	J	0.000086	mg/L	0.0002	7/22/2019			SW846-6020	=
Uranium-234		2.13	pCi/L	1.12	7/22/2019	1.27	1.31	HASL 300, U-02-RC M	=
Uranium-235	U	0.569	pCi/L	0.988	7/22/2019	0.819	0.823	HASL 300, U-02-RC M	=
Uranium-238	U	0.927	pCi/L	1.23	7/22/2019	0.947	0.955	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

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

Sampling Point: MW93A REG Upgradient URGA **Period:** Semiannual Report

AKGWA Well Tag #: 8007-4851

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic		0.00602	mg/L	0.005	7/22/2019			SW846-6020	=
Arsenic, Dissolved	BJ	0.00209	mg/L	0.005	7/22/2019			SW846-6020	U
Barometric Pressure Reading		29.92	Inches/Hg		7/22/2019				X
Cadmium	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	7/22/2019			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	7/22/2019			SW846-6020	=
Conductivity		434	umho/cm		7/22/2019				X
Depth to Water		46.28	ft		7/22/2019				X
Dissolved Oxygen		1.91	mg/L		7/22/2019				X
Lead	J	0.00051	mg/L	0.002	7/22/2019			SW846-6020	=
Lead, Dissolved	J	0.00074	mg/L	0.002	7/22/2019			SW846-6020	U
Mercury	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
pH		6.2	Std Unit		7/22/2019				X
Redox		159	mV		7/22/2019				X
Selenium	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Sulfate		26	mg/L	0.8	7/22/2019			SW846-9056	=
Technetium-99	U	8.82	pCi/L	20.2	7/22/2019	12	12	HASL 300, Tc-02-RC M	=
Temperature		66.2	deg F		7/22/2019				X
Trichloroethene	Y1	789	ug/L	20	7/22/2019			SW846-8260B	=
Turbidity		61.2	NTU		7/22/2019				X
Uranium		0.00056	mg/L	0.0002	7/22/2019			SW846-6020	=
Uranium-234		2.38	pCi/L	1.58	7/22/2019	1.49	1.54	HASL 300, U-02-RC M	=
Uranium-235	U	0.0651	pCi/L	1.42	7/22/2019	0.681	0.681	HASL 300, U-02-RC M	=
Uranium-238	U	0.662	pCi/L	1.04	7/22/2019	0.839	0.844	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	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Arsenic, Dissolved	BJ	0.00264	mg/L	0.005	7/22/2019			SW846-6020	U
Barometric Pressure Reading		29.92	Inches/Hg		7/22/2019				X
Cadmium	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	7/22/2019			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	7/22/2019			SW846-6020	=
Conductivity		805	umho/cm		7/22/2019				X
Depth to Water		12.35	ft		7/22/2019				X
Dissolved Oxygen		0.58	mg/L		7/22/2019				X
Lead	J	0.00054	mg/L	0.002	7/22/2019			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	7/22/2019			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
pH		6.39	Std Unit		7/22/2019				X
Redox		283	mV		7/22/2019				X
Selenium	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Sulfate		74.7	mg/L	4	7/22/2019			SW846-9056	=
Technetium-99		1210	pCi/L	20.6	7/22/2019	31.9	138	HASL 300, Tc-02-RC M	=
Temperature		64.8	deg F		7/22/2019				X
Trichloroethene	Y1	1.54	ug/L	1	7/22/2019			SW846-8260B	=
Turbidity		24.3	NTU		7/22/2019				X
Uranium		0.00183	mg/L	0.0002	7/22/2019			SW846-6020	=
Uranium-234		3.89	pCi/L	1.79	7/22/2019	1.89	1.98	HASL 300, U-02-RC M	=
Uranium-235	U	0.847	pCi/L	1.33	7/22/2019	1.07	1.08	HASL 300, U-02-RC M	=
Uranium-238		1.67	pCi/L	1.44	7/22/2019	1.29	1.31	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	J	0.00359	mg/L	0.005	7/22/2019			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Barometric Pressure Reading		29.91	Inches/Hg		7/22/2019				X
Cadmium	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	7/22/2019			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	7/22/2019			SW846-6020	=
Conductivity		328	umho/cm		7/22/2019				X
Depth to Water		45.91	ft		7/22/2019				X
Dissolved Oxygen		1.71	mg/L		7/22/2019				X
Lead	U	0.002	mg/L	0.002	7/22/2019			SW846-6020	=
Lead, Dissolved	J	0.00084	mg/L	0.002	7/22/2019			SW846-6020	U
Mercury	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
pH		5.92	Std Unit		7/22/2019				X
Redox		190	mV		7/22/2019				X
Selenium	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Sulfate		5.99	mg/L	0.4	7/22/2019			SW846-9056	=
Technetium-99	U	4.16	pCi/L	20.5	7/22/2019	12	12	HASL 300, Tc-02-RC M	=
Temperature		65.6	deg F		7/22/2019				X
Trichloroethene	Y1	600	ug/L	10	7/22/2019			SW846-8260B	=
Turbidity		6	NTU		7/22/2019				X
Uranium	U	0.0002	mg/L	0.0002	7/22/2019			SW846-6020	=
Uranium-234	U	1.04	pCi/L	1.42	7/22/2019	1.08	1.09	HASL 300, U-02-RC M	=
Uranium-235	U	0.181	pCi/L	1.14	7/22/2019	0.677	0.678	HASL 300, U-02-RC M	=
Uranium-238	U	-0.0384	pCi/L	1.35	7/22/2019	0.577	0.577	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: 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	7/22/2019			SW846-6020	=
Cadmium	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	7/22/2019			SW846-6020	=
Lead	U	0.002	mg/L	0.002	7/22/2019			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
Selenium	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Technetium-99	U	-3.47	pCi/L	19.9	7/22/2019	11.4	11.4	HASL 300, Tc-02-RC M	=
Trichloroethene	UY1	1	ug/L	1	7/22/2019			SW846-8260B	=
Uranium	U	0.0002	mg/L	0.0002	7/22/2019			SW846-6020	=
Uranium-234	U	0.795	pCi/L	1.75	7/22/2019	1.12	1.13	HASL 300, U-02-RC M	=
Uranium-235	U	1.44	pCi/L	1.44	7/22/2019	1.37	1.39	HASL 300, U-02-RC M	=
Uranium-238	U	1.23	pCi/L	1.77	7/22/2019	1.28	1.29	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	7/22/2019			SW846-6020	=
Cadmium	U	0.001	mg/L	0.001	7/22/2019			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	7/22/2019			SW846-6020	=
Lead	U	0.002	mg/L	0.002	7/22/2019			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/22/2019			SW846-7470A	=
Selenium	U	0.005	mg/L	0.005	7/22/2019			SW846-6020	=
Technetium-99	U	-7.29	pCi/L	19	7/22/2019	10.8	10.8	HASL 300, Tc-02-RC M	=
Trichloroethene	UY1	1	ug/L	1	7/22/2019			SW846-8260B	=
Uranium	U	0.0002	mg/L	0.0002	7/22/2019			SW846-6020	=
Uranium-234	U	1.05	pCi/L	2.45	7/22/2019	1.58	1.6	HASL 300, U-02-RC M	=
Uranium-235	U	0.697	pCi/L	1.9	7/22/2019	1.37	1.37	HASL 300, U-02-RC M	=
Uranium-238	U	0.884	pCi/L	1.54	7/22/2019	1.27	1.28	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	UY1	1	ug/L	1	7/22/2019			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.
B Analyte found in the associated blank
Y1 MS/MSD recovery outside acceptance criteria

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 Duplicate as defined in sampling procedure.
REP Field Duplicate as defined in permit.
REG Regular
RI QC Equipment Rinseate/Decon
TB Trip Blank

VALIDATION Codes

= 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 the C-404 Hazardous Waste Landfill (C-404 Landfill) were performed in accordance with procedures provided in Appendix E of the Hazardous Waste Management Facility 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 the second reporting period 2019 semiannual report, the reporting period data set includes data from July 2017, January 2018, August 2018, January 2019, and July 2019.

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 Regional Gravel Aquifer (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	MW93A*, MW420
Downgradient compliance wells	MW84A*, MW87A*, MW90A*

*MW90 was abandoned in 2001 and replaced with MW90A. MW84, MW87, and MW93 were abandoned in 2019 and replaced with MW84A, MW87A, and MW93A, respectively.

For the second reporting period 2019 semiannual report, the reporting period data set from July 2017 through July 2019 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 data and type of statistical test chosen for each of the parameters required by Part VIII.E of the Permit.

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	6	19
Cadmium	25	0	18	7
Chromium	25	0	12	13
Lead	25	0	12	13
Mercury	25	0	25	0
Selenium	25	0	24	1
Technetium-99	25	0	21	4
Trichloroethene	25	0	0	25
Uranium (Metals)	25	0	13	12
Uranium-234	25	0	21	4
Uranium-235	25	0	25	0
Uranium-238	25	0	23	2

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

Parameter	Total Samples (Nonmissing)	Uncensored (Detects)	Censored (Nondetects)	Percent Censored	Statistical Test Set*
URGA					
Arsenic	25	19	6	24.00	3
Cadmium	25	7	18	72.00	2
Chromium	25	13	12	48.00	3
Lead	25	13	12	48.00	3
Mercury	25	0	25	100.00	1
Selenium	25	1	24	96.00	1
Technetium-99	25	4	21	84.00	2
Trichloroethene	25	25	0	0.00	4/3**
Uranium (Metals)	25	12	13	52.00	2
Uranium-234	25	4	21	84.00	2
Uranium-235	25	0	25	100.00	1
Uranium-238	25	2	23	92.00	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 C-404 Landfill statistical analyses for the second reporting period 2019, 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 B8. The statistician qualification statement is presented in Attachment B9.

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

Parameter	LOD Values	½ LOD Values
URGA		
Mercury (mg/L)	0.0002	0.0001
Selenium (mg/L)	0.005	0.0025
Uranium-235 (pCi/L)	1.52	0.76
Uranium-238 (pCi/L)	1.64	0.82

In summary, Statistical Test 2, Test of Proportions, for technetium-99, uranium, and uranium-234 in the URGA indicated no statistically significant difference between concentrations in downgradient wells and concentrations in background wells.

Statistical Test 2, Test of Proportions, for cadmium in the URGA indicated a statistically significant evidence that the proportion of detects in one group of data exceeds the proportion of detects in the other group. For cadmium, downgradient wells had a higher proportion of detects; therefore, the data were

evaluated further using Nonparametric ANOVA. Nonparametric ANOVA identified a statistically significant difference between concentrations in downgradient well MW87A and concentrations in background wells; therefore, the data were compared to the UTL. The 95% UTL did not indicate a statistically significant difference between concentrations in downgradient well MW87A and concentrations in background wells.

Statistical Test 3, Nonparametric ANOVA, for arsenic in the URGA identified a statistically significant difference between concentrations in downgradient well MW84A 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 well MW84A 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., performed a comparison of downgradient well (MW84A) results to upgradient westernmost well (MW93A) results]. Results of the paired (parametric) ANOVA identified there to be a significant difference between upgradient and downgradient wells. A Mann-Kendall test was performed to further evaluate the data, and no trend was identified for arsenic in MW84A.

