Appendix C

Evaluation of Analytical Data

Appendix C1

PAH / PCB Totals Calculation Results

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ACRONYMS AND ABBREVIATIONS

BaP	benzo(a)pyrene
BTV	background threshold value
ERA	Ecological Risk Assessment
HHRA	Human Health Risk Assessment
HMW	high molecular weight
KM	Kaplan-Meier
LMW	low molecular weight
LOD	limit of detection
ND	non-detect
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
TEF	toxicity equivalence factor
TEQ	toxicity equivalence
USEPA	United States Environmental Protection Agency

1.0 INTRODUCTION

Total polycyclic aromatic hydrocarbon (PAH), total low molecular weight (LMW) PAH, and total high molecular weight (HMW) PAH concentrations were derived for each sample to support the background threshold value (BTV) calculations and hypothesis testing for the Ecological Risk Assessment (ERA) and Human Health Risk Assessment (HHRA) background analysis.

2.0 POLYCYCLIC AROMATIC HYDROCARBON SUMMATION CONCENTRATIONS

PAHs constitute a class of organic substances made up of carbon and hydrogen atoms grouped into at least two condensed aromatic ring structures. The LMW PAHs are composed of fewer than four rings, and the HMW PAHs are composed of four or more rings. The bioavailability of PAHs in soil is influenced by organic carbon quality and quantity, aging and weather, microbial action, methylation/hydroxylation, adsorption/desorption hysteresis, and ultraviolet light interaction (Fairbrother 2005). The United States Environmental Protection Agency (USEPA) has grouped the PAHs into LMW and HMW categories as a means to address the differences in physical and chemical properties of individual PAHs that influence toxicity and environmental fate (USEPA 2007). The following table presents the LMW and HMW PAHs categories and the molecular weight of each individual PAH.

LMW PAHs	CAS No.	Molecular Weight	HMW PAHs	CAS No.	Molecular Weight
1-Methylnaphthalene	90-12-0	142.2	Benzo(a)anthracene	56-55-3	228.3
2-Methylnaphthalene	91-57-6	142.2	Benzo(a)pyrene	50-32-8	252.3
Acenaphthene	83-32-9	154.2	Benzo(b)fluoranthene	205-99-2	252.3
Acenaphthylene	208-96-8	152.2	Benzo(g,h,i)perylene	191-24-2	276.3
Anthracene	120-12-7	178.2	Benzo(k)fluoranthene	207-08-9	252.3
Fluoranthene	206-44-0	202.3	Chrysene	218-01-9	228.3
Fluorene	86-73-7	166.2	Dibenz(a,h)anthracene	53-70-3	278.4
Naphthalene	91-20-3	128.2	Indeno(1,2,3-cd)pyrene	193-39-5	276.3
Phenanthrene	85-01-8	178.2	Pyrene	129-00-0	202.3

No. = number
Source: USEPA 2007 and ATSDR 1995.

To derive the LMW and HMW PAH concentrations, the PAHs were broken into the aforementioned categories for each sample result and the concentrations were summed. To derive the total PAH concentration, the concentrations of all PAHs listed above were summed for each sample. For data sets with non-detects (NDs), the limit of detection (LOD) was applied and the concentration values were summed using the Kaplan-Meier (KM) method (Helsel 2009). This approach addressed the issue of summing a data set containing NDs (i.e., censored values). The KM method required at least two distinct detected results; if this condition was not met (i.e., only one distinct detected result or all results were NDs), a simple sum of detected result and LOD of NDs was used to represent the total concentration. Thus, each sample had representative total PAH, total LMW PAH, and total HMW PAH concentration values.

Benzo(a)pyrene (BaP) toxicity equivalence (TEQ) concentrations were also derived for each sample to support the BTV calculations and HHRA background analysis. Carcinogenic PAHs exhibit similar toxicological properties, but differ from BaP in the degree of toxicity. Toxicity equivalence factors (TEFs) were applied to adjust the measured concentration of the carcinogenic PAHs in relation to BaP, which is the most toxic. The following table presents the carcinogenic PAHs and their corresponding TEFs (USEPA 1993, 2016).

Carcinogenic PAHs	TEFs
Benzo(a)anthracene	0.1
Benzo(a)pyrene	1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.01
Chrysene	0.001
Dibenz(a,h)anthracene	1
Indeno(1,2,3-cd)pyrene	0.1

Source: USEPA 1993 and 2016.

The individual carcinogenic PAH concentrations were multiplied by the TEF, then the TEF-multiplied concentrations were summed for each sample. When one or more of the carcinogenic PAHs were NDs, similar to the total PAH summation, the LOD was applied and the TEF-multiplied concentrations were summed using the KM method (Helsel 2009).

The PAH summation results of each sample are provided in Appendix B2 of the RI Report.

3.0 POLYCHLORINATED BIPHENYL SUMMATION CONCENTRATIONS

Similar to the total PAH concentrations, the summation of aroclor concentrations (aroclor 1016, aroclor 1221, aroclor 1232, aroclor 1242, aroclor 1248, aroclor 1254, aroclor 1260, aroclor 1262, and aroclor 1268) was also performed to represent the total polychlorinated biphenyl (PCB) concentration of each sample for ERA and HHRA. The KM method (Helsel 2009) was also used for the summation process when feasible.

The PCB summation results of each sample are provided in Appendix B2 of the RI Report.

4.0 SUMMATIONS USING THE KAPLAN-MEIER METHOD

The KM method is a non-parametric statistical method and does not require assumptions of normality (Kaplan and Meier 1958). It is currently the recommended method used in USEPA ProUCL software (USEPA 2016) for calculating the 95% UCL for data sets with one or more censored results (Singh and Maichle 2015a; Singh and Singh 2015b). In the application of summing a group of related compounds, the KM mean was estimated from a set data (consisting of detected and non-detected values) coming from a given sample. This KM mean was then multiplied by the number of compounds (mean × *n*) to compute the sum for the sample.

In this calculation process, the KM method (as encoded in the ProUCL software) was used to sum the total PCB and PAH concentrations, and calculate the weighted sum of BaP TEQ, with the incorporation of the Efron's bias correction; the minimum result (if it is a censored value) was re-coded as a detected result (USEPA 2010). This bias correction has been implemented by the latest version of the ProUCL software (Version 5.1.002). The KM method was used with the ProUCL software whenever feasible (i.e., when there were five or more components to the sum and at least two distinct detected results). To safeguard against a potential biased-high estimate of the KM mean, if the KM summation result in a total concentration was greater than a simple summation (or weighted-summation) of detected concentrations and full censoring concentrations (i.e., LOD) of the non-detected data, the simple sum was used to establish an upper bound of the total concentration value.

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Attachment A

References

References

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Appendix C2

Hexavalent Chromium Ratio Memo

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Memorandum – Technical Approach to Determining the Chromium Ratio

Remedial Investigation, Feasibility Study, Proposed Plan and Decision Document
Camp Hero, Montauk, New York

Subject:	Technical Approach to Determining the Chromium Ratio
Date:	7 March 2018
To:	Megan Cullen, U.S. Army Corps of Engineers (USACE) – New England District Greg Goepfert, USACE – New York District

Summary

Camp Hero is a formerly used defense site (FUDS) undergoing a Remedial Investigation and Feasibility Study (RI/FS) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Three phases of field investigation were conducted to support the RI, which included collection of chromium (Cr) samples in soil, groundwater, surface water, and sediment to determine if Cr poses an unacceptable risk to human or ecological receptors. Hexavalent chromium (Cr VI) data were also collected in some samples to assess what, if any, fraction of total Cr is present in the more toxic Cr VI form. Rather than evaluating Cr VI in every sample or defaulting to the conservative presumption that all Cr could be in the Cr VI form, the data collected were used to generate ratios of Cr VI to total Cr for use in the Human Health Risk Assessment (HHRA) and Ecological Risk Assessment (ERA).

The objective of this memorandum is to document the rationale and approach for generating the ratios and confirming the assumption that not all Cr is 100% Cr VI. Based on the details provided below, the ratios of Cr VI to total Cr established for this project are:

- **0.073 for soil (surface and subsurface)**
- **0.25 for sediment**
- **0.3 for groundwater (filtered and unfiltered) and surface water (filtered and unfiltered)**

For soil, sediment, groundwater, and surface water, the ratios presented above will be used to derive a representative Cr VI concentration for each sample (where Cr VI was not analyzed at the laboratory) by applying the ratio to the total Cr result at that sample location. The derived Cr VI results will be used in conjunction with the actual analytical Cr VI results in the HHRA and ERA. Although an insufficient number of detected total Cr and Cr VI results were available to estimate a specific ratio for dissolved (filtered) surface water, the 0.3 ratio has been determined to be reasonable for estimating Cr VI values for filtered surface water.

Background

Cr is a polyvalent element and can exist in several distinct oxidation states, but only trivalent chromium (Cr III] and Cr VI occur with any frequency in the natural environment. The total Cr results discussed in this memo do not distinguish what oxidation state of Cr is likely present in the result. From a human health perspective, Cr VI is the most toxic form of Cr; the purpose of collecting Cr VI data is to determine whether concentrations of Cr VI may be (or may not be) present in the environmental media at the Camp Hero site. Typically, a HHRA will assume that total Cr is present as 100% Cr VI in order to be protective of possible Cr VI exposure. However, a lesser percentage (i.e., less than 100%) of Cr VI may be assumed if supported by site-specific information and data.

The Phase I field investigation evaluated the presence or the absence of suspected CERCLA hazardous and toxic Department of Defense (DoD) waste at potential areas of concern (AOCs) at Camp Hero, where biased sampling was performed on the target areas of suspected contamination. It should be noted that Cr VI data were not collected during the Phase I field investigation. The preliminary screening of Phase I soil data identified total Cr as exceeding preliminary screening criteria. Therefore, the Phase II and Phase III field efforts included collection of Cr VI data, as well as total Cr data.

The Phase II field investigation evaluated the nature and extent of residual light non-aqueous phase liquid (LNAPL) and related constituents identified during the Phase I field investigation at the former Building

203 AOC by collecting unbiased surface soil and groundwater samples to be used in the HHRA and ERA. Biased subsurface soil samples were also collected to refine the Conceptual Site Model (CSM). Additionally, fifteen permanent background monitoring wells were installed and sampled for the collection of a sitewide background groundwater data set. Since total Cr was identified as exceeding preliminary screening criteria during Phase I, soil and groundwater samples collected during Phase II were analyzed for both total Cr and Cr VI in 100% of samples analyzed for metals.

The Phase III field investigation included the following:

- Collection of unbiased data for potentially impacted surface and subsurface soil associated within decision units (DUs) identified at Camp Hero;
- Collection of unbiased, representative surface water and sediment data within stream exposure areas in the vicinity of DUs;
- Collection of a representative background data set for surface water and sediment at a sitewide scale;
- Installation of a representative sitewide groundwater monitoring well network and collection of groundwater samples on a sitewide as well as DU-specific scale to evaluate potential groundwater impacts; and
- Collection of additional physical and chemical data to support the RI, CSM, and HHRA/ERA.

As part of the Phase III sampling effort, and as outlined in the Phase III Sampling and Analysis Plan, speciated Cr data were collected in 10% of the metal samples in all media to ascertain what, if any, fraction of total Cr presents in the medium is in the more toxic Cr VI form.
The ratio (referred as “ratio” below) of Cr VI to total Cr was used to estimate Cr VI concentration value where analytical result was not available for a given sample, for each exposure medium and horizon. The ratio was derived using the following equation:

$$\text{Ratio (unitless)} = \frac{Cr\ VI\ Concentration\ \left({}^{mg}/_{kg}\right)}{Total\ Cr\ Concentration\ \left({}^{mg}/_{kg}\right)}$$

Chromium VI Ratio Development Method

1. Available Cr VI Data (Note: All samples have total Cr results.)

Table 1 summarizes the data available and used to calculate the medium-specific ratios for Cr presented in Table 2.

Table 1: Data Used for Chromium Ratio Analysis

Medium	Phase II	Phase III	Background
Surface Soil [0 to 1 ft bgs]	All samples analyzed for total Cr and Cr VI (32 samples from DU01)	10% of metals samples were analyzed for Cr VI (21 samples)	None for Cr VI
Subsurface Soil [> 1 ft bgs]	All samples analyzed for total Cr and Cr VI (36 samples from DU01)	10% of metals samples were analyzed for Cr VI (64 samples)	None for Cr VI
Groundwater [Total (unfiltered) and Dissolved (filtered)]	All samples analyzed for total Cr and Cr VI [5 dissolved (filtered) and 5 total (unfiltered) samples]	10% of metals samples were analyzed for Cr VI [3 dissolved (filtered) and 3 total (unfiltered) samples] [(a)]	14 background samples analyzed for total Cr and Cr VI

Surface Water	X	10% of metals samples were analyzed for Cr VI (12 samples)	30 background samples analyzed for total Cr and Cr VI
Sediment	X	10% of metals samples were analyzed for Cr VI (12 samples)	30 background samples analyzed for total Cr and Cr VI

Notes:

ft	foot
bgs	below ground surface
X	not part of field effort
(a)	Phase III groundwater results for total and dissolved Cr VI were non-detect and therefore not used in the ratio analysis.

2. Handling of Non-detects and Detections Below Limit of Quantitation (LOQ)

For soil and sediment, only samples with both detected Cr VI and total Cr results above LOQ were used to calculate the ratio, as ratios based on detection limits (one or both), or “J” estimated values below LOQ, may not be reliable to reflect the true “partition” for Cr VI. For groundwater and surface water, because of insufficient number of samples detected above LOQ, “J” estimated values below LOQ were used (in addition to detected results above LOQ), and the subsequent average ratio was rounded to one significant figure, owing to the uncertainty associated with estimating the Cr concentrations and the ratio. Of the 44 samples used to calculate Cr ratios for groundwater and surface water, 43 total Cr and 13 Cr VI results were “J” qualified.

3. Handling of Duplicates

For samples with a primary/duplicate pair, the average concentration of each pair was calculated first, and then the ratio was calculated as a single data point using these averaged concentration values.

4. Combining Data Sets

The ratios were first calculated on a medium-specific basis, and for soil, separately for surface and subsurface soil. The total Cr and Cr VI results, as well as the calculated ratios, are presented in Attachment 1. When sufficient number of samples were available (n ≥ 8 for each data set), box-and-whisker plots and hypothesis tests were used to determine if the following data sets could be combined (i.e., not statistically different):

- Phase II (if available) and Phase III
- Background (if available) and site
- Filtered and unfiltered groundwater
- Surface and subsurface soils
- Groundwater and surface water

If the data sets could be pooled, calculation of the ratios would benefit from larger sample size. The results of this assessment indicated that all subsets of data noted above could be combined, and therefore, three distinct data sets were established for the calculation of mean Cr ratios:

- Soil (combined surface and subsurface, and combined Phase II and Phase III)
- Sediment (combined background and site)
- Groundwater and surface water (combined filtered groundwater, unfiltered groundwater, and surface water)

The statistical outputs for this evaluation are presented in Attachment 2 (soil and sediment) and Attachment 3 (groundwater and surface water). The statistical evaluation was jointly performed by AECOM and USACE Environmental and Munitions Center of Expertise (EM CX). The relevant electronic communications are documented in Attachment 4.

5. Testing and Treatment of Statistical Outliers

For each set of ratios (after combining data sets as described above), normal probability plots and scatterplots were used to graphically inspect whether there were potential outlier(s) or non-representative concentration(s)/ratio(s); for example, if the Cr VI result was much higher than the respective total Cr result, or unusually large total Cr concentrations.

This outlier evaluation resulted in two unfiltered groundwater samples being excluded (for having unusual large total Cr concentrations), and one surface soil sample being excluded (as the Cr VI concentration was more than three times the total Cr concentration). These outliers were excluded from subsequent analysis.

6. Calculating Arithmetic Mean and Other Summary Statistics

The arithmetic mean and other summary statistics (standard deviation, minimum, maximum, and coefficient of variation [CV]) were calculated for each distinct set of ratios. The results are presented in Table 2.

Table 2: Summary Statistics of Chromium Ratio (Cr VI/Total Cr)

Matrix	No. of Paired Detected Total Cr and Cr VI	Average (Arithmetic Mean)[1]	Standard Deviation	Minimum	Maximum	CV
Soil (surface and subsurface)	49	0.073	0.072	0.011	0.432	0.99
Sediment	15	0.25	0.13	0.11	0.56	0.52
Groundwater (filtered and unfiltered) and Surface Water (unfiltered)[2]	44	0.3	0.2	0.0089	0.73	0.78

Notes:

CV = coefficient of variation

[1] Suggested chromium ratio to use per media is shaded.

[2] Insufficient number of samples and detects to estimate the ratio for dissolved (filtered) surface water.

Usage of Chromium Ratio

Table 2 summarizes the ratios calculated for each medium according to the method described above. The following steps will be taken in order to estimate a result in a Cr VI concentration for all samples with total Cr data:

- The average medium-specific ratios will be used to weight (i.e., "partition") the corresponding Cr VI concentrations in each sample of the combined data set, where analytical result for Cr VI is not available for a given sample.
- The reporting detection limit (i.e., limit of detection [LOD]) will be used as the censoring limit for non-detects (NDs) and will also be weighted. For example, if a given total Cr sediment result is

reported to be a non-detect and the associated LOD is 1 mg/kg, the estimated Cr VI result will also be a non-detect, with a LOD of 0.25 mg/kg.

- A representative Cr VI concentration value will be derived for each sample, either the actual measured analytical result (when available) or estimated by the ratio. Total Cr analytical results are available for all samples.
- The laboratory-derived Cr III concentrations will not be carried forward into the HHRA and ERA because they do not represent measured concentrations.
- The ratio established for soil will be applied directly to the total Cr background threshold values (BTVs) to derive the Cr VI BTVs in soil, as there were no Cr VI background samples collected in soil.

The maximum detected concentrations for Cr VI and total Cr will be carried forward separately into the risk-based screening for each medium. The HHRA will use the U.S. Environmental Protection Agency's Cr III regional screening levels (RSLs) to screen the representative total Cr concentrations, and Cr VI RSLs to screen the representative Cr VI concentrations. If Cr VI is identified as a chemical of potential concern (COPC), then an exposure point concentration (EPC) will be derived using Cr VI data, using a combination of ratio-estimated and actual analytical results. If total Cr is identified as a COPC, the actual analytical results for total Cr will be used to derive an EPC for the HHRA and ERA.

The average (arithmetic mean) medium-specific ratio recommended because it represents an unbiased estimate associated with the likelihood of the portion of total Cr is Cr VI. Ultimately, because the EPC of Cr VI will be derived by the 95% upper confidence limit (95% UCL) of the mean (a conservative upper estimate of arithmetic mean) for a group or a set of data points, the deviation or reliability related to this ratio (i.e., the actual ratio of a given sample may be higher or lower than the average ratio) could be addressed or alleviated by using a group of samples for decision making (i.e., some are lower and some are higher, unbiased). Since the 95% UCL is already a very conservative estimate, another conservative estimate of the ratio is not to be warranted.

It should be noted that the standard deviation is less than the average in all cases (i.e., coefficient of variation [CV] less than one), indicating that the variation for each set of ratios is low to moderate. Also, as shown in Attachments 2 and 3, the relationship between Cr and Cr VI is not strongly concentration-dependent, and thus the average ratio is appropriate to use.

Other statistical methods which were considered for estimation of the ratios included: median ratio (similar to average), maximum ratio (likely too conservative), 95% UCL of the ratios (more conservative), and linear regression estimate of Cr VI concentration using total Cr concentration as the explanatory variable (similar to average if intercept is set to zero). However, the aforementioned approach represents the most direct estimation of the ratios and was determined to be the most appropriate for the Camp Hero project as agreed upon by USACE.

