Department of Energy

Portsmouth/Paducah Project Office
1017 Majestic Drive, Suite 200
Lexington, Kentucky 40513
(859) 219-4000

November 19, 2020

Ms. Lauren Linehan
Division of Waste Management
Kentucky Department for Environmental Protection
625 Hospital Drive
Madisonville, Kentucky 42431

PPPO-02-10008451-21B

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

Dear Ms. Linehan and Ms. Webb:

C-404 HAZARDOUS WASTE LANDFILL NOVEMBER 2020 SEMIANNUAL GROUNDWATER REPORT (APRIL 2020–SEPTEMBER 2020), PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY, FRNP-RPT-0135/V2, HAZARDOUS WASTE MANAGEMENT FACILITY PERMIT NO. KY8-890-008-982, AGENCY INTEREST ID NO. 3059
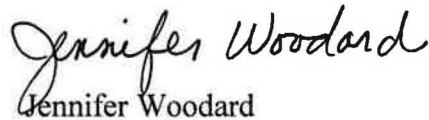
Enclosed is the subject report for the second reporting period of 2020. This report is required in accordance with Part II, Specific Condition II.K.6.d, of Hazardous Waste Management Facility Permit No. KY8-890-008-982 (Permit).

Results of the statistical analyses indicate that compliance well concentrations of permit-required parameters are not statistically different from those in background wells, except for trichloroethene (TCE) in monitoring well MW87A. The plume discussed in the 2007 *C-404 Landfill Source Demonstration, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, PRS-ENM-0031/R2 (ASD) appears to have continued to migrate eastward, impacting upgradient well MW420 and downgradient well MW87A. The ASD demonstrated that the C-404 Landfill was not the source of the historical, statistically significant background exceedance of TCE in MW84. Consistent with the 2007 ASD, the C-404 landfill is not the source of the statistical exceedance observed in MW87A.

Notification of the statistically significant difference for TCE in MW87A was submitted, pursuant to Part II, Specific Condition II.K.6.a, to your department under separate correspondence.

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

Sincerely,

Jennifer Woodard

Jennifer Woodard
Paducah Site Lead
Portsmouth/Paducah Project Office

Enclosures:
1. Certification Page
2. C-404 Hazardous Waste Landfill November 2020 Semiannual Groundwater Report (April 2020–September 2020), FRNP-RPT-0135/V2
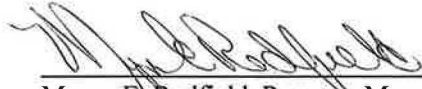
cc w/enclosures:
abigal.parish@pppo.gov, PPPO
april.webb@ky.gov, KDEP
brandy.mitchell@pad.pppo.gov, FRNP
brian.begley@ky.gov, KDEP
bruce.ford@pad.pppo.gov, FRNP
bryan.smith@pad.pppo.gov, FRNP
christopher.jung@ky.gov, KDEP
christopher.travis@ky.gov, KDEP
dave.dollins@pppo.gov, PPPO
dennis.greene@pad.pppo.gov, FRNP
frnpcorrespondence@pad.pppo.gov, FRNP
jennifer.woodard@pppo.gov, PPPO
joel.bradburne@pppo.gov, PPPO
kelly.layne@pad.pppo.gov, FRNP
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robert.edwards@pppo.gov, PPPO
stephaniec.brock@ky.gov, KYRHB
tracey.duncan@pppo.gov, PPPO
victor.weeks@epa.gov EPA

CERTIFICATION

Document Identification: *C-404 Hazardous Waste Landfill November 2020 Semiannual Groundwater Report (April 2020–September 2020), Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, **FRNP-RPT-0135/V2, Permit No. KY8-890-008-982, Agency Interest ID No. 3059, dated November 2020**

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision according to a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.
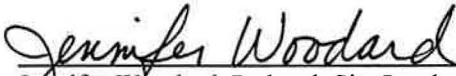
Four Rivers Nuclear Partnership, LLC

_____ _____
Myrna E. Redfield, Program Manager   Date Signed
Four Rivers Nuclear Partnership, LLC
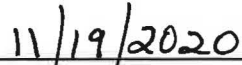
I certify under penalty of law that this document and all attachments were prepared under my direction or supervision according to a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

U.S. Department of Energy

_____ _____
Jennifer Woodard, Paducah Site Lead   Date Signed
Portsmouth/Paducah Project Office
U.S. Department of Energy

C-404 Hazardous Waste Landfill November 2020 Semiannual Groundwater Report (April–September 2020), Paducah Gaseous Diffusion Plant, Paducah, Kentucky

FOUR RIVERS NUCLEAR PARTNERSHIP, LLC

This document is approved for public release per review by:

Daniel Hayden   _11-11-2020_

FRNP Classification Support   Date

**C-404 Hazardous Waste Landfill
November 2020 Semiannual
Groundwater Report
(April–September 2020),
Paducah Gaseous Diffusion Plant,
Paducah, Kentucky**

Date Issued—November 2020

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

CONTENTS

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TABLES

FIGURES

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ACRONYMS

AKGWA	Assembled Kentucky Groundwater
ASD	alternate source demonstration
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 2020 Semiannual Groundwater Report (April–September 2020), Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* FRNP-RPT-0135/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 2020 covers April through September 2020 and includes analytical data from the July 2020 sampling of monitoring wells located in the vicinity of the closed C-404 Hazardous Waste Landfill (C-404 Landfill).

The groundwater monitoring analytical data were subjected to statistical analyses. The analyses were conducted in accordance with the Hazardous Waste Management Facility Permit. The trichloroethene (TCE) concentration in downgradient compliance monitoring well (MW) MW87A was statistically different from concentrations in the background wells. The statistical tests on all other parameters showed no statistical difference between concentrations in the compliance and background wells.

TCE concentration trends have increased for both background and compliance well locations, indicating that the plume discussed in the 2007 *C-404 Landfill Source Demonstration, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, PRS-ENM-0031/R2 (PRS 2007a) (ASD) appears to have continued to migrate northeastward impacting upgradient well MW420 and compliance well MW87A. Additionally, with one exception (July 2017—0.44 µg/L), none of the C-404 Landfill leachate samples collected over the past 10 years have had detectable concentrations of TCE; therefore, consistent with the findings in the 2007 ASD, the C-404 Landfill cannot be the source of the TCE found in the MWs. The exceedance in TCE concentration in MW87A over background concentrations is consistent with the findings in the 2007 ASD (PRS 2007a) as well as the *C-404 Semiannual Groundwater Report May 2020 (October 2019—January 2020), Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, FRNP-RPT-0135/V1 (FRNP 2020), the latter of which was approved by Kentucky Division of Waste Management in a letter dated July 14, 2020.

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 maximum depth of the leachate was 12 inches, as measured on August 19, September 2, and September 22, 2020. Since the depth of the leachate had not exceeded 3 ft during the reporting period of April through September 2020, no leachate was removed and no leachate sample was collected. A leachate sample was collected on March 23, 2020, which was in the previous reporting period; however, results for this sampling event were not received in time to be included in the May 2020 C-404 Hazardous Waste Landfill groundwater report, but have been included in Appendix C of this report.

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 2020), Specific Condition II.K.6.d—Recordkeeping, Reporting, and Response. The period covered by this report is April through September 2020.

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. The leachate then 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 2020).

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 TCE 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 better assess groundwater quality at the C-404 Landfill (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.

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 Upper Continental Recharge System (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 background well 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 MW93 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 and are identified relative to 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.
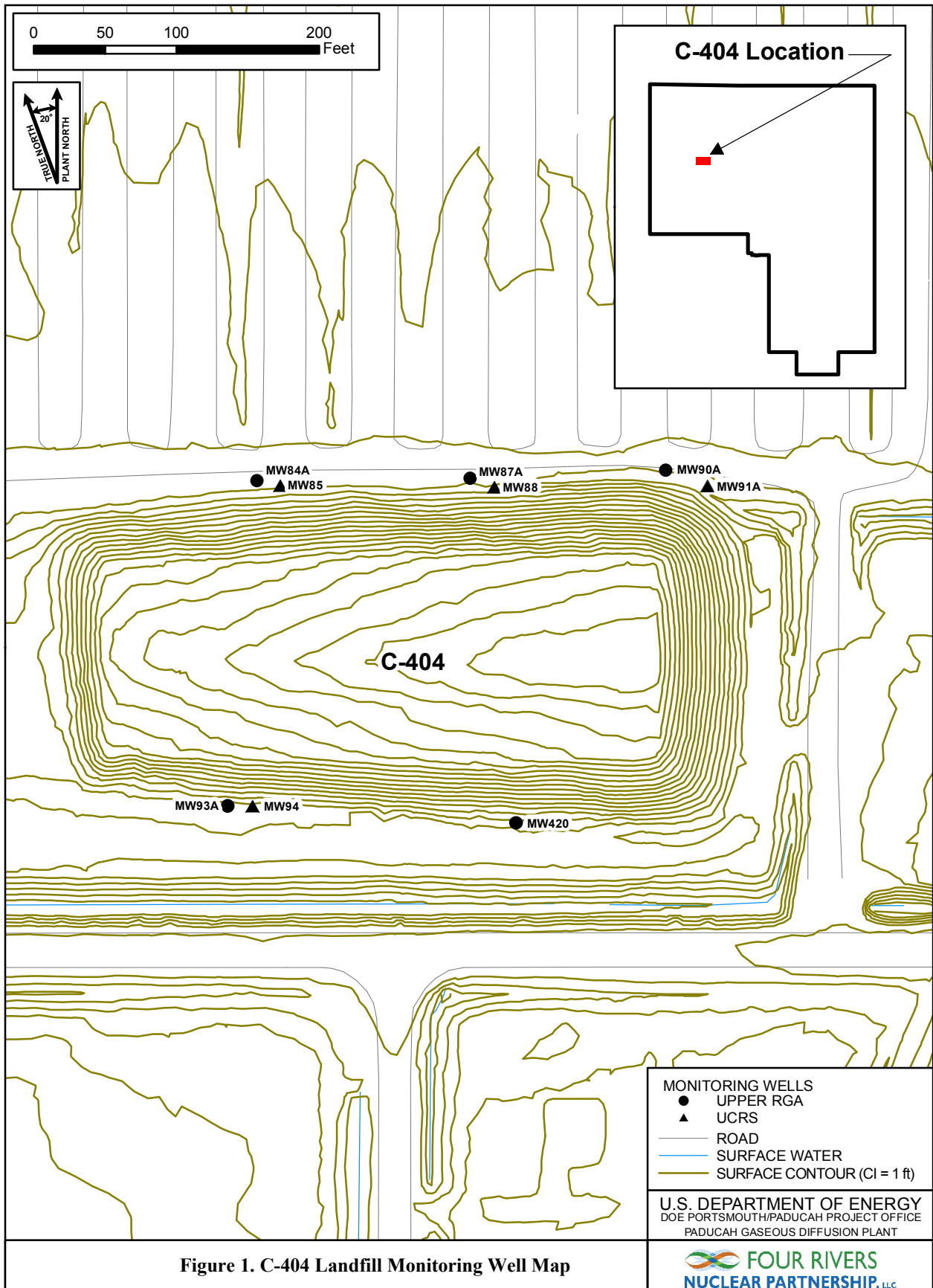
Figure 1. C-404 Landfill Monitoring Well Map

Source: Hazardous Waste Management Facility Permit (FRNP 2020)

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 2020 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. During this reporting period, the maximum depth of the leachate was 12 inches, as measured on August 19, September 2, and September 22, 2020. Since the depth of the leachate had not exceeded 3 ft during the reporting period of April through September 2020, no leachate was removed, nor was a leachate sample collected. A leachate sample was collected on March 23, 2020, which was during the previous reporting period; however, results for this sampling event were not received in time to be included in the May 2020 C-404 Hazardous Waste Landfill groundwater report, but have been included in Appendix C of this report.

The annual leachate integrity test, as required by Section 1.2 of Appendix I2 of the Permit, was conducted between July 30 and September 2, 2020. Data was collected at a known depth at 1-hour increments to determine the change in leachate levels over time. Results of the integrity test were within normal limits.