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

Statistical Test 3, Nonparametric ANOVA, for lead in the URGA identified a statistically significant difference between concentrations in downgradient well MW87A and concentrations in background wells; therefore, the data were evaluated further by comparing results to the UTL. The 95% UTL did not indicate a statistically significant difference between concentrations in downgradient well MW87A 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. Nonparametric ANOVA identified a statistically significant difference between concentrations in downgradient well MW84A 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 well MW84A 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., performed a comparison of downgradient well (MW84A) results to upgradient westernmost well (MW93A) results]. Results of the paired (parametric) ANOVA identified there to be a significant difference between upgradient and downgradient wells. A Mann-Kendall test was performed to further evaluate the data, and it identified a positive trend for trichloroethene in MW84A.

Table B.5. Summary of Conclusions from the C-404 Hazardous Waste Landfill Statistical Analyses for the Second Reporting Period 2019

Attachment	RGA Well Type	Parameter	Applied Statistical Test	Results
B1	URGA	Arsenic	Statistical Test 3, Nonparametric ANOVA with 95% UTL, paired ANOVA (MW84A vs. MW93A), and Mann-Kendall.	Because Nonparametric ANOVA indicated a statistically significant difference between concentrations in downgradient wells and concentrations in background wells for compliance well MW84A, a comparison to the 95% UTL, paired ANOVA, and Mann-Kendall was performed, as required by the Hazardous Waste Management Facility Permit. Results of the paired ANOVA have identified there is a significant difference between upgradient and downgradient wells. The Mann-Kendall identified no trend in MW84A.
B2	URGA	Cadmium	Statistical Test 2, Test of Proportions with Statistical Test 3, Nonparametric ANOVA and 95% UTL	Because Test of Proportions indicated statistically significant evidence that the proportion of detects in one group of data exceeds the proportion of detects in the other group, Statistical Test 3, Nonparametric ANOVA, and a comparison to the 95% UTL were performed. Results of the comparison to the 95% UTL have not identified a statistically significant difference between concentrations in downgradient well MW87A and concentrations in background wells.
B3	URGA	Chromium	Statistical Test 3, Nonparametric ANOVA	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B4	URGA	Lead	Statistical Test 3, Nonparametric ANOVA with 95% UTL	Because Nonparametric ANOVA indicated a statistically significant difference between concentrations in downgradient wells and concentrations in background wells for compliance well MW87A, a comparison to the 95% UTL was performed, as required by the Hazardous Waste Management Facility Permit. Results of the comparison to the 95% UTL have not identified a statistically significant difference between concentrations in downgradient well MW87A or concentrations in background wells.

Table B.5. Summary of Conclusions from the C-404 Hazardous Waste Landfill Statistical Analyses for the Second Reporting Period 2019 (Continued)

Attachment	RGA Well Type	Parameter	Applied Statistical Test	Results
B5	URGA	Technetium-99	Statistical Test 2, Test of Proportions	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B6	URGA	Trichloroethene	Statistical Test 4, Parametric ANOVA/Statistical Test 3, Nonparametric ANOVA with 95% UTL, paired ANOVA (MW84A vs. MW93A), Mann-Kendall, and data review	Because equality of variance could not be confirmed, Statistical Test 4 was abandoned and Statistical Test 3, Nonparametric ANOVA, was performed. Because Nonparametric ANOVA indicated a statistically significant difference between concentrations in downgradient wells and concentrations in background wells for compliance well MW84A, a comparison to the 95% UTL, paired ANOVA, Mann-Kendall, and an attempt to review data were performed, as required by the Hazardous Waste Management Facility Permit. Results of the paired ANOVA have identified there is a significant difference between upgradient and downgradient wells. The Mann-Kendall identified a positive trend in MW84A.
B7	URGA	Uranium	Statistical Test 2, Test of Proportions	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B8	URGA	Uranium-234	Statistical Test 2, Test of Proportions	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.

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ATTACHMENT B1

ARSENIC
STATISTICAL TEST 3

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Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Arsenic (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	**0.00755**	**0.00207**	**0.0191**	**0.00907**	0.0025
Jan-18	**0.00807**	0.0025	**0.0185**	**0.0087**	0.0025
Aug-18	**0.00619**	**0.00304**	**0.0289**	**0.0105**	0.0025
Jan-19	**0.00462**	**0.00414**	**0.0275**	**0.0116**	0.0025
Jul-19	**0.00602**	**0.00359**	**0.0168**	**0.00723**	0.0025
Sum	0.0478		0.11080	0.04710	0.0125
n_i	10		5	5	5
$(x_i)_{avg}$	0.00478		0.02216	0.00942	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.. = 0.00873

N =	25	N = the total number of samples
p =	4	p = the number of n_i groups
x.. =	0.22	x.. = the sum of the total number of samples

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	Arsenic (mg/L)	Adjusted Rank	Tie Number
1	0	3.5	Tie 1
2	0	3.5	
3	0	3.5	
4	0	3.5	
5	0	3.5	
6	0	3.5	
7	**0.00207**	7	
8	**0.00304**	8	
9	**0.00359**	9	
10	**0.00414**	10	
11	**0.00462**	11	
12	**0.00602**	12	
13	**0.00619**	13	
14	**0.00723**	14	
15	**0.00755**	15	
16	**0.00807**	16	
17	**0.0087**	17	
18	**0.00907**	18	
19	**0.0105**	19	
20	**0.0116**	20	
21	**0.0168**	21	
22	**0.0185**	22	
23	**0.0191**	23	
24	**0.0275**	24	
25	**0.0289**	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 that are considered nondetects (i.e., U qualified data) are reported as a concentration of 0.

n_{tie}	Adjustment for Ties: $(n_{tie}^3 - n_{tie})$
6	Tie 1 = 210
	$\sum T_i$ = 210

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Sums of Ranks and Averages

Arsenic (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	**0.00755**	**0.00207**	**0.0191**	**0.00907**	0
Jan-18	**0.00807**	0	**0.0185**	**0.0087**	0
Aug-18	**0.00619**	**0.00304**	**0.0289**	**0.0105**	0
Jan-19	**0.00462**	**0.00414**	**0.0275**	**0.0116**	0
Jul-19	**0.00602**	**0.00359**	**0.0168**	**0.00723**	0

Observation Ranks for Arsenic					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	15	7	23	18	3.5
Jan-18	16	3.5	22	17	3.5
Aug-18	13	8	25	19	3.5
Jan-19	11	10	24	20	3.5
Jul-19	12	9	21	14	3.5
R_i	104.5		115	88	17.5
$(R_i)_{avg}$	10.5		23.0	17.6	3.5
R_i^2/n_i	1092.0		2645.0	1548.8	61.3

$\Sigma R_i^2/n_i$ = 5347.1

K = 4

N = 25

mg/L = milligrams per liter

BG = background

DL = detection limit

Bolded values indicate a detected result.

K = the number of n_i groups

N = the total number of samples

NOTE: For this method, observations below the detection limit that are considered nondetects (i.e., U qualified data) are reported as a concentration of 0.

Calculation of Kruskal-Wallis Statistic

H =	20.715	Kruskal-Wallis Statistic	$H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$
H' =	20.998	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).

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Calculate Critical Values

Average Background Ranking = 10.5

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93A			
BG Well	MW420			
	MW84A	8.578	12.6	**evidence of contamination**
	MW87A	8.578	7.2	not contaminated
	MW90A	8.578	-7.0	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 MW84A, there is a statistically significant difference between downgradient compliance test wells and background wells in MW84A from the C-404 Landfill.

Because nonparametric ANOVA indicated a statistically significant difference between compliance test wells and background wells at the C-404 Landfill in compliance well MW84A, the 95% UTL was performed.

Since $(R_i)_{avg} - (R_b)_{avg} < C_i$ for MW87A and MW90A, there is no statistically significant difference between background wells and these downgradient compliance test wells; however, the negative value indicates 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 B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

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 2019 Data, Second Reporting Period
Observations (mg/L)

Well No.						
MW93A	**0.00755**	**0.00807**	**0.00619**	**0.00462**	**0.00602**	**Upgradient Well!**
MW420	**0.00207**	0.0025	**0.00304**	**0.00414**	**0.00359**	**Upgradient Well!**
						Current Data
MW84A		X: Mean Value =	0.0048			**0.0168**
		S: Standard Deviation =	0.0021			
		K* factor =	2.911	(for n = 10)		
		CV = S/X	0.4381	<1, assume normal distribution		
		Upper Tolerance Interval: TL = X +(KxS) =		**0.0109**	(mg/L)	

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

Result: **MW84A 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 MW84A, the paired ANOVA was performed.

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Paired (Parametric) ANOVA

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.

Arsenic (mg/L)				
Date	Background	Compliance		
	MW93A	MW84A	n_i^2	
Jul-17	**0.00755**	**0.0191**	0.0000570	0.0003648
Jan-18	**0.00807**	**0.0185**	0.0000651	0.0003423
Aug-18	**0.00619**	**0.0289**	0.0000383	0.0008352
Jan-19	**0.00462**	**0.0275**	0.0000213	0.0007563
Jul-19	**0.00602**	**0.0168**	0.0000362	0.0002822
Sum (x_i)	0.0325	0.11080	0.1433	Total Sum (x..)
n_i	5	5		
$(x_i)_{avg}$	0.00649	0.02216		
$(x_i)^2$	0.00105	0.01228		

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

Overall mean x.. =	0.01433	
N =	10	N = the total number of samples
p =	2	p = the number of n_i groups
$x_{..}$ =	0.1433	x.. = the sum of the total number of samples

Determine Normality of Dataset

Coefficient of Variability Test

Table of Residuals ($x_i - x_{iavg}$)

Date	Background	Compliance
	MW93A	MW84A
Jul-17	0.00106	-0.00306
Jan-18	0.00158	-0.00366
Aug-18	-0.00030	0.00674
Jan-19	-0.00187	0.00534
Jul-19	-0.00047	-0.00536

X: Mean Value =	1.82E-18	
S: Standard Deviation =	0.00384	
K* Factor =	2.911	(for n = 10)
CV = S/X =	2.11E+15	≥1, data are NOT normally distributed

Data are not normally distributed (i.e., ≥1).

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

If the coefficient of variation (CV) is < 1, the data are normally distributed.
If the coefficient of variation (CV) is > or = 1, data are not normally distributed.

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Determine Equality of Variance of Dataset

p = number of wells	$x_{..} = 0.1433$
n_i = number of data points per well	$(x_{avg})_{..} = 0.01433$
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	$f_iS_i^2$	$f_i\ln(S_i^2)$
0.00136	0.00000185695	-13.197	5	0.0000074	-52.8
0.00560	0.00003135800	-10.370	5	0.0001254	-41.5

$\sum(S_i^2)$ = 0.00003 $\sum f_i\ln(S_i^2)$ = -94.26647

Equality of Variance: Bartlett's Test

f =	8	
Sp^2 =	0.0000166	
ln Sp^2 =	-11.006	
χ^2 =	6.221	(If calculated $\chi^2 \leq$ tabulated χ^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)

NOTE: The variances are NOT equal. (i.e., calculated $\chi^2 > \chi^2_{crit}$)

Variances are not equal, transform the original data to lognormal (i.e., since calculated $\chi^2 > \chi^2_{crit}$).