Attachment 1

Data for Total Chromium, Hexavalent Chromium, and Ratios

Attachment 1. Data for Total Chromium, Hexavalent Chromium, and Ratios

Medium	Fraction	Area	Location	Phase	Sample Date	start_depth	end_depth	depth_unit	Unit	D_Conc Chromium	D_Conc Chromium (VI)	Conc Chromium	Conc Chromium (VI)	Ratio	Outlier
Sediment	Total	Background	CH-SWSD001	2017 MAY PHASEIII	6/8/2017	0	0.5	ft	mg/kg	1	1	4.63	0.96	0.207343	
Sediment	Total	Background	CH-SWSD002	2017 MAY PHASEIII	6/8/2017	0	0.5	ft	mg/kg	1	1	5.94	1.1	0.185185	
Sediment	Total	Background	CH-SWSD007	2017 MAY PHASEIII	6/9/2017	0	0.5	ft	mg/kg	1	1	6.2	0.83	0.133871	
Sediment	Total	Background	CH-SWSD011	2017 MAY PHASEIII	6/10/2017	0	0.5	ft	mg/kg	1	1	5.51	1.1	0.199637	
Sediment	Total	Background	CH-SWSD012	2017 MAY PHASEIII	6/10/2017	0	0.5	ft	mg/kg	1	1	1.92	0.82	0.427083	
Sediment	Total	Background	CH-SWSD022	2017 MAY PHASEIII	6/8/2017	0	0.5	ft	mg/kg	1	1	8.18	1.6	0.195599	
Sediment	Total	Background	CH-SWSD024	2017 MAY PHASEIII	6/10/2017	0	0.5	ft	mg/kg	1	1	9.14	0.99	0.108315	
Sediment	Total	Background	CH-SWSD025	2017 MAY PHASEIII	6/10/2017	0	0.5	ft	mg/kg	1	1	6.78	0.86	0.126844	
Sediment	Total	Background	CH-SWSD027	2017 MAY PHASEIII	6/7/2017	0	0.5	ft	mg/kg	1	1	9.75	2.8	0.287179	
Sediment	Total	Background	CH-SWSD029	2017 MAY PHASEIII	6/7/2017	0	0.5	ft	mg/kg	1	1	14.8	3.5	0.236486	
Sediment	Total	Site	CH-SWSD050	2017 MAY PHASEIII	6/3/2017	0	0.5	ft	mg/kg	1	1	24.6	3.7	0.150407	
Sediment	Total	Site	CH-SWSD060	2017 MAY PHASEIII	6/3/2017	0	0.5	ft	mg/kg	1	1	7.54	1.6	0.212202	
Sediment	Total	Site	CH-SWSD080	2017 MAY PHASEIII	6/5/2017	0	0.5	ft	mg/kg	1	1	2.01	0.8	0.39801	
Sediment	Total	Site	CH-SWSD090	2017 MAY PHASEIII	6/5/2017	0	0.5	ft	mg/kg	1	1	3.6	1.4	0.388889	
Sediment	Total	Site	CH-SWSD110	2017 MAY PHASEIII	6/1/2017	0	0.5	ft	mg/kg	1	1	18.8	10.5	0.558511	
Subsurface Soil	Total	Site	203-SB08	2016 DEC PHASEII	12/14/2016	11	12	ft	mg/kg	1	1	22.6	0.54	0.023894	
Subsurface Soil	Total	Site	203-SB09	2016 DEC PHASEII	12/13/2016	25	26	ft	mg/kg	1	1	57.8	0.64	0.011073	
Subsurface Soil	Total	Site	203-SB11	2016 DEC PHASEII	12/15/2016	34	35	ft	mg/kg	1	1	67	0.72	0.010746	
Subsurface Soil	Total	Site	203-SB16	2016 DEC PHASEII	12/14/2016	18	19	ft	mg/kg	1	1	23.3	0.7	0.030043	
Subsurface Soil	Total	Site	203-SB17	2016 DEC PHASEII	12/15/2016	39	40	ft	mg/kg	1	1	26.5	2.6	0.098113	
Subsurface Soil	Total	Site	203-SB18	2016 DEC PHASEII	12/13/2016	22	23	ft	mg/kg	1	1	9.89	0.45	0.045501	
Subsurface Soil	Total	Site	203-SB20	2016 DEC PHASEII	12/13/2016	23	24	ft	mg/kg	1	1	9.7	0.75	0.07732	
Subsurface Soil	Total	Site	203-SB25	2016 DEC PHASEII	12/12/2016	6	7	ft	mg/kg	1	1	19.2	0.69	0.035938	
Subsurface Soil	Total	Site	203-SB29	2016 DEC PHASEII	12/12/2016	8	9	ft	mg/kg	1	1	16.9	0.45	0.026627	
Subsurface Soil	Total	Site	203-SB34	2016 DEC PHASEII	12/12/2016	9	10	ft	mg/kg	1	1	16.1	0.61	0.037888	
Subsurface Soil	Total	Site	203-SB36	2016 DEC PHASEII	12/8/2016	25	26	ft	mg/kg	1	1	27.55	0.61	0.022142	
Subsurface Soil	Total	Site	DU01-S001	2017 MAY PHASEIII	6/14/2017	1	10	ft	mg/kg	1	1	24.3	0.86	0.035391	
Subsurface Soil	Total	Site	DU01-S011	2017 MAY PHASEIII	6/14/2017	1	10	ft	mg/kg	1	1	15.3	2.5	0.163399	
Subsurface Soil	Total	Site	DU05-S001	2017 MAY PHASEIII	6/13/2017	1	10	ft	mg/kg	1	1	6.48	2.8	0.432099	
Subsurface Soil	Total	Site	DU05-S011	2017 MAY PHASEIII	6/13/2017	1	3	ft	mg/kg	1	1	20.7	1.3	0.062802	
Subsurface Soil	Total	Site	DU06-S011	2017 MAY PHASEIII	6/12/2017	1	10	ft	mg/kg	1	1	13.65	1.2	0.087912	
Subsurface Soil	Total	Site	DU07-S011	2017 MAY PHASEIII	6/15/2017	1	3	ft	mg/kg	1	1	11.1	2	0.18018	
Surface Soil	Total	Site	203-SB06	2016 DEC PHASEII	12/15/2016	0	1	ft	mg/kg	1	1	21.5	0.96	0.044651	
Surface Soil	Total	Site	203-SB07	2016 DEC PHASEII	12/14/2016	0	1	ft	mg/kg	1	1	23.5	1	0.042553	
Surface Soil	Total	Site	203-SB08	2016 DEC PHASEII	12/14/2016	0	1	ft	mg/kg	1	1	18.8	0.6	0.031915	
Surface Soil	Total	Site	203-SB09	2016 DEC PHASEII	12/13/2016	0	1	ft	mg/kg	1	1	17.4	0.72	0.041379	
Surface Soil	Total	Site	203-SB10	2016 DEC PHASEII	12/13/2016	0	1	ft	mg/kg	1	1	18.3	0.72	0.039344	
Surface Soil	Total	Site	203-SB11	2016 DEC PHASEII	12/15/2016	0	1	ft	mg/kg	1	1	23.9	1.4	0.058577	
Surface Soil	Total	Site	203-SB13	2016 DEC PHASEII	12/14/2016	0	1	ft	mg/kg	1	1	23.3	0.79	0.033906	
Surface Soil	Total	Site	203-SB14	2016 DEC PHASEII	12/13/2016	0	1	ft	mg/kg	1	1	18.3	1.1	0.060109	
Surface Soil	Total	Site	203-SB15	2016 DEC PHASEII	12/13/2016	0	1	ft	mg/kg	1	1	23.6	0.82	0.034746	
Surface Soil	Total	Site	203-SB16	2016 DEC PHASEII	12/14/2016	0	1	ft	mg/kg	1	1	21.85	0.745	0.034096	
Surface Soil	Total	Site	203-SB17	2016 DEC PHASEII	12/15/2016	0	1	ft	mg/kg	1	1	21.3	1.1	0.051643	
Surface Soil	Total	Site	203-SB18	2016 DEC PHASEII	12/13/2016	0	1	ft	mg/kg	1	1	22.8	1.2	0.052632	
Surface Soil	Total	Site	203-SB20	2016 DEC PHASEII	12/13/2016	0	1	ft	mg/kg	1	1	21.3	1.3	0.061033	
Surface Soil	Total	Site	203-SB21	2016 DEC PHASEII	12/12/2016	0	1	ft	mg/kg	1	1	20.2	1	0.049505	
Surface Soil	Total	Site	203-SB23	2016 DEC PHASEII	12/12/2016	0	1	ft	mg/kg	1	1	18.4	5.2	0.282609	
Surface Soil	Total	Site	203-SB25	2016 DEC PHASEII	12/12/2016	0	1	ft	mg/kg	1	1	21.4	0.53	0.024766	
Surface Soil	Total	Site	203-SB26	2016 DEC PHASEII	12/12/2016	0	1	ft	mg/kg	1	1	22.9	0.55	0.024017	
Surface Soil	Total	Site	203-SB27	2016 DEC PHASEII	12/12/2016	0	1	ft	mg/kg	1	1	20.8	1.7	0.081731	
Surface Soil	Total	Site	203-SB29	2016 DEC PHASEII	12/12/2016	0	1	ft	mg/kg	1	1	24.2	2.5	0.103306	

Attachment 1. Data for Total Chromium, Hexavalent Chromium, and Ratios

Medium	Fraction	Area	Location	Phase	Sample Date	start_depth	end_depth	depth_unit	Unit	D_Conc Chromium	D_Conc Chromium (VI)	Conc Chromium	Conc Chromium (VI)	Ratio	Outlier
Surface Soil	Total	Site	203-SB30	2016 DEC PHASEII	12/12/2016	0	1	ft	mg/kg	1	1	18.8	0.91	0.048404	
Surface Soil	Total	Site	203-SB32	2016 DEC PHASEII	12/12/2016	0	1	ft	mg/kg	1	1	22.7	1.1	0.048458	
Surface Soil	Total	Site	203-SB34	2016 DEC PHASEII	12/12/2016	0	1	ft	mg/kg	1	1	19.5	0.69	0.035385	
Surface Soil	Total	Site	203-SB36	2016 DEC PHASEII	12/8/2016	0	1	ft	mg/kg	1	1	17.7	2.6	0.146893	
Surface Soil	Total	Site	203-SB37	2016 DEC PHASEII	12/8/2016	0	1	ft	mg/kg	1	1	9.11	1	0.109769	
Surface Soil	Total	Site	DU03-S001	2017 MAY PHASEIII	6/15/2017	0	1	ft	mg/kg	1	1	7.78	1	0.128535	
Surface Soil	Total	Site	DU04-S001	2017 MAY PHASEIII	6/15/2017	0	1	ft	mg/kg	1	1	9.4	1.1	0.117021	
Surface Soil	Total	Site	DU06-S001	2017 MAY PHASEIII	6/12/2017	0	1	ft	mg/kg	1	1	7.56	0.88	0.116402	
Surface Soil	Total	Site	DU07-S001	2017 MAY PHASEIII	6/14/2017	0	1	ft	mg/kg	1	1	16.7	0.68	0.040719	
Surface Soil	Total	Site	DU09-S011	2017 MAY PHASEIII	6/16/2017	0	1	ft	mg/kg	1	1	7.76	0.5	0.064433	
Surface Soil	Total	Site	DU11-S011	2017 MAY PHASEIII	6/20/2017	0	1	ft	mg/kg	1	1	13.4	0.97	0.072388	
Surface Soil	Total	Site	DU13-S011	2017 MAY PHASEIII	6/20/2017	0	1	ft	mg/kg	1	1	12.4	0.51	0.041129	
Surface Soil	Total	Site	DU17-S001	2017 MAY PHASEIII	6/19/2017	0	1	ft	mg/kg	1	1	11.6	0.96	0.082759	
Surface Soil	Total	Site	DU04-S011	2017 MAY PHASEIII	6/15/2017	0	1	ft	mg/kg	1	1	8.66	29.5	3.406467	Excluded
Groundwater	Dissolved	Background	CH-MW002	2016 DEC PHASEII	12/11/2016				ug/L	1	1	0.96	0.57	0.59375	
Groundwater	Dissolved	Background	CH-MW005	2016 DEC PHASEII	12/13/2016				ug/L	1	1	0.65	0.45	0.692308	
Groundwater	Dissolved	Background	CH-MW006	2016 DEC PHASEII	12/14/2016				ug/L	1	1	0.65	0.19	0.292308	
Groundwater	Dissolved	Background	CH-MW011	2016 DEC PHASEII	12/14/2016				ug/L	1	1	7.8	0.48	0.061538	
Groundwater	Dissolved	Site	CH-MW021	2016 DEC PHASEII	12/14/2016				ug/L	1	1	1.6	0.026	0.01625	
Groundwater	Total	Background	CH-MW002	2016 DEC PHASEII	12/11/2016				ug/L	1	1	0.8	0.55	0.6875	
Groundwater	Total	Background	CH-MW006	2016 DEC PHASEII	12/14/2016				ug/L	1	1	1.3	0.22	0.169231	
Groundwater	Total	Background	CH-MW007	2016 DEC PHASEII	12/14/2016				ug/L	1	1	3.7	0.033	0.008919	
Groundwater	Total	Background	CH-MW011	2016 DEC PHASEII	12/14/2016				ug/L	1	1	27.5	0.36	0.013091	Excluded
Groundwater	Total	Site	CH-MW021	2016 DEC PHASEII	12/14/2016				ug/L	1	1	18	0.018	0.001	Excluded
Surface Water	Total	Background	CH-SWSD001	2017 MAY PHASEIII	6/8/2017				ug/L	1	1	0.93	0.068	0.073118	
Surface Water	Total	Background	CH-SWSD002	2017 MAY PHASEIII	6/8/2017				ug/L	1	1	0.83	0.11	0.13253	
Surface Water	Total	Background	CH-SWSD003	2017 MAY PHASEIII	6/8/2017				ug/L	1	1	1.2	0.16	0.133333	
Surface Water	Total	Background	CH-SWSD004	2017 MAY PHASEIII	6/9/2017				ug/L	1	1	0.73	0.095	0.130137	
Surface Water	Total	Background	CH-SWSD005	2017 MAY PHASEIII	6/9/2017				ug/L	1	1	0.72	0.11	0.152778	
Surface Water	Total	Background	CH-SWSD006	2017 MAY PHASEIII	6/9/2017				ug/L	1	1	0.81	0.094	0.116049	
Surface Water	Total	Background	CH-SWSD007	2017 MAY PHASEIII	6/9/2017				ug/L	1	1	0.63	0.092	0.146032	
Surface Water	Total	Background	CH-SWSD008	2017 MAY PHASEIII	6/9/2017				ug/L	1	1	0.69	0.26	0.376812	
Surface Water	Total	Background	CH-SWSD009	2017 MAY PHASEIII	6/9/2017				ug/L	1	1	0.87	0.084	0.096552	
Surface Water	Total	Background	CH-SWSD010	2017 MAY PHASEIII	6/9/2017				ug/L	1	1	0.79	0.28	0.35443	
Surface Water	Total	Background	CH-SWSD011	2017 MAY PHASEIII	6/10/2017				ug/L	1	1	1.2	0.43	0.358333	
Surface Water	Total	Background	CH-SWSD012	2017 MAY PHASEIII	6/10/2017				ug/L	1	1	1.9	0.37	0.194737	
Surface Water	Total	Background	CH-SWSD013	2017 MAY PHASEIII	6/10/2017				ug/L	1	1	1.8	0.46	0.255556	
Surface Water	Total	Background	CH-SWSD014	2017 MAY PHASEIII	6/9/2017				ug/L	1	1	1.1	0.13	0.118182	
Surface Water	Total	Background	CH-SWSD015	2017 MAY PHASEIII	6/9/2017				ug/L	1	1	1	0.15	0.15	
Surface Water	Total	Background	CH-SWSD016	2017 MAY PHASEIII	6/8/2017				ug/L	1	1	0.68	0.13	0.191176	
Surface Water	Total	Background	CH-SWSD017	2017 MAY PHASEIII	6/8/2017				ug/L	1	1	0.69	0.15	0.217391	
Surface Water	Total	Background	CH-SWSD018	2017 MAY PHASEIII	6/8/2017				ug/L	1	1	0.66	0.087	0.131818	
Surface Water	Total	Background	CH-SWSD019	2017 MAY PHASEIII	6/8/2017				ug/L	1	1	0.63	0.088	0.139683	
Surface Water	Total	Background	CH-SWSD020	2017 MAY PHASEIII	6/8/2017				ug/L	1	1	0.71	0.12	0.169014	
Surface Water	Total	Background	CH-SWSD021	2017 MAY PHASEIII	6/8/2017				ug/L	1	1	0.76	0.37	0.486842	
Surface Water	Total	Background	CH-SWSD022	2017 MAY PHASEIII	6/8/2017				ug/L	1	1	1.4	0.86	0.614286	
Surface Water	Total	Background	CH-SWSD023	2017 MAY PHASEIII	6/8/2017				ug/L	1	1	1.3	0.95	0.730769	
Surface Water	Total	Background	CH-SWSD024	2017 MAY PHASEIII	6/10/2017				ug/L	1	1	1.1	0.19	0.172727	
Surface Water	Total	Background	CH-SWSD025	2017 MAY PHASEIII	6/10/2017				ug/L	1	1	1.1	0.13	0.118182	
Surface Water	Total	Background	CH-SWSD026	2017 MAY PHASEIII	6/10/2017				ug/L	1	1	1.2	0.14	0.116667	
Surface Water	Total	Background	CH-SWSD027	2017 MAY PHASEIII	6/7/2017				ug/L	1	1	1.6	0.41	0.25625	

Attachment 1. Data for Total Chromium, Hexavalent Chromium, and Ratios

Medium	Fraction	Area	Location	Phase	Sample Date	start_depth	end_depth	depth_unit	Unit	D_Conc Chromium	D_Conc Chromium (VI)	Conc Chromium	Conc Chromium (VI)	Ratio	Outlier
Surface Water	Total	Background	CH-SWSD028	2017 MAY PHASEIII	6/7/2017				ug/L	1	1	1.3	0.4	0.307692	
Surface Water	Total	Background	CH-SWSD029	2017 MAY PHASEIII	6/7/2017				ug/L	1	1	1.5	0.43	0.286667	
Surface Water	Total	Background	CH-SWSD030	2017 MAY PHASEIII	6/7/2017				ug/L	1	1	1.6	0.45	0.28125	
Surface Water	Total	Site	CH-SWSD073	2017 MAY PHASEIII	6/4/2017				ug/L	1	1	0.9	0.53	0.588889	
Surface Water	Total	Site	CH-SWSD100	2017 MAY PHASEIII	6/7/2017				ug/L	1	1	0.92	0.15	0.163043	
Surface Water	Total	Site	CH-SWSD120	2017 MAY PHASEIII	6/3/2017				ug/L	1	1	1.8	0.22	0.122222	
Surface Water	Total	Site	CH-SWSD130	2017 MAY PHASEIII	6/7/2017				ug/L	1	1	0.93	0.61	0.655914	
Surface Water	Total	Site	CH-SWSD140	2017 MAY PHASEIII	6/7/2017				ug/L	1	1	1.2	0.18	0.15	
Surface Water	Total	Site	CH-SWSD150	2017 MAY PHASEIII	6/9/2017				ug/L	1	1	1.7	0.12	0.070588	

Attachment 2

Statistical Outputs for Soil and Sediment

Chromium and Hexavalent Chromium Ratios
Soil and Sediment Outputs

Figure 1.

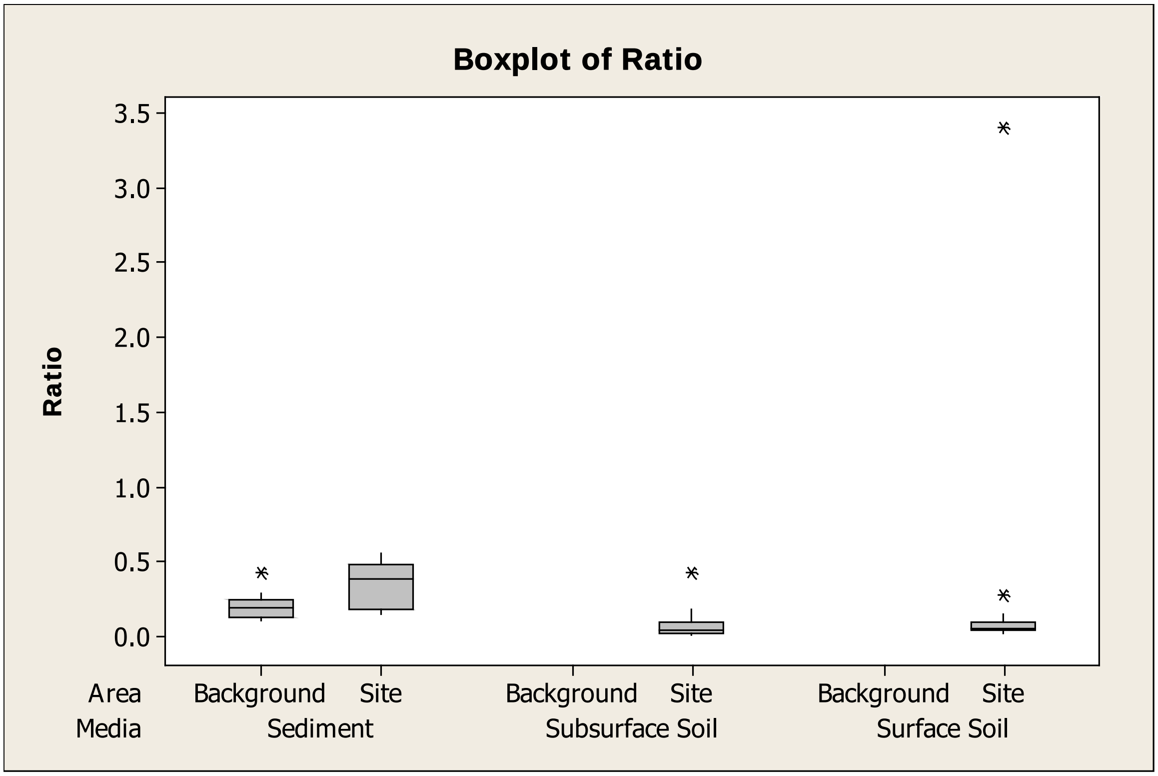
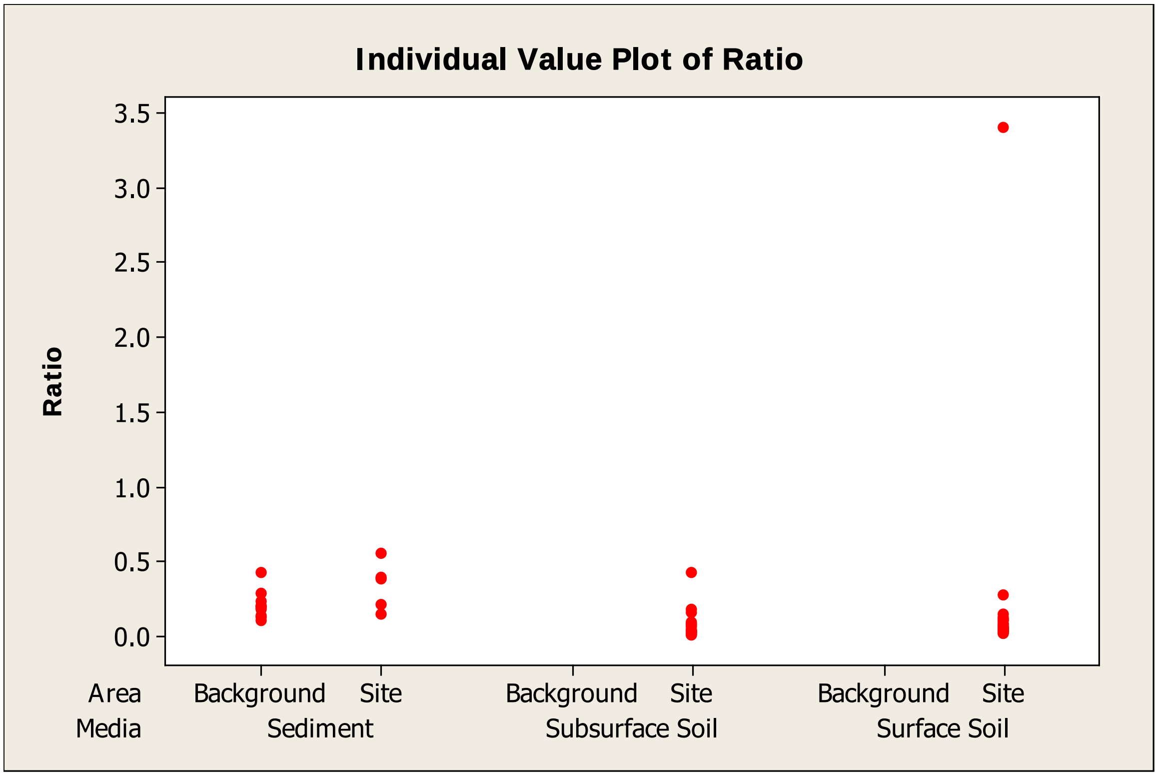


Figure 2.