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 February 2020. 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 August 2018, January 2019, July 2019, January 2020, and July 2020.

The TCE concentration in compliance well MW87A was statistically different from concentrations in the background wells. Appendix B provides a summary of the statistical analyses performed. The statistical tests on all other parameters showed no statistical difference between concentrations in the compliance and background wells. Notification of the statistically significant difference for TCE in MW87A was submitted, pursuant to Part II, Specific Condition II.K.6.a, to the Kentucky Department of Waste Management (KDWM) under separate correspondence.

STATISTICALLY SIGNIFICANT EXCEEDANCE OF TCE BACKGROUND IN MW87A

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) (ASD) 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 compliance well MW84 appeared to be due to an upgradient source whose TCE is migrating through the C-404 Landfill area.

A comparison of TCE concentration trends in western C-404 Landfill URGA wells indicates that the increasing trends are consistent in both background and compliance wells, as demonstrated in Figure 2. As TCE concentration trends have increased for both background and compliance well locations, the plume continues to migrate northeastward, impacting upgradient well MW420 and compliance well MW87A.
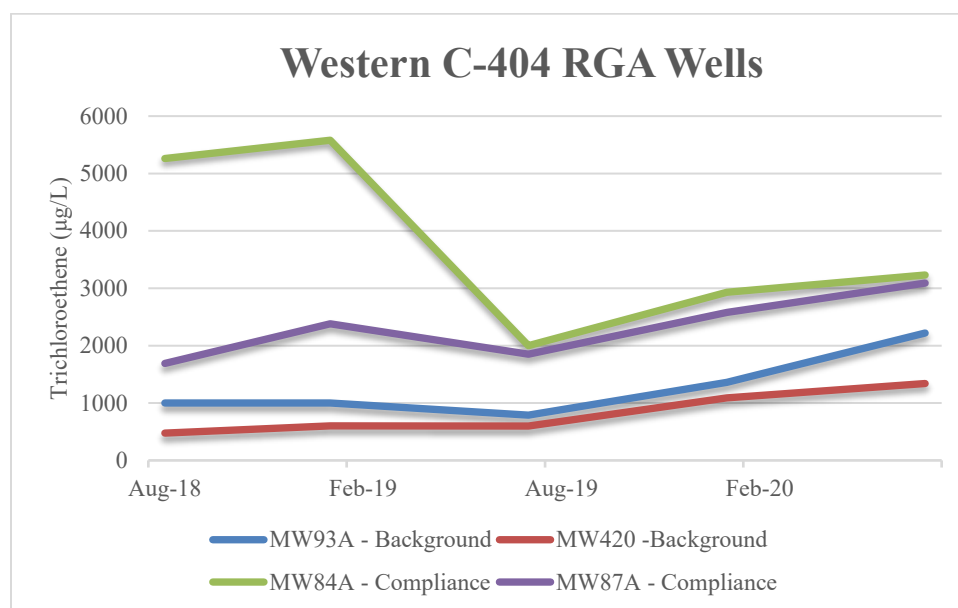
Figure 2. TCE Trends in C-404 Landfill Western URGA Wells

The exceedance of TCE concentrations in MW87A over background concentrations is consistent with the findings in the 2007 ASD (PRS 2007a) as well as the *C-404 Semiannual Groundwater Report May 2020 (October 2019—January 2020),* FRNP-RPT-135/V1, (FRNP 2020) that was approved by KDWM in a letter dated July 14, 2020.

Additionally, groundwater flow directions are to the northeast—similarly indicating an upgradient, non-C-404 Landfill source of MW84A and MW87A impacts (Figure 3). This condition is consistent with flow patterns found in 2007 during the ASD. Recent increasing TCE concentration trends in both compliance and background wells at the C-404 Landfill further indicate that the source of the TCE is upgradient to the C-404 Landfill.

Finally, with one exception (July 2017—0.44 µg/L), none of the C-404 Landfill leachate samples collected over the past 10 years have had detectable concentrations of TCE; therefore, the C-404 Landfill cannot be the source of the TCE found in the MWs.

This demonstration fulfills Section II.K.8 of the Hazardous Waste Management Facility Permit, which allows for demonstrating that the exceedance is consistent with the findings in the 2007 ASD and allows for the demonstration to be submitted within the semiannual report.

0 50 100 200
Feet

TRUE NORTH
PLANT NORTH
20°

MW67
329.27

MW84A
329.14

MW87A
329.11

MW90A
329.08

329.10

MW337
329.44

MW338
329.43

329.20

C-404

329.30

329.40

MW93A
329.56

MW333
329.73

MW420
329.49

MW76
329.39

329.50

329.60

329.70

MW227
329.75

329.80

TYPICAL REGIONAL GROUNDWATER FLOW DIRECTION

C-400 LANDFILL

UPPER RGA MONITORING WELLS

EQUIPOTENTIAL LINE (PIEZOMETRIC CONTOUR [AMSL]) (CI = 0.10 ft)

GROUNDWATER FLOW DIRECTION

ROAD
SURFACE WATER
SURFACE CONTOUR (CI = 1 ft)

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

FOUR RIVERS
NUCLEAR PARTNERSHIP, LLC

Figure 3. Potentiometric Surface for the Upper Regional Gravel Aquifer for C-404 Landfill, July 28 and July 29, 2020

Note: Contour lines and labels applied with Microsoft Powerpoint.

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7/7/2014

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3. DATA VALIDATION AND QA/QC SUMMARY

The data and the data validation qualifiers for the July 2020 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

Per the Permit Part VIII.E, Appendix E3, *Monitoring Well Requirements*, Section 1.5, *Field Quality Control*, field duplicate samples were collected as specified below (KDWM 2020).

> Field duplicates consist of two aliquots of a sample (i.e., the original sample and its duplicate) that are collected at the same time, using the same procedures, the same type of equipment, and in the same types of sample containers as the original samples. Duplicate samples also are preserved in the same manner and submitted for the same analyses as the original samples. Field duplicates are used to determine the total variability (i.e., imprecision) associated with the sampling and analysis effort.
>
> Field duplicates should be collected at a minimum rate of one for each 20 samples.
>
> 1. Determine the number of duplicates to be obtained.
>
> 2. Collect samples following the appropriate procedure.
>
> 3. Collect field duplicates and analyze them for the same parameters as other original samples being collected.

The field duplicate sample for the current reporting period is MW85 FR. See Appendix A for data.

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4. PROFESSIONAL GEOLOGIST AUTHORIZATION

DOCUMENT IDENTIFICATION: *C-404 Hazardous Waste Landfill*
November 2020 Semiannual Groundwater Report
(April–September 2020),
Paducah Gaseous Diffusion Plant, Paducah, Kentucky
(FRNP-RPT-0135/V2)

Stamped and signed pursuant to my authority as a duly registered geologist under the provisions of *KRS* Chapter 322A.
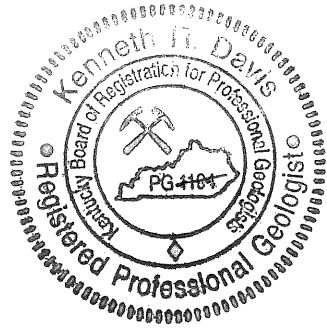
PG 113927
K Davis 11-10-2020

_____   _____   ___11-10-2020___
Kenneth R. Davis   PG113927   Date

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5. REFERENCES

FRNP (Four Rivers Nuclear Partnership, LLC) 2018. *C-404 Hazardous Waste Landfill November 2018 Semiannual Groundwater Report (April 2018—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.

FRNP 2020. *C-404 Semiannual Groundwater Report May 2020 (October 2019—January 2020), Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, FRNP-RPT-0135/V1, U.S. Department of Energy, Paducah, KY, May.

KDWM (Kentucky Division of Waste Management) 2020. Hazardous Waste Management Facility Permit for the U.S. Department of Energy, Paducah Gaseous Diffusion Plant, KY8-890-008-982, effective February 21.

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		0.0222	mg/L	0.005	7/14/2020			SW846-6020	=
Arsenic, Dissolved		0.0175	mg/L	0.005	7/14/2020			SW846-6020	=
Barometric Pressure Reading		30.02	Inches/Hg		7/14/2020				X
Cadmium	U	0.001	mg/L	0.001	7/14/2020			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/14/2020			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	7/14/2020			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	7/14/2020			SW846-6020	=
Conductivity		530	umho/cm		7/14/2020				X
Depth to Water		45.32	ft		7/14/2020				X
Dissolved Oxygen		0.89	mg/L		7/14/2020				X
Lead	U	0.002	mg/L	0.002	7/14/2020			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	7/14/2020			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/14/2020			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/14/2020			SW846-7470A	=
pH		5.95	Std Unit		7/14/2020				X
Redox		392	mV		7/14/2020				X
Selenium	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Sulfate	W	73.8	mg/L	2	7/14/2020			SW846-9056	=
Technetium-99		332	pCi/L	19.5	7/14/2020	18.4	41.2	HASL 300, Tc-02-RC M	=
Temperature		63.6	deg F		7/14/2020				X
Trichloroethene		3230	ug/L	50	7/14/2020			SW846-8260B	=
Turbidity		2.4	NTU		7/14/2020				X
Uranium		0.000219	mg/L	0.0002	7/14/2020			SW846-6020	=
Uranium-234	U	-0.35	pCi/L	1.88	7/14/2020	0.745	0.745	HASL 300, U-02-RC M	=
Uranium-235	U	0.0586	pCi/L	1.28	7/14/2020	0.612	0.613	HASL 300, U-02-RC M	=
Uranium-238	U	-0.0677	pCi/L	1.47	7/14/2020	0.632	0.633	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		0.00696	mg/L	0.005	7/14/2020			SW846-6020	=
Arsenic, Dissolved		0.00575	mg/L	0.005	7/14/2020			SW846-6020	=
Barometric Pressure Reading		30.02	Inches/Hg		7/14/2020				X
Cadmium	U	0.001	mg/L	0.001	7/14/2020			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/14/2020			SW846-6020	=
Chromium	J	0.00337	mg/L	0.01	7/14/2020			SW846-6020	=
Chromium, Dissolved	J	0.00384	mg/L	0.01	7/14/2020			SW846-6020	=
Conductivity		350	umho/cm		7/14/2020				X
Depth to Water		8.93	ft		7/14/2020				X
Dissolved Oxygen		1.33	mg/L		7/14/2020				X
Lead	U	0.002	mg/L	0.002	7/14/2020			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	7/14/2020			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/14/2020			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/14/2020			SW846-7470A	=
pH		6.26	Std Unit		7/14/2020				X
Redox		290	mV		7/14/2020				X
Selenium	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Sulfate	W	10.1	mg/L	0.4	7/14/2020			SW846-9056	=
Technetium-99		43	pCi/L	21	7/14/2020	13.3	14.2	HASL 300, Tc-02-RC M	=
Temperature		63.8	deg F		7/14/2020				X
Trichloroethene		1.95	ug/L	1	7/14/2020			SW846-8260B	J
Turbidity		18.7	NTU		7/14/2020				X
Uranium		0.00252	mg/L	0.0002	7/14/2020			SW846-6020	=
Uranium-234	U	0.714	pCi/L	2.75	7/14/2020	1.54	1.55	HASL 300, U-02-RC M	=
Uranium-235	U	-0.168	pCi/L	1.93	7/14/2020	0.741	0.744	HASL 300, U-02-RC M	=
Uranium-238	U	1.49	pCi/L	1.73	7/14/2020	1.49	1.51	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