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

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Paired (Parametric) ANOVA—Lognormal Data

ln[Arsenic (mg/L)]				
Date	Background	Compliance		
	MW93A	MW84A	n_i^2	
Jul-17	**-4.89**	**-3.96**	23.88	15.67
Jan-18	**-4.82**	**-3.99**	23.23	15.92
Aug-18	**-5.08**	**-3.54**	25.86	12.56
Jan-19	**-5.38**	**-3.59**	28.92	12.91
Jul-19	**-5.11**	**-4.09**	26.14	16.70
Sum (x_i)	-25.28	-19.17	-44.45	Total Sum (x..)
n_i	5	5		
$(x_i)_{avg}$	-5.06	-3.83		
$(x_i)^2$	639.11	367.56		

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

Overall mean x.. =	-4.45	
N =	10	N = the total number of samples
p =	2	p = the number of n_i groups
$x_{..}$ =	-44.45	x.. = the sum of the total number of samples

Determine Normality of Dataset

Coefficient of Variability Test—Lognormal Data

Table of Residuals (x_i-$x_i$avg) for Lognormal Data

Date	Background	Compliance
	MW93A	MW84A
Jul-17	0.17	-0.12
Jan-18	0.24	-0.16
Aug-18	-0.03	0.29
Jan-19	-0.32	0.24
Jul-19	-0.06	-0.25

X: Mean Value =	-3.11E-16	
S: Standard Deviation =	0.22	
K* Factor =	2.911	(for n = 10)
CV = S/X =	–7.09E+14	<1, data are normally distributed

Data are normally distributed (i.e., <1)

*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 are normally distributed.
If the coefficient of variation is > or = 1, the residuals are not normally distributed.

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Determine Equality of Variance—Lognormal Data

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)
$f_i = n_i - 1$

$x_{..} = -44.45$
$(x_{avg})_{..} = -4.45$
$n_i = 5$
$p = 2$
$N = 10$
$f_i = 4$

Calculations for Equality of Variance: Bartlett's Test

S_i	S_i^2	$\ln(S_i^2)$	n_i	$f_i S_i^2$	$f_i \ln(S_i^2)$
0.22	0.05	-3.04	5	0.19	-12.1
0.25	0.06	-2.79	5	0.25	-11.2

$\sum(S_i^2) =$ 0.11 $\sum f_i \ln(S_i^2) =$ -23.31

Equality of Variance: Bartlett's Test

f = 8
Sp^2 = 0.05
ln Sp^2 = -2.91
χ^2 = 0.06 (If calculated $\chi^2 \leq$ tabulated χ^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)

NOTE: The variances are equal. (i.e., calculated $\chi^2 \leq \chi^2_{crit}$)

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).

**Section 5.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989)].

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Between Well Sum of Squares

Source of	Sums of Squares		Degrees of	Mean Squares	Calculated F	F Statistic**
Between Wells	SS_{wells} =	3.73168	1	3.73168	68.25	5.32
Error	SS_{Error} =	0.43740	8	0.054675		
Total	SS_{Total} =	4.16908	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 identified a significant difference between background and downgradient wells.**

Because the paired ANOVA for the two wells indicated a statistically significant difference between compliance test wells and background wells at the C-404 Landfill in compliance well MW84A, a Mann-Kendall statistical analysis was performed.

**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.

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Mann-Kendall Statistical Analysis for Arsenic in MW84A

Input Data

Date Collected	Result (mg/L)
Jan-16	**0.0103**
Jul-16	**0.0137**
Jan-17	**0.017**
Jul-17	**0.0191**
Jan-18	**0.0185**
Aug-18	**0.0289**
Jan-19	**0.0275**
Jul-19	**0.0168**

Bolded values indicate a detected result.

Mann-Kendall Trend Test Analysis

User Selected Options	
Date/Time of Computation	ProUCL 5.19/30/2019 9:08:49 AM
From File	WorkSheet.xls
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

MW84A arsenic 2H 2019

General Statistics

Number or Reported Events Not Used	0
Number of Generated Events	8
Number Values Reported (n)	8
Minimum	0.0103
Maximum	0.0289
Mean	0.019
Geometric Mean	0.0181
Median	0.0178
Standard Deviation	0.00636
Coefficient of Variation	0.335

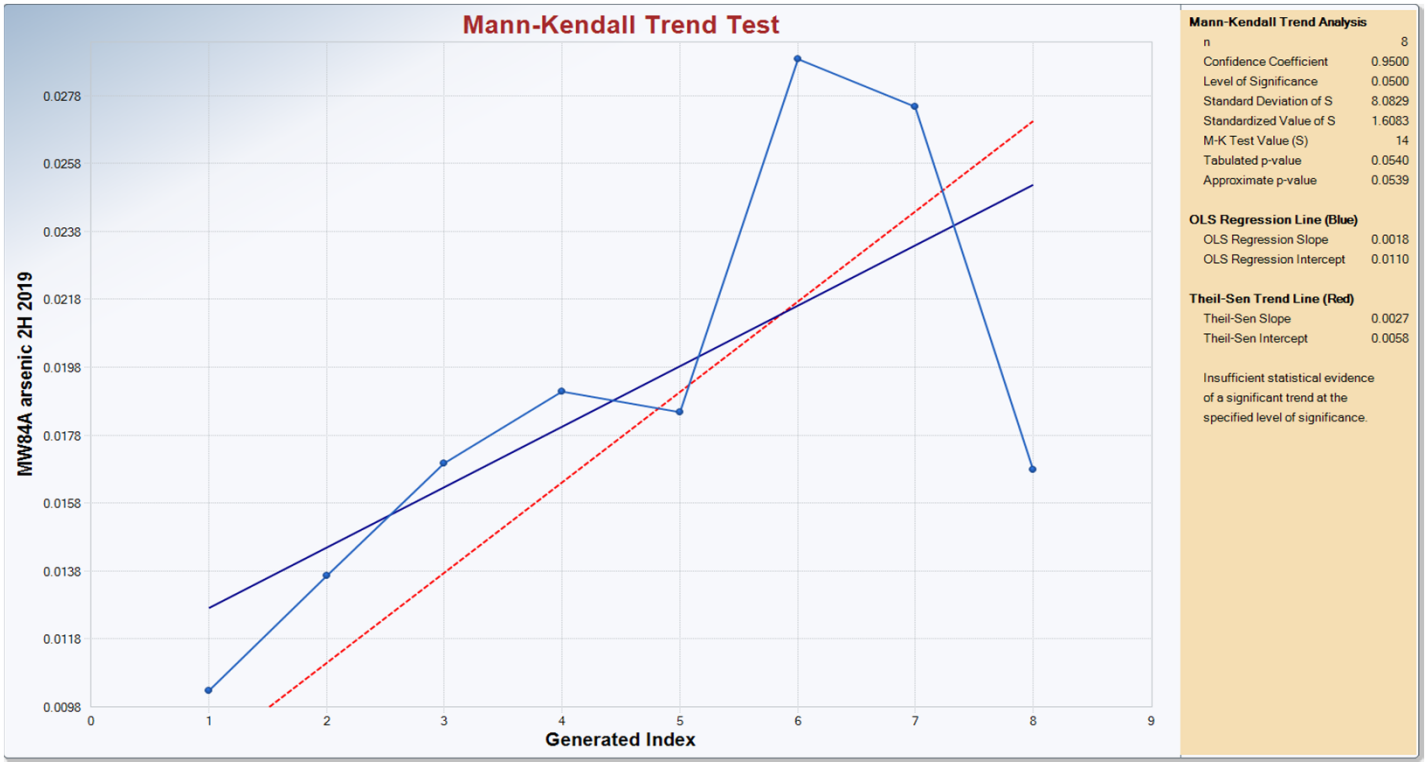
Mann-Kendall Test

M-K Test Value (S)	14
Tabulated p-value	0.054
Standard Deviation of S	8.083
Standardized Value of S	1.608
Approximate p-value	0.0539

Insufficient evidence to identify a significant trend at the specified level of significance.

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Mann-Kendall Statistical Analysis for Arsenic in MW84A



ATTACHMENT B2

CADMIUM
STATISTICAL TEST 2

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Attachment B2: Cadmium URGA, Statistical Test 2, Test of Proportions, Second Reporting Period 2019

Cadmium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	0.0005	0.0005	**0.000396**	**0.000304**	0.0005
Jan-18	0.0005	0.0005	0.0005	**0.000375**	0.0005
Aug-18	0.0005	0.0005	**0.000323**	**0.000372**	0.0005
Jan-19	0.0005	0.0005	**0.000415**	**0.000481**	0.0005
Jul-19	0.0005	0.0005	0.0005	0.0005	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 =	0	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 =	0.280	P = (x+y)/n
nP =	7	$n = n_b+n_c$
n(1-P) =	18	

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

P_b =	0.000	P_b = proportion of detects in background wells
P_c =	0.467	P_c = proportion of detects in compliance wells
S_D =	0.183	S_D = standard error of difference in proportions
Z =	-2.546	$Z = (P_b-P_c)/S_D$
absolute value of Z =	2.546	

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 greater than 1.96, Nonparameteric ANOVA was performed.**

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

Attachment B2: Cadmium URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Cadmium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	0.0005	0.0005	**0.000396**	**0.000304**	0.0005
Jan-18	0.0005	0.0005	0.0005	**0.000375**	0.0005
Aug-18	0.0005	0.0005	**0.000323**	**0.000372**	0.0005
Jan-19	0.0005	0.0005	**0.000415**	**0.000481**	0.0005
Jul-19	0.0005	0.0005	0.0005	0.0005	0.0005
Sum	0.0050		0.00213	0.00203	0.0025
n_i	10		5	5	5
$(x_i)_{avg}$	0.00050		0.00043	0.00041	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.

Overall mean x.. = 0.00047

N =	25	N = the total number of samples
p =	4	p = the number of n_i groups
x.. =	0.01	x.. = the sum of the total number of samples

Attachment B2: Cadmium URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	Cadmium (mg/L)	Adjusted Rank	Tie Number
1	0	9.5	Tie 1
2	0	9.5	
3	0	9.5	
4	0	9.5	
5	0	9.5	
6	0	9.5	
7	0	9.5	
8	0	9.5	
9	0	9.5	
10	0	9.5	
11	0	9.5	
12	0	9.5	
13	0	9.5	
14	0	9.5	
15	0	9.5	
16	0	9.5	
17	0	9.5	
18	0	9.5	
19	**0.000304**	19	
20	**0.000323**	20	
21	**0.000372**	21	
22	**0.000375**	22	
23	**0.000396**	23	
24	**0.000415**	24	
25	**0.000481**	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 that are considered nondetects (i.e., U qualified data) are reported as a concentration of 0.

n_{tie}	Adjustment for Ties: $(n_{tie}^3-n_{tie})$	
18	Tie 1 =	5814
	$\sum T_i$ =	5814

Attachment B2: Cadmium URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Sums of Ranks and Averages

Cadmium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	0	0	**0.000396**	**0.000304**	0
Jan-18	0	0	0	**0.000375**	0
Aug-18	0	0	**0.000323**	**0.000372**	0
Jan-19	0	0	**0.000415**	**0.000481**	0
Jul-19	0	0	0	0	0

Observation Ranks for Cadmium					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	9.5	9.5	23	19	9.5
Jan-18	9.5	9.5	9.5	22	9.5
Aug-18	9.5	9.5	20	21	9.5
Jan-19	9.5	9.5	24	25	9.5
Jul-19	9.5	9.5	9.5	9.5	9.5
R_i	95		86	96.5	47.5
$(R_i)_{avg}$	9.5		17.2	19.3	9.5
R_i^2/n_i	902.5		1479.2	1862.5	451.3

$\Sigma R_i^2/n_i$ = 4695.4

K = 4

N = 25

mg/L = milligrams per liter

BG = background

DL = detection limit

K = the number of n_i groups

N = the total number of samples

Bolded values indicate a detected result.

NOTE: For this method, observations below the detection limit that are considered nondetects (i.e., U qualified data) are reported as a concentration of 0.