Results for Media = Sediment

```
Variable  Area         N    Mean  SE Mean   StDev  Minimum  Median  Maximum
Ratio     Background  10  0.2108   0.0294  0.0930   0.1083  0.1976   0.4271
          Site         5  0.3416   0.0727  0.1626   0.1504  0.3889   0.5585
```

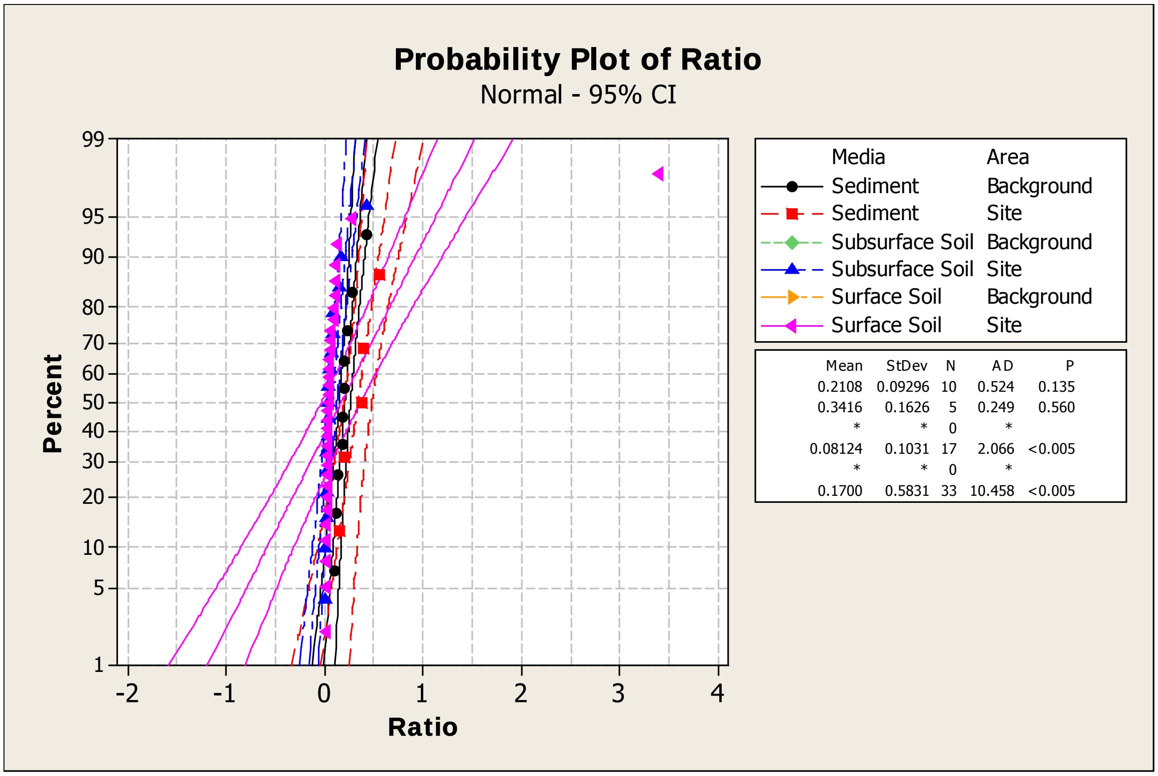
Results for Media = Subsurface Soil

```
Variable  Area   N    Mean  SE Mean   StDev  Minimum  Median  Maximum
Ratio     Site  17  0.0812   0.0250  0.1031   0.0107  0.0379   0.4321
```

Results for Media = Surface Soil

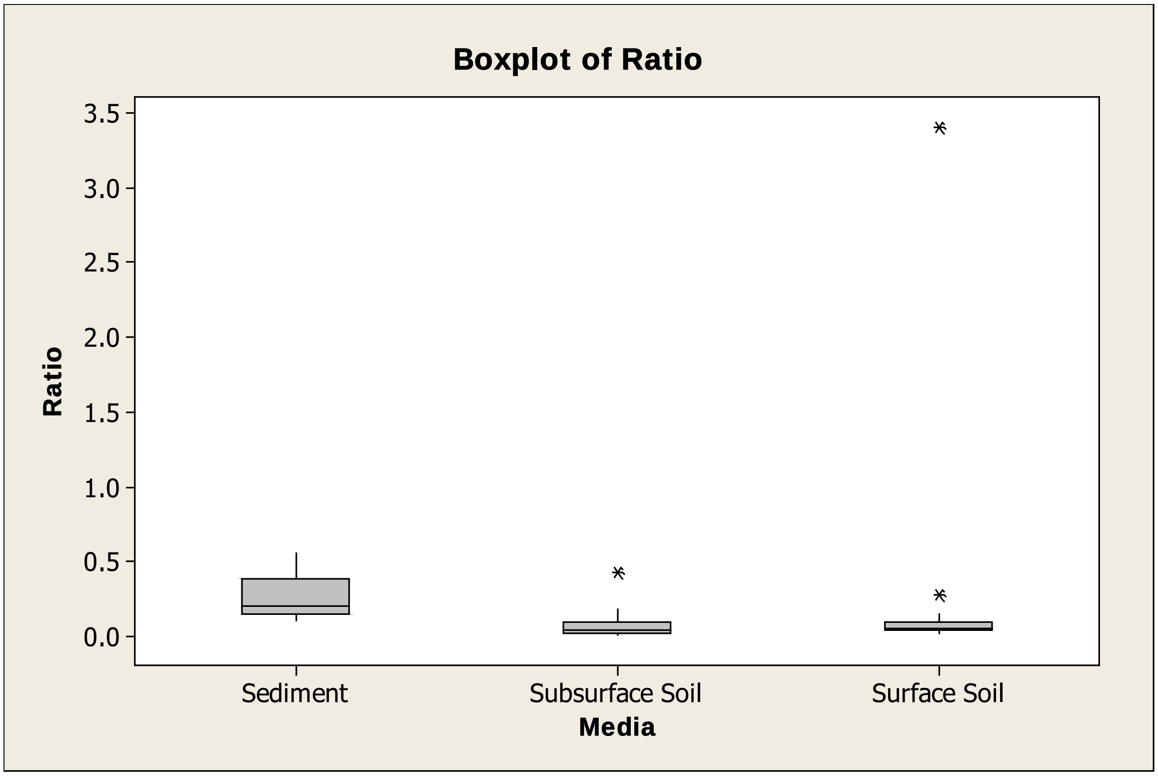
```
Variable  Area   N   Mean  SE Mean  StDev  Minimum  Median  Maximum
Ratio     Site  33  0.170    0.102  0.583    0.024   0.052    3.406
```

Figure 3.



Mean	StDev	N	AD	P
0.2108	0.09296	10	0.524	0.135
0.3416	0.1626	5	0.249	0.560
*	*	0	*	
0.08124	0.1031	17	2.066	<0.005
*	*	0	*	
0.1700	0.5831	33	10.458	<0.005

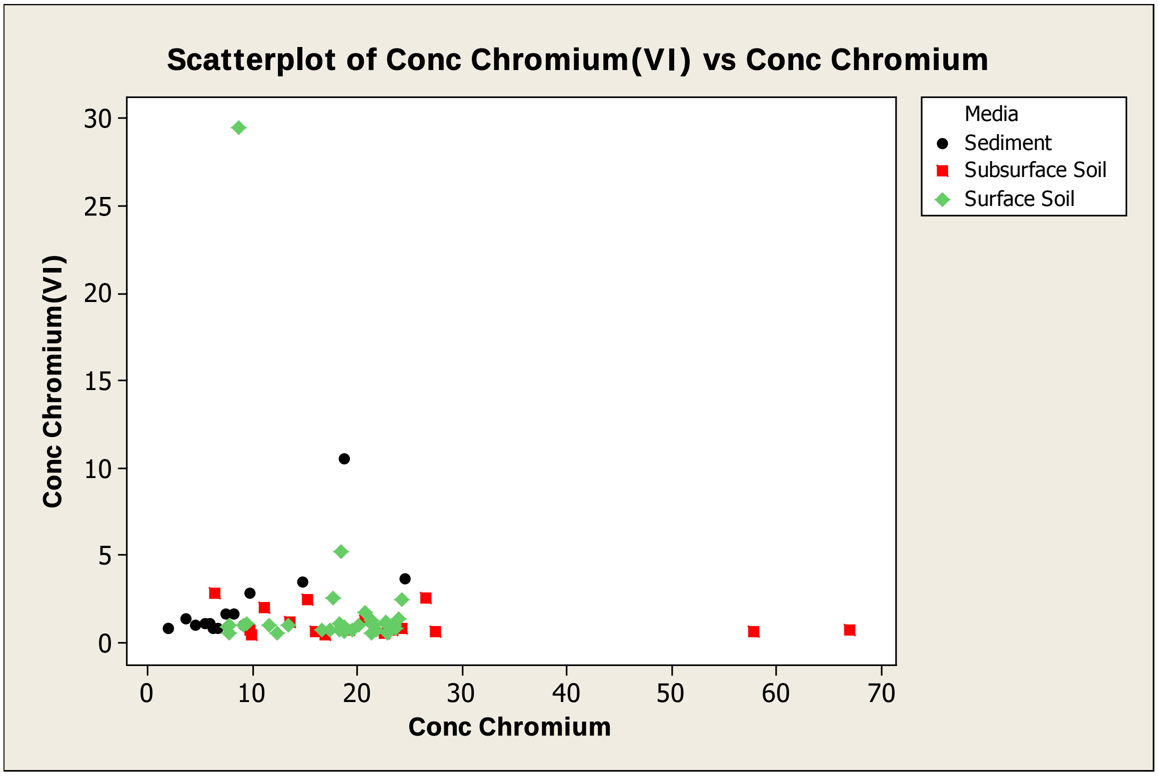
Figure 4.



Two-Sample T-Test and CI: Ratio_1, Area_1

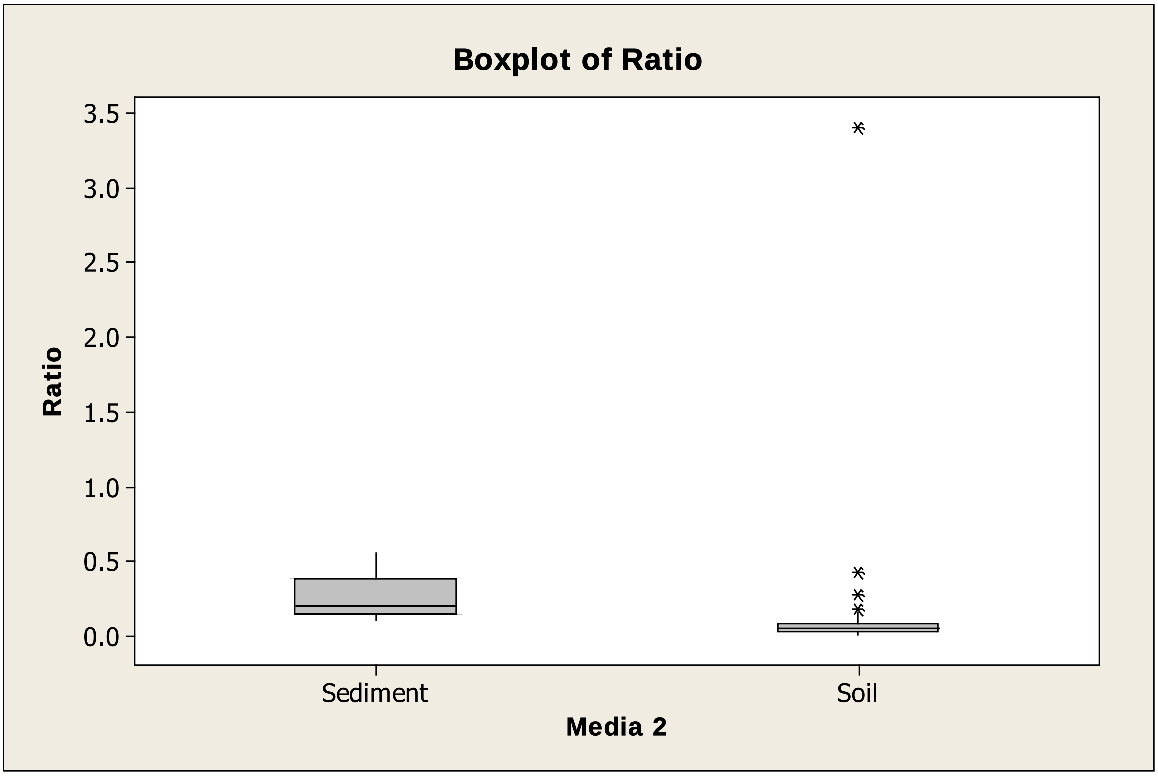
```
Two-sample T for Ratio_1

Area_1        N    Mean   StDev  SE Mean
Background   10  0.2108  0.0930    0.029
Site          5   0.342   0.163    0.073


Difference = mu (Background) - mu (Site)
Estimate for difference:  -0.1308
95% CI for difference:  (-0.3325, 0.0708)
T-Test of difference = 0 (vs not =): T-Value = -1.67  P-Value = 0.156  DF = 5
```

Figure 5.



The plots suggest background and site sediment ratios may be pooled; and the surface and subsurface soil ratios may be pooled. There is also one clear soil outlier with several potential outliers.

Figure 6.



Kruskal-Wallis Test: Ratio_1_1 versus Media_1_1

```
Kruskal-Wallis Test on Ratio_1_1

Media_1_1         N   Median  Ave Rank      Z
Subsurface Soil  17  0.03789      22.3  -1.12
Surface Soil     33  0.05164      27.2   1.12
Overall          50               25.5

H = 1.25  DF = 1  P = 0.264
```

Kruskal-Wallis Test: Ratio versus Media 2

```
Kruskal-Wallis Test on Ratio

Media 2    N   Median  Ave Rank      Z
Sediment  15  0.20734      54.3   4.98
Soil      50  0.04898      26.6  -4.98
Overall   65               33.0

H = 24.82  DF = 1  P = 0.000
```

Figure 7.

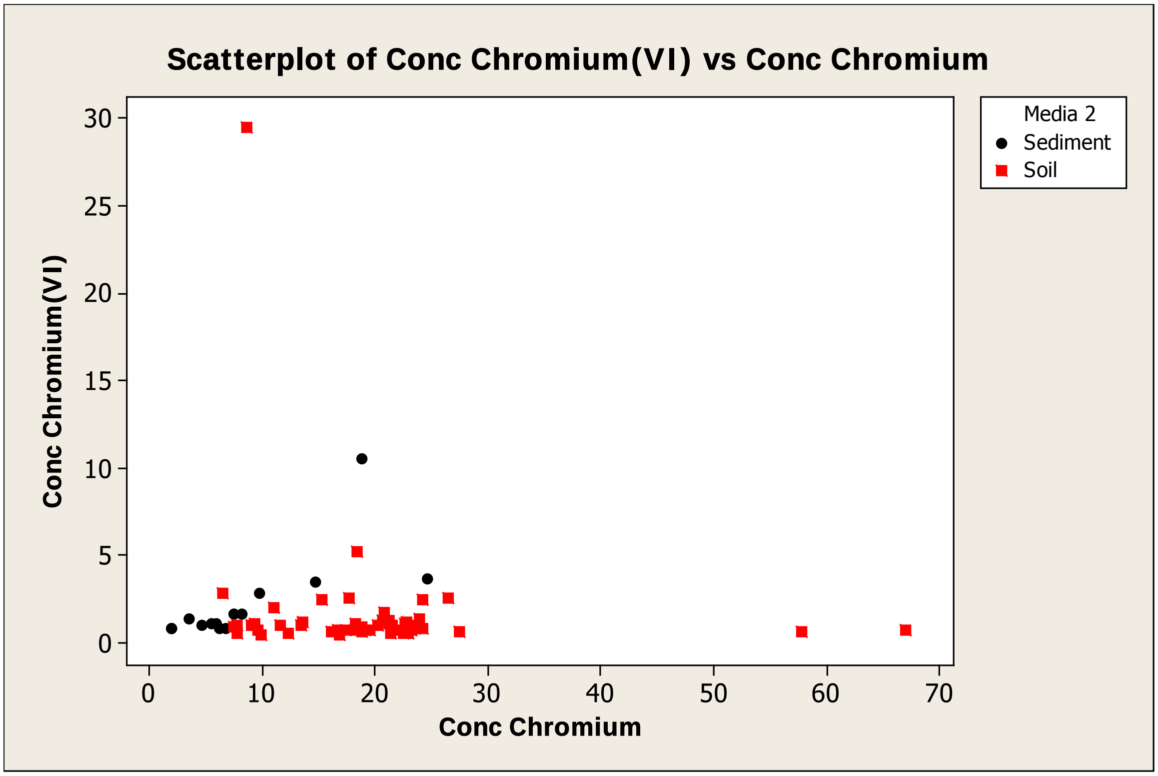
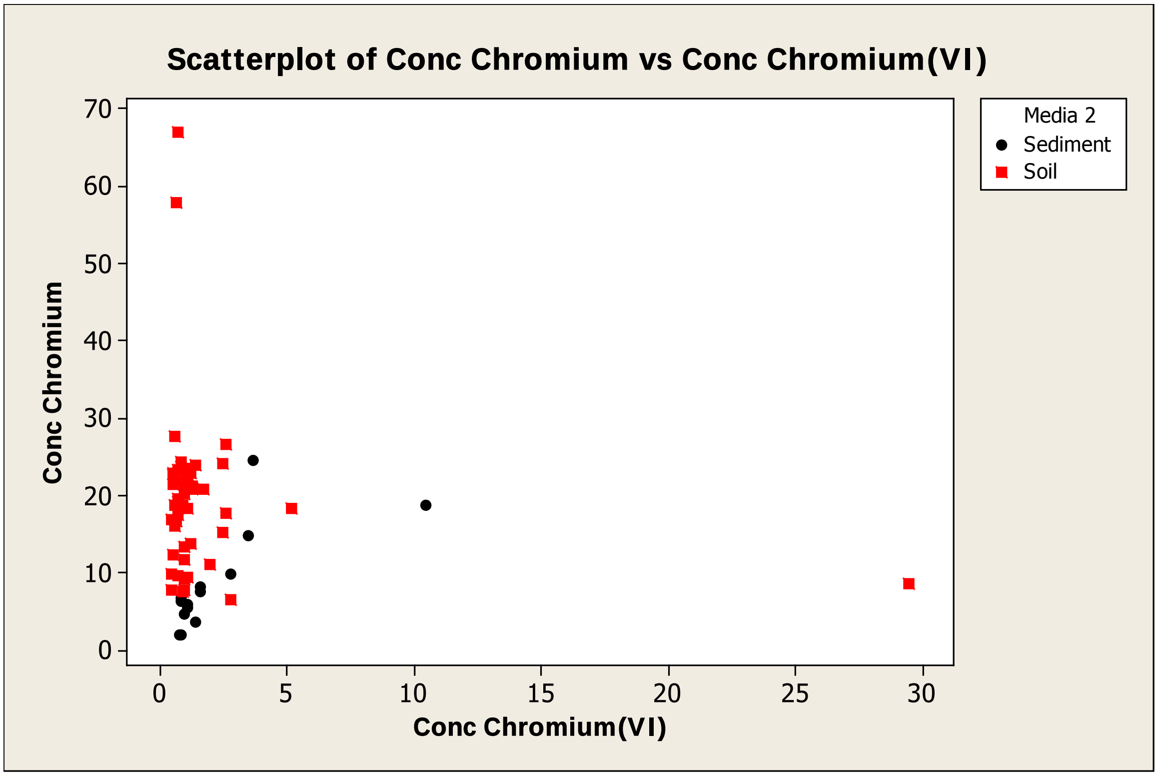


Figure 8.



Descriptive Statistics: Ratio

```
Variable  Media 2    N    Mean  SE Mean   StDev  Minimum  Median  Maximum
Ratio     Sediment  15  0.2544   0.0338  0.1311   0.1083  0.2073   0.5585
          Soil      50  0.1398   0.0674  0.4768   0.0107  0.0490   3.4065
```

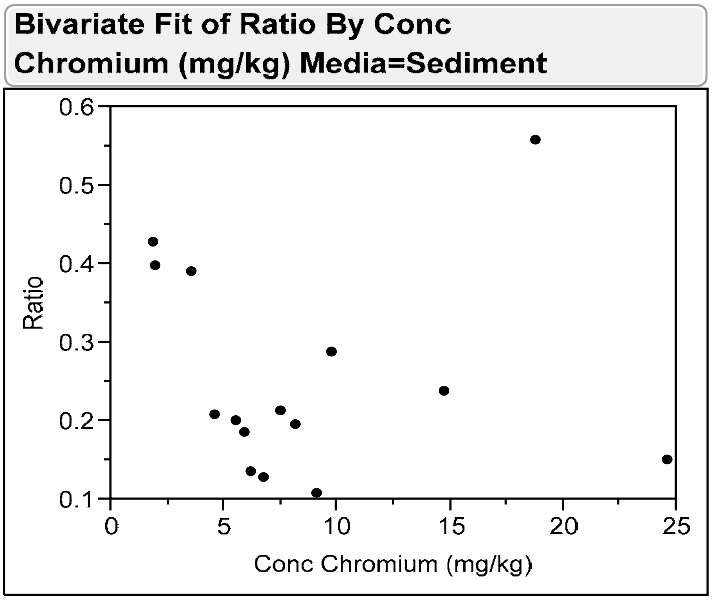
Outlier Row 65: (8.66 Cr, 29.500 CrVI) – The CrVI concentration cannot physically exceed the concentration of total Cr. The outlier should be removed.