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

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

AKGWA Well Tag #: 8000-5234

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic		0.00712	mg/L	0.005	7/14/2020			SW846-6020	=
Arsenic, Dissolved		0.00577	mg/L	0.005	7/14/2020			SW846-6020	=
Cadmium	U	0.001	mg/L	0.001	7/14/2020			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/14/2020			SW846-6020	=
Chromium	J	0.00348	mg/L	0.01	7/14/2020			SW846-6020	=
Chromium, Dissolved	J	0.00369	mg/L	0.01	7/14/2020			SW846-6020	=
Lead	U	0.002	mg/L	0.002	7/14/2020			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	7/14/2020			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/14/2020			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/14/2020			SW846-7470A	=
Selenium	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Sulfate	W	9.98	mg/L	0.4	7/14/2020			SW846-9056	=
Technetium-99		48	pCi/L	20.4	7/14/2020	13.1	14.1	HASL 300, Tc-02-RC M	=
Trichloroethene		1.31	ug/L	1	7/14/2020			SW846-8260B	J
Uranium		0.00262	mg/L	0.0002	7/14/2020			SW846-6020	=
Uranium-234	U	0.388	pCi/L	1.62	7/14/2020	0.902	0.905	HASL 300, U-02-RC M	=
Uranium-235	U	0.339	pCi/L	1.23	7/14/2020	0.778	0.779	HASL 300, U-02-RC M	=
Uranium-238	U	0.281	pCi/L	1.33	7/14/2020	0.741	0.742	HASL 300, U-02-RC M	=

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		0.00895	mg/L	0.005	7/14/2020			SW846-6020	=
Arsenic, Dissolved		0.00718	mg/L	0.005	7/14/2020			SW846-6020	=
Barometric Pressure Reading		30.02	Inches/Hg		7/14/2020				X
Cadmium	U	0.001	mg/L	0.001	7/14/2020			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/14/2020			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	7/14/2020			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	7/14/2020			SW846-6020	=
Conductivity		341	umho/cm		7/14/2020				X
Depth to Water		45.41	ft		7/14/2020				X
Dissolved Oxygen		1.53	mg/L		7/14/2020				X
Lead	U	0.002	mg/L	0.002	7/14/2020			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	7/14/2020			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/14/2020			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/14/2020			SW846-7470A	=
pH		5.84	Std Unit		7/14/2020				X
Redox		382	mV		7/14/2020				X
Selenium	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Sulfate	W	6.85	mg/L	0.4	7/14/2020			SW846-9056	=
Technetium-99	U	5.04	pCi/L	19.7	7/14/2020	11.6	11.6	HASL 300, Tc-02-RC M	=
Temperature		62.9	deg F		7/14/2020				X
Trichloroethene		3090	ug/L	50	7/14/2020			SW846-8260B	=
Turbidity		0	NTU		7/14/2020				X
Uranium	U	0.0002	mg/L	0.0002	7/14/2020			SW846-6020	=
Uranium-234	U	-0.297	pCi/L	1.65	7/14/2020	0.587	0.587	HASL 300, U-02-RC M	=
Uranium-235	U	0	pCi/L	0.708	7/14/2020	0.475	0.477	HASL 300, U-02-RC M	=
Uranium-238	U	0.343	pCi/L	1.34	7/14/2020	0.78	0.781	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		0.00845	mg/L	0.005	7/14/2020			SW846-6020	=
Arsenic, Dissolved		0.00582	mg/L	0.005	7/14/2020			SW846-6020	=
Barometric Pressure Reading		30.02	Inches/Hg		7/14/2020				X
Cadmium	U	0.001	mg/L	0.001	7/14/2020			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/14/2020			SW846-6020	=
Chromium	J	0.00496	mg/L	0.01	7/14/2020			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	7/14/2020			SW846-6020	=
Conductivity		645	umho/cm		7/14/2020				X
Depth to Water		8.54	ft		7/14/2020				X
Dissolved Oxygen		0.7	mg/L		7/14/2020				X
Lead	J	0.00141	mg/L	0.002	7/14/2020			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	7/14/2020			SW846-6020	=
Mercury	J	0.000122	mg/L	0.0002	7/14/2020			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/14/2020			SW846-7470A	=
pH		5.83	Std Unit		7/14/2020				X
Redox		356	mV		7/14/2020				X
Selenium	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Sulfate	W	129	mg/L	4	7/14/2020			SW846-9056	=
Technetium-99		20.3	pCi/L	19.7	7/14/2020	12	12.2	HASL 300, Tc-02-RC M	=
Temperature		63.6	deg F		7/14/2020				X
Trichloroethene		8.25	ug/L	1	7/14/2020			SW846-8260B	=
Turbidity		37.6	NTU		7/14/2020				X
Uranium	J	0.000199	mg/L	0.0002	7/14/2020			SW846-6020	=
Uranium-234	U	0.591	pCi/L	1.3	7/14/2020	0.839	0.845	HASL 300, U-02-RC M	=
Uranium-235	U	0.25	pCi/L	1.19	7/14/2020	0.688	0.688	HASL 300, U-02-RC M	=
Uranium-238	U	0.0884	pCi/L	1.17	7/14/2020	0.571	0.571	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	7/14/2020			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Barometric Pressure Reading		30.02	Inches/Hg		7/14/2020				X
Cadmium	U	0.001	mg/L	0.001	7/14/2020			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/14/2020			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	7/14/2020			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	7/14/2020			SW846-6020	=
Conductivity		215	umho/cm		7/14/2020				X
Depth to Water		44.62	ft		7/14/2020				X
Dissolved Oxygen		3.03	mg/L		7/14/2020				X
Lead	U	0.002	mg/L	0.002	7/14/2020			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	7/14/2020			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/14/2020			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/14/2020			SW846-7470A	=
pH		5.93	Std Unit		7/14/2020				X
Redox		340	mV		7/14/2020				X
Selenium	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Sulfate	W	4.17	mg/L	0.4	7/14/2020			SW846-9056	=
Technetium-99	U	12.5	pCi/L	20.5	7/14/2020	12.2	12.3	HASL 300, Tc-02-RC M	=
Temperature		64.3	deg F		7/14/2020				X
Trichloroethene		52	ug/L	1	7/14/2020			SW846-8260B	=
Turbidity		0	NTU		7/14/2020				X
Uranium	U	0.0002	mg/L	0.0002	7/14/2020			SW846-6020	=
Uranium-234	U	0.0569	pCi/L	1.84	7/14/2020	0.865	0.866	HASL 300, U-02-RC M	=
Uranium-235	U	0.39	pCi/L	1.42	7/14/2020	0.896	0.898	HASL 300, U-02-RC M	=
Uranium-238	U	0.532	pCi/L	1.54	7/14/2020	0.946	0.949	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		0.00983	mg/L	0.005	7/14/2020			SW846-6020	=
Arsenic, Dissolved		0.00539	mg/L	0.005	7/14/2020			SW846-6020	=
Barometric Pressure Reading		30.02	Inches/Hg		7/14/2020				X
Cadmium	U	0.001	mg/L	0.001	7/14/2020			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/14/2020			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	7/14/2020			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	7/14/2020			SW846-6020	=
Conductivity		989	umho/cm		7/14/2020				X
Depth to Water		12.22	ft		7/14/2020				X
Dissolved Oxygen		1.04	mg/L		7/14/2020				X
Lead	U	0.002	mg/L	0.002	7/14/2020			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	7/14/2020			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/14/2020			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/14/2020			SW846-7470A	=
pH		6.23	Std Unit		7/14/2020				X
Redox		206	mV		7/14/2020				X
Selenium	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Sulfate	W	113	mg/L	4	7/14/2020			SW846-9056	=
Technetium-99		31.8	pCi/L	22	7/14/2020	13.7	14.1	HASL 300, Tc-02-RC M	=
Temperature		65	deg F		7/14/2020				X
Trichloroethene		26.4	ug/L	1	7/14/2020			SW846-8260B	=
Turbidity		4.4	NTU		7/14/2020				X
Uranium	J	0.00008	mg/L	0.0002	7/14/2020			SW846-6020	=
Uranium-234	U	-0.18	pCi/L	1.78	7/14/2020	0.769	0.77	HASL 300, U-02-RC M	=
Uranium-235	U	0.45	pCi/L	1.21	7/14/2020	0.796	0.798	HASL 300, U-02-RC M	=
Uranium-238	U	-0.383	pCi/L	1.39	7/14/2020	0.4	0.401	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		0.0109	mg/L	0.005	7/14/2020			SW846-6020	=
Arsenic, Dissolved		0.0087	mg/L	0.005	7/14/2020			SW846-6020	=
Barometric Pressure Reading		30.02	Inches/Hg		7/14/2020				X
Cadmium	U	0.001	mg/L	0.001	7/14/2020			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/14/2020			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	7/14/2020			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	7/14/2020			SW846-6020	=
Conductivity		364	umho/cm		7/14/2020				X
Depth to Water		48.31	ft		7/14/2020				X
Dissolved Oxygen		1.26	mg/L		7/14/2020				X
Lead	U	0.002	mg/L	0.002	7/14/2020			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	7/14/2020			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/14/2020			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/14/2020			SW846-7470A	=
pH		6.07	Std Unit		7/14/2020				X
Redox		279	mV		7/14/2020				X
Selenium	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Sulfate	W	7.39	mg/L	0.4	7/14/2020			SW846-9056	=
Technetium-99	U	-0.977	pCi/L	20.7	7/14/2020	12	12	HASL 300, Tc-02-RC M	=
Temperature		65.6	deg F		7/14/2020				X
Trichloroethene		2220	ug/L	25	7/14/2020			SW846-8260B	=
Turbidity		6.7	NTU		7/14/2020				X
Uranium	J	0.000089	mg/L	0.0002	7/14/2020			SW846-6020	=
Uranium-234	U	-0.297	pCi/L	1.66	7/14/2020	0.588	0.589	HASL 300, U-02-RC M	=
Uranium-235	U	0.0662	pCi/L	1.44	7/14/2020	0.692	0.693	HASL 300, U-02-RC M	=
Uranium-238	U	0.107	pCi/L	1.41	7/14/2020	0.692	0.692	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