Calculation of Kruskal-Wallis Statistic

H = 8.684 Kruskal-Wallis Statistic $H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$

H' = 13.844 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 B2: Cadmium URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Calculate Critical Values

Average Background Ranking = 9.5

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93A			
BG Well	MW420			
	MW84A	8.578	7.70	not contaminated
	MW87A	8.578	9.80	**evidence of contamination**
	MW90A	8.578	0.00	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 MW87A, there is a statistically significant difference between downgradient compliance test wells and background wells in MW87A from the C-404 Landfill.

Because nonparametric ANOVA indicated a statistically significant difference between compliance test wells and background wells at the C-404 Landfill in compliance well MW87A, the 95% UTL was performed.

Since $(R_i)_{avg} - (R_b)_{avg} < C_i$ for MW84A and MW90A, there is no statistically significant difference between compliance test wells and background wells at the C-404 Landfill.

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

Attachment B2: Cadmium URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

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 2019 Data, Second Reporting Period
Observations (mg/L)

Well No.						
MW93A	0.0005	0.0005	0.0005	0.0005	0.0005	**Upgradient Well!**
MW420	0.0005	0.0005	0.0005	0.0005	0.0005	**Upgradient Well!**
						Current Data
MW87A		X: Mean Value =	0.0005			0.0005
	S: Standard Deviation =		0.0000			
		K* factor =	2.911	(for n = 10)		
		CV = S/X	0.0000	<1, assume normal distribution		
	Upper Tolerance Interval: TL = X +(KxS) =			**0.0005**	(mg/L)	

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

Result: **The Test Well has not exceeded the UTL, which is statistically significant evidence that the well has no elevated concentration with respect to background data.**

ATTACHMENT B3

CHROMIUM
STATISTICAL TEST 3

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Attachment B3: Chromium URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Chromium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	**0.261**	0.005	**0.103**	**0.0557**	0.005
Jan-18	**0.151**	0.005	**0.143**	**1.18**	**0.00381**
Aug-18	**0.11**	0.005	**0.0752**	**0.275**	0.005
Jan-19	**0.0561**	0.005	**0.0251**	**0.0424**	0.005
Jul-19	0.005	0.005	0.005	0.005	0.005
Sum	0.6081		0.35130	1.55810	0.0238
n_i	10		5	5	5
$(x_i)_{avg}$	0.06081		0.07026	0.31162	0.0048

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.. = 0.10165

N =	25	N = the total number of samples
p =	4	p = the number of n_i groups
x.. =	2.54	x.. = the sum of the total number of samples

Attachment B3: Chromium URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	Chromium (mg/L)	Adjusted Rank	Tie Number
1	0	6.5	Tie 1
2	0	6.5	
3	0	6.5	
4	0	6.5	
5	0	6.5	
6	0	6.5	
7	0	6.5	
8	0	6.5	
9	0	6.5	
10	0	6.5	
11	0	6.5	
12	0	6.5	
13	**0.00381**	13	
14	**0.0251**	14	
15	**0.0424**	15	
16	**0.0557**	16	
17	**0.0561**	17	
18	**0.0752**	18	
19	**0.103**	19	
20	**0.11**	20	
21	**0.143**	21	
22	**0.151**	22	
23	**0.261**	23	
24	**0.275**	24	
25	**1.18**	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 that are considered nondetects (i.e., U qualified data) are reported as a concentration of 0.

n_{tie}	Adjustment for Ties: $(n_{tie}^3 - n_{tie})$
12	Tie 1 = 1716
	$\sum T_i$ = 1716

Attachment B3: Chromium URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Sums of Ranks and Averages

Chromium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	**0.261**	0	**0.103**	**0.0557**	0
Jan-18	**0.151**	0	**0.143**	**1.18**	**0.00381**
Aug-18	**0.11**	0	**0.0752**	**0.275**	0
Jan-19	**0.0561**	0	**0.0251**	**0.0424**	0
Jul-19	0	0	0	0	0

Observation Ranks for Chromium					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	23	6.5	19	16	6.5
Jan-18	22	6.5	21	25	13
Aug-18	20	6.5	18	24	6.5
Jan-19	17	6.5	14	15	6.5
Jul-19	6.5	6.5	6.5	6.5	6.5
R_i	121		78.5	86.5	39
$(R_i)_{avg}$	12.1		15.7	17.3	7.8
R_i^2/n_i	1464.1		1232.5	1496.5	304.2

$\Sigma R_i^2/n_i$ = 4497.2

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 that are considered nondetects (i.e., U qualified data) are reported as a concentration of 0.

Calculation of Kruskal-Wallis Statistic

H = 5.025 Kruskal-Wallis Statistic $H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$

H' = 5.646 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.

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

Calculate Critical Values

NOTE: Not required due to $H' < \chi^2_{crit}$

Since $H' < \chi^2_{crit}$, there is no statistically significant evidence of a difference between background wells and compliance wells at the C-404 Landfill.

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ATTACHMENT B4

LEAD
STATISTICAL TEST 3

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Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Lead (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	**0.00213**	0.001	**0.00267**	**0.00533**	0.001
Jan-18	**0.00186**	0.001	**0.00191**	**0.00579**	**0.000634**
Aug-18	**0.000802**	0.001	**0.00319**	**0.00682**	0.001
Jan-19	0.001	0.001	**0.00204**	**0.00502**	0.001
Jul-19	**0.00051**	0.001	0.001	0.001	0.001
Sum	0.0113		0.01081	0.02396	0.0046
n_i	10		5	5	5
$(x_i)_{avg}$	0.00113		0.00216	0.00479	0.0009

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.. = 0.00203

N =	25	N = the total number of samples
p =	4	p = the number of n_i groups
x.. =	0.05	x.. = the sum of the total number of samples

Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	Lead (mg/L)	Adjusted Rank	Tie Number
1	0	6.5	Tie 1
2	0	6.5	
3	0	6.5	
4	0	6.5	
5	0	6.5	
6	0	6.5	
7	0	6.5	
8	0	6.5	
9	0	6.5	
10	0	6.5	
11	0	6.5	
12	0	6.5	
13	**0.00051**	13	
14	**0.000634**	14	
15	**0.000802**	15	
16	**0.00186**	16	
17	**0.00191**	17	
18	**0.00204**	18	
19	**0.00213**	19	
20	**0.00267**	20	
21	**0.00319**	21	
22	**0.00502**	22	
23	**0.00533**	23	
24	**0.00579**	24	
25	**0.00682**	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 that are considered nondetects (i.e., U qualified data) are reported as a concentration of 0.

n_{tie}	Adjustment for Ties: $(n_{tie}^3-n_{tie})$	
12	Tie 1 =	1716
	$\sum T_i$ =	1716

Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Sums of Ranks and Averages

Lead (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	**0.00213**	0	**0.00267**	**0.00533**	0
Jan-18	**0.00186**	0	**0.00191**	**0.00579**	**0.000634**
Aug-18	**0.000802**	0	**0.00319**	**0.00682**	0
Jan-19	0	0	**0.00204**	**0.00502**	0
Jul-19	**0.00051**	0	0	0	0

Observation Ranks for Lead					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	19	6.5	20	23	6.5
Jan-18	16	6.5	17	24	14
Aug-18	15	6.5	21	25	6.5
Jan-19	6.5	6.5	18	22	6.5
Jul-19	13	6.5	6.5	6.5	6.5
R_i	102		82.5	100.5	40
$(R_i)_{avg}$	10.2		16.5	20.1	8.0
R_i^2/n_i	1040.4		1361.3	2020.1	320.0

$\Sigma R_i^2/n_i$ = 4741.7

mg/L = milligrams per liter
BG = background
DL = detection limit
K = the number of n_i groups
N = the total number of samples

Bolded values indicate a detected result.

K = 4
N = 25

NOTE: For this method, observations below the detection limit that are considered nondetects (i.e., U qualified data) are reported as a concentration of 0.

Calculation of Kruskal-Wallis Statistic

H = 9.539 Kruskal-Wallis Statistic $H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$

H' = 10.718 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: Lead URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Calculate Critical Values

Average Background Ranking = 10.2

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93A			
BG Well	MW420			
	MW84A	8.578	6.30	not contaminated
	MW87A	8.578	9.90	**evidence of contamination**
	MW90A	8.578	-2.20	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 MW87A, there is a statistically significant difference between downgradient compliance test wells and background wells in MW87A from the C-404 Landfill.

Because nonparametric ANOVA indicated a statistically significant difference between compliance test wells and background wells at the C-404 Landfill in compliance well MW87A, the 95% UTL was performed.

Since $(R_i)_{avg} - (R_b)_{avg} < C_i$ for MW84A and MW90A, there is no statistically significant difference between background wells and downgradient compliance test wells; however, the negative value indicates that the background wells have elevated concentrations.

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

Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

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 2019 Data, Second Reporting Period
Observations (mg/L)

Well No.						
MW93A	**0.00213**	**0.00186**	**0.000802**	0.001	**0.00051**	**Upgradient Well[!]**
MW420	0.001	0.001	0.001	0.001	0.001	**Upgradient Well[!]**
						Current Data
MW847A		X: Mean Value =	0.0011			0.001
		S: Standard Deviation =	0.0005			
		K* factor =	2.911	(for n = 10)		
		CV = S/X	0.4301	<1, assume normal distribution		
	Upper Tolerance Interval: TL = X +(KxS) =			**0.0025**	(mg/L)	

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

Result: **The Test Well has not exceeded the UTL, which is statistically significant evidence that the well has no elevated concentration with respect to background data.**

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ATTACHMENT B5

TECHNETIUM-99
STATISTICAL TEST 2

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Attachment B5: Technetium-99 URGA, Statistical Test 2, Test of Proportions, Second Reporting Period 2019

Technetium-99 (pCi/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	9.85	9.7	10.05	9.9	9.55
Jan-18	9.4	**21.5**	**34.4**	9.45	9.2
Aug-18	7.35	9.2	6.75	7.5	7.3
Jan-19	11.05	9.5	**28.8**	9.5	7.9
Jul-19	10.1	10.25	**126**	9.95	9.7

pCi/L = picocuries 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 B6

TRICHLOROETHENE
STATISTICAL TESTS 4/3

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Attachment B6: Trichloroethene URGA, Statistical Test 4, Parametric ANOVA, Second Reporting Period 2019

Trichloroethene (TCE, µg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	**1400**	**264**	**2910**	**1620**	**46.1**
Jan-18	**994**	**232**	**3160**	**1400**	**40.6**
Aug-18	**1000**	**476**	**5260**	**1690**	**53.3**
Jan-19	**1000**	**601**	**5580**	**2380**	**69.9**
Jul-19	**789**	**600**	**2000**	**1850**	**55.7**
n_i	10		5	5	5
Sum	7356		18910	8940	265.60
(x_i)avg	735.60		3782.00	1788.00	53.12

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

Overall mean x.. =	1418.86	
N =	25	N = the total number of samples
p =	4	p = the number of n_i groups
x.. =	35471.60	x.. = the sum of the total number of samples

Determine Normality of Dataset

Coefficient of Variability Test

Table of Residuals

Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	664.40	-471.60	-872.00	-168.00	-7.02
Jan-18	258.40	-503.60	-622.00	-388.00	-12.52
Aug-18	264.40	-259.60	1478.00	-98.00	0.18
Jan-19	264.40	-134.60	1798.00	592.00	16.78
Jul-19	53.40	-135.60	-1782.00	62.00	2.58

X: Mean Value =	2.84E-15	
S: Standard Deviation =	692.6	
K* Factor =	2.292	(for n = 25)
CV = S/X =	2.44E+17	> or = 1, 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 data are normally distributed.
If the coefficient of variation is > or = 1, data are not normally distributed.