Descriptive Statistics: Ratio with Outlier Removed

```
Variable         N    Mean  SE Mean   StDev  Minimum  Median  Maximum
Ratio_1_1_No OL  49  0.0732   0.0103  0.0724   0.0107  0.0485   0.4321
```

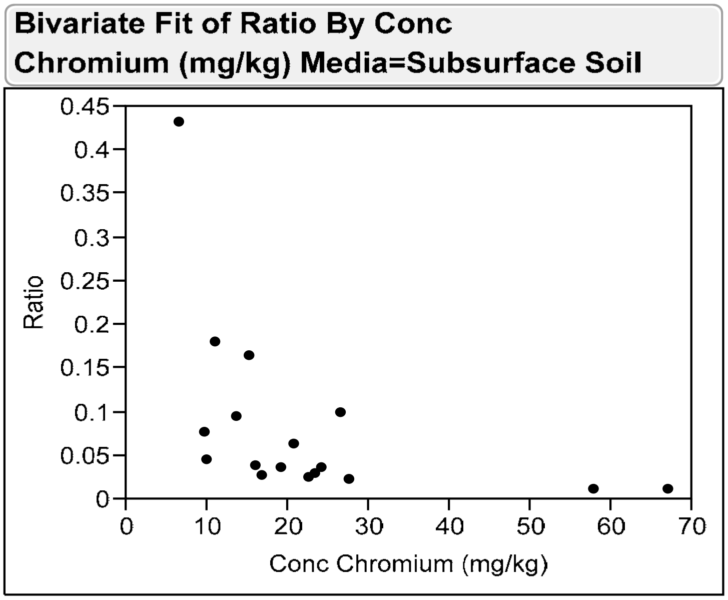
Based on the scatter plots, there is one potential outlier for sediment: Row 15 (18.80 Cr, 10.500 CrVI, ratio = 0.5585). This point does not appear as an outlier in the box plot. Based on the scatter plots, there are two potential outliers for soil: Row 17 (57.80 Cr, 0.640 CrVI, ratio = 0.0111) and row 18 (67 Cr, 0.720 CrVI, ratio =0.0107). However, there is no clear reason to remove these data points.

Figure 9.



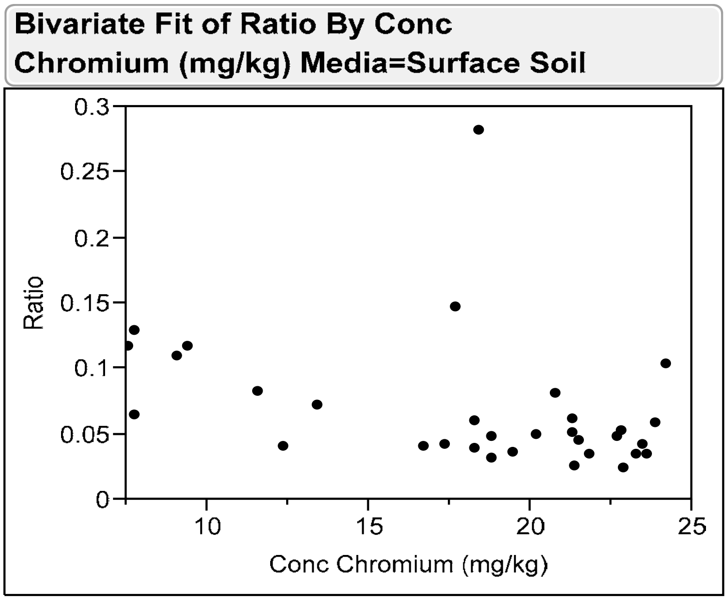
Bivariate Fit of Ratio By Conc Chromium (mg/kg) Media=Sediment

Figure 10.



Bivariate Fit of Ratio By Conc Chromium (mg/kg) Media=Subsurface Soil

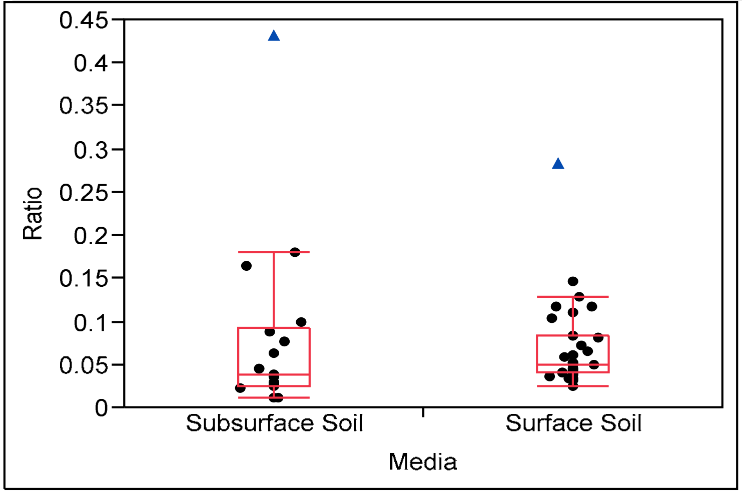
Figure 11.



The ratios are not strongly concentration dependent for all 3 media.

Figure 12.

Oneway Analysis of Ratio By Media



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

```
                                      Expected
Level            Count  Score Sum       Score  Score Mean  (Mean-Mean0)/Std0
Subsurface Soil     17    379.000     425.000     22.2941             -0.956
Surface Soil        32    846.000     800.000     26.4375              0.956
```

2-Sample Test, Normal Approximation

```
  S          Z   Prob>|Z|
379   -0.95569     0.3392
```

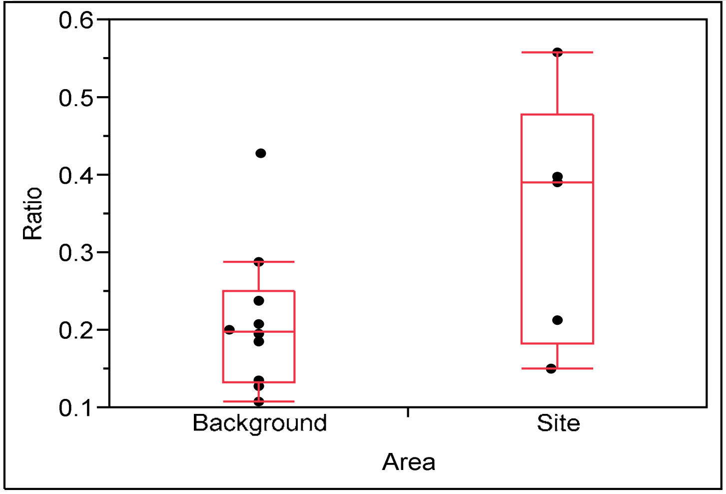
1-way Test, ChiSquare Approximation

```
ChiSquare    DF   Prob>ChiSq
   0.9335     1       0.3339
```

Soil: No difference between surface and subsurface soils. Ratios are pooled. (n=49)
(Note: No background CrVI data for soil. All data are site.)

Figure 13.

Oneway Analysis of Ratio By Area



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
Background	10	67.000	80.000	6.7000	-1.531
Site	5	53.000	40.000	10.6000	1.531

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
53	1.53093	0.1258

1-way Test, ChiSquare Approximation

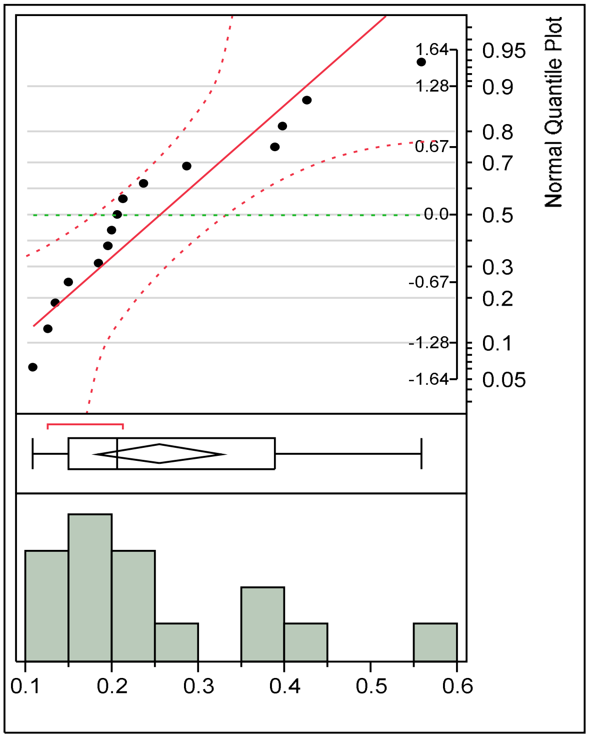
ChiSquare	DF	Prob>ChiSq
2.5350	1	0.1113

Sediment: No difference between background and site. Ratios are pooled. (n=15)

Figure 14.

Distributions Media 2=Sediment

Ratio



Quantiles

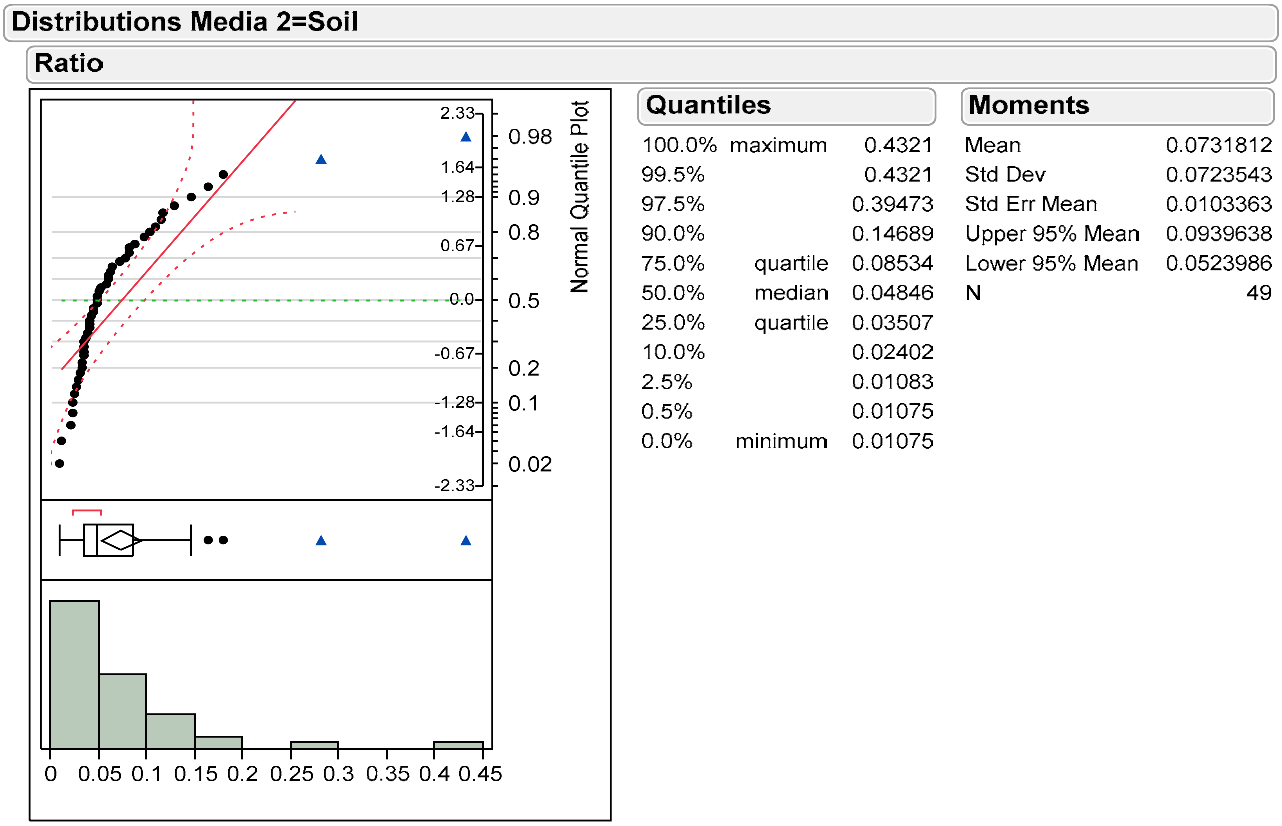
100.0%	maximum	0.55851
99.5%		0.55851
97.5%		0.55851
90.0%		0.47965
75.0%	quartile	0.38889
50.0%	median	0.20734
25.0%	quartile	0.15041
10.0%		0.11943
2.5%		0.10832
0.5%		0.10832
0.0%	minimum	0.10832

Moments

Mean	0.2543707
Std Dev	0.1310956
Std Err Mean	0.0338487
Upper 95% Mean	0.3269691
Lower 95% Mean	0.1817724
N	15

Sediment: No outlier.

Figure 15.



Distributions Media 2=Soil

Ratio

Quantiles

100.0%	maximum	0.4321
99.5%		0.4321
97.5%		0.39473
90.0%		0.14689
75.0%	quartile	0.08534
50.0%	median	0.04846
25.0%	quartile	0.03507
10.0%		0.02402
2.5%		0.01083
0.5%		0.01075
0.0%	minimum	0.01075

Moments

Mean	0.0731812
Std Dev	0.0723543
Std Err Mean	0.0103363
Upper 95% Mean	0.0939638
Lower 95% Mean	0.0523986
N	49

Soil: 1 clear outlier excluded. 2 potential outliers shown (in triangle).

Attachment 3

Statistical Outputs for Groundwater and Surface Water

Attachment 3

Chromium and Hexavalent Chromium Ratios
Groundwater and Surface Water Outputs

Table 1. Descriptive Statistics: Ratio

Results for Medium = Groundwater

```
Variable  Area        N     Mean  SE Mean    StDev  Minimum   Median  Maximum
Ratio     Background  8    0.315    0.106    0.300    0.009    0.231    0.692
          Site        2  0.00862  0.00762  0.01078  0.00100  0.00862  0.01625
```

Results for Medium = Surface Water

```
Variable  Area         N    Mean  SE Mean   StDev  Minimum  Median  Maximum
Ratio     Background  30  0.2336   0.0284  0.1554   0.0731  0.1709   0.7308
          Site         6   0.292    0.106   0.259    0.071   0.157    0.656
```

Figure 1.

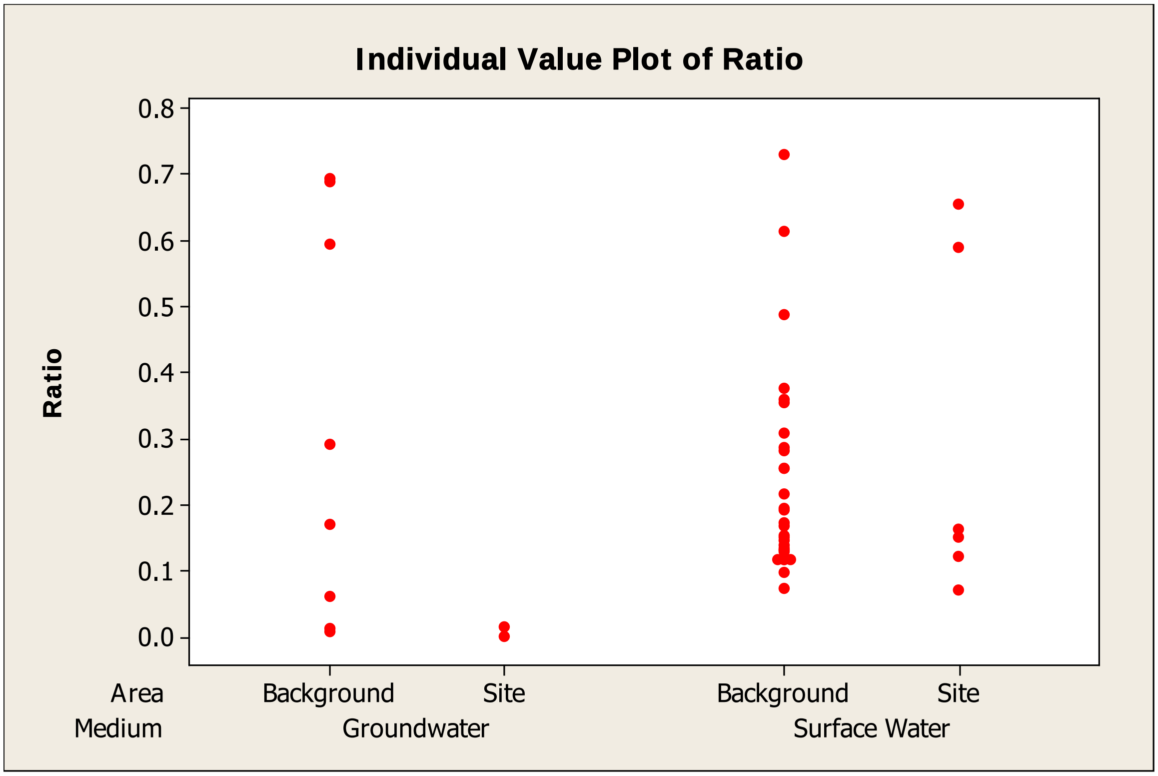


Figure 2.

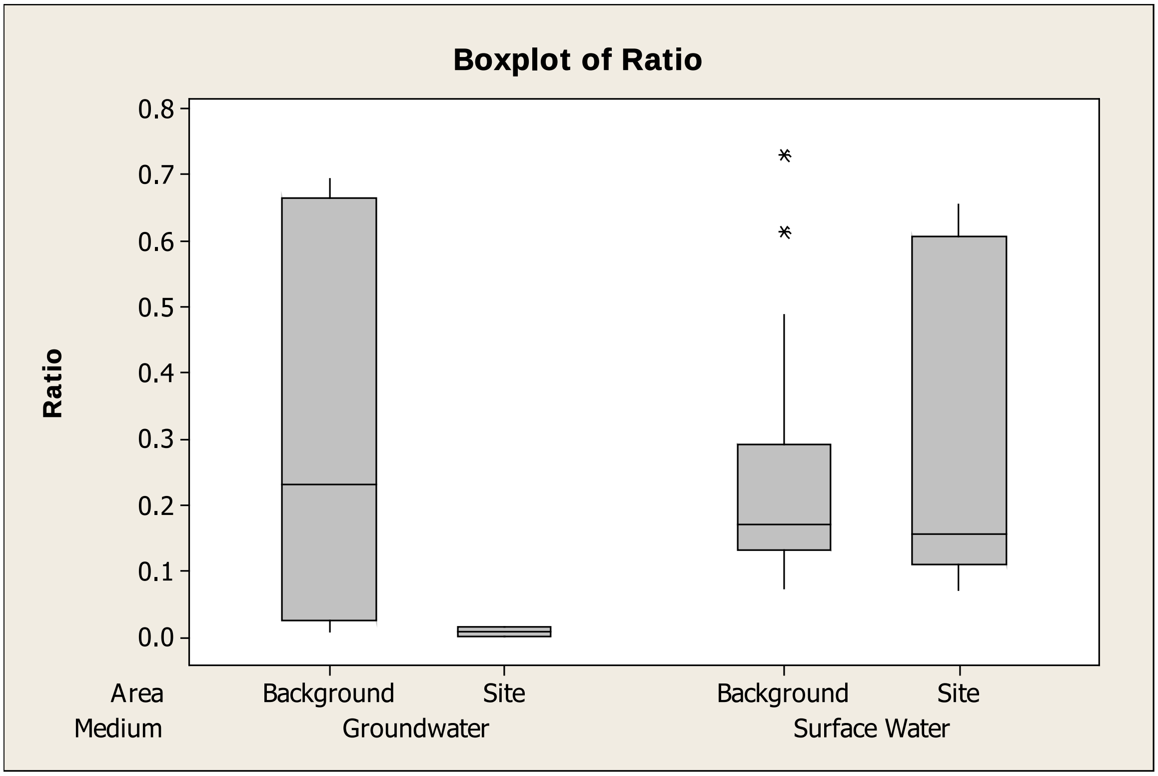


Figure 3.

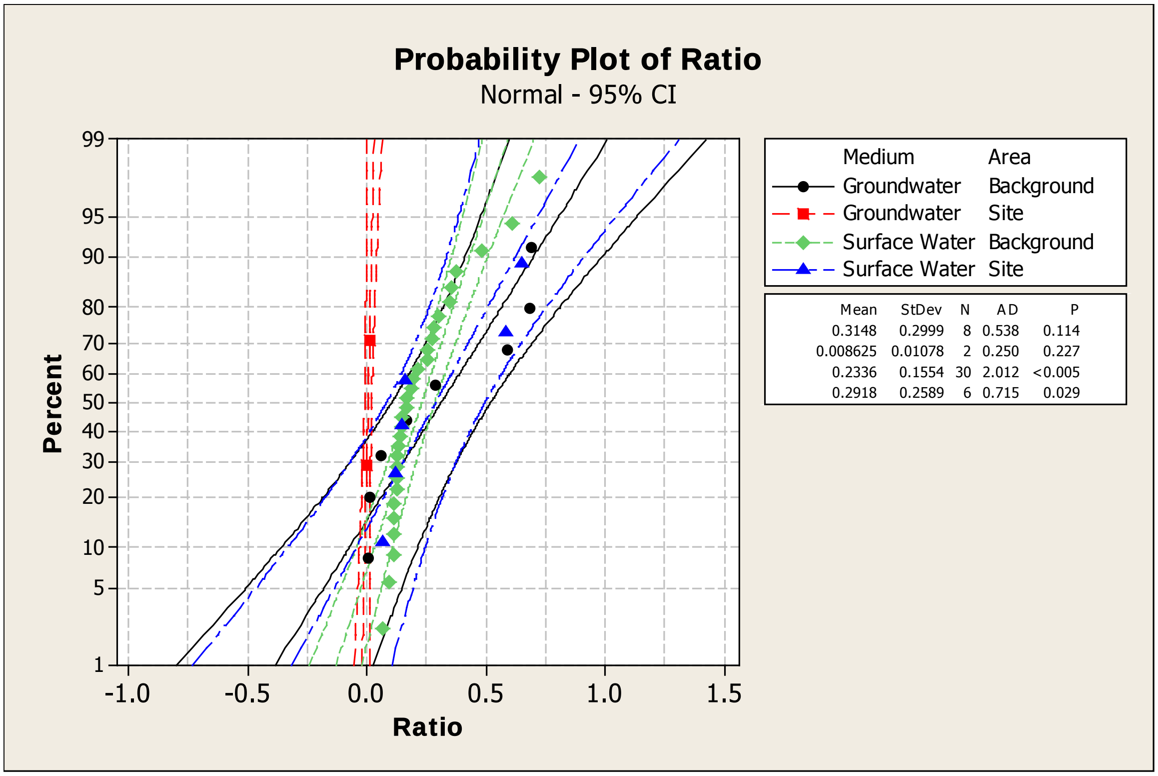


Figure 4.