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

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

AKGWA Well Tag #: 8000-5103

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic	J	0.0029	mg/L	0.005	7/14/2020			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Barometric Pressure Reading		30.03	Inches/Hg		7/14/2020				X
Cadmium	U	0.001	mg/L	0.001	7/14/2020			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/14/2020			SW846-6020	=
Chromium		0.0104	mg/L	0.01	7/14/2020			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	7/14/2020			SW846-6020	=
Conductivity		822	umho/cm		7/14/2020				X
Depth to Water		12.9	ft		7/14/2020				X
Dissolved Oxygen		0.55	mg/L		7/14/2020				X
Lead	J	0.00164	mg/L	0.002	7/14/2020			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	7/14/2020			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/14/2020			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/14/2020			SW846-7470A	=
pH		6.45	Std Unit		7/14/2020				X
Redox		272	mV		7/14/2020				X
Selenium	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Sulfate	W	80.3	mg/L	2	7/14/2020			SW846-9056	=
Technetium-99		1440	pCi/L	20.6	7/14/2020	33.2	163	HASL 300, Tc-02-RC M	=
Temperature		66.5	deg F		7/14/2020				X
Trichloroethene		3.4	ug/L	1	7/14/2020			SW846-8260B	=
Turbidity		48	NTU		7/14/2020				X
Uranium		0.00162	mg/L	0.0002	7/14/2020			SW846-6020	=
Uranium-234	U	0.444	pCi/L	1.95	7/14/2020	1.09	1.09	HASL 300, U-02-RC M	=
Uranium-235	U	0.0826	pCi/L	1.8	7/14/2020	0.864	0.865	HASL 300, U-02-RC M	=
Uranium-238	U	0.601	pCi/L	1.32	7/14/2020	0.956	0.96	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		0.00534	mg/L	0.005	7/14/2020			SW846-6020	=
Arsenic, Dissolved	J	0.00498	mg/L	0.005	7/14/2020			SW846-6020	=
Barometric Pressure Reading		30.02	Inches/Hg		7/14/2020				X
Cadmium	U	0.001	mg/L	0.001	7/14/2020			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	7/14/2020			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	7/14/2020			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	7/14/2020			SW846-6020	=
Conductivity		346	umho/cm		7/14/2020				X
Depth to Water		47.3	ft		7/14/2020				X
Dissolved Oxygen		0.98	mg/L		7/14/2020				X
Lead	U	0.002	mg/L	0.002	7/14/2020			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	7/14/2020			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/14/2020			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	7/14/2020			SW846-7470A	=
pH		6.06	Std Unit		7/14/2020				X
Redox		257	mV		7/14/2020				X
Selenium	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Sulfate	W	6.38	mg/L	0.4	7/14/2020			SW846-9056	=
Technetium-99	U	1.66	pCi/L	21.4	7/14/2020	12.5	12.5	HASL 300, Tc-02-RC M	=
Temperature		65.5	deg F		7/14/2020				X
Trichloroethene		1340	ug/L	20	7/14/2020			SW846-8260B	=
Turbidity		0	NTU		7/14/2020				X
Uranium	U	0.0002	mg/L	0.0002	7/14/2020			SW846-6020	=
Uranium-234	U	0.0478	pCi/L	1.91	7/14/2020	0.903	0.904	HASL 300, U-02-RC M	=
Uranium-235	U	0.836	pCi/L	1.32	7/14/2020	1.06	1.07	HASL 300, U-02-RC M	=
Uranium-238	U	0.0538	pCi/L	1.17	7/14/2020	0.563	0.563	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	7/14/2020			SW846-6020	=
Cadmium	U	0.001	mg/L	0.001	7/14/2020			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	7/14/2020			SW846-6020	=
Lead	U	0.002	mg/L	0.002	7/14/2020			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/14/2020			SW846-7470A	=
Selenium	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Technetium-99	U	-2.57	pCi/L	22.3	7/14/2020	12.9	12.9	HASL 300, Tc-02-RC M	=
Trichloroethene	U	1	ug/L	1	7/14/2020			SW846-8260B	=
Uranium	U	0.0002	mg/L	0.0002	7/14/2020			SW846-6020	=
Uranium-234	U	-0.0005	pCi/L	2.4	7/14/2020	1.08	1.08	HASL 300, U-02-RC M	=
Uranium-235	U	-0.177	pCi/L	2.04	7/14/2020	0.782	0.784	HASL 300, U-02-RC M	=
Uranium-238	U	-0.072	pCi/L	1.43	7/14/2020	0.617	0.619	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	7/14/2020			SW846-6020	=
Cadmium	U	0.001	mg/L	0.001	7/14/2020			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	7/14/2020			SW846-6020	=
Lead	U	0.002	mg/L	0.002	7/14/2020			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	7/14/2020			SW846-7470A	=
Selenium	U	0.005	mg/L	0.005	7/14/2020			SW846-6020	=
Technetium-99	U	2.9	pCi/L	21.2	7/14/2020	12.4	12.4	HASL 300, Tc-02-RC M	=
Trichloroethene	U	1	ug/L	1	7/14/2020			SW846-8260B	=
Uranium	U	0.0002	mg/L	0.0002	7/14/2020			SW846-6020	=
Uranium-234	U	-0.328	pCi/L	2	7/14/2020	0.725	0.726	HASL 300, U-02-RC M	=
Uranium-235	U	0.221	pCi/L	1.4	7/14/2020	0.83	0.832	HASL 300, U-02-RC M	=
Uranium-238	U	0.066	pCi/L	1.44	7/14/2020	0.69	0.691	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

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

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

AKGWA Well Tag #: 0000-0000

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-)	TPU	Method	Validation
Trichloroethene	U	1	ug/L	1	7/14/2020			SW846-8260B	=

MEDIA Codes

WG   Groundwater

QUALIFIER Codes

J   Estimated quantitation.
W   Post-digestion spike recovery out of control limits

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.
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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C-404 HAZARDOUS WASTE LANDFILL
November 2020 SEMIANNUAL
Facility: US DOE—Paducah Gaseous Diffusion Plant

Finds/Unit: KY8-980-008-982/1
LAB ID:
For Official Use Only

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 2020 semiannual report, the reporting period data set includes data from August 2018, January 2019, July 2019, January 2020, and July 2020.

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. 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 2020 semiannual report, the reporting period data set from August 2018 through July 2020 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.

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	4	21
Cadmium	25	0	19	6
Chromium	25	0	19	6
Lead	25	0	19	6
Mercury	25	0	25	0
Selenium	25	0	25	0
Technetium-99	25	0	21	4
Trichloroethene	25	0	0	25
Uranium (Metals)	25	0	15	10
Uranium-234	25	0	21	4
Uranium-235	25	0	25	0
Uranium-238	25	0	23	2

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.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	21	4	16	3
Cadmium	25	6	19	76	2
Chromium	25	6	19	76	2
Lead	25	6	19	76	2
Mercury	25	0	25	100	1
Selenium	25	0	25	100	1
Technetium-99	25	4	21	84	2
Trichloroethene	25	25	0	0	4
Uranium (Metals)	25	10	15	60	2
Uranium-234	25	4	21	84	2
Uranium-235	25	0	25	100	1
Uranium-238	25	2	23	92	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.

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 2020, 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)	1.44	0.72
Uranium-238 (pCi/L)	1.54	0.77

Table B.5. Summary of Conclusions from the C-404 Hazardous Waste Landfill Statistical Analyses for the Second Reporting Period 2020

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	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 was performed. Statistical Test 3 indicated no statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B3	URGA	Chromium	Statistical Test 2, Test of Proportions	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B4	URGA	Lead	Statistical Test 2, Test of Proportions	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
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, 95% UTL, Paired ANOVA (MW93A vs. MW84A and MW87A), Mann-Kendall	Because Parametric ANOVA indicated a statistically significant difference between concentrations in downgradient wells and concentrations in background wells for compliance wells MW84A and MW87A, a comparison to the 95% UTL and paired ANOVA 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 no trend in MW84A and an increasing trend in MW87A.

Table B.5. Summary of Conclusions from the C-404 Hazardous Waste Landfill Statistical Analyses for the Second Reporting Period 2020 (Continued)

Attachment	RGA Well Type	Parameter	Applied Statistical Test	Results
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.

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

Statistical Test 3, Nonparametric ANOVA, for arsenic in the URGA identified a statistically significant difference between concentrations in downgradient wells and concentrations in background wells; therefore, the data were evaluated further by comparing results to the UTL. The 95% UTL indicated a statistically significant difference between concentrations in downgradient 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 a significant difference between upgradient and downgradient wells. A Mann-Kendall test was performed to evaluate the data further, and no trend was identified for arsenic in MW84A.

Statistical Test 4, Parametric ANOVA, for trichloroethene in the URGA indicated statistically significant difference between concentrations in downgradient wells and concentrations in background wells; therefore, the data were evaluated further by comparing results to the UTL. The 95% UTL indicated a statistically significant difference between concentrations in both downgradient wells MW84A and MW87A 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 and MW87A) results to upgradient westernmost well MW93A]. Results of the paired (parametric) ANOVA identified a significant difference between upgradient and downgradient wells MW84A and MW87A. A Mann-Kendall test was performed to further evaluate the data, and no trend was identified for trichloroethene in MW84A while an increasing trend was identified for trichloroethene in MW87A.

ATTACHMENT B1

**ARSENIC
STATISTICAL TEST 3**

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Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2020

Date	Arsenic (mg/L)				
	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
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
Jan-20	**0.00817**	**0.00518**	**0.0202**	**0.00928**	**0.00211**
Jul-20	**0.0109**	**0.00534**	**0.0222**	**0.00895**	0.0025
Sum	0.0572		0.11560	0.04756	0.0121
n_i	10		5	5	5
$(x_i)_{avg}$	0.00572		0.02312	0.00951	0.0024

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.. = 0.00930

N =	25	N = the total number of samples
p =	4	p = the number of n_i groups
x.. =	0.23	x.. = the sum of the total number of samples

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	Arsenic (mg/L)	Adjusted Rank	Tie Number
1	0	2.5	
2	0	2.5	Tie 1
3	0	2.5	
4	0	2.5	
5	**0.00211**	5	
6	**0.00304**	6	
7	**0.00359**	7	
8	**0.00414**	8	
9	**0.00462**	9	
10	**0.00518**	10	
11	**0.00534**	11	
12	**0.00602**	12	
13	**0.00619**	13	
14	**0.00723**	14	
15	**0.00817**	15	
16	**0.00895**	16	
17	**0.00928**	17	
18	**0.01050**	18	
19	**0.01090**	19	
20	**0.01160**	20	
21	**0.01680**	21	
22	**0.02020**	22	
23	**0.02220**	23	
24	**0.02750**	24	
25	**0.02890**	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}
4   Tie 1 =   60

                     $\sum T_i$ =   60

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2020

Sums of Ranks and Averages

	Arsenic (mg/L)				
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Aug-18	**0.00619**	**0.00304**	**0.0289**	**0.01050**	0
Jan-19	**0.00462**	**0.00414**	**0.0275**	**0.01160**	0
Jul-19	**0.00602**	**0.00359**	**0.0168**	**0.00723**	0
Jan-20	**0.00817**	**0.00518**	**0.0202**	**0.00928**	**0.00211**
Jul-20	**0.01090**	**0.00534**	**0.0222**	**0.00895**	0

	Observation Ranks for Arsenic				
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Aug-18	13	6	25	18	2.5
Jan-19	9	8	24	20	2.5
Jul-19	12	7	21	14	2.5
Jan-20	15	10	22	17	5
Jul-20	19	11	23	16	2.5
R_i	110		115	85	15
$(R_i)_{avg}$	11.0		23.0	17.0	3.0
R_i^2/n_i	1210.0		2645.0	1445.0	45.0

$\Sigma R_i^2/n_i =$ 5345.0

mg/L = milligrams per liter   K = the number of n_i groups
BG = background   N = the total number of samples
DL = detection limit
Bolded values indicate a detected result.

$K =$ 4   NOTE: For this method, observations below the detection limit
$N =$ 25   that are considered nondetects (i.e., U qualified data) are reported
as a concentration of 0.

Calculation of Kruskal-Wallis Statistic

$H =$ 20.677   Kruskal-Wallis Statistic $H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$

$H' =$ 20.757   Corrected Kruskal-Wallis $H' = H/[1-(\Sigma T_i/N^3-N)]$

$\chi^2_{crit}* =$ 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
$\alpha =$ 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 B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2020

Calculate Critical Values

Average Background Ranking = 11.0

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93A			
BG Well	MW420			
	MW84A	8.578	12.0	**evidence of contamination**
	MW87A	8.578	6.0	not contaminated
	MW90A	8.578	-8.0	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 2020

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 2020 Data, Second Reporting Period
Observations (mg/L)

Well No.						
MW93A	0.00619	0.00462	0.00602	0.00817	0.01090	Upgradient Well!
MW420	0.00304	0.0041	0.00359	0.00518	0.00534	Upgradient Well!

				Current Data
MW84A	X: Mean Value =	0.0057		**0.0222**
	S: Standard Deviation =	0.0023		
	K* factor =	2.911	(for n = 10)	
	CV = S/X	0.4080	<1, assume normal distribution	
	Upper Tolerance Interval: TL = X +(KxS) =	**0.0125**	(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.

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.

	Arsenic (mg/L)			
Date	Background	Compliance		
	MW93A	MW84A	n_i^2	
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
Jan-20	**0.00817**	**0.0202**	0.0000667	0.0004080
Jul-20	**0.01090**	**0.0222**	0.0001188	0.0004928
Sum (x_i)	0.0359	0.1156	0.1515	Total Sum (x..)
n_i	5	5		
$(x_i)_{avg}$	0.00718	0.02312		
$(x_i)^2$	0.00129	0.01336		

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

Overall mean x.. =	0.01515		
N =	10	N = the total number of samples	
p =	2	p = the number of n_i groups	
x.. =	0.1515	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
Aug-18	-0.00099	0.00578
Jan-19	-0.00256	0.00438
Jul-19	-0.00116	-0.00632
Jan-20	0.00099	-0.00292
Jul-20	0.00372	-0.00092

X: Mean Value =	4.34E-19	
S: Standard Deviation =	0.00374	
K* Factor =	2.911	(for n = 10)
CV = S/X =	8.61E+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 data are normally distributed.
If the coefficient of variation is > or = 1, data are not normally distributed.