Attachment B6: Trichloroethene URGA, Statistical Test 4, Parametric ANOVA, Second Reporting Period 2019

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)
$f_i = n_i - 1$

$x_{..} =$ 35471.60
$(x_{avg})_{..} =$ 1418.86

p = 4
N = 25

Calculations for Equality of Variance: Bartlett's Test

S_i	S_i^2	$\ln(S_i^2)$	n_i	$f_i S_i^2$	$f_i \ln(S_i^2)$
369.802	136753.38	11.826	10	1230780.4	106.4
1560.455	2435020.00	14.705	5	9740080.000	58.8
368.334	135670.00	11.818	5	542680.000	47.3
11.116	123.57	4.817	5	494.288	19.3

$\sum(S_i^2) =$ 2707566.95 $\sum f_i \ln(S_i^2) =$ 231.8

Equality of Variance: Bartlett's Test

f = 21
$Sp^2 =$ 548287.366
$\ln Sp^2 =$ 13.215
$\chi^2 =$ 45.711 (If $\chi^2 \leq \chi^2_{crit}$, then variances are equal at the given significance level).
χ^2_{crit} * = 7.815 at a 5% significance level with 3 degrees of freedom

NOTE: The variances are NOT equal. (i.e., $\chi^2 > \chi^2_{crit}$)

Variances are not equal, transform the original data to lognormal (i.e., since $\chi^2 > \chi^2_{crit}$).

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

Attachment B6: Trichloroethene URGA, Statistical Test 4, Parametric ANOVA, Second Reporting Period 2019

Lognormal Data for TCE

ln [TCE (µg/L)]					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	7.24	5.58	7.98	7.39	3.83
Jan-18	6.90	5.45	8.06	7.24	3.70
Aug-18	6.91	6.17	8.57	7.43	3.98
Jan-19	6.91	6.40	8.63	7.77	4.25
Jul-19	6.67	6.40	7.60	7.52	4.02
x_i	64.62		40.83	37.36	19.78
(x_i)avg	6.46		8.17	7.47	3.96

µg/L = micrograms per liter

Determine Normality of Dataset

Coefficient of Variability Test

Table of Residuals for Lognormal Data

Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	0.78	-0.89	-0.19	-0.08	-0.12
Jan-18	0.44	-1.01	-0.11	-0.23	-0.25
Aug-18	0.45	-0.30	0.40	-0.04	0.02
Jan-19	0.45	-0.06	0.46	0.30	0.29
Jul-19	0.21	-0.06	-0.57	0.05	0.06

X: Mean Value =	3.38E-16	
S: Standard Deviation =	0.42	
K* Factor =	2.292	(for n = 25)
CV = S/X =	1.24E+15	≥1, 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)].

Attachment B6: Trichloroethene URGA, Statistical Test 4, Parametric ANOVA, Second Reporting Period 2019

Determine Equality of Variance of Dataset for Lognormal Data

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)

$f_i = n_i - 1$

$x_{..} = 162.59$

$(x_{avg})_{..} = 6.50$

p = 4

N = 25

Calculations for Equality of Variance: Bartlett's Test

S_i	S_i^2	$\ln(S_i^2)$	ni	$f_iS_i^2$	$f_i\ln(S_i^2)$
0.592	0.351	-1.047	10	3.158	-9.4
0.430	0.185	-1.686	5	0.741	-6.7
0.196	0.039	-3.254	5	0.154	-13.0
0.205	0.042	-3.167	5	0.169	-12.7

$\sum(S_i^2) =$ 0.62 $\sum f_i\ln(S_i^2) =$ -41.9

Equality of Variance: Bartlett's Test

$f =$ 21

$Sp^2 =$ 0.201

$\ln Sp^2 =$ -1.604

$\chi^2 =$ 8.167 (If $\chi^2 \leq \chi^2_{crit}$, then variances are equal at the given significance level).

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

NOTE: The variances are NOT equal. (i.e., $\chi^2 > \chi^2_{crit}$)

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

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

**Section 5.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989)].

Attachment B6: Trichloroethene URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Statistical Test 3, Nonparametric ANOVA

TCE (µg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	**1400**	**264**	**2910**	**1620**	**46.1**
Jan-18	**994**	**232**	**3160**	**1400**	**40.6**
Aug-18	**1000**	**476**	**5260**	**1690**	**53.3**
Jan-19	**1000**	**601**	**5580**	**2380**	**69.9**
Jul-19	**789**	**600**	**2000**	**1850**	**55.7**
n_i	10		5	5	5
x_i	7356		18910	8940	265.60
$(x_i)avg$	735.60		3782.00	1788.00	53.12

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.. = 1418.86

N =	25	N = the total number of samples
p =	4	p = the number of n_i groups
x.. =	35471.60	x.. = the sum of the total number of samples

Attachment B6: Trichloroethene URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	TCE (µg/L)	Adjusted Rank	Tie Number
1	**40.6**	1	
2	**46.1**	2	
3	**53.3**	3	
4	**55.7**	4	
5	**69.9**	5	
6	**232**	6	
7	**264**	7	
8	**476**	8	
9	**600**	9	
10	**601**	10	
11	**789**	11	
12	**994**	12	
13	**1000**	13.5	Tie 1
14	**1000**		
15	**1400**	15.5	Tie 2
16	**1400**		
17	**1620**	17	
18	**1690**	18	
19	**1850**	19	
20	**2000**	20	
21	**2380**	21	
22	**2910**	22	
23	**3160**	23	
24	**5260**	24	
25	**5580**	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 that are considered nondetects (i.e., U qualified data) are reported as a concentration of 0.

n_{tie}	Adjustment for Ties: $(n_{tie}^3 - n_{tie})$	
2	Tie 1 =	6
2	Tie 2 =	6
	$\sum T_i$ =	12

Attachment B6: Trichloroethene URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Sums of Ranks and Averages

TCE (µg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	**1400**	**264**	**2910**	**1620**	**46.1**
Jan-18	**994**	**232**	**3160**	**1400**	**40.6**
Aug-18	**1000**	**476**	**5260**	**1690**	**53.3**
Jan-19	**1000**	**601**	**5580**	**2380**	**69.9**
Jul-19	**789**	**600**	**2000**	**1850**	**55.7**

Observation Ranks for TCE					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	15.5	7	22	17	2
Jan-18	12	6	23	15.5	1
Aug-18	13.5	8	24	18	3
Jan-19	13.5	10	25	21	5
Jul-19	11	9	20	19	4
$R_{i.}$	105.5		114	90.5	15
$(R_i)_{avg}$	10.6		22.8	18.1	3
R_i^2/n_i	1113.0		2599.2	1638.1	45

$\Sigma R_i^2/n_i$ = 5395.3

K = 4

N = 25

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

K = the number of n_i groups
N = the total number of samples

Bolded values indicate a detected result.

NOTE: For this method, observations below the detection limit that are considered nondetects (i.e., U qualified data) are reported as a concentration of 0.

Calculation of Kruskal-Wallis Statistic

H = 21.605 Kruskal-Wallis Statistic $H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$

H' = 21.622 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* (USEPA 1989).
**Table 4, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (USEPA 1989).

Attachment B6: Trichloroethene URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Calculate Critical Values

Average Background Ranking = 10.6

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93A			
BG Well	MW420			
	MW84A	8.578	12.25	**evidence of contamination**
	MW87A	8.578	7.55	not contaminated
	MW90A	8.578	-7.55	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 concentrations in downgradient compliance test wells and background wells.

Since $(R_i)_{avg} - (R_b)_{avg} > C_i$ for MW84A, there is a statistically significant difference between compliance test wells and background wells in MW84A at the C-404 Landfill.

Because nonparametric ANOVA indicated a statistically significant difference between compliance test wells and background wells at the C-404 Landfill in compliance well MW84A, the 95% UTL was performed.

Since $(R_i)_{avg} - (R_b)_{avg} < C_i$ for MW87A 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 background wells have elevated concentrations.

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

Attachment B6: Trichloroethene URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

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 2019 Data, Second Reporting Period
Observations (µg/L)

Well No.						
MW93A	**1400**	**994**	**1000**	**1000**	**789**	**Upgradient Well[!]**
MW420	**264**	**232**	**476**	**601**	**600**	**Upgradient Well[!]**
						Current Data
MW84A	X: Mean Value =		736			**2000**
	S: Standard Deviation =		370			
	K* factor =		2.911	(for n = 10)		
	CV = S/X		0.5027	<1, assume normal distribution		
	Upper Tolerance Interval: TL = X +(KxS) =			**1812**	(µg/L)	

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

Result: **MW84A 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 MW84A, the paired ANOVA was performed.

Attachment B6: Trichloroethene URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Paired (Parametric) ANOVA - MW93A and MW84A

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.

TCE (µg/L)				
Date	Background	Compliance		
	MW93A	MW84A	n_i^2	
Jul-17	**1400**	**2910**	1960000	8468100
Jan-18	**994**	**3160**	988036	9985600
Aug-18	**1000**	**5260**	1000000	27667600
Jan-19	**1000**	**5580**	1000000	31136400
Jul-19	**789**	**2000**	622521	4000000
Sum (x_i)	5183	18910	24093	Total Sum (x..)
n_i	5	5		
$(x_i)_{avg}$	1037	3782		
$(x_i)^2$	26863489	357588100		

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

Overall mean x.. =	2409	
N =	10	N = the total number of samples
p =	2	p = the number of n_i groups
$x_{..}$ =	24093	x.. = the sum of the total number of samples

Determine Normality of Dataset

Coefficient of Variability Test

Table of Residuals ($x_i - x_{iavg}$)

Date	Background	Compliance
	MW93A	MW84A
Jul-17	363	-872
Jan-18	-43	-622
Aug-18	-37	1478
Jan-19	-37	1798
Jul-19	-248	-1782

X: Mean Value =	0.00E+00	
S: Standard Deviation =	1051	
K* Factor =	2.911	(for n = 10)
CV = S/X =	#ΔIς/0!	#DIV/0!

†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 data are normally distributed.
If the coefficient of variation is > or = 1, data are not normally distributed.

Attachment B6: Trichloroethene URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Determine Equality of Variance of Dataset

p = number of wells	$x_{..} =$ 24093
n_i = number of data points per well	$(x_{avg})_{..} =$ 2409
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	$f_iS_i^2$	$f_i\ln(S_i^2)$†
222	49465	10.809	5	197859	43.2
1560	2435020	14.705	5	9740080	58.8

$\sum(S_i^2) =$ 2,484,485 $\sum f_i\ln(S_i^2) =$ 102

Equality of Variance: Bartlett's Test

f =	8	
$Sp^2 =$	1242242	
$\ln Sp^2 =$	14.032	
$\chi^2 =$	10.202	(If calculated $\chi^2 \leq$ tabulated χ^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)

NOTE: The variances are NOT equal. (i.e., calculated $\chi^2 > \chi^2_{crit}$)

Variances are not equal, transform the original data to lognormal (i.e., since calculated $\chi^2 > \chi^2_{crit}$).