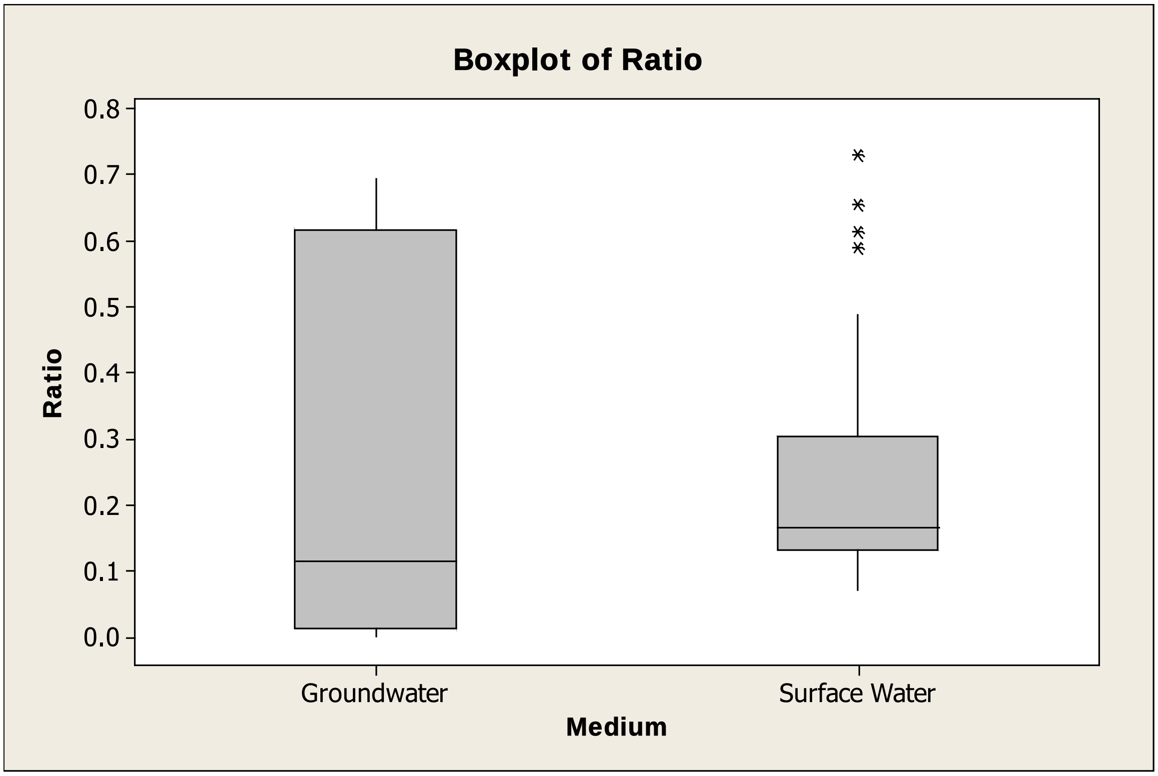


Figure 5.

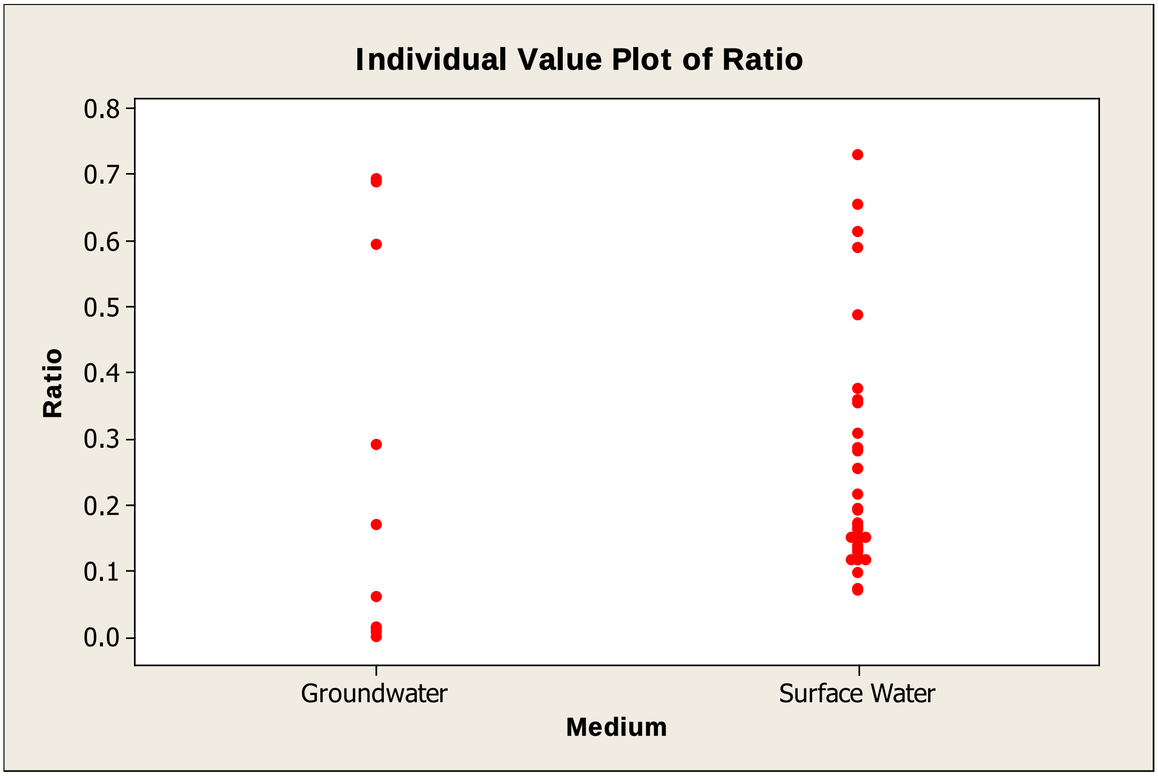


Table 2. Kruskal-Wallis Test: Ratio versus Medium

```
Kruskal-Wallis Test on Ratio

Medium          N  Median  Ave Rank      Z
Groundwater    10  0.1154      20.4  -0.83
Surface Water  36  0.1660      24.4   0.83
Overall        46              23.5

H = 0.68  DF = 1  P = 0.409
H = 0.68  DF = 1  P = 0.409  (adjusted for ties)
```

Table 3. Kruskal-Wallis Test: Ratio versus Area

```
Kruskal-Wallis Test on Ratio

Area         N  Median  Ave Rank      Z
Background  38  0.1710      24.5   1.09
Site         8  0.1361      18.8  -1.09
Overall     46              23.5

H = 1.18  DF = 1  P = 0.277
H = 1.18  DF = 1  P = 0.277  (adjusted for ties)
```

Table 4. Descriptive Statistics: Ratio

```
Variable   N    Mean  SE Mean   StDev  Minimum  Median  Maximum
Ratio     46  0.2456   0.0298  0.2018   0.0010  0.1660   0.7308
```

Figure 6.

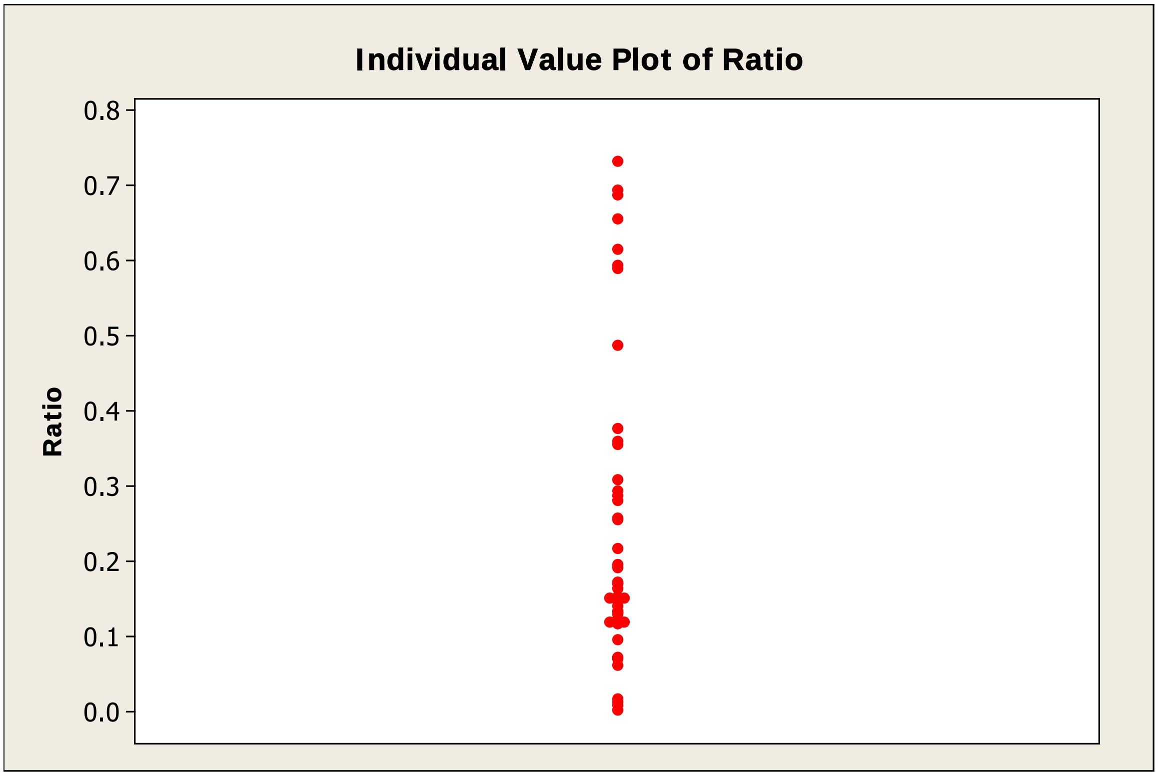


Figure 7.

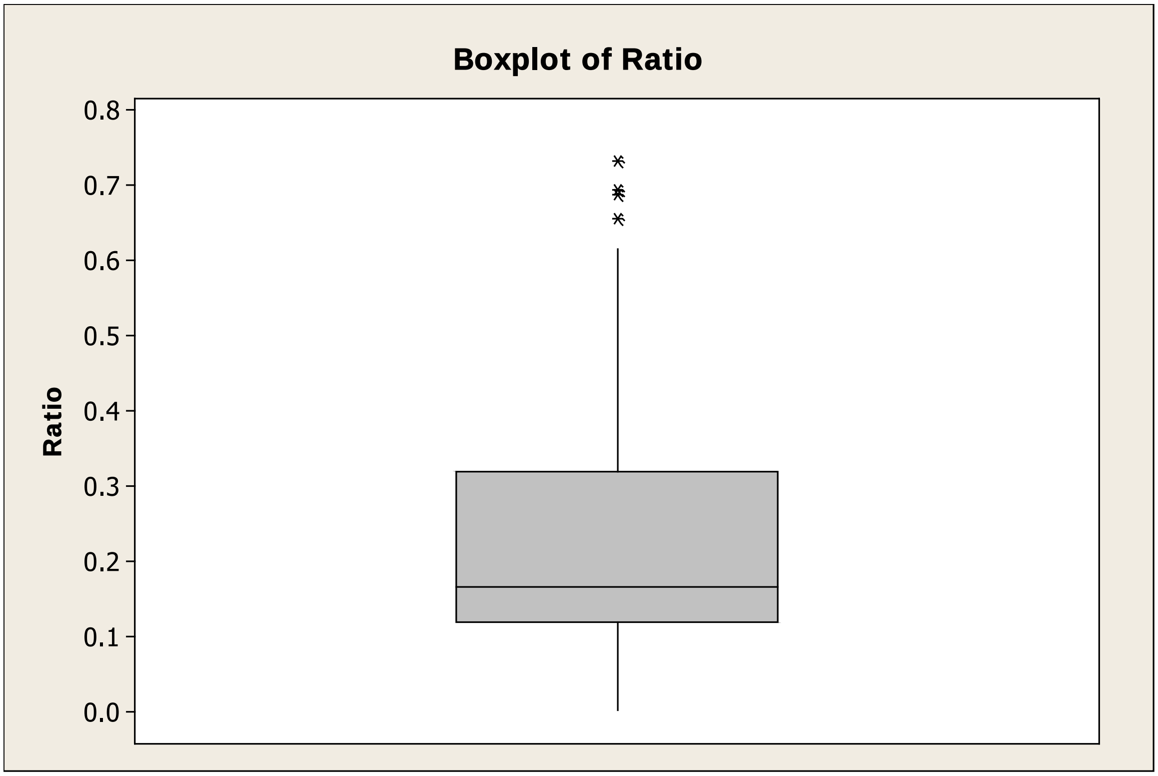


Figure 8.

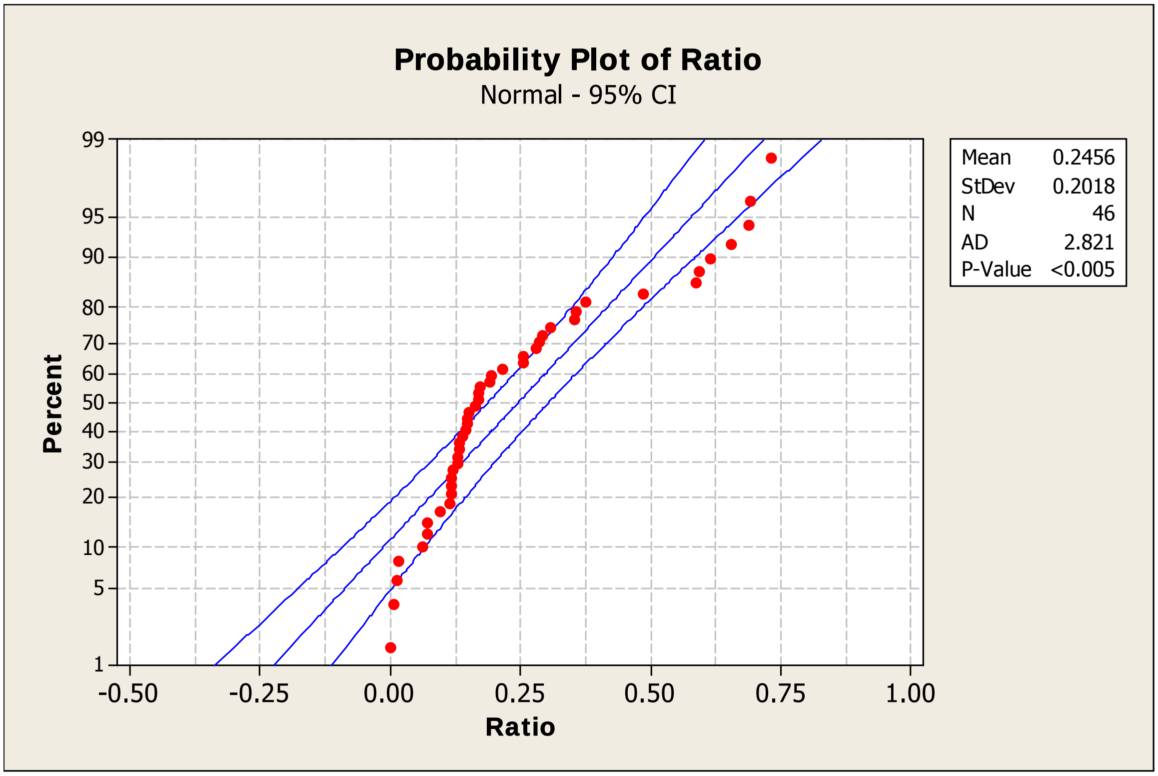


Figure 9.

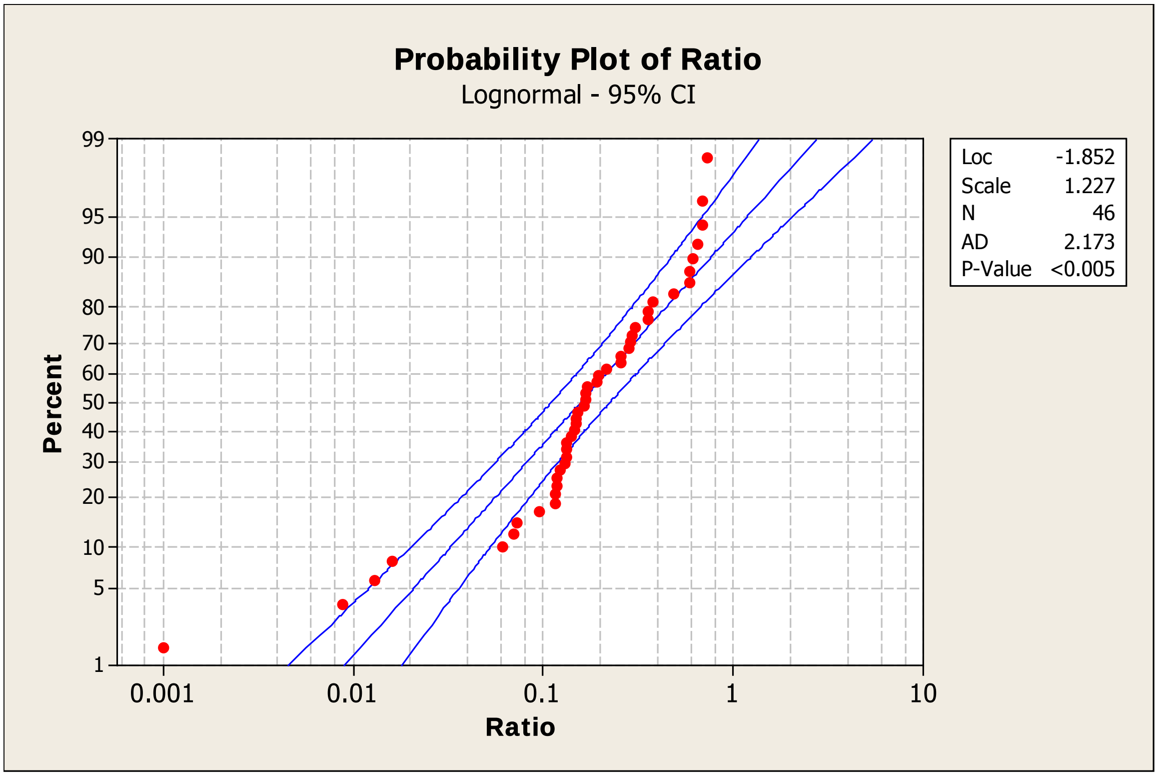


Figure 10.

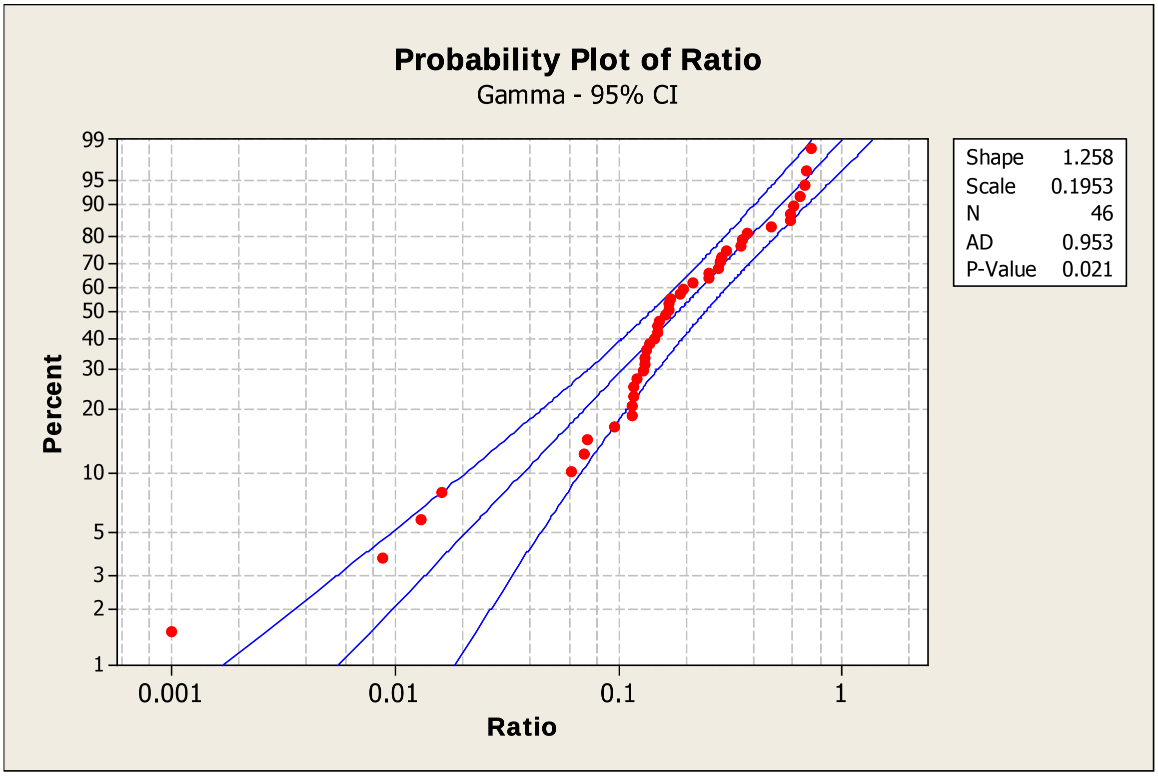


Figure 11.