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2020

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)

$f_i = n_i - 1$

$x_{..}$ = 0.15150

$(x_{avg})_{..}$ = 0.01515

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	$f_i S_i^2$	$f_i \ln(S_i^2)$†
0.00243	0.00000592445	-12.036	5	0.0000237	-48.1
0.00505	0.00002547700	-10.578	5	0.0001019	-42.3

$\sum(S_i^2) =$ 0 $\sum f_i \ln(S_i^2) =$ -90.45663

Equality of Variance: Bartlett's Test

f = 8

Sp^2 = 0

$\ln Sp^2$ = -11.062

χ^2 = 1.962   (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).

Between Well Sum of Squares

Source of Variation	Sums of Squares		Degrees of Freedom	Mean Squares	Calculated F	F Statistic**
Between Wells	SS_{wells} =	0.0006352	1	0.0006352	40.46	5.32
Error	SS_{Error} =	0.0001256	8	0.0000157		
Total	SS_{Total} =	0.0007608	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.

Mann-Kendall Statistical Analysis for Arsenic in MW84A

Input Data

Date Collected	Result (mg/L)
Jan-17	**0.017**
Jul-17	**0.0191**
Jan-18	**0.0185**
Aug-18	**0.0289**
Jan-19	**0.0275**
Jul-19	**0.0168**
Jan-20	**0.0202**
Jul-20	**0.0222**

Bolded values indicate a detected result.

Mann-Kendall Trend Test Analysis

User Selected Options

Date/Time of Computation	ProUCL 5.110/5/2020 2:18:17 PM
From File	WorkSheet.xls
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

MW84A_Arsenic

General Statistics

Number or Reported Events Not Used	0
Number of Generated Events	8
Number Values Reported (n)	8
Minimum	0.0168
Maximum	0.0289
Mean	0.0213
Geometric Mean	0.0209
Median	0.0197
Standard Deviation	0.00462
Coefficient of Variation	0.217

Mann-Kendall Test
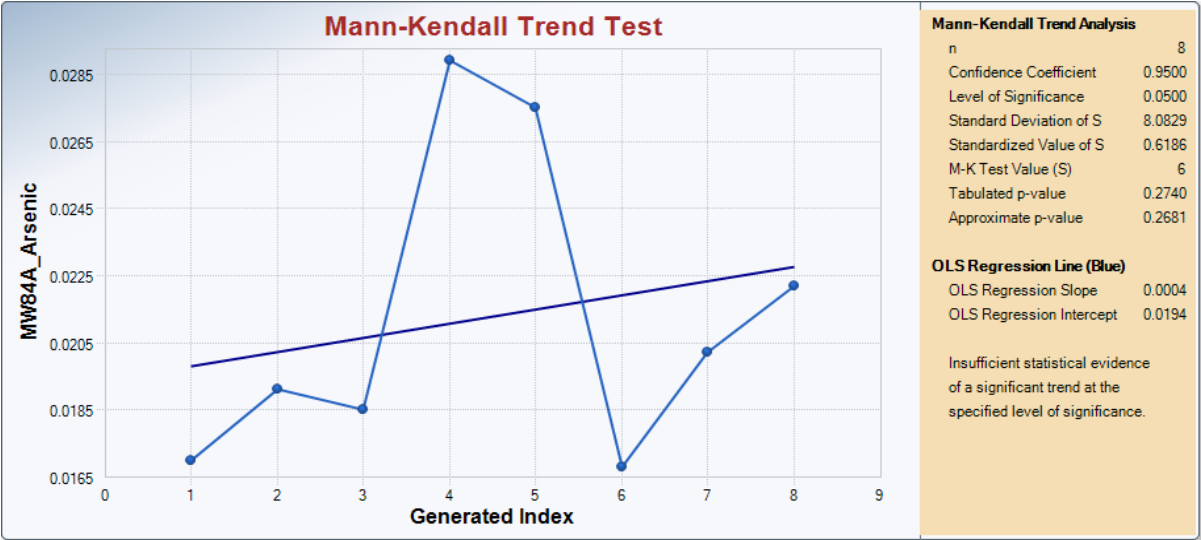
M-K Test Value (S)	6
Tabulated p-value	0.274
Standard Deviation of S	8.083
Standardized Value of S	0.619
Approximate p-value	0.268

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

Mann-Kendall Statistical Analysis for Arsenic in MW84A

Mann-Kendall Trend Analysis

n	8
Confidence Coefficient	0.9500
Level of Significance	0.0500
Standard Deviation of S	8.0829
Standardized Value of S	0.6186
M-K Test Value (S)	6
Tabulated p-value	0.2740
Approximate p-value	0.2681

OLS Regression Line (Blue)

OLS Regression Slope	0.0004
OLS Regression Intercept	0.0194

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

ATTACHMENT B2

**CADMIUM
STATISTICAL TEST 2**

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Attachment B2: Cadmium URGA, Statistical Test 2, Test of Proportions, Second Reporting Period 2020

Cadmium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
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
Jan-20	0.0005	0.0005	**0.000385**	**0.000503**	0.0005
Jul-20	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 =	6	Y = number of samples above DL in compliance wells
n_b =	10	n_b = count of background well results/samples analyzed
n_c =	15	n_c = count of compliance well results/samples analyzed
n =	25	n = total number of samples

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

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

P_b =	0.000	P_b = proportion of detects in background wells
P_c =	0.400	P_c = proportion of detects in compliance wells
S_D =	0.174	S_D = standard error of difference in proportions
Z =	-2.294	$Z = (P_b - P_c)/S_D$
absolute value of Z =	2.294	

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 2020

Date	Cadmium (mg/L)				
	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
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
Jan-20	0.0005	0.0005	**0.000385**	**0.000503**	0.0005
Jul-20	0.0005	0.0005	0.0005	0.0005	0.0005
Sum	0.0050		0.00212	0.00236	0.0025
n_i	10		5	5	5
$(x_i)_{avg}$	0.00050		0.00042	0.00047	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.. =   0.00048

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

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	Cadmium (mg/L)	Adjusted Rank	Tie Number
1	0	10	
2	0	10	
3	0	10	
4	0	10	
5	0	10	
6	0	10	
7	0	10	
8	0	10	
9	0	10	
10	0	10	Tie 1
11	0	10	
12	0	10	
13	0	10	
14	0	10	
15	0	10	
16	0	10	
17	0	10	
18	0	10	
19	0	10	
20	**0.000323**	20	
21	**0.000372**	21	
22	**0.000385**	22	
23	**0.000415**	23	
24	**0.000481**	24	
25	**0.000503**	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: $(n_{tie}^3 - n_{tie})$	
19	Tie 1 =	6840
	$\sum T_i =$	6840

Attachment B2: Cadmium URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2020

Sums of Ranks and Averages

Cadmium (mg/L)				
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
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
Jan-20	0	0	**0.000385**	**0.000503**	0
Jul-20	0	0	0	0	0

Observation Ranks for Cadmium				
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Aug-18	10	10	20	21	10
Jan-19	10	10	23	24	10
Jul-19	10	10	10	10	10
Jan-20	10	10	22	25	10
Jul-20	10	10	10	10	10
R_i	100		85	90	50
$(R_i)_{avg}$	10.0		17.0	18.0	10.0
R_i^2/n_i	1000.0		1445.0	1620.0	500.0

$\Sigma R_i^2/n_i =$ 4565.0

mg/L = milligrams per liter   K = the number of n_i groups
BG = background   N = the total number of samples
DL = detection limit
Bolded values indicate a detected result.

K = 4   NOTE: For this method, observations below the detection limit
N = 25   that are considered nondetects (i.e., U qualified data) are reported as a
             concentration of 0.

Calculation of Kruskal-Wallis Statistic

H = 6.277   Kruskal-Wallis Statistic $H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$

H' = 11.178   Corrected Kruskal-Wallis $H' = H/[1-(\Sigma T_i/N^3 - N)]$

$\chi^2_{crit}* =$ 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 B2: Cadmium URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2020

Calculate Critical Values

Average Background Ranking =   10.0

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93A			
BG Well	MW420			
	MW84A	8.578	7.00	not contaminated
	MW87A	8.578	8.00	not contaminated
	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 MW84A, MW87A, 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).

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ATTACHMENT B3

CHROMIUM
STATISTICAL TEST 2

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Attachment B3: Chromium URGA, Statistical Test 2, Test of Proportions, Second Reporting Period 2020

Chromium (mg/L)				
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Aug-18	**0.1100**	0.0050	**0.0752**	**0.2750**	0.0050
Jan-19	**0.0561**	0.0050	**0.0251**	**0.0424**	0.0050
Jul-19	0.0050	0.0050	0.0050	0.0050	0.0050
Jan-20	0.0050	0.0050	0.0050	0.0050	0.0050
Jul-20	0.0050	0.0050	0.0050	0.0050	0.0050

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

[1]**Test of Proportions**

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

$X =$ 2   X = number of samples above DL in background wells
$Y =$ 4   Y = number of samples above DL in compliance wells
$n_b =$ 10 n_b = count of background well results/samples analyzed
$n_c =$ 15 n_c = count of compliance well results/samples analyzed
$n =$ 25   n = total number of samples

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

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

$P_b =$ 0.200 P_b = proportion of detects in background wells
$P_c =$ 0.267 P_c = proportion of detects in compliance wells
$S_D =$ 0.174 S_D = standard error of difference in proportions
$Z =$ -0.382 $Z = (P_b-P_c)/S_D$
absolute value of $Z =$ 0.382

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.**

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

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ATTACHMENT B4

LEAD
STATISTICAL TEST 2

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Attachment B4: Lead URGA, Statistical Test 2, Test of Proportions, Second Reporting Period 2020

Date	Lead (mg/L)				
	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
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
Jan-20	0.001	0.001	0.001	0.001	0.001
Jul-20	0.001	0.001	0.001	0.001	0.001

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

[1]**Test of Proportions**

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

$X =$	2	X = number of samples above DL in background wells
$Y =$	4	Y = number of samples above DL in compliance wells
$n_b =$	10	n_b = count of background well results/samples analyzed
$n_c =$	15	n_c = count of compliance well results/samples analyzed
$n =$	25	n = total number of samples

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

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

$P_b =$	0.200	P_b = proportion of detects in background wells
$P_c =$	0.267	P_c = proportion of detects in compliance wells
$S_D =$	0.174	S_D = standard error of difference in proportions
$Z =$	-0.382	$Z = (P_b - P_c)/S_D$
absolute value of $Z =$	0.382	

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.**

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

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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 2020

Technetium-99 (pCi/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
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
Jan-20	10.25	10.6	**297**	10.5	11.7
Jul-20	10.35	10.7	**332**	9.85	10.25

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 =	0	X = number of samples above DL in background wells
Y =	4	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 =	0.000	P_b = proportion of detects in background wells
P_c =	0.267	P_c = proportion of detects in compliance wells
S_D =	0.150	S_D = standard error of difference in proportions
Z =	-1.782	$Z = (P_b-P_c)/S_D$
absolute value of Z =	1.782	

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).