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

Attachment B6: Trichloroethene URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Paired (Parametric) ANOVA—Lognormal Data

ln[TCE (µg/L)]				
Date	Background	Compliance		
	MW93A	MW84A	n_i^2	
Jul-17	**7.24**	**7.98**	52.48	63.62
Jan-18	**6.90**	**8.06**	47.63	64.94
Aug-18	**6.91**	**8.57**	47.72	73.41
Jan-19	**6.91**	**8.63**	47.72	74.42
Jul-19	**6.67**	**7.60**	44.50	57.77
Sum (x_i)	34.63	40.83	75.46	Total Sum (x..)
n_i	5	5		
$(x_i)_{avg}$	6.93	8.17		
$(x_i)^2$	1199.39	1667.09		

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

Overall mean x.. =	7.55	
N =	10	N = the total number of samples
p =	2	p = the number of n_i groups
$x_{..}$ =	75.46	x.. = the sum of the total number of samples

Determine Normality of Dataset

Coefficient of Variability Test—Lognormal Data

Table of Residuals (x_i-$x_i$avg) for Lognormal Data

Date	Background	Compliance
	MW93A	MW84A
Jul-17	0.32	-0.19
Jan-18	-0.02	-0.11
Aug-18	-0.02	0.40
Jan-19	-0.02	0.46
Jul-19	-0.26	-0.57

X: Mean Value =	1.78E-16	
S: Standard Deviation =	0.32	
K* Factor =	2.911	(for n = 10)
CV = S/X =	1.79E+15	≥1, data are NOT normally distributed

Data are not normally distributed (i.e., ≥1)

*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 are normally distributed.
If the coefficient of variation is > or = 1, the residuals are not normally distributed.

Attachment B6: Trichloroethene URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Determine Equality of Variance—Lognormal Data

p = number of wells	$x_{..} =$ 75.46
n_i = number of data points per well	$(x_{avg})_{..} =$ 7.55
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	$f_iS_i^2$	$f_i\ln(S_i^2)$
0.20	0.04	-3.17	5	0.17	-12.7
0.43	0.19	-1.69	5	0.74	-6.7

$\sum(S_i^2)$ = 0.23 $\sum f_i\ln(S_i^2)$ = -19.43

Equality of Variance: Bartlett's Test

f =	8	
Sp^2 =	0.11	
ln Sp^2 =	-2.18	
χ^2 =	2.03	(If calculated $\chi^2 \leq$ tabulated χ^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)

NOTE: The variances are equal. (i.e., calculated $\chi^2 \leq \chi^2_{crit}$)

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).

**Section 5.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989)].

Attachment B6: Trichloroethene URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Between Well Sum of Squares

Source of Variation	Sums of Squares		Degrees of Freedom	Mean Squares	Calculated F	F Statistic**
Between Wells	SS_{wells} =	3.84	1	3.84	33.82	5.32
Error	SS_{Error} =	0.91	8	0.11		
Total	SS_{Total} =	4.75	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 identified a significant difference between background and downgradient wells.**

Because the paired ANOVA for the two wells indicated a statistically significant difference between compliance test wells and background wells at the C-404 Landfill in compliance well MW84A, a Mann-Kendall statistical analysis was performed.

**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.

Attachment B6: Trichloroethene URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Mann-Kendall Statistical Analysis for TCE in MW84A

Input Data

Date Collected	Result (µg/L)
Jan-16	**1350**
Jul-16	**1820**
Jan-17	**2620**
Jul-17	**2910**
Jan-18	**3160**
Aug-18	**5260**
Jan-19	**5580**
Jul-19	**2000**

Bolded values indicate a detected result.

Mann-Kendall Trend Test Analysis

User Selected Options	
Date/Time of Computation	ProUCL 5.19/30/2019 11:23:24 AM
From File	WorkSheet.xls
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

MW84A TCE 2H 2019

General Statistics

Number or Reported Events Not Used	0
Number of Generated Events	8
Number Values Reported (n)	8
Minimum	1350
Maximum	5580
Mean	3088
Geometric Mean	2771
Median	2765
Standard Deviation	1558
Coefficient of Variation	0.505

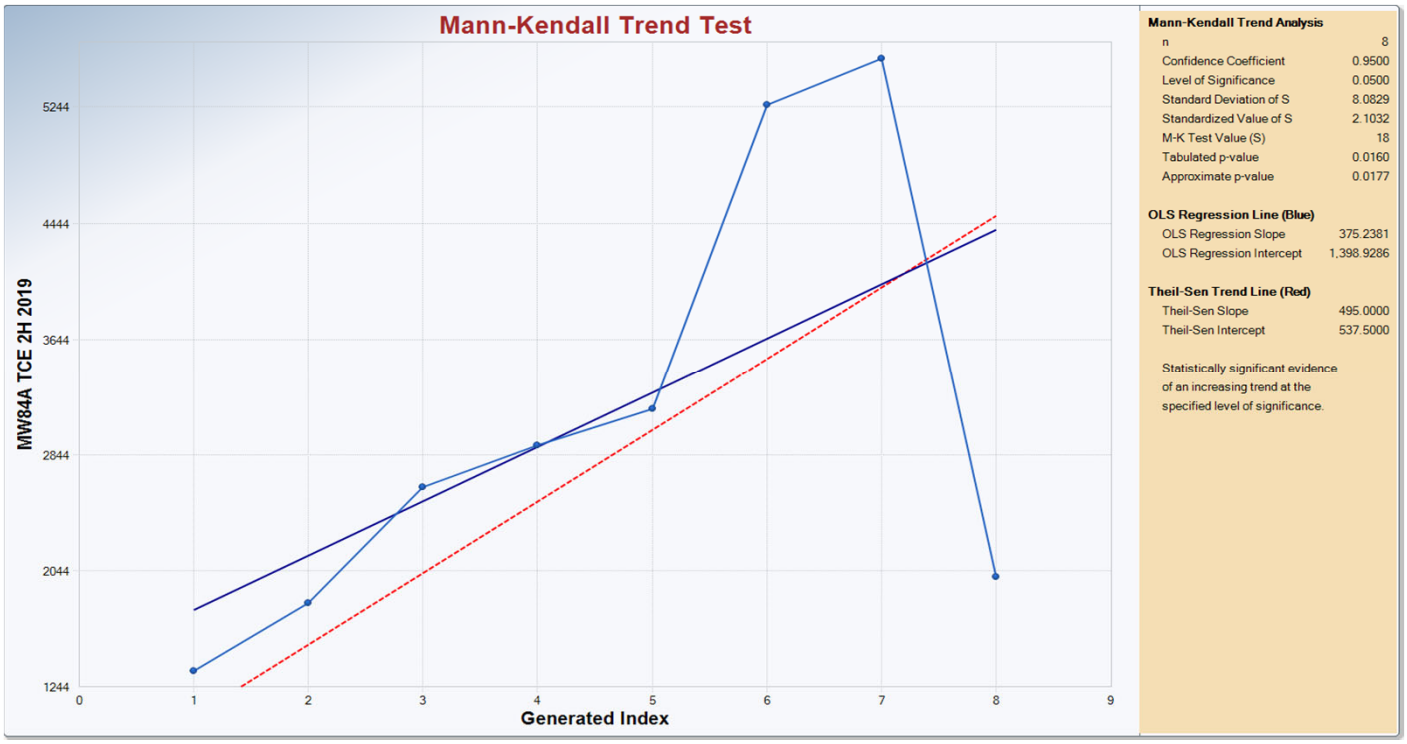
Mann-Kendall Test

M-K Test Value (S)	18
Tabulated p-value	0.016
Standard Deviation of S	8.083
Standardized Value of S	2.103
Approximate p-value	0.0177

Statistically significant evidence of an increasing trend at the specified level of significance.

Attachment B6: Trichloroethene URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2019

Mann-Kendall Statistical Analysis for TCE in MW84A



ATTACHMENT B7

URANIUM
STATISTICAL TEST 2

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Attachment B7: Uranium URGA, Statistical Test 2, Test of Proportions, Second Reporting Period 2019

Uranium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	**0.000224**	0.0001	**0.000355**	**0.000571**	0.0001
Jan-18	0.0001	0.0001	**0.0002**	**0.000681**	0.0001
Aug-18	**0.000113**	0.0001	**0.000302**	**0.000722**	0.0001
Jan-19	0.0001	0.0001	**0.000193**	**0.00042**	0.0001
Jul-19	**0.00056**	0.0001	**0.00089**	0.0001	0.0001

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 =	3	X = number of samples above DL in background wells
Y =	9	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 =	0.480	P=(x+y)/n
nP =	12	$n=n_b+n_c$
n(1-P) =	13	

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 =	0.600	P_c = proportion of detects in compliance wells
S_D =	0.204	S_D = standard error of difference in proportions
Z =	-1.471	$Z = (P_b-P_c)/S_D$
absolute value of Z =	1.471	

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

URANIUM-234
STATISTICAL TEST 2

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Attachment B8: Uranium-234 URGA, Statistical Test 2, Test of Proportions, Second Reporting Period 2019

Uranium-234 (pCi/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Jul-17	0.635	0.765	0.4835	0.79	0.63
Jan-18	1.1	0.73	0.58	0.955	1.035
Aug-18	0.78	0.78	0.525	0.865	1.305
Jan-19	0.685	1.115	0.715	1.19	**1.89**
Jul-19	**2.38**	0.71	**1.77**	1.01	**1.67**

pCi/L = picocuries 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

STATISTICIAN STATEMENT

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FOUR RIVERS
NUCLEAR PARTNERSHIP, LLC

Four Rivers Nuclear Partnership, LLC
5511 Hobbs Road
Kevil, KY 42053
www.fourriversnuclearpartnership.com

September 30, 2019

Ms. Kelly Layne
Four Rivers Nuclear Partnership, LLC
5511 Hobbs Road
Kevil, KY 42053

Dear Ms. Layne:

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

As an Environmental Scientist, with a bachelor's degree in science, 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 with Four Rivers Nuclear Partnership, LLC.

For this project, the statistical analyses on groundwater data from July 2017 through July 2019 were performed in accordance with the Hazardous Waste Management Facility Permit, Appendix E using Microsoft Excel 2010 and U.S. Environmental Protection Agency's (EPA's) ProUCL 5.1. The spreadsheets include the results for the following statistical tests:

- Test of Proportions
- Parametric Analysis of Variance (ANOVA)
- Nonparametric ANOVA
- 95% Upper Tolerance Limit
- Mann-Kendall

The statistical analyses procedures were based on EPA's *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Interim Final Guidance* (1989).