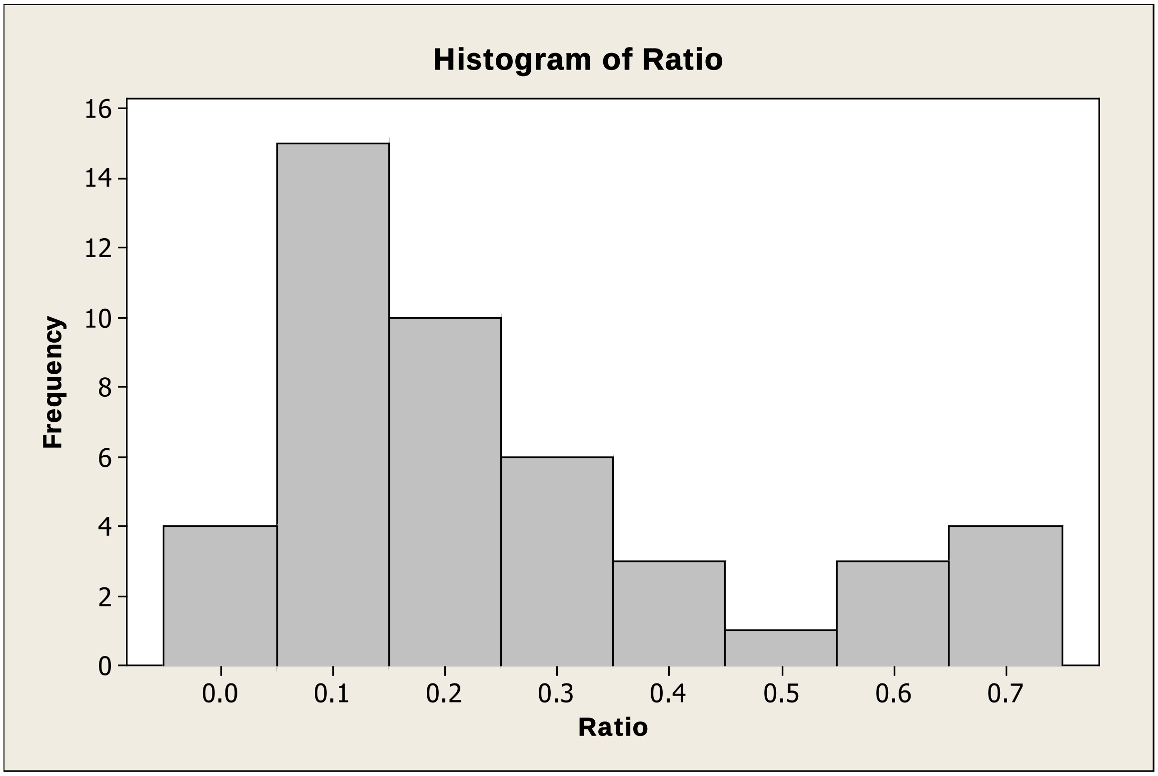


Figure 12.

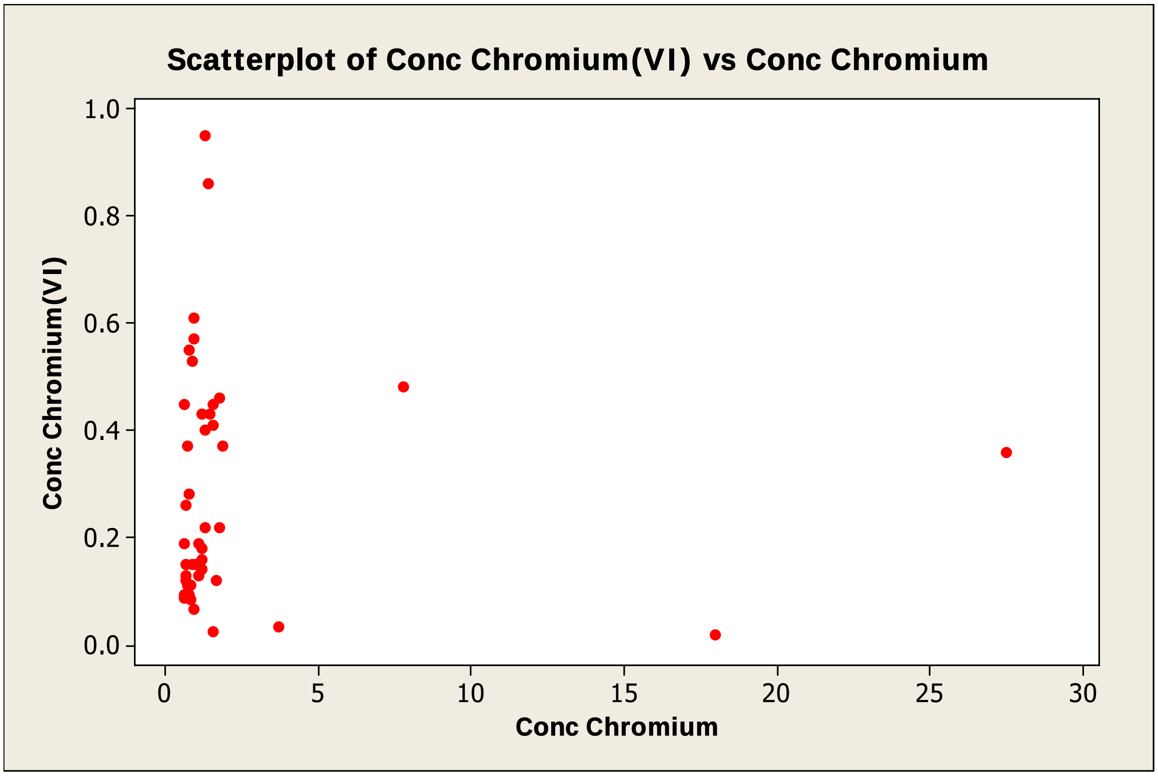
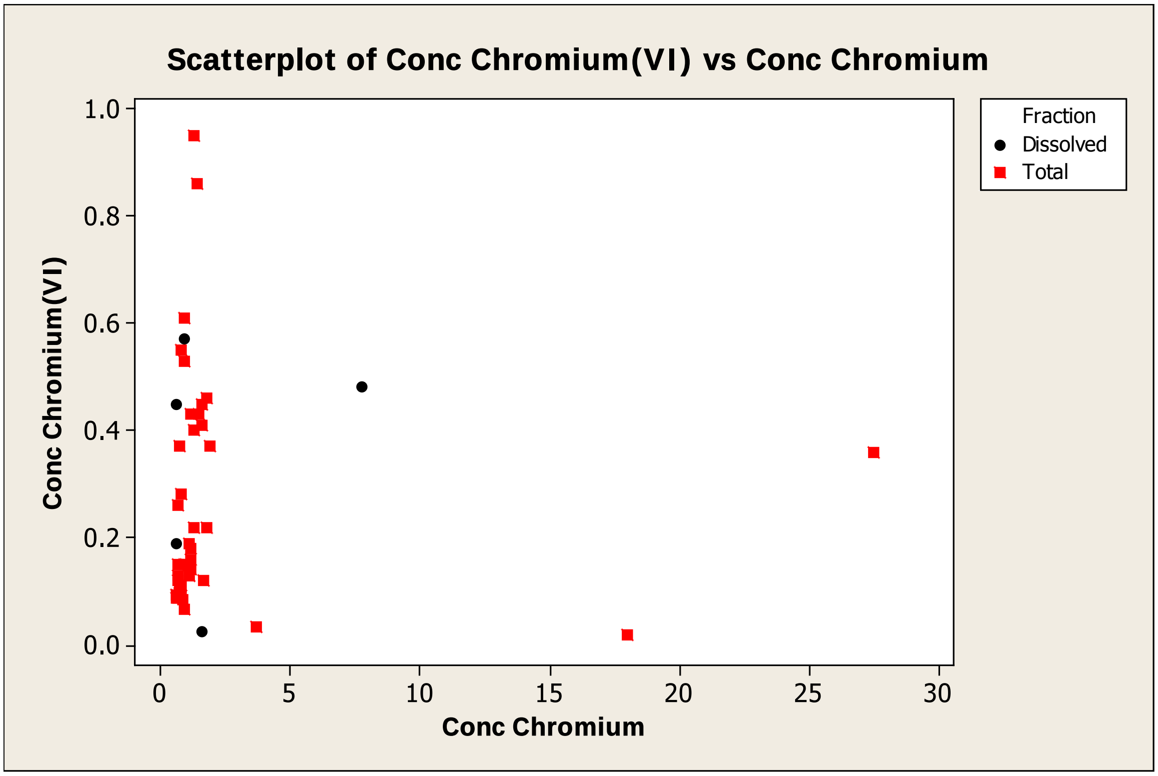

Scatterplot of Conc Chromium(VI) vs Conc Chromium
Conc Chromium(VI)
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
25
30
Conc Chromium

Figure 12.1.



Outliers, Row 9 and 10 removed.

Table 4.1 Descriptive Statistics: Ratio_

```
Variable    N  N*    Mean  SE Mean   StDev  Minimum      Q1  Median      Q3
Ratio_     44   2  0.2564   0.0301  0.1996   0.0089  0.1242  0.1691  0.3427

Variable  Maximum
Ratio_     0.7308
```

Figure 12.2.

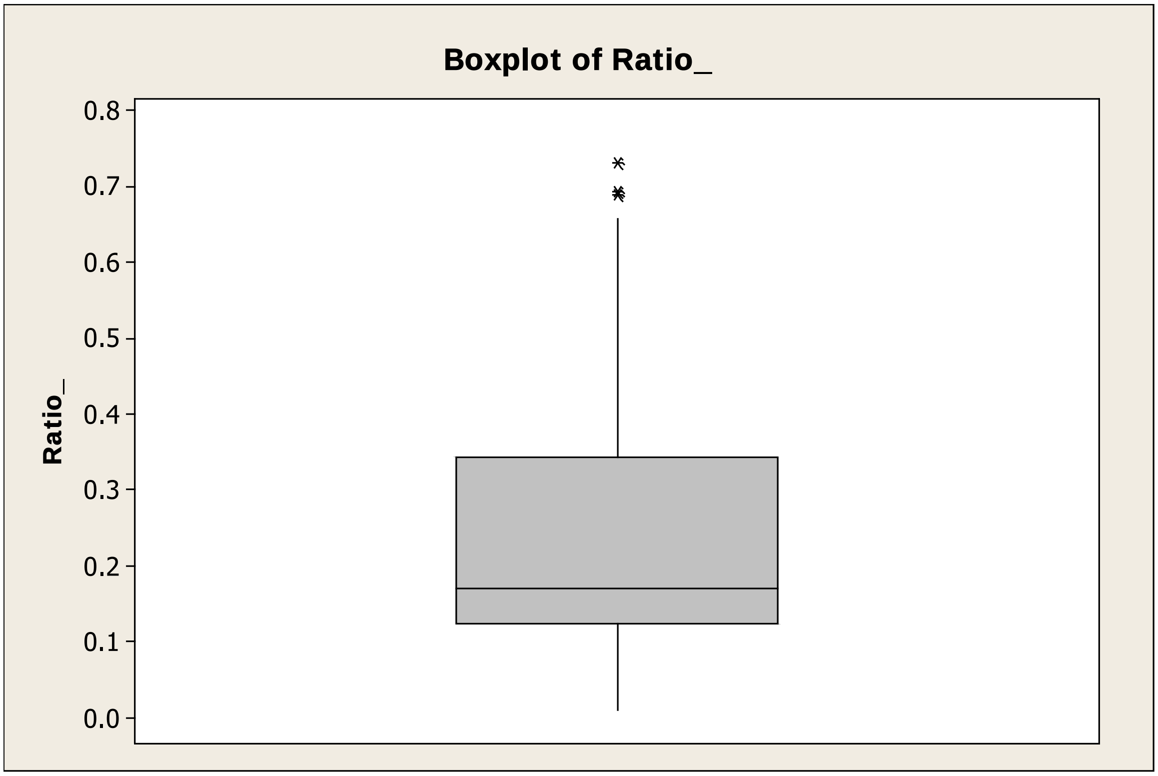


Figure 12.3.

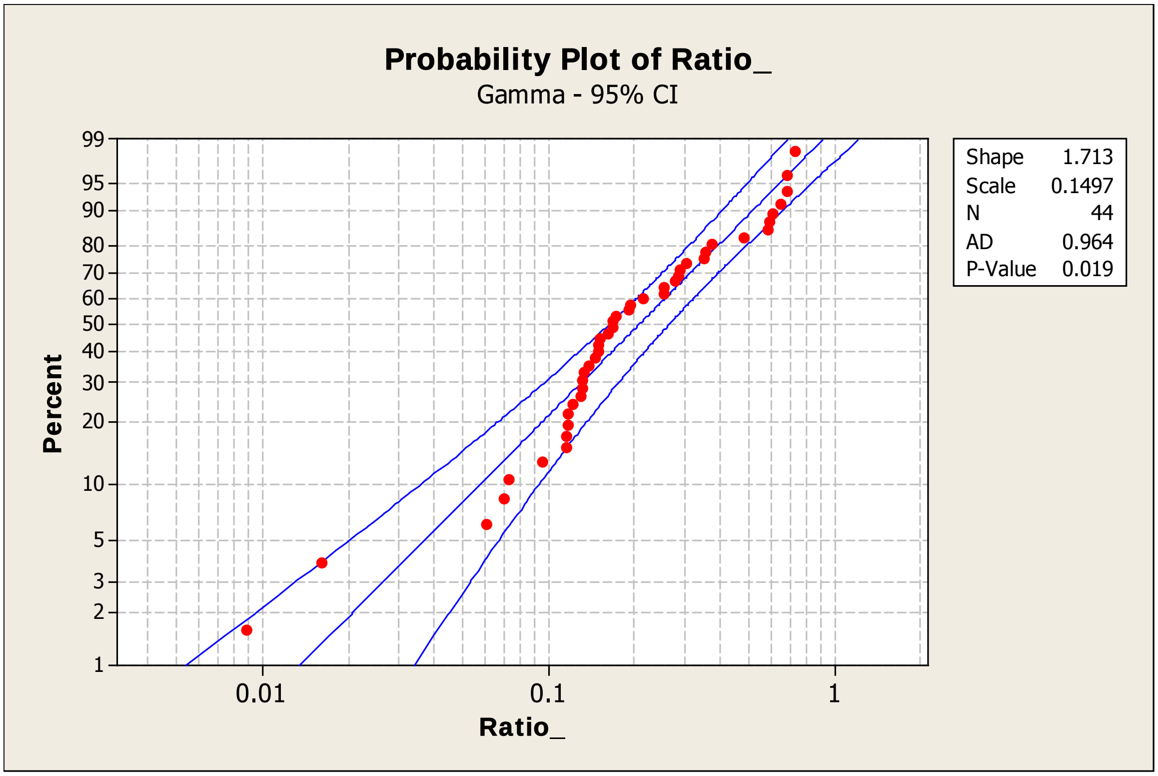
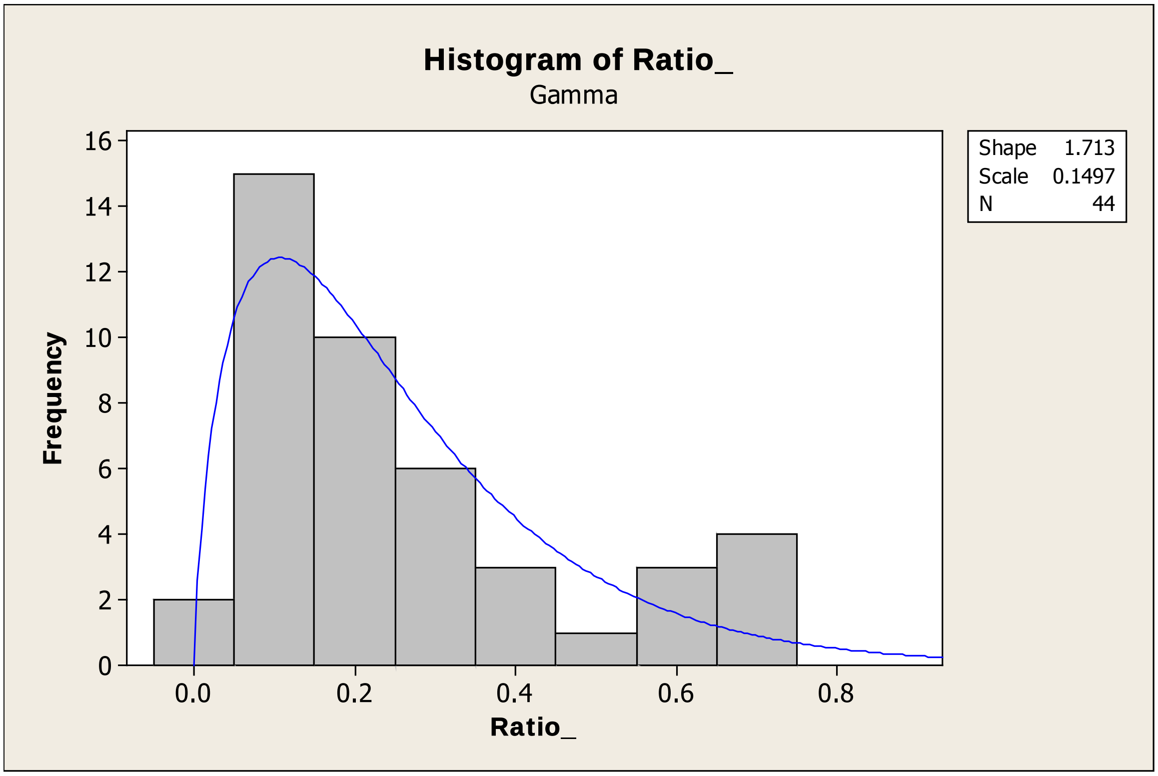


Figure 12.4.



Outliers, Row 4, 10, 9 removed.

Table 5. Descriptive Statistics: Ratio_1

```
Variable    N     Mean  SE Mean   StDev  Minimum  Median  Maximum
Ratio_1    43  0.2609    0.0305  0.1997   0.0089  0.1692   0.7308
```

Figure 13.

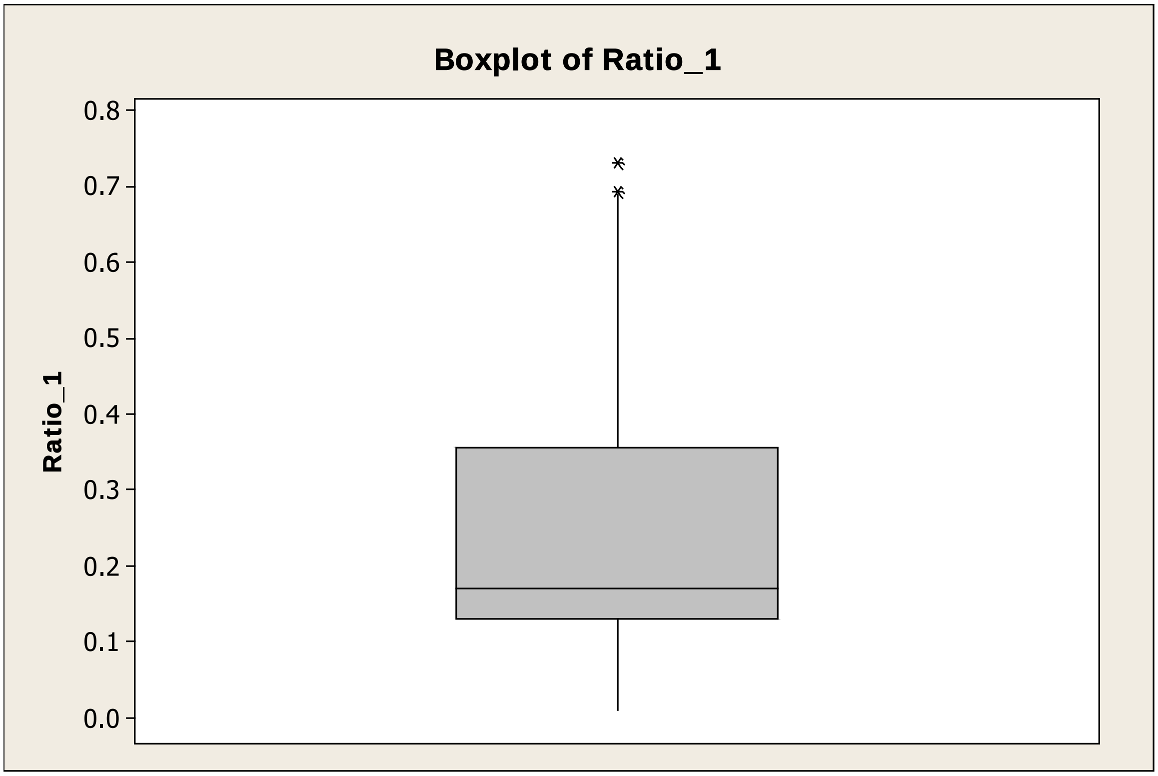


Figure 14.