ATTACHMENT B6

TRICHLOROETHENE
STATISTICAL TESTS 4

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Attachment B6: Trichloroethene URGA, Statistical Test 4, Parametric ANOVA, Second Reporting Period 2020

Trichloroethene (TCE, µg/L)				
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
Aug-18	**1000**	**476**	**5260**	**1690**	**53.3**
Jan-19	**1000**	**601**	**5580**	**2380**	**69.9**
Jul-19	**789**	**600**	**2000**	**1850**	**55.7**
Jan-20	**1360**	**1090**	**2930**	**2580**	**92.9**
Jul-20	**2220**	**1340**	**3230**	**3090**	**52**
n_i	10		5	5	5
Sum	10476		19000	11590	323.80
(x_i)avg	1047.60		3800.00	2318.00	64.76

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

Overall mean x.. =	1655.59	
N =	25	N = the total number of samples
p =	4	p = the number of n_i groups
x.. =	41389.80	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
Aug-18	-47.60	-571.60	1460.00	-628.00	-11.46
Jan-19	-47.60	-446.60	1780.00	62.00	5.14
Jul-19	-258.60	-447.60	-1800.00	-468.00	-9.06
Jan-20	312.40	42.40	-870.00	262.00	28.14
Jul-20	1172.40	292.40	-570.00	772.00	-12.76

X: Mean Value =	4.49E-14	
S: Standard Deviation =	743.4	
K* Factor =	2.292	(for n = 25)
CV = S/X =	1.66E+16	> 1, data are not normally distributed

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

*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 2020

Determine Equality of Variance of Dataset

p = number of well groups

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.. = the sum of the total number of samples

$(x_{avg})_{..}$ = the mean of the total number of samples

$x_{..}$ = 41389.80

$(x_{avg})_{..}$ = 1655.59

p = 4

N = 25

Calculations for Equality of Variance: Bartlett's Test

S_i	S_i^2	$\ln(S_i^2)$	n_i	$f_i S_i^2$	$f_i \ln(S_i^2)$
511.788	261926.71	12.476	10	2357340.4	112.3
1550.951	2405450.00	14.693	5	9621800.000	58.8
566.101	320470.00	12.678	5	1281880.000	50.7
17.281	298.63	5.699	5	1194.512	22.8

$\sum(S_i^2)$ = 2988145.34 $\sum f_i \ln(S_i^2)$ = 244.6

Equality of Variance: Bartlett's Test

f = 21

Sp^2 = 631534.043

$\ln Sp^2$ = 13.356

c^2 = 35.912   (If $c^2 \leq c^2_{crit}$, then variances are equal at the given significance level).

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

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

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

*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 2020

Lognormal Data for TCE

	ln[TCE (μg/L)]				
Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
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
Jan-20	7.22	6.99	7.98	7.86	4.53
Jul-20	7.71	7.20	8.08	8.04	3.95
Mean x_i	7.08	6.63	8.17	7.72	4.15
Background Mean	6.86		NA	NA	NA
Grand Mean	6.75				
x_i^2	47.72	38.01	73.41	55.24	15.81
	47.72	40.94	74.42	60.45	18.04
These values needed for ANOVA	44.50	40.92	57.77	56.59	16.16
	52.06	48.92	63.72	61.71	20.53
	59.37	51.85	65.29	64.58	15.61
Sum x_i^2	1191				

μg/L = micrograms per liter

Determine Normality of Dataset

Coefficient of Variability Test

Table of ln[TCE (μg/L)] Data

Date	Background	Background	Compliance	Compliance	Compliance
	MW93A	MW420	MW84A	MW87A	MW90A
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
Jan-20	7.22	6.99	7.98	7.86	4.53
Jul-20	7.71	7.20	8.08	8.04	3.95

X: Mean Value =	6.75E+00	
S: Standard Deviation =	1.47	
K* Factor =	2.292	(for n = 25)
CV = S/X =	2.18E-01	<1, data are normally distributed

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

*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 2020

Determine Equality of Variance of Dataset for Lognormal Data

p = number of wells (background wells considered as one group)	$x_{..} = 168.77$
n_i = number of data points per well	$(x_{avg})_{..} = 6.75$
N = total sample size	$n_i = 5$
S^2 = the square of the standard deviation	$p = 4$
$\ln(S_i^2)$ = natural logarithm of each variance	$N = 25$
f = total sample size minus the number of wells (groups)	
$f_i = n_i - 1$	
x.. = the sum of the total lognormal dataset	
$(x_{avg})_{..} =$ the mean of the lognormal dataset	

Calculations for Equality of Variance: Bartlett's Test

S_i	S_i^2	$\ln(S_i^2)$	ni	$f_i S_i^2$	$f_i \ln(S_i^2)$
0.462	0.214	-1.543	10	1.924	-13.9
0.428	0.184	-1.695	5	0.734	-6.8
0.246	0.061	-2.803	5	0.243	-11.2
0.246	0.060	-2.807	5	0.242	-11.2

$\sum(S_i^2) =$ 0.52 $\sum f_i \ln(S_i^2) =$ -43.1

Equality of Variance: Bartlett's Test

f =	21	
$Sp^2 =$	0.150	
$\ln Sp^2 =$	-1.899	
$c^2 =$	3.215	(If $c^2 \leq c^2_{crit}$, then variances are equal at the given significance level).
$c^2_{crit} * =$	7.815	at a 5% significance level with 3 degrees of freedom

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

Because variances are equal, the Parametric ANOVA for the lognormal dataset will proceed.

*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 4, Parametric ANOVA, Second Reporting Period 2020

Parametric ANOVA

Between Well Sum of Squares[1]

Source of Variation	Sums of Squares	df	Mean Squares	$F_{calculated}$
Between Wells (SS wells)	48.89	3	16.298	108.90
Error within wells (SS error)	3.14	21	0.150	
Total (SS total)	52.04	24		

If $F_{calculated} > F_{tabulated}$, then reject the hypothesis of equal well means. If $F_{calculated}$ is less than or equal to

$F_{tabulated}$, it can be concluded that there is no significant difference between concentrations, therefore,

there is no evidence of well contamination.

$F_{tabulated} = 3.07**$

CONCLUSION: $F_{calculated} > F_{tabulated}$; therefore, evidence of well contamination. Additional comparisons must be made.

NOTE: ** Table 2, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* , USEPA, 1989. $F_{tabulated}$ taken at the 5% significance level.

Comparison of Compliance Wells to Background Wells (Bonferroni Test)

$n_b =$	10	$N-p =$	21	$\alpha =$	0.05	
$(x_b)_{avg} =$	6.86	$m =$	3	$1-\alpha/m =$	0.9833	

n_b = total sample size of all background wells

$(x_b)_{avg}$ = average concentration from all background wells

Well No.	Well Mean	Differences of Avg.	Standard Error	Bonferroni's t^2	D_i	Conclusion
	$(x_b)_{avg}$	$(x_i)_{avg}-(x_b)_{avg}$	SE_i	$t_{(N-p),(\alpha/m)}$		
MW93A						
MW420						
MW84A	8.17	1.32	0.21	2.27	0.48	evidence of contamination
MW87A	7.72	0.87	0.21	2.27	0.48	evidence of contamination
MW90A	4.15	-2.71	0.21	2.27	0.48	not contaminated

CONCLUSION: If the "Differences of Averages" is greater than D_i, then the well is contaminated.

After performing Bonferroni's t calculation, the following can be concluded:

MW84A and MW87A show statistically significantly levels of contamination as compared background wells.

MW90A does not show statistically significant levels of contamination.

[1]Section 5.2.1, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance* , (EPA, 1989).

[2]Appendix B, Table 3 (EPA, 1989).

A 95% UTL comparison is performed.

Attachment B6: Trichloroethene URGA, Statistical Test 4, Parametric ANOVA, Second Reporting Period 2020

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 2020 Data, Second Reporting Period
Observations (µg/L)

Well No.							
MW93A	1000	1000	789	1360	2220	Upgradient Well[!]	
MW420	476	601	600	1090	1340	Upgradient Well[!]	
						Current Data	
MW84A						**3230**	
MW87A	X: Mean Value =	1048				**3090**	
	S: Standard Deviation =	512					
	K* factor =	2.911	(for n = 10)				
	CV = S/X	0.4885	<1, assume normal distribution				
	Upper Tolerance Interval: TL = X +(KxS) =	**2537**	(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: **Both MW84A and MW87A 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 wells MW84A and MW87A, the paired ANOVA was performed.

Paired (Parametric) ANOVA - MW93A and MW87A

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.

Date	TCE (µg/L) Background	Compliance	n_i^2	
	MW93A	MW87A		
Aug-18	**1000**	**1690**	1000000	2856100
Jan-19	**1000**	**2380**	1000000	5664400
Jul-19	**789**	**1850**	622521	3422500
Jan-20	**1360**	**2580**	1849600	6656400
Jul-20	**2220**	**3090**	4928400	9548100
Sum (x_i)	6369	11590	17959	Total Sum (x..)
n_i	5	5		
$(x_i)_{avg}$	1274	2318		
$(x_i)^2$	40564161	134328100		

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

Overall mean x.. =	1796	
N =	10	N = the total number of samples
p =	2	p = the number of n_i groups
$x_{..}$ =	17959	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	MW87A
Aug-18	-274	-628
Jan-19	-274	62
Jul-19	-485	-468
Jan-20	86	262
Jul-20	946	772

X: Mean Value =	0.00E+00	
S: Standard Deviation =	534	
K* Factor =	2.911	(for n = 10)
CV = S/X =	#ΔIç/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 4, Parametric ANOVA, Second Reporting Period 2020

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)

$f_i = n_i - 1$

$x_{..} = 17959$

$(x_{avg})_{..} = 1796$

$n_{i} = 5$

$p = 2$

$N = 10$

$f_i = 4$

Calculations for Equality of Variance: Bartlett's Test

S_i	S_i^2	$\ln(S_i^2)$†	n_i	$f_iS_i^2$	$f_i\ln(S_i^2)$†
567	321922	12.682	5	1287689	50.7
566	320470	12.678	5	1281880	50.7

$\sum(S_i^2) =$ 642,392 $\sum f_i\ln(S_i^2) =$ 101

Equality of Variance: Bartlett's Test

$f =$ 8

$Sp^2 =$ 321196

$\ln Sp^2 =$ 12.680

$\chi^2 =$ 0.000   (If calculated $\chi^2 \leq$ tabulated χ^2_{crit}, then variances are equal at the given significance level).

$\chi^2_{crit} * =$ 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).

Attachment B6: Trichloroethene URGA, Statistical Test 4, Parametric ANOVA, Second Reporting Period 2020

Between Well Sum of Squares

Source of Variation	Sums of Squares		Degrees of Freedom	Mean Squares	Calculated F	F Statistic**
Between Wells	$SS_{wells} =$	2725884.10	1	2725884.10	8.49	5.32
Error	$SS_{Error} =$	2569568.80	8	321196.10		
Total	$SS_{Total} =$	5295452.90	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 upgradient 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 MW87A, 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.

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	
Aug-18	**1000**	**5260**	1000000	27667600
Jan-19	**1000**	**5580**	1000000	31136400
Jul-19	**789**	**2000**	622521	4000000
Jan-20	**1360**	**2930**	1849600	8584900
Jul-20	**2220**	**3230**	4928400	10432900
Sum (x_i)	6369	19000	25369	Total Sum $(x..)$
n_i	5	5		
$(x_i)_{avg}$	1274	3800		
$(x_i)^2$	40564161	361000000		

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

Overall mean x.. = 2537
N = 10   N = the total number of samples
p = 2   p = the number of n_i groups
$x.._=$ 25369   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
Aug-18	-274	1460
Jan-19	-274	1780
Jul-19	-485	-1800
Jan-20	86	-870
Jul-20	946	-570

X: Mean Value = 0.00E+00
S: Standard Deviation = 1101
K* Factor = 2.911   (for n = 10)
CV = S/X = #ΔIç/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 4, Parametric ANOVA, Second Reporting Period 2020

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)

$f_i = n_i - 1$

$x_{..}$ = 25369

$(x_{avg})_{..}$ = 2537

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	$f_i S_i^2$	$f_i \ln(S_i^2)$†
567	321922	12.682	5	1287689	50.7
1551	2405450	14.693	5	9621800	58.8

$\sum(S_i^2) =$ 2,727,372 $\qquad$ $\sum f_i \ln(S_i^2) =$ 110

Equality of Variance: Bartlett's Test

f = 8

Sp^2 = 1363686

$\ln Sp^2$ = 14.126

χ^2 = 3.504 (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. $\qquad$ **(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).

Attachment B6: Trichloroethene URGA, Statistical Test 4, Parametric ANOVA, Second Reporting Period 2020

Between Well Sum of Squares

Source of Variation	Sums of Squares		Degrees of Freedom	Mean Squares	Calculated F	F Statistic**
Between Wells	$SS_{wells} =$	15954216.10	1	15954216.1	11.70	5.32
Error	$SS_{Error} =$	10909488.80	8	1363686.1		
Total	$SS_{Total} =$	26863704.90	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 upgradient 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.