Sincerely,

Jennifer R. Watson

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APPENDIX C

C-404 HAZARDOUS WASTE LANDFILL LEACHATE ANALYTICAL RESULTS

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March 21, 2019
Leachate Analytical Results

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Paducah OREIS Report for 404L19-03

L1404L3-19 from: C404L on 3/21/2019 Media: WW SmpMethod: GR

Comments: WL is @ 4.85' below rim of manhole. SM 3-21-19

Analysis	Results	Units	Result Qual	Foot Note	Reporting Limit	Counting Error	TPU	Method	LabCode	V/V/A*
ANION										
Fluoride	5.88	mg/L			1			SW846-9056	GEL	I / X /
FS										
Conductivity	516	umho/cm						FS	FS	/ /
Dissolved Oxygen	9.79	mg/L						FS	FS	/ /
pH	6.76	Std Unit						FS	FS	/ /
Redox	420	mV						FS	FS	/ /
Temperature	52.8	deg F						FS	FS	/ /
METAL										
Arsenic	0.00234	mg/L	J		0.005			SW846-6020	GEL	/ X /
Barium	0.0735	mg/L			0.002			SW846-6020	GEL	/ X /
Cadmium	0.001	mg/L	U		0.001			SW846-6020	GEL	/ X /
Chromium	0.00547	mg/L	J		0.01			SW846-6020	GEL	S / X /
Copper	0.0195	mg/L			0.001			SW846-6020	GEL	/ X /
Iron	1.05	mg/L			0.1			SW846-6020	GEL	/ X /
Lead	0.00245	mg/L			0.002			SW846-6020	GEL	/ X /
Mercury	0.000123	mg/L	J		0.0002			SW846-7470A	GEL	/ X /
Nickel	0.0221	mg/L			0.002			SW846-6020	GEL	/ X /
Selenium	0.005	mg/L	U		0.005			SW846-6020	GEL	/ X /
Silver	0.001	mg/L	U		0.001			SW846-6020	GEL	/ X /
Uranium	49.3	mg/L			0.004			SW846-6020	GEL	I / X /
Zinc	0.0136	mg/L			0.01			SW846-6020	GEL	/ X /
PPCB										
PCB-1016	0.1	ug/L	U		0.1			SW846-8082	GEL	/ X /
PCB-1221	0.1	ug/L	U		0.1			SW846-8082	GEL	/ X /
PCB-1232	0.1	ug/L	U		0.1			SW846-8082	GEL	/ X /
PCB-1242	0.1	ug/L	U		0.1			SW846-8082	GEL	/ X /
PCB-1248	1.25	ug/L			0.1			SW846-8082	GEL	/ X /
PCB-1254	0.1	ug/L	U		0.1			SW846-8082	GEL	/ X /
PCB-1260	0.1	ug/L	U		0.1			SW846-8082	GEL	/ X /
Polychlorinated biphenyl	1.25	ug/L			0.1			SW846-8082	GEL	I / X /
RADS										
Cesium-137	2.05	pCi/L	U		6.84	8.72	8.72	EPA-901.1	GEL	/ X /
Neptunium-237	1.46	pCi/L			1.1	1.02	1.03	ASTM-1475-00aM	GEL	/ X /
Plutonium-239/240	0.0572	pCi/L	U		1.38	0.652	0.652	HASL 300, Pu-11-RC M	GEL	/ X /
Technetium-99	163	pCi/L			11.3	9.84	20.6	HASL 300, Tc-02-RC M	GEL	/ X /
Thorium-230	0.195	pCi/L	U		2.25	1.11	1.12	HASL 300, Th-01-RC M	GEL	/ X /
Uranium-234	1940	pCi/L			119	323	417	HASL 300, U-02-RC M	GEL	/ X /
Uranium-235	329	pCi/L			93.4	152	158	HASL 300, U-02-RC M	GEL	/ X /
Uranium-238	22500	pCi/L			75.5	1090	3220	HASL 300, U-02-RC M	GEL	/ X /
VOA										
Trichloroethene	1	ug/L	U		1			SW846-8260B	GEL	/ X /
WETCHEM										
Ammonia as Nitrogen	0.185	mg/L			0.05			EPA-350.1	GEL	/ X /

*Verification/Validation/Assessment

Paducah OREIS Report for 404L19-03

TB404L3-19 from: QC on 3/21/2019 Media: WQ SmpMethod:

Comments:

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

*Verification/Validation/Assessment

June 20, 2019
Leachate Analytical Results

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Paducah OREIS Report for 404L19-04

L1404L4-19 from: C404L on 6/20/2019 Media: WW SmpMethod: GR

Comments: Water was very clear. Sampled a vertical profile from water surface to 1' below water surface. JB 6-20-19

Analysis	Results	Units	Result Qual	Foot Note	Reporting Limit	Counting Error	TPU	Method	LabCode	V/V/A*
ANION										
Fluoride	5.55	mg/L			1			SW846-9056	GEL	I / X /
FS										
Conductivity	550	umho/cm						FS	FS	/ /
Dissolved Oxygen	4.83	mg/L						FS	FS	/ /
pH	7.56	Std Unit						FS	FS	/ /
Redox	408	mV						FS	FS	/ /
Temperature	70.4	deg F						FS	FS	/ /
METAL										
Arsenic	0.00225	mg/L	J		0.005			SW846-6020	GEL	/ X /
Barium	0.0817	mg/L	E		0.004			SW846-6020	GEL	/ X /
Cadmium	0.001	mg/L	U		0.001			SW846-6020	GEL	/ X /
Chromium	0.01	mg/L	U		0.01			SW846-6020	GEL	/ X /
Copper	0.00719	mg/L			0.002			SW846-6020	GEL	/ X /
Iron	0.1	mg/L	U		0.1			SW846-6020	GEL	/ X /
Lead	0.002	mg/L	U		0.002			SW846-6020	GEL	/ X /
Mercury	0.0002	mg/L	U		0.0002			SW846-7470A	GEL	/ X /
Nickel	0.00282	mg/L			0.002			SW846-6020	GEL	S / X /
Selenium	0.005	mg/L	U		0.005			SW846-6020	GEL	/ X /
Silver	0.001	mg/L	U		0.001			SW846-6020	GEL	/ X /
Uranium	42.6	mg/L			0.01			SW846-6020	GEL	I / X /
Zinc	0.00466	mg/L	J		0.02			SW846-6020	GEL	S / X /
PPCB										
PCB-1016	0.0962	ug/L	UY1		0.0962			SW846-8082	GEL	/ X /
PCB-1221	0.0962	ug/L	U		0.0962			SW846-8082	GEL	/ X /
PCB-1232	0.0962	ug/L	U		0.0962			SW846-8082	GEL	/ X /
PCB-1242	0.0962	ug/L	U		0.0962			SW846-8082	GEL	/ X /
PCB-1248	0.561	ug/L			0.0962			SW846-8082	GEL	/ X /
PCB-1254	0.0962	ug/L	U		0.0962			SW846-8082	GEL	/ X /
PCB-1260	0.0962	ug/L	U		0.0962			SW846-8082	GEL	/ X /
Polychlorinated biphenyl	0.561	ug/L			0.0962			SW846-8082	GEL	I / X /
RADS										
Cesium-137	3.28	pCi/L	U		7.05	6.89	6.9	EPA-901.1	GEL	/ X /
Neptunium-237	0.89	pCi/L	U		1.6	1.1	1.11	ASTM-1475-00aM	GEL	/ X /
Plutonium-239/240	-0.0495	pCi/L	U		0.989	0.427	0.428	HASL 300, Pu-11-RC M	GEL	/ X /
Technetium-99	466	pCi/L			21.7	22.5	56	HASL 300, Tc-02-RC M	GEL	S / X / BH-LABPR
Thorium-230	-0.0178	pCi/L	U		2.06	0.917	0.918	HASL 300, Th-01-RC M	GEL	/ X /
Uranium-234	1480	pCi/L			150	323	391	HASL 300, U-02-RC M	GEL	/ X /
Uranium-235	195	pCi/L			64.9	134	138	HASL 300, U-02-RC M	GEL	/ X /
Uranium-238	16300	pCi/L			96.9	1050	2640	HASL 300, U-02-RC M	GEL	/ X /
VOA										
Trichloroethene	1	ug/L	U		1			SW846-8260B	GEL	/ X /
WETCHEM										
Ammonia as Nitrogen	0.457	mg/L	BN		0.05			EPA-350.1	GEL	S / X /

*Verification/Validation/Assessment

Paducah OREIS Report for 404L19-04

TB404L4-19 from: QC on 6/20/2019 Media: WQ SmpMethod:

Comments:

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

*Verification/Validation/Assessment

APPENDIX D

C-404 HAZARDOUS WASTE LANDFILL
ANNUAL HYDRAULIC FLOW RATE AND DIRECTION

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2019 ANNUAL REPORT OF THE C-404 HAZARDOUS WASTE LANDFILL HYDRAULIC FLOW RATE AND DIRECTION

The Hazardous Waste Management Facility Permit, KY8-890-008-982, (Permit) requires annual determination of average hydraulic flow rate and direction of flow in the uppermost aquifer at the C-404 Hazardous Waste Landfill (C-404 Landfill). The uppermost aquifer below C-404 Landfill is the Regional Gravel Aquifer (RGA). Water level measurements currently are taken from several monitoring wells (MWs) at the perimeter of the C-404 Landfill on a semiannual basis. The water levels used for this analysis (taken on January 29 and July 29, 2019) were measured as closely as possible and within a 24-hour period to ensure the comparability of the data. Table D.1 documents the datums used for the water level measurements. These measurements were used to plot the potentiometric surface of the upper RGA for the January and July 2019 semiannual 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 1.22×10^{-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* (June 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.2 summarizes the annual average results of the calculations. Table D.3 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.4 and D.5, and potentiometric surface maps are presented in Figures D.1 and D.2. All water level measurements for January 29, 2019, and July 29, 2019, were measured using the reference points specified in the Permit, with the exception of MW90A and MW420. The Permit specified these reference points as being the Well Wizard plate. Because these MWs no longer have a Well Wizard plate, an alternate reference point was needed. Additionally, wells MW84, MW87, and MW93 were abandoned in June 2019, with replacement completed (new wells MW84A, MW87A, and MW93A) on July 19, 2019. Top of outside casing was the reference point for water level measurements in July for these new wells.

Table D.1. Measurement Control Datums Used for Upper Regional Gravel Aquifer C-404 Monitoring Wells During 2019

Well	Datum Point		Datum Point Elevation (ft amsl)
	January 29, 2019	July 29, 2019	
MW84	Well Wizard Plate	NA	375.82
MW84A	NA	Top of Outside Casing	375.29
MW87	Well Wizard Plate	NA	375.73
MW87A	NA	Top of Outside Casing	375.30
MW90A	Top of Inside Casing	Top of Inside Casing	374.15
MW93	Well Wizard Plate	NA	377.60
MW93A	NA	Top of Outside Casing	378.67
MW420	Top of Inside Casing	--	377.55
MW420	--	Top of Outside Casing	378.18

NA = not applicable

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. C-404 Landfill Annual Average Groundwater Flow Rate for 2019

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	0.170 (6.01×10^{-5})	0.681 (2.40×10^{-4})
Low K	0.0255 (9.01×10^{-6})	0.102 (3.60×10^{-5})

Table D.3. Calculation Information for the C-404 Landfill Annual Groundwater Flow Rate 2019

Upper RGA K = 21 ft/d					
	i (ft/ft)	q (ft/d)	q (cm/s)	v (ft/d)	v (cm/s)
January 2019	1.02×10^{-3}	0.0214	7.54×10^{-6}	0.0855	3.02×10^{-5}
July 2019	1.41×10^{-3}	0.0297	1.05×10^{-5}	0.119	4.19×10^{-5}
Annual Average	**1.22×10^{-3}**	**0.0255**	**9.01×10^{-6}**	**0.102**	**3.60×10^{-5}**
Upper RGA K = 140 ft/d					
	i (ft/ft)	q (ft/d)	q (cm/s)	v (ft/d)	v (cm/s)
January 2019	1.02×10^{-3}	0.142	5.03×10^{-5}	0.570	2.01×10^{-4}
July 2019	1.41×10^{-3}	0.198	6.99×10^{-5}	0.792	2.80×10^{-4}
Annual Average	**1.22×10^{-3}**	**0.170**	**6.01×10^{-5}**	**0.681**	**2.40×10^{-4}**
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.4. Barometric Pressure Corrections

C-404 Landfill (January 2019) 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)
1/29/2019	8:54	MW67	374.89	30.26	-0.01	48.39	326.50	48.38	326.52
1/29/2019	8:39	MW76	376.56	30.24	0.01	50.06	326.50	50.07	326.49
1/29/2019	8:10	MW84	375.82	30.24	0.01	49.33	326.49	49.34	326.48
1/29/2019	8:46	MW87	375.73	30.24	0.01	49.28	326.45	49.29	326.44
1/29/2019	8:42	MW90A	374.15	30.24	0.01	47.80	326.35	47.81	326.34
1/29/2019	8:30	MW93	377.60	30.24	0.01	50.91	326.69	50.92	326.68
1/29/2019	9:20	MW227	378.81	30.26	-0.01	52.09	326.72	52.08	326.74
1/29/2019	8:23	MW333	377.33	30.24	0.01	50.44	326.89	50.45	326.88
1/29/2019	8:05	MW337	374.39	30.24	0.01	47.76	326.63	47.77	326.62
1/29/2019	8:07	MW338	374.85	30.24	0.01	48.11	326.74	48.12	326.73
1/29/2019	8:37	MW420	377.55	30.24	0.01	51.02	326.53	51.03	326.52

Initial Barometric Pressure **30.25**

Elev = elevation

amsl = above mean sea level

BP = barometric pressure

DTW = depth to water in feet below datum

*On 1/29/2019, water levels were measured from alternate reference points to those specified in the Permit (Well Wizard Plate). Depth to water was measured from the top of inner casing in MW90A and MW420. MW90A and MW420 no longer have a Well Wizard Plate.