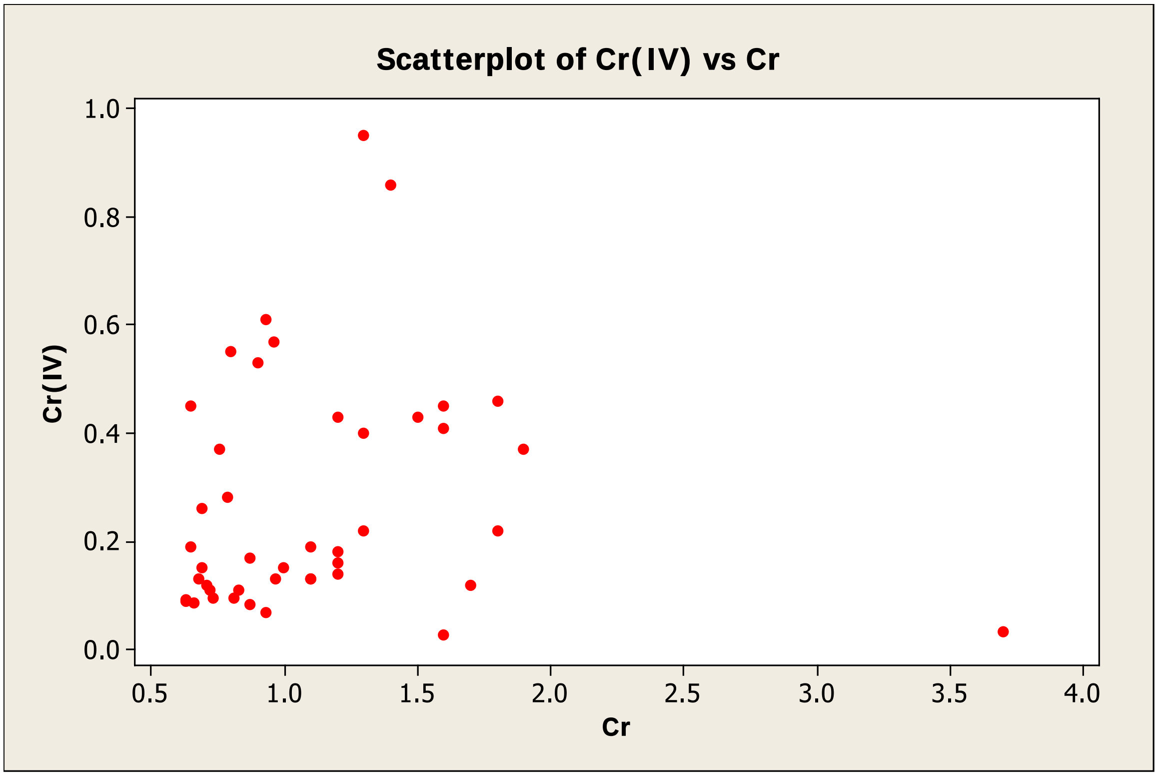
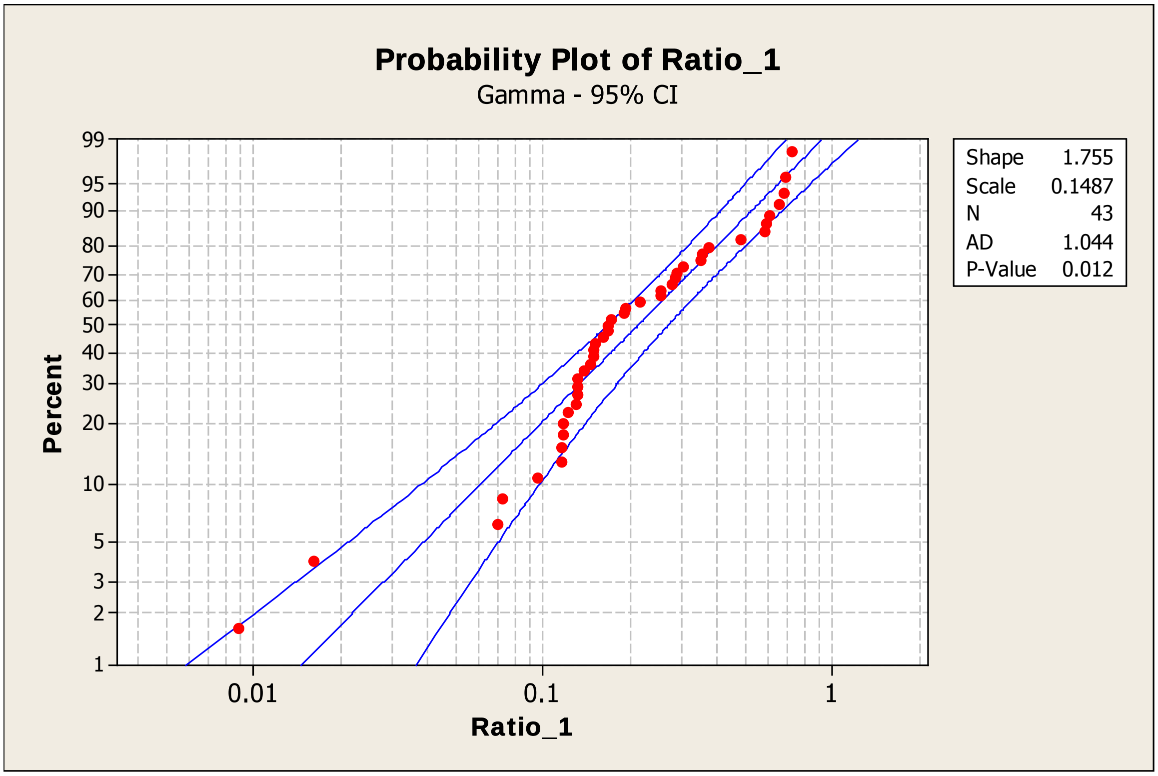


Figure 15.



Outlier row 8 removed.

Table 6. Descriptive Statistics: Ratio_2

```
Variable   N    Mean  SE Mean   StDev  Minimum  Median  Maximum
Ratio_2   42  0.2669   0.0306  0.1981   0.0162  0.1710   0.7308
```

Figure 16.

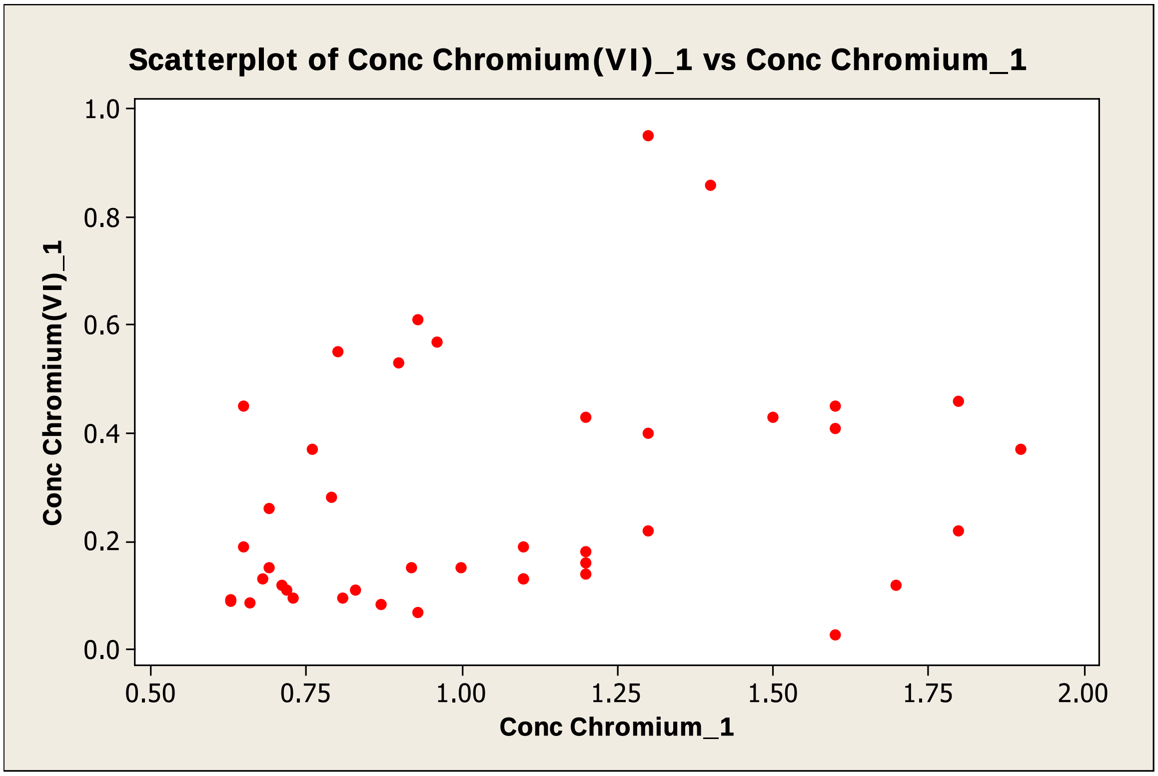


Table 7: Kruskal-Wallis Test on Ratio_2

```
Area          N  Median  Ave Rank      Z
Background   35  0.1912      22.3   0.94
Site          7  0.1500      17.5  -0.94
Overall      42              21.5

H = 0.89  DF = 1  P = 0.345
H = 0.89  DF = 1  P = 0.345  (adjusted for ties)
```

Table 8: Kruskal-Wallis Test on Ratio_2

```
Medium          N  Median  Ave Rank      Z
Groundwater     6  0.4430      28.3   1.47
Surface Water  36  0.1660      20.4  -1.47
Overall        42              21.5

H = 2.17  DF = 1  P = 0.141
H = 2.17  DF = 1  P = 0.141  (adjusted for ties)
```

Figure 17.

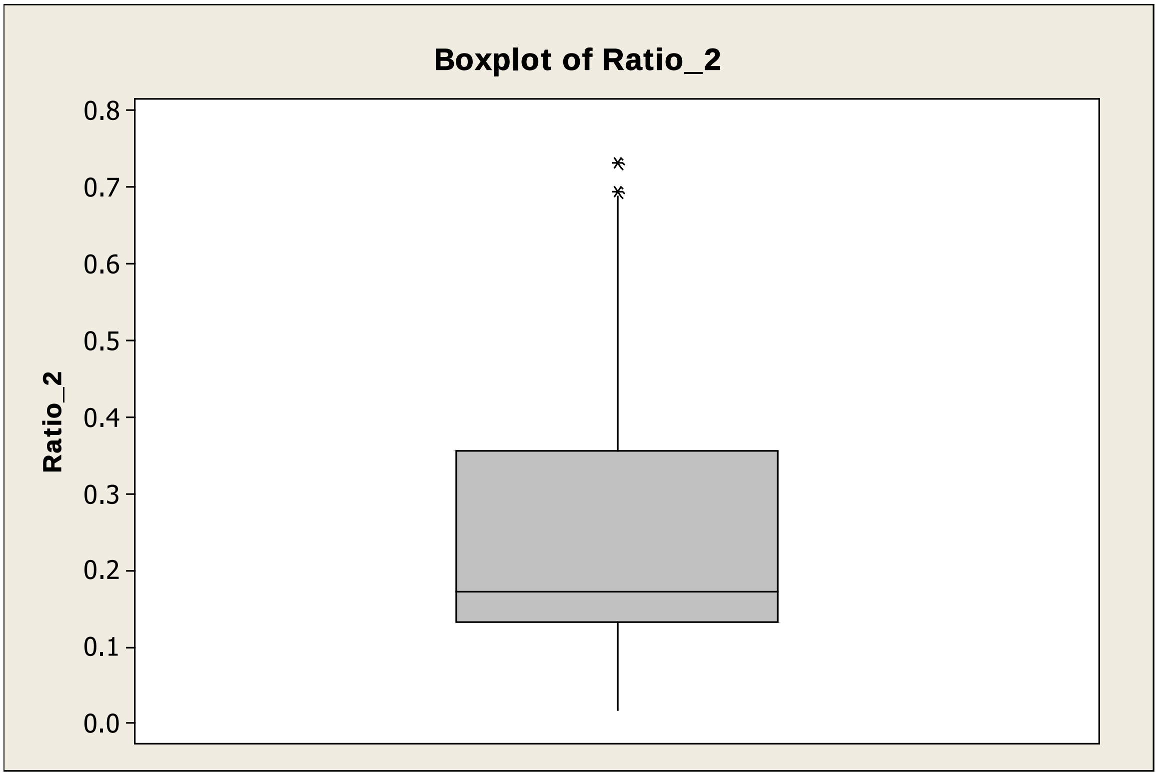


Figure 18.

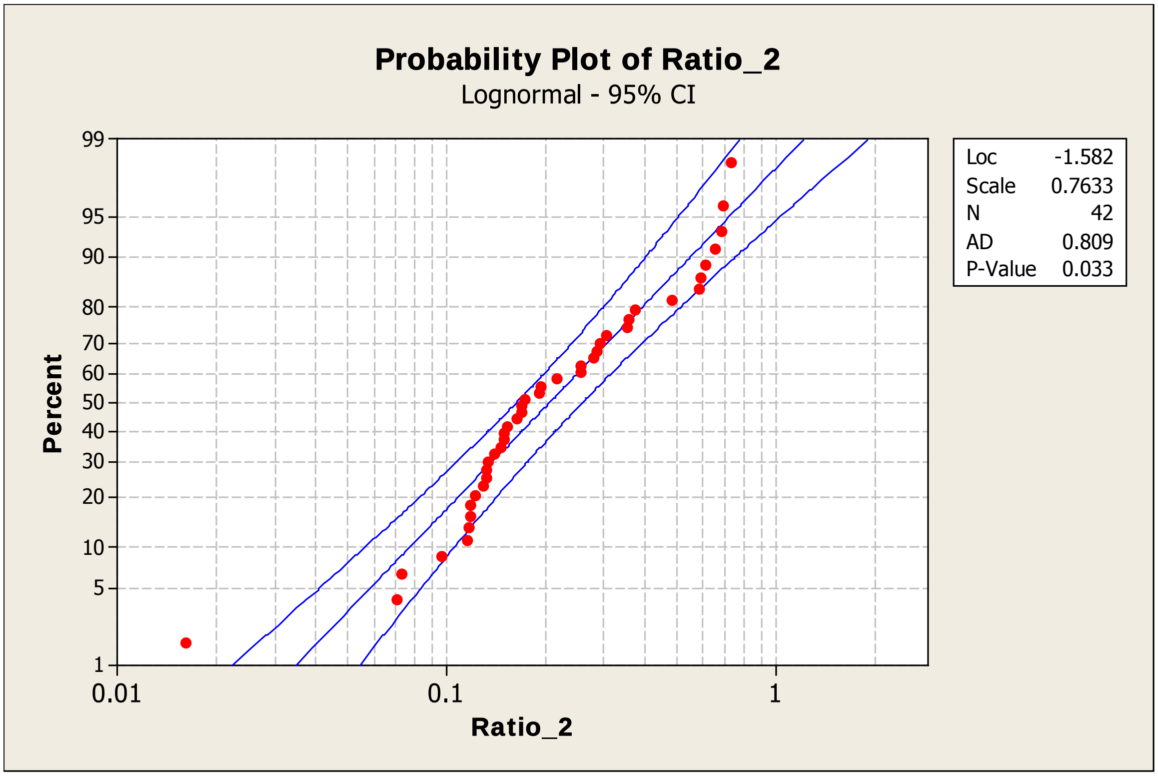


Figure 19.

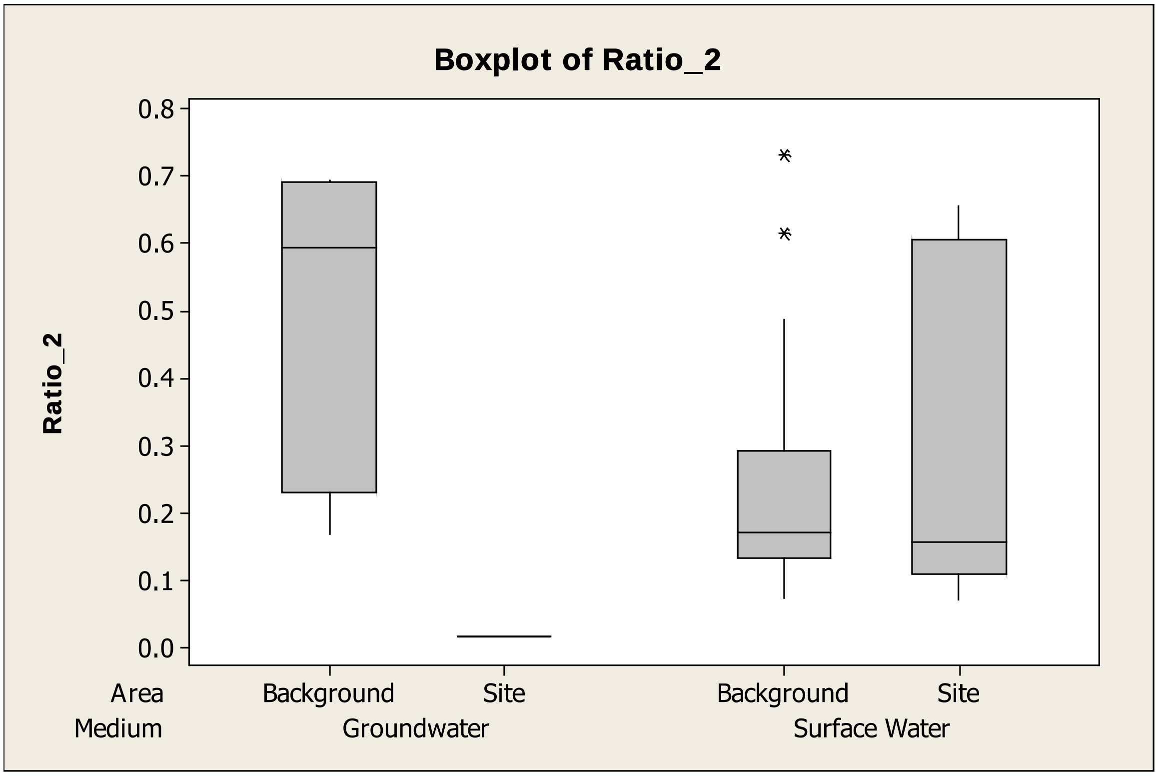
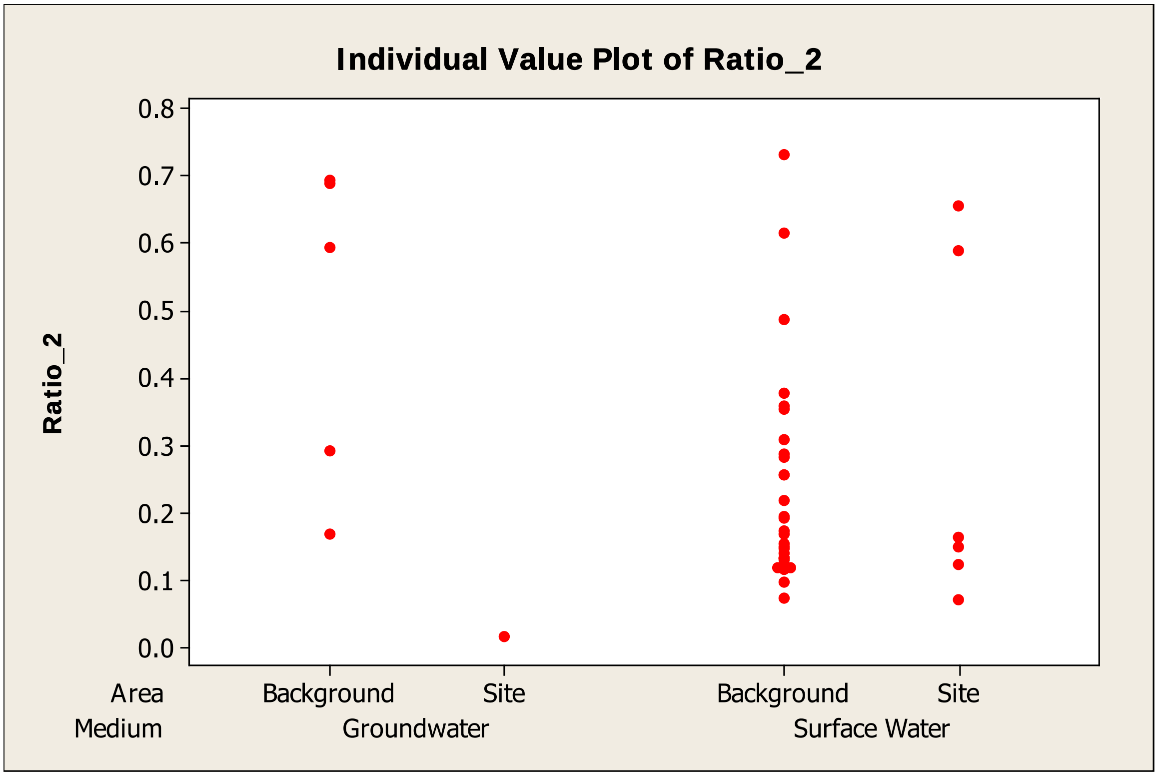


Figure 20.



Attachment 4

Electronic Communications

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From:	Wong, Chi-Wah (Oakland)
To:	"Georgian, Thomas CIV USARMY USACE (US)"
Cc:	MacEwan, Mark; Auld, Cynthia A CIV USARMY USACE (US)
Subject:	RE: Follow-up on Chromium Ratio Memo
Date:	Tuesday, February 06, 2018 11:04:00 AM

Hi Thomas,

Thanks again for your inputs on this, and I concur with your conclusions. I agree that those 2 "potential" outliers do not have strong weights of evidence to exclude them, and they could very well be part of a skewed distribution.

So, to sum up our discussion, there are the final ratios to be used by the risk assessors:

GW (both filtered and unfiltered) and SW: 0.3
Soil (both surface and subsurface): 0.073
Sediment: 0.25

For soil CrVI BTV, we will apply the ratio directly on the currently calculated BTV for total Cr.

I will revise/update the tech memo accordingly.

Again, thanks for your help on this. We all very much appreciate it!

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-----Original Message-----
From: Georgian, Thomas CIV USARMY USACE (US) [mailto:Thomas.Georgian@usace.army.mil]
Sent: Tuesday, February 06, 2018 5:00 AM
To: Wong, Chi-Wah (Oakland)
Cc: MacEwan, Mark; Auld, Cynthia A CIV USARMY USACE (US)
Subject: RE: Follow-up on Chromium Ratio Memo

The data sets were independently reviewed. The results are consist with all your conclusions.

1. The relationship between Cr and Cr(VI) is not strongly concentration dependent.

2. The background and site sediment ratios may be pooled.

3. The surface and subsurface soil ratios may be pooled.

4. There is a clear outlier for surface soil, where the ratio of hexavalent Cr to total Cr > 1. As the Cr(IV)/Cr ratio cannot be greater than one and this result heavily influences the calculation of the mean soil ratio, the outlier should be removed from the data set.

5. The box plots indicate there several potential lesser outliers for soil, but there did not appear to be adequate

evidence to remove them from the data sets. The soil results may appear as outliers in the box plots simply because the distribution is positively skewed. The scatter plot of Cr(IV) versus total Cr suggests there are two potential additional soil outliers and one potential sediment outliers, but there does appear to be a strong weight of evidence (e.g., a physical rationale) to remove the data points.

6. Therefore, the following mean ratios are recommended: 0.073 for soil and 0.25 for sediment

-----Original Message-----
From: Wong, Chi-Wah (Oakland) [mailto:chi-wah.wong@aecom.com]
Sent: Monday, February 05, 2018 7:34 PM
To: Georgian, Thomas CIV USARMY USACE (US) <Thomas.Georgian@usace.army.mil>
Cc: MacEwan, Mark <Mark.MacEwan@aecom.com>; Auld, Cynthia A CIV USARMY USACE (US) <Cynthia.A.Auld@usace.army.mil>
Subject: [Non-DoD Source] RE: Follow-up on Chromium Ratio Memo

Hi Thomas,

Attached is an Excel workbook which contains sediment and soil ratios revised results, plus various diagnostic plots. Here are some assessments for you to consider:

1. The "Ratio Calculation" worksheet contains all data (after duplicate averaged) used, which are not NDs and not J-values, for both total Cr and CrVI (i.e., all data are >LOQ).

2. There is a very clear outlier (last row in yellow), which should be excluded, as the detected CrVI concentration is 3 times higher than total Cr. There are 2 potential outliers (also shown in worksheet "Normal Prob Plot"), and I would like to seek your advice whether we should include or exclude them.

3. Worksheet "Scatterplot" -- The ratio is not strongly concentration dependent, and so it is appropriate to use.

4. Worksheet "Boxplot - Soil" -- Surface and subsurface soils could be combined.

5. Worksheet "Boxplot - Sediment" -- Background and site could be combined.

6. The "Ratio Summary" worksheet provides the final ratios to be used for sediment and soil. Again, I would like to hear your suggestion which one of the soil ratios we should use, as there are some differences.