Mann-Kendall Analysis MW84A - TCE

Input Data	
Date	**Result (μg/L)**
Jan-17	**2620**
Jul-17	**2910**
Jan-18	**3160**
Aug-18	**5260**
Jan-19	**5580**
Jul-19	**2000**
Jan-20	**2930**
Jul-20	**3230**
Bolded results indicate a detected result	

Mann-Kendall Trend Test Analysis

User Selected Options	
Date/Time of Computation	ProUCL 5.110/5/2020 2:38:41 PM
From File	WorkSheet.xls
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

MW84A_TCE

General Statistics

Number or Reported Events Not Used	0
Number of Generated Events	8
Number Values Reported (n)	8
Minimum	2000
Maximum	5580
Mean	3461
Geometric Mean	3280
Median	3045
Standard Deviation	1270
Coefficient of Variation	0.367

Mann-Kendall Test

M-K Test Value (S)	8
Tabulated p-value	0.119
Standard Deviation of S	8.083
Standardized Value of S	0.866
Approximate p-value	0.193

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

Mann-Kendall Analysis MW84A - TCE

Mann-Kendall Trend Analysis

n	8
Confidence Coefficient	0.9500
Level of Significance	0.0500
Standard Deviation of S	8.0829
Standardized Value of S	0.8660
M-K Test Value (S)	8
Tabulated p-value	0.1190
Approximate p-value	0.1932

OLS Regression Line (Blue)

OLS Regression Slope	14.4048
OLS Regression Intercept	3,396.4286

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

Attachment B6: Trichloroethene URGA, Statistical Test 4, Parametric ANOVA, Second Reporting Period 2020

Mann-Kendall Analysis MW87A - TCE

Input Data	
Date	**Result (µg/L)**
Jan-17	**2240**
Jul-17	**1620**
Jan-18	**1400**
Aug-18	**1690**
Jan-19	**2380**
Jul-19	**1850**
Jan-20	**2580**
Jul-20	**3090**

Bolded results indicate a detected result

Mann-Kendall Trend Test Analysis

User Selected Options

Date/Time of Computation	ProUCL 5.110/5/2020 2:48:22 PM
From File	WorkSheet_a.xls
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

MW87A_TCE

General Statistics

Number or Reported Events Not Used	0
Number of Generated Events	8
Number Values Reported (n)	8
Minimum	1400
Maximum	3090
Mean	2106
Geometric Mean	2041
Median	2045
Standard Deviation	568.1
Coefficient of Variation	0.27

Mann-Kendall Test

M-K Test Value (S)	16
Tabulated p-value	0.031
Standard Deviation of S	8.083
Standardized Value of S	1.856
Approximate p-value	0.0317

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

Mann-Kendall Analysis MW87A - TCE

Mann-Kendall Trend Test

Mann-Kendall Trend Analysis	
n	8
Confidence Coefficient	0.9500
Level of Significance	0.0500
Standard Deviation of S	8.0829
Standardized Value of S	1.8558
M-K Test Value (S)	16
Tabulated p-value	0.0310
Approximate p-value	0.0317

OLS Regression Line (Blue)

OLS Regression Slope	152.2619
OLS Regression Intercept	1,421.0714

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

ATTACHMENT B7

**URANIUM
STATISTICAL TEST 2**

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Attachment B7: Uranium URGA, Statistical Test 2, Test of Proportions, Second Reporting Period 2020

| Date | Uranium (mg/L) | | | | |
| | Background | Background | Compliance | Compliance | Compliance |
	MW93A	MW420	MW84A	MW87A	MW90A
Aug-18	**0.000113**	0.0001	**0.000302**	**0.000722**	0.0001
Jan-19	0.000100	0.0001	**0.000193**	**0.00042**	0.0001
Jul-19	**0.000560**	0.0001	**0.00089**	0.0001	0.0001
Jan-20	0.000100	0.0001	**0.000305**	0.0001	0.0001
Jul-20	**0.000089**	0.0001	**0.000219**	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
$Y =$	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

$P =$	0.400	$P = (x+y)/n$
$nP =$	10	$n = n_b + n_c$
$n(1-P) =$	15	

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
$P_c =$	0.467	$P_c =$ proportion of detects in compliance wells
$S_D =$	0.200	$S_D =$ standard error of difference in proportions
$Z =$	-0.833	$Z = (P_b - P_c)/S_D$
absolute value of $Z =$	0.833	

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 2020

Date	Background MW93A	Background MW420	Compliance MW84A	Compliance MW87A	Compliance MW90A
			Uranium-234 (pCi/L)		
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**
Jan-20	0.755	0.56	0.695	0.675	0.655
Jul-20	0.83	0.955	0.94	0.825	0.92

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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October 14, 2020

Mr. Dennis Greene
Four Rivers Nuclear Partnership, LLC
5511 Hobbs Road
Kevil, KY 42053

Dear Mr. Greene:

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.
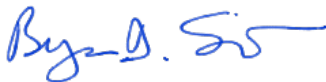
As an Environmental Scientist, with a bachelor's degree in Earth Sciences/Geology, I have over 30 years of experience in reviewing and assessing laboratory analytical results associated with environmental sampling and investigation activities.

For this project, the statistical analyses on groundwater data from August 2018 through July 2020 were performed in accordance with the Hazardous Waste Management Facility Permit, Appendix E using Microsoft Excel 2016 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
- Paired (parametric) ANOVA
- 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,

Bryan Smith

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APPENDIX C

**C-404 HAZARDOUS WASTE LANDFILL
LEACHATE ANALYTICAL RESULTS**

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Paducah OREIS Report for 404L20-03

L1404L3-20 from: C404L on 3/23/2020 Media: WW SmpMethod: GR

Comments: Water level is 5.75' from ground level. MH 3-23-20

Analysis	Results	Units	Result Qual	Foot Note	Reporting Limit	Counting Error	TPU	Method	LabCode	V/V/A*
ANION										
Fluoride	6.91	mg/L			0.2			SW846-9056	GEL	I / X /
FS										
Conductivity	590	umho/cm						FS	FS	/ /
Dissolved Oxygen	7.07	mg/L						FS	FS	/ /
pH	7.08	Std Unit						FS	FS	/ /
Redox	425	mV						FS	FS	/ /
Temperature	58.4	deg F						FS	FS	/ /
METAL										
Arsenic	0.00202	mg/L	J		0.005			SW846-6020	GEL	/ X /
Barium	0.0856	mg/L			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	0.0083	mg/L			0.002			SW846-6020	GEL	/ X /
Iron	0.0524	mg/L	J		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	0.00447	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	47.9	mg/L			0.2			SW846-6020	GEL	I / X /
Zinc	0.00495	mg/L	J		0.02			SW846-6020	GEL	S / X /
PPCB										
PCB-1016	0.11	ug/L	U		0.11			SW846-8082	GEL	/ X /
PCB-1221	0.11	ug/L	U		0.11			SW846-8082	GEL	/ X /
PCB-1232	0.11	ug/L	U		0.11			SW846-8082	GEL	/ X /
PCB-1242	0.11	ug/L	U		0.11			SW846-8082	GEL	/ X /
PCB-1248	0.875	ug/L			0.11			SW846-8082	GEL	/ X /
PCB-1254	0.11	ug/L	U		0.11			SW846-8082	GEL	/ X /
PCB-1260	0.11	ug/L	U		0.11			SW846-8082	GEL	/ X /
Polychlorinated biphenyl	0.875	ug/L			0.11			SW846-8082	GEL	I / X /
RADS										
Cesium-137	2.03	pCi/L	U		11.7	5.83	5.9	EPA-901.1	GEL	/ X /
Neptunium-237	0.161	pCi/L	U		3.96	1.92	1.92	ASTM-1475-00M	GEL	/ X /
Plutonium-239/240	0.0977	pCi/L	U		1.04	0.543	0.543	HASL 300, Pu-11-RC M	GEL	/ X /
Technetium-99	142	pCi/L			17.5	14.1	21.1	HASL 300, Tc-02-RC M	GEL	/ X /
Thorium-230	0.296	pCi/L	U		2.1	1.09	1.09	HASL 300, Th-01-RC M	GEL	/ X /
Uranium-234	1550	pCi/L			128	314	385	HASL 300, U-02-RC M	GEL	/ X /
Uranium-235	203	pCi/L			121	135	138	HASL 300, U-02-RC M	GEL	/ X /
Uranium-238	17400	pCi/L			118	1040	2700	HASL 300, U-02-RC M	GEL	/ X /
VOA										
Trichloroethene	1	ug/L	UY1		1			SW846-8260B	GEL	/ X /
WETCHEM										
Ammonia as Nitrogen	0.221	mg/L	*B		0.05			EPA-350.1	GEL	/ X /

Paducah OREIS Report for 404L20-03

TB404L3-20   from: QC   on 3/23/2020   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	UY1		1			SW846-8260B	GEL	/ X /

APPENDIX D

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

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2020 ANNUAL REPORT OF THE C-404 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 wells at the perimeter of the C-404 Landfill on a semiannual basis. The water levels used for this analysis (taken on January 27 and 28, and July 28 and 29, 2020) 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 2020 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 1.34×10^{-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 the porosity equals 25% 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.

**Table D.1. Measurement Control Datums Used for Upper Regional
Gravel Aquifer C-404 Monitoring Wells During 2020**

Well		Datum Point Elevation (ft amsl)
MW84A	Top of Outside Casing	375.29
MW87A	Top of Outside Casing	375.30
MW90A	Top of Inside Casing	374.15
MW93A	Top of Outside Casing	378.67
MW420	Top of Inside Casing	377.55

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 2020

Hydraulic Conductivity (K) Range	Annual Average Specific Discharge (q) ft/day (cm/s)	Annual Average Linear Flow Velocity (v) ft/day (cm/s)
Low K	0.0281 (9.89×10^{-6})	0.112 (3.96×10^{-5})
High K	0.187 (6.60×10^{-5})	0.749 (2.64×10^{-4})

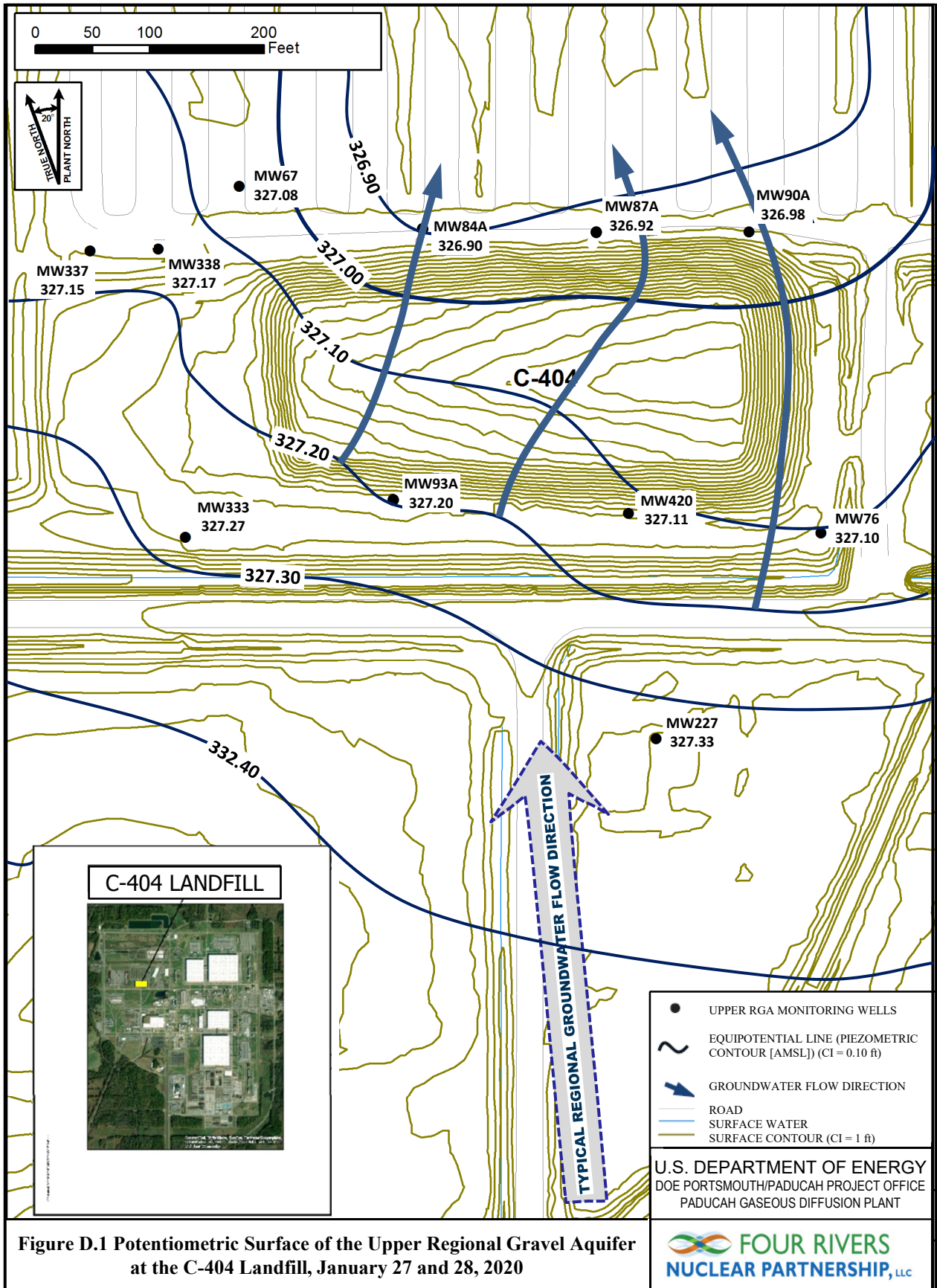**Table D.3. Calculation Information for the C-404 Landfill Annual Groundwater Flow Rate 2020**