**Assumes a barometric efficiency of 1.0. Apparent discrepancies in the Corrected Data elevation values result from numerical rounding of the values.

Table D.5. Barometric Pressure Corrections

C-404 Landfill (July 2019) Water Levels									
						Raw Data		Corrected Data**	
Date	Time	Well	Datum Elev* (ft amsl)	BP (in Hg)	Delta BP (ft H20)	DTW (ft)	Elev (ft amsl)	DTW (ft)	Elev (ft amsl)
7/29/2019	10:25	MW67	375.02	30.01	-0.01	43.19	331.83	43.18	331.85
7/29/2019	10:27	MW76	376.68	30.01	-0.01	44.75	331.93	44.74	331.95
7/29/2019	10:20	MW84A	375.29	30.01	-0.01	43.53	331.76	43.52	331.78
7/29/2019	10:15	MW87A	375.30	30.01	-0.01	43.60	331.70	43.59	331.71
7/29/2019	10:03	MW90A	374.15	30.01	-0.01	42.48	331.67	42.47	331.68
7/29/2019	10:40	MW93A	378.67	30.01	-0.01	46.54	332.13	46.53	332.15
7/29/2019	10:56	MW227	378.81	29.99	0.01	46.52	332.29	46.53	332.28
7/29/2019	10:46	MW333	377.35	30.01	-0.01	45.06	332.29	45.05	332.30
7/29/2019	9:28	MW337	374.53	30.03	-0.03	42.60	331.93	42.57	331.97
7/29/2019	9:29	MW338	374.86	30.03	-0.03	42.88	331.98	42.85	332.01
7/29/2019	10:30	MW420	378.18	30.01	-0.01	46.23	331.95	46.22	331.97

Initial Barometric Pressure **30.00**

Elev = elevation

amsl = above mean sea level

BP = barometric pressure

DTW = depth to water in feet below datum

*On 7/29/2019, water levels were measured from alternate reference points to those specified in the Permit (Well Wizard Plate) for MW90A and MW420. Depth to water was measured from the top of inside casing in MW90A and from the top of the outside casing in MW420. MW90A and MW420 no longer have a Well Wizard Plate. MW84A, MW87A, and MW93A are new wells, completed July 19, 2019. The datum in these wells was the top of outside casing.

**Assumes a barometric efficiency of 1.0. Apparent discrepancies in the Corrected Data elevation values result from numerical rounding of the values.

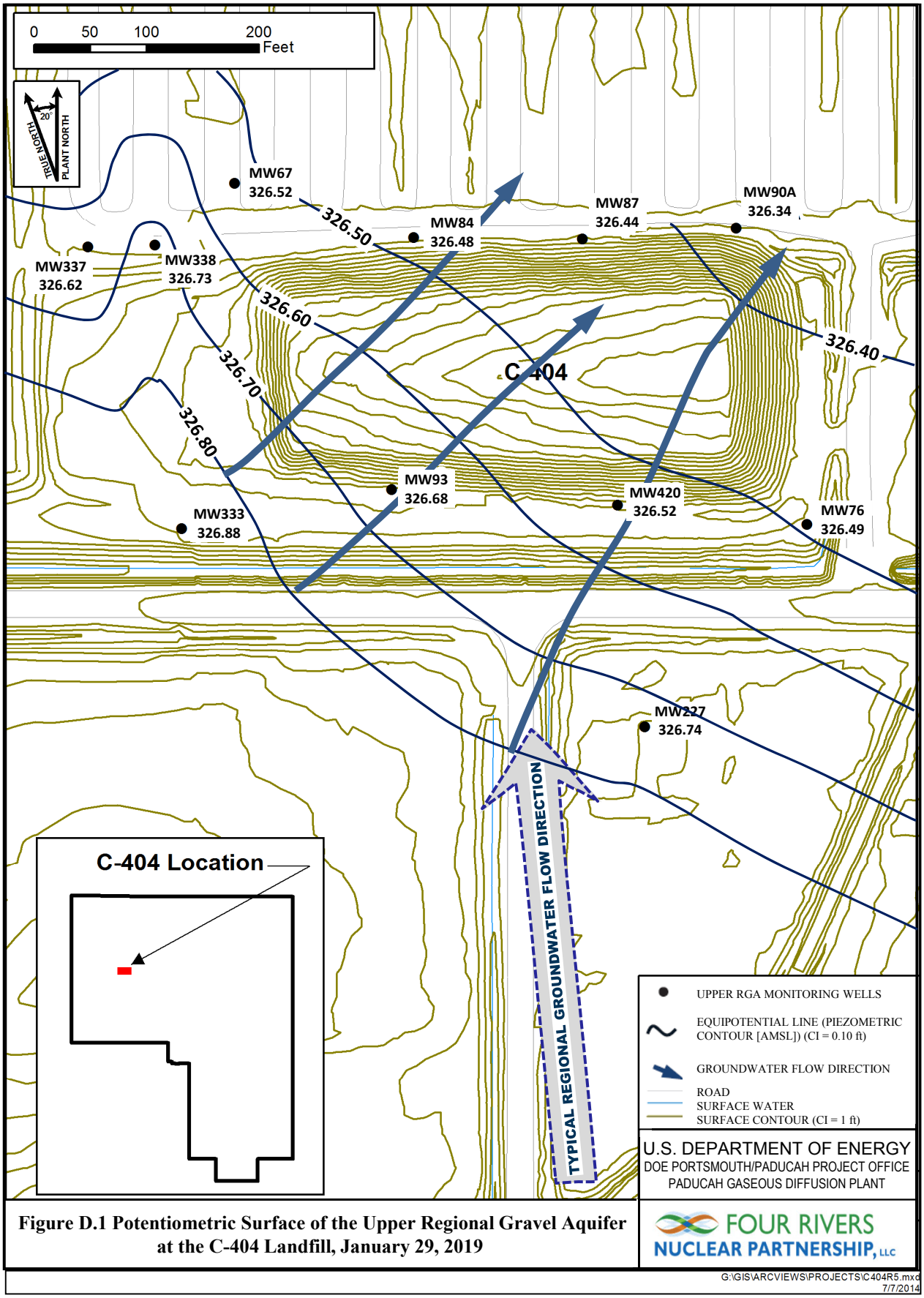

Figure D.1 Potentiometric Surface of the Upper Regional Gravel Aquifer at the C-404 Landfill, January 29, 2019

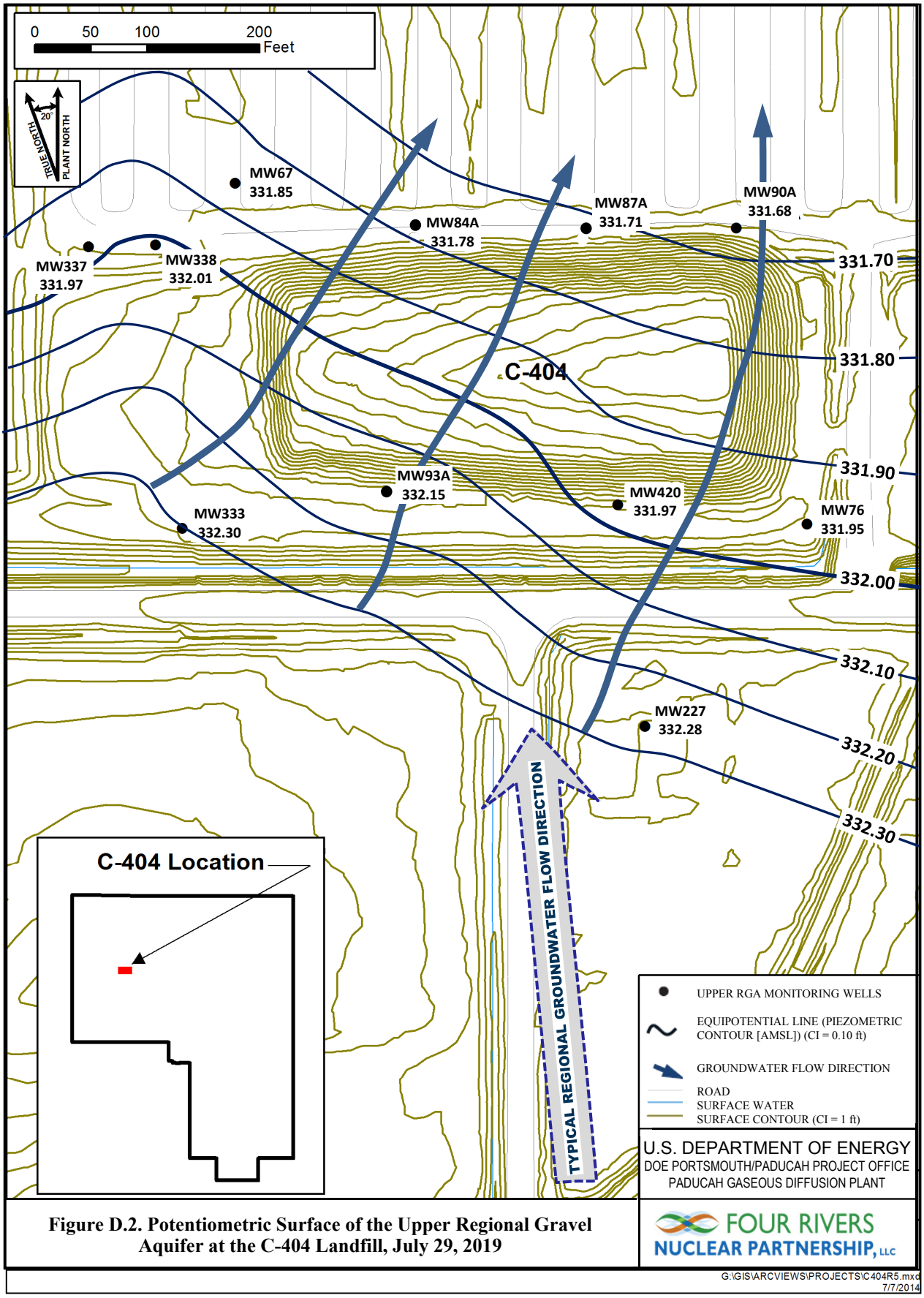

Figure D.2. Potentiometric Surface of the Upper Regional Gravel Aquifer at the C-404 Landfill, July 29, 2019