	i (ft/ft)	q (ft/d)	q (cm/s)	v (ft/d)	v (cm/s)
Upper RGA K = 21 ft/d					
January 2020	-1.03×10^{-3}	0.0216	7.62×10^{-6}	0.0865	3.05×10^{-5}
July 2020	-1.64×10^{-3}	0.0345	1.22×10^{-5}	0.138	4.87×10^{-5}
Annual Average	**-1.34×10^{-3}**	**0.0281**	**9.89×10^{-6}**	**0.112**	**3.96×10^{-5}**
Upper RGA K = 140 ft/d					
January 2020	-1.03×10^{-3}	0.144	5.08×10^{-5}	0.576	2.03×10^{-4}
July 2020	-1.64×10^{-3}	0.230	8.12×10^{-5}	0.921	3.25×10^{-4}
Annual Average	**-1.34×10^{-3}**	**0.187**	**6.60×10^{-5}**	**0.749**	**2.64×10^{-4}**

q = K*i   v = q/n

where: where:
q = specific discharge   v = average linear velocity
K = hydraulic conductivity   q = specific discharge
i = hydraulic gradient (from potentiometric map) n_e = porosity (assumed to be 25%)

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

Table D.4. January 2020 RGA Potentiometric Surface Data

						Raw Data		*Corrected Data	
C-404 Landfill (January 2020) Water Levels									
Date	**Time**	**Well**	**Datum Elev (ft amsl)**	**BP (in Hg)**	**Delta BP (ft H20)**	**DTW (ft)**	**Elev (ft amsl)**	**DTW (ft)**	**Elev (ft amsl)**
1/27/2020	7:50	MW67	374.89	29.99	0.00	47.81	327.08	47.81	327.08
1/27/2020	7:47	MW76	376.56	29.99	0.00	49.46	327.10	49.46	327.10
1/27/2020	7:52	MW84A	375.29	29.99	0.00	48.39	326.90	48.39	326.90
1/27/2020	7:54	MW87A	375.30	29.99	0.00	48.38	326.92	48.38	326.92
1/28/2020	7:08	MW90A	374.15	30.12	-0.15	47.32	326.83	47.17	326.98
1/27/2020	7:40	MW93A	378.67	29.99	0.00	51.47	327.20	51.47	327.20
1/27/2020	7:28	MW227	378.81	29.99	0.00	51.48	327.33	51.48	327.33
1/27/2020	7:42	MW333	377.20	29.99	0.00	49.93	327.27	49.93	327.27
1/27/2020	8:07	MW337	374.39	29.99	0.00	47.24	327.15	47.24	327.15
1/27/2020	8:09	MW338	374.85	29.99	0.00	47.68	327.17	47.68	327.17
1/27/2020	7:35	MW420	377.55	29.99	0.00	50.44	327.11	50.44	327.11

Reference Barometric Pressure **29.99**

Elev = elevation
amsl = above mean sea level
BP = barometric pressure
DTW = depth to water in feet below datum
The Datum Elevation for MW333 is based on a 9/16/2020 resurvey.
*Assumes a barometric efficiency of 1.0

Table D.5. July 2020 RGA Potentiometric Surface Data

						Raw Data		*Corrected Data	
C-404 Landfill (July 2020) Water Levels									
Date	**Time**	**Well**	**Datum Elev (ft amsl)**	**BP (in Hg)**	**Delta BP (ft H20)**	**DTW (ft)**	**Elev (ft amsl)**	**DTW (ft)**	**Elev (ft amsl)**
7/28/2020	8:01	MW67	374.89	30.01	0.00	45.62	329.27	45.62	329.27
7/28/2020	9:07	MW76	376.56	30.02	-0.01	47.19	329.37	47.18	329.39
7/28/2020	8:05	MW84A	375.29	30.01	0.00	46.15	329.14	46.15	329.14
7/28/2020	8:13	MW87A	375.30	30.01	0.00	46.19	329.11	46.19	329.11
7/28/2020	8:32	MW90A	374.15	30.01	0.00	45.07	329.08	45.07	329.08
7/28/2020	8:48	MW93A	378.67	30.01	0.00	49.11	329.56	49.11	329.56
7/28/2020	7:04	MW227	378.81	30.00	0.01	49.05	329.76	49.06	329.75
7/28/2020	8:44	MW333	377.20	30.01	0.00	47.47	329.73	47.47	329.73
7/28/2020	7:31	MW337	374.39	30.00	0.01	44.94	329.45	44.95	329.44
7/29/2020	7:37	MW338	374.85	29.98	0.03	45.39	329.46	45.42	329.43
7/28/2020	9:05	MW420	377.55	30.02	-0.01	48.08	329.47	48.07	329.49

Reference Barometric Pressure **30.01**

Elev = elevation
amsl = above mean sea level
BP = barometric pressure
DTW = depth to water in feet below datum
The Datum Elevation for MW333 is based on a 9/16/2020 resurvey.
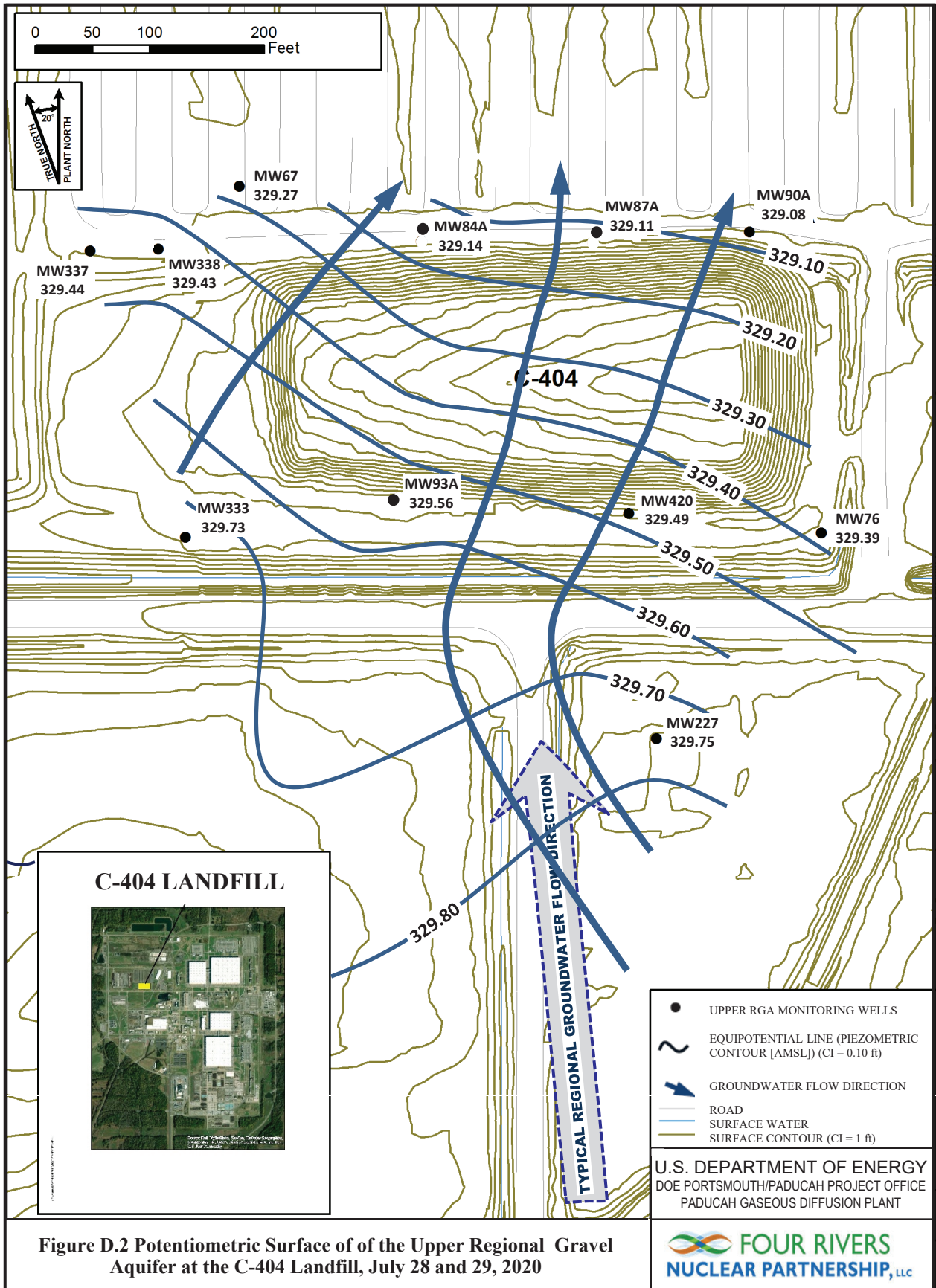*Assumes a barometric efficiency of 1.0

Figure D.1 Potentiometric Surface of the Upper Regional Gravel Aquifer at the C-404 Landfill, January 27 and 28, 2020

Note: Contour lines and labels applied with Microsoft Powerpoint.

Monitoring well data shown on figure:

- MW67 — 327.08
- MW337 — 327.15
- MW338 — 327.17
- MW84A — 326.90
- MW87A — 326.92
- MW90A — 326.98
- MW93A — 327.20
- MW333 — 327.27
- MW420 — 327.11
- MW76 — 327.10
- MW227 — 327.33

Contour labels: 326.90, 327.00, 327.10, 327.20, 327.30, 332.40

C-404

C-404 LANDFILL

Legend:
- UPPER RGA MONITORING WELLS
- EQUIPOTENTIAL LINE (PIEZOMETRIC CONTOUR [AMSL]) (CI = 0.10 ft)
- GROUNDWATER FLOW DIRECTION
- ROAD
- SURFACE WATER
- SURFACE CONTOUR (CI = 1 ft)

TYPICAL REGIONAL GROUNDWATER FLOW DIRECTION

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

FOUR RIVERS NUCLEAR PARTNERSHIP, LLC

G:\GIS\ARCVIEWS\PROJECTS\C404R5.mxd
7/7/2014

TRUE NORTH / PLANT NORTH 20°

0 50 100 200 Feet

Figure D.2 Potentiometric Surface of of the Upper Regional Gravel Aquifer at the C-404 Landfill, July 28 and 29, 2020

Note: Contour lines and labels applied with Microsoft PowerPoint.

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