Please let me know if you have any questions. As always, thanks again for your inputs and feedbacks!

Chi-Wah Wong
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AECOM and URS have joined together as one company.

-----Original Message-----
From: Georgian, Thomas CIV USARMY USACE (US) [mailto:Thomas.Georgian@usace.army.mil]
Sent: Monday, February 05, 2018 12:11 PM
To: Wong, Chi-Wah (Oakland)
Cc: MacEwan, Mark; Auld, Cynthia A CIV USARMY USACE (US)
Subject: RE: Follow-up on Chromium Ratio Memo

I would be pleased to review the additional information.

-----Original Message-----
From: Wong, Chi-Wah (Oakland) [mailto:chi-wah.wong@aecom.com]
Sent: Monday, February 05, 2018 1:50 PM
To: Auld, Cynthia A CIV USARMY USACE (US) <Cynthia.A.Auld@usace.army.mil>; Georgian, Thomas CIV USARMY USACE (US) <Thomas.Georgian@usace.army.mil>
Cc: MacEwan, Mark <Mark.MacEwan@aecom.com>
Subject: [Non-DoD Source] RE: Follow-up on Chromium Ratio Memo

Hi Thomas,

Thanks for giving such an in-depth look on this, and we really appreciate it!

I concur with your approach and recommendation. I also agree that given the J-estimated nature of reported concentrations, this is the best we could come up with for the aqueous chromium ratio. It is good news that the ratio is relatively insensitive to outliers, and the recommended ratio is very close to what we originally suggested in the tech memo. I will double-check the numbers, and if everything looks good, the final recommended ratio for GW and SW will be 0.3 (i.e., rounding 0.26 to one significant figure) for the risk assessors.

If you don't mind, I am planning to revise the soil ratio and send via email for your review/concurrence (but we will also formerly revise the tech memo at the end). Here are the key updates for soil:

1. Demonstrate the ratio is not strongly concentration dependent.
2. J-values will not be used (since we have enough samples).
3. Check surface and subsurface soil could be combined or not (but keep sediment separate).
4. One outlier needs to be remained excluded (because CrVI is 3 times higher than total Cr!).

Thanks again for all your help!

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chi-wah.wong@aecom.com

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AECOM and URS have joined together as one company.

-----Original Message-----
From: Auld, Cynthia A CIV USARMY USACE (US) [mailto:Cynthia.A.Auld@usace.army.mil]
Sent: Monday, February 05, 2018 7:16 AM
To: Georgian, Thomas CIV USARMY USACE (US); Wong, Chi-Wah (Oakland)
Cc: Goepfert, Gregory J CIV USARMY CENAN (US); Cullen, Megan E CIV USARMY CENAE (US); MacEwan, Mark
Subject: FW: Follow-up on Chromium Ratio Memo

Thanks Thomas.

Chi-Wah: Please review Thomas's evaluation of the Cr data and his recommendation. Then, let me know your thoughts about how Camp Hero should include & use the total Cr & CrVI data.

Thanks ~

Cynthia Auld
Human Health Risk Assessor
Cynthia.A.Auld@usace.army.mil

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US Army Corps of Engineers
New England District
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-----Original Message-----
From: Georgian, Thomas CIV USARMY USACE (US)
Sent: Monday, February 5, 2018 10:02 AM
To: Auld, Cynthia A CIV USARMY USACE (US) <Cynthia.A.Auld@usace.army.mil>; Wong, Chi-Wah (Oakland) <chi-wah.wong@aecom.com>
Subject: RE: Follow-up on Chromium Ratio Memo

I reviewed the hexavalent chromium (CrIV) and total chromium (Cr) results. Most of the results are J-qualified. There is concurrence removing them would result in insufficient data for statistical evaluations.

It appears all of the aqueous results can be pooled to calculate a mean ratio (CrIV/Cr). As the data sets are not normal (Figure 3), the Kruskal-Wallis test was used to compare the medians (Tables 2 and 3). The medians of the ratios for the surface and groundwater samples are not statistically different. Similarly, the medians of the ratios for the site and background data sets are not statistically different. If there are actual differences, the large variability and relatively small sample sizes preclude detecting them.

The mean ratio of all of the aqueous results is about 0.25. This distribution of ratios exhibits relatively large variability and is positively skewed (e.g., Figure 7), vaguely resembling a gamma distribution (Figure 10).

The scatter plot of CrIV versus Cr (Figure 12.1) suggests there are outliers in the data set. These paired values have unusually large total Cr concentrations, resulting in small CrIV/Cr ratios. With one exception these suspected outliers were for unfiltered results. Therefore, it is suspected the ratios do accurately reflect dissolved chromium species. Various combinations of the suspected outliers were removed or retained in the data sets. However, the mean ratio was relatively insensitive to the outliers. The mean ratio ranged from about 0.25 to 0.27, depending on which subset of suspected outliers are removed.

It is recommended a ratio of 0.26 (Table 4.1) be used for the aqueous samples; this is the mean ratio that is calculated after the two largest reported total unfiltered Cr concentrations are removed, resulting in a slightly more "conservative" estimate of the ratio. After multiplying the total Cr value with this result to obtain CrIV, the resulting product should probably be rounded to one significant figure owing to the uncertainty associated with estimating the total Cr mean and the ratio.

However, given the less-than-optimal quality of the data, if you have other thoughts Chi-Wah, please do not hesitate to share them.

-----Original Message-----
From: Auld, Cynthia A CIV USARMY USACE (US)
Sent: Friday, February 02, 2018 7:50 AM
To: Georgian, Thomas CIV USARMY USACE (US) <Thomas.Georgian@usace.army.mil>
Cc: Wong, Chi-Wah (Oakland) <chi-wah.wong@aecom.com>
Subject: FW: Follow-up on Chromium Ratio Memo

Hi Thomas,
Please see Chi-Wah's responses to your questions & plan below. Please let me know if you agree with the approach.

Thanks ~ Cindy

Cynthia Auld
Human Health Risk Assessor
Cynthia.A.Auld@usace.army.mil

GeoEnvironmental Branch
US Army Corps of Engineers
New England District
696 Virginia Road
Concord, MA 01742

(978) 318-8042
FAX: (978) 318-8663

-----Original Message-----
From: Wong, Chi-Wah (Oakland) [mailto:chi-wah.wong@aecom.com]
Sent: Thursday, February 1, 2018 3:20 PM
To: Auld, Cynthia A CIV USARMY USACE (US) <Cynthia.A.Auld@usace.army.mil>
Cc: Goepfert, Gregory J CIV USARMY CENAN (US) <Gregory.J.Goepfert@usace.army.mil>; MacEwan, Mark <Mark.MacEwan@aecom.com>
Subject: [Non-DoD Source] RE: Follow-up on Chromium Ratio Memo

Hi Thomas/Cindy,

Thanks for the quick and insightful response!

Per your request, attached you will find 2 spreadsheets -- One is the actual ratio calculation with total Cr and Cr VI side-by-side; and the second worksheet is the actual lab raw data, with the reported result, LOQ, LOD, and MDL in red font. Please note that there is one normal/duplicate pair for surface water. Only GW (total and dissolved) and SW (total) are shown, and only samples which are detected (including J values) for both total Cr and Cr VI are shown. Please let us know what your thoughts are.

For the second question about BTV, we will go with your suggestion to apply the ratio on the total Cr soil (surface and subsurface) BTV.

Thanks again for all your help and advice!!

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AECOM and URS have joined together as one company.

-----Original Message-----
From: Auld, Cynthia A CIV USARMY USACE (US) [mailto:Cynthia.A.Auld@usace.army.mil]

Sent: Thursday, February 01, 2018 4:49 AM
To: Wong, Chi-Wah (Oakland)
Cc: Goepfert, Gregory J CIV USARMY CENAN (US); MacEwan, Mark
Subject: FW: Follow-up on Chromium Ratio Memo

Hi Chi-Wah,
Please see Thomas's responses below & let me know if you would like to have a conference call or if his responses can easily bring us to resolution.

Thanks ~

Cynthia Auld
Human Health Risk Assessor
Cynthia.A.Auld@usace.army.mil

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New England District
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-----Original Message-----
From: Georgian, Thomas CIV USARMY USACE (US)
Sent: Wednesday, January 31, 2018 3:38 PM
To: Auld, Cynthia A CIV USARMY USACE (US) <Cynthia.A.Auld@usace.army.mil>
Subject: RE: Follow-up on Chromium Ratio Memo

Please see annotated comments.

-----Original Message-----
From: Auld, Cynthia A CIV USARMY USACE (US)
Sent: Wednesday, January 31, 2018 1:24 PM
To: Georgian, Thomas CIV USARMY USACE (US) <Thomas.Georgian@usace.army.mil>
Cc: MacEwan, Mark <Mark.MacEwan@aecom.com>; Wong, Chi-Wah (Oakland) <chi-wah.wong@aecom.com>; Goepfert, Gregory J CIV USARMY CENAN (US) <Gregory.J.Goepfert@usace.army.mil>
Subject: FW: Follow-up on Chromium Ratio Memo

** Read in html ***

Hi Thomas,

Our contractor has some follow-up questions (see below). Please let me know if you'd like us to set up a call to resolve these questions.

Thanks ~ Cindy

Cynthia Auld

Human Health Risk Assessor
Cynthia.A.Auld@usace.army.mil

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FAX: (978) 318-8663

-----Original Message-----

From: Wong, Chi-Wah (Oakland) [mailto:chi-wah.wong@aecom.com]
Sent: Wednesday, January 31, 2018 2:19 PM
To: Auld, Cynthia A CIV USARMY USACE (US) <Cynthia.A.Auld@usace.army.mil>
Cc: MacEwan, Mark <Mark.MacEwan@aecom.com>
Subject: [Non-DoD Source] Follow-up on Chromium Ratio Memo

Hi Cindy - We have some follow-up questions on the comments about chromium ratio. Might you please forward the following email to Thomas? If it is easier, I would be more than happy to give him a quick call to resolve it this week. Thanks!

Hi Thomas,

After reviewing the comments for the Chromium Ratio Memo, we have some follow-up questions and would like to seek your inputs. Per Comment #2:

T. Georgian Comment:
Assuming there is no concentration dependency, only results greater than the LOQs should be used to calculate the average ratios. Detections less than the LOQ are not quantitatively reliable.

AECOM Response:

If we only use data where both total chromium and chromium IV are above LOQ (i.e., not using J values below LOQ), then the sample sizes will be significantly reduced for GW and SW. (Note: All NDs are already excluded; that is, if either total chromium or chromium IV, or both, are NDs, the pairs are exluded.)

TG: Thank you for raising the concern. When making the comment I failed to not take into account the resulting small sample sizes for the chromium ratios. Can you send me a spreadsheet with the individual reported SW and GW results for total Cr and CrIV with the laboratory's DLs, LODs and LOQs (e.g., for the aqueous site and background samples)? It appears calculating the ratios using results < LOQs and subsequently rounding to only one significant figure may be the only viable option for the aqueous samples, given the data currently available. However, what is done to calculate the ratios for SW and GW need not be identical for what is done for soil and sediment. The sample sizes for soil and sediment would be adequate to use only results > LOQs for soil and sediment samples.

Media
No. of available chromium ratios, as presented in the Memo (i.e., including J values <LOQ, and detects above LOQ)
No. of available chromium ratios if only detects above LOQ are used

Groundwater (Filtered)
5
1

Groundwater (Unfiltered)
5
1
Sediment
15
15

Subsurface Soil
23

17
Surface Soil

37

33

Surface water

36

0

Here are some options for consideration:

Option 1: Keep data between MDL and LOQ, as presented in the Memo.

Option 2: Only use data where both total chromium and chromium IV are above LOQ. Effectively, we will not have a ratio for GW and SW (and it is not possible to test to see if we could pool them together, per Comment #6). For all site samples without chromium IV results, the risk assessors will assume all total chromium concentrations are chromium IV concentrations (the most conservative approach as chromium IV is the most toxic).

Option 3: "Borrow" chromium ratio from sediment and apply it to GW and SW?

Any other suggestions are welcome!

On a second and un-related topic, there is a need for surface and subsurface soil BTVs for chromium IV for the risk assessors to use. We did not collect chromium IV background data in the very early phase of this project. We are suggesting that once the chromium ratio is finalized/approved, we could apply the ratio to the surface and subsurface soil background total chromium data, and then calculate the BTVs (i.e., UTL95-95) for chromium IV. Do you concur with this approach? (Note: We already have background data and BTVs for chromium IV for groundwater, sediment, and surface water.)

TG: Concur with the proposed approach. However, assuming that BTVs for total Cr have already been calculated, wouldn't it be more convenient to simply multiply them the ratios of CrIV/total Cr, rather than multiplying the individual concentrations with the ratios and then calculating the BTVs for CrIV? Were the CrIV/total Cr ratios for the background results similar to the ratios for the site SW and GW results? Can the results be pooled?

As always, thanks again for your help and we very much appreciate and value your inputs and feedbacks.

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AECOM and URS have joined together as one company.

Appendix C3

Dissolved Metals Memo

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AECOM Any Task – Anywhere TIDEWATER INC

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Memorandum

Remedial Investigation, Feasibility Study, Proposed Plan and Decision Document

Camp Hero, Montauk, New York

Subject:	Data Gap From Phase III Field Event, Filtered Surface Water Samples for Dissolved Metals
Date:	11 October 2017
To:	Megan Cullen, U.S. Army Corps of Engineers (USACE) – New England District Greg Goepfert, USACE – New York District

Attachments:

- None

The following information is a summary of AECOM's proposed solution to a data gap that was recently identified for the surface water dataset collected during the Camp Hero Remedial Investigation (RI) Phase III field event, conducted from 30 May through 28 June 2017.

During the Phase III field effort, a sitewide network of 30 co-located background surface water and sediment samples were collected upstream of the decision units (DUs) to establish sitewide background levels for naturally-occurring constituents and anthropogenic impacts. Additionally, a sitewide network of 125 co-located surface water and sediment samples were collected from exposure areas in the vicinity of DUs for assessment of potential impacts from DU constituents that could potentially impact downgradient surface water and sediment. A total of 148 unfiltered and 30 filtered surface water samples were collected during the Phase III event (inclusive of the sitewide background locations). Surface water could not be collected at 7 of the 155 locations because they were dry at the time of sampling.

Filtered surface water samples were collected when the turbidity of the surface water was generally greater than 10 nephelometric turbidity units (NTUs). Although the Phase III Sampling and Analysis Plan (SAP) established that filtered samples would only be collected for organic parameter groups (SVOCs, PAHs, PCBs) in surface water if the turbidity was elevated (>10 NTU), the SAP inferred that filtered surface water samples were to be collected for dissolved metals analysis regardless of the turbidity. Due to a misinterpretation of the SAP, filtered surface water samples (in addition to unfiltered samples) were generally only collected when the turbidity was elevated (>10 NTU). A few exceptions to this rule included some locations where the field team thought the field turbidity meter was not working properly, thus erred on the side of caution by filtering, and at locations CH-SWSD150 through CH-SWSD155, where samples were collected by wading into the pond and were filtered due to do the potential for stirring up sediment in the pond during collection. Due to these exceptions, field-filtered surface water locations were collected at eight locations where the NTUs were less than 10.

This potential data gap was identified by AECOM's ecological risk assessor during initial Phase III data review as filtered surface water data for dissolved metals at some surface water sampling locations could be beneficial in the evaluation of impacts to aquatic life in the ecological risk assessment (ERA). Dissolved metals more closely approximate the bioavailable fraction of metals in the water column than do total recoverable metals, and regulatory-based freshwater screening criteria for metals are often expressed in terms of the dissolved metals in the water column. Evaluating only total recoverable metals in the water column may result in an overestimate of risks to aquatic life.

After identifying the data gap, the AECOM team has initiated a solution to obtain the filtered surface water dataset for metals except for mercury and hexavalent chromium. It was determined that the laboratory (Eurofins Lancaster Laboratories Environmental, LLC; Lancaster. PA) had additional sample volume (unpreserved) on hold for all 148 surface water locations. The 197 surface water samples were kept in cold storage in amber bottles since the Phase III field event. The laboratory has been instructed to filter the 197 surface water samples through a 0.45 µm, acidify, and analyze dissolved metals (6020A) on an expedited two-week turn-around-time. Included in the 197 samples are all 148 surface water locations, 30 field-filtered locations, and 19 field duplicate locations. All 197 samples will be analyzed for the Phase III SAP metals list minus mercury and hexavalent chromium. The field filtered and lab filtered results will be used to assess the comparability of results. Surface water samples are out of hold for both filtration and total metals analysis. Biological activity can occur under cool conditions in an amber bottle and will be discussed in the ERA. However, we do not anticipate that the metals sample results from the 30 surface water samples filtered in the field to be statistically different to those filtered in the laboratory 100 days later.

The AECOM chemists will flag the new metals data “J” and “UJ” for detected and non-detected results, respectively indicating that these lab-filtered results are estimated values. If the original results were nondetects and the lab-filtered results were detected, the AECOM chemists will reject (“R” flag) those results. This flagging scheme was discussed with the USACE Chemist and is based on a comparison assessment between the lab-filtered results and the original metals results. The validated surface water data will be included in the surface water data set for the ERA; however, based on the USACE Chemist’s recommendation, the lab-filtered data will only be considered qualitatively. Any potential data gaps related to this approach will be discussed in the uncertainties section of the ERA.

Appendix C4

Uncensored Data Memo

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Memorandum – Uncensored Data Analysis

Remedial Investigation, Feasibility Study, Proposed Plan and Decision Document

Camp Hero, Montauk, New York

Subject:	Uncensored Data Analysis
Date:	17 January 2018
To:	Megan Cullen, U.S. Army Corps of Engineers (USACE) – New England District Greg Goepfert, USACE – New York District

Attachments:

- Uncensored Data Tables (Excel)
- Table 1 – Uncensored Sediment Background Threshold Value Analysis

During the development of the Camp Hero Phase III Sampling and Analysis Plan, it was suggested by USACE Centers of Expertise Omaha District (CX) to consider the use of “uncensored” background metals data to calculate background threshold values (BTVs). Specifically, Mr. Thomas Georgian of the CX provided the following questions related to his Question #34 (dated May 2016):

1. What was the overall percentage of metals with results reported below the detection limit (DL)?
2. Did beryllium, thallium, and arsenic have reported values below the DL? If so, what percentage?
3. For metals, were there any negative values reported for uncensored data?

As a result of this request, it was agreed that AECOM would provide the following information (per our email from Mr. MacEwan to Ms. Cullen dated 22 September 2017):

- Review the current data (censored) in EQuIS to provide answers to Mr. Georgian’s questions #1 and #2.
- Obtain the uncensored data from our laboratory (Eurofins- Lancaster).
- Have the lab submit the uncensored data as a raw data dump.
- Request background data (uncensored) from the lab as a priority.
- Request the data in format that could eventually be inputted into our EQuIS database.
- The validation flags from the censored data will be added to the uncensored data for reference.
- Review the uncensored data to provide a count on how many negative (and zero) values there are to answer Mr. Georgian’s question #3.
- Report back to USACE on all of the above in addition to any other general trends that are observed. Follow-on work including the actual calculation of BTVs using uncensored data can be discussed at that time.

Since September 2017 and as provided in more detail below, AECOM has reviewed the uncensored data from the Phase III field effort to provide a count on the number of negative (and zero) values. We have taken the analysis a step further by calculating BTVs using the uncensored data for one representative media (sediment) and then completed a comparison of the BTVs (censored and uncensored) for two metals to the rest of the sediment data to determine how much of an impact there would be to using uncensored data BTVs. Based on this analysis and in consideration of current EPA methodology, AECOM does not recommend using uncensored data in the decision making processes within the Remedial Investigation Report for the following reasons:

1. Stakeholder acceptance of using uncensored data to support risk assessment decisions would require significant outreach due to anticipated unfamiliarity with the use of this type of data. Use of uncensored data in risk assessments is not a standard approach in EPA guidance documents.

2. If uncensored data were used, stakeholders would likely require or expect a consistent approach to calculate BTVs (use data sets with censored values, or use data sets with uncensored data, for all media). However, for this project, uncensored data were not available from the laboratory for soil background samples previously collected in the Phase I event.
3. The use of uncensored data derived BTVs would have limited use or differences for screening out any metals per decision unit because:
    a. The uncensored data BTVs that were calculated were well within the same order of magnitude of the censored data BTVs, sometimes down to the third significant figure, so there would not be significant value to screening with uncensored data BTVs.
    b. The use of the higher uncensored sediment data BTVs for beryllium and selenium (as opposed to the censored sediment data BTVs) only resulted in the screening out of three additional data points (one for beryllium and two for selenium). However, it would not eliminate the need altogether to consider these two metals in sediment during the risk assessment process since these two metals exceed the uncensored data BTVs at multiple other locations.
    c. Most analytes are either "100% detected" or "100% below the LOQs" in various media and therefore will not be affected by uncensored data. Only a few analytes will be affected if uncensored data are used.
    d. Based the AECOM statistician’s review of the uncensored data for the groundwater and surface water background data sets, it is likely that the uncensored data BTVs could be both higher and lower than the censored data BTVs. The Department of Defense cannot choose the higher BTV in order to benefit the overall analysis of data to BTVs.

Additional details related to this analysis are provided below.

Discussion Items Related to Overall Uncensored Data Analysis

1. An Excel spreadsheet is attached to this memo that provides the complete set of uncensored data in the first tab EXCEPT for the cases where the respective sample values were rejected during the validation process. The second tab provides the background data, and the third tab provides the overall statistics for the complete uncensored data sets and for three metals (beryllium, arsenic, and thallium) which were specifically referenced by Mr. Thomas Georgian of the USACE Omaha District during a Technical Project Planning session where uncensored data was discussed prior to the completion of the Phase III Sampling and Analysis Plan.
2. There are approximately 0 to 23% of non-detect data which have a zero or negative value if uncensored data are considered (see column “E” of the “Analysis of Results” tab in the attached Excel file). Previously, it was suggested that the Camp Hero team should not be too worried about zero or negative values unless they are indeed present. The uncensored data obtained from the laboratory, however, do contain zero and negative values, particularly for groundwater samples (19%) in the total data and sediment (23%) in the background only data set.
3. There are very few negative values in the uncensored data for the three metals that Mr. Georgian requested to be reviewed, except for thallium in groundwater (6%) and surface water (9%) samples. It should be noted a data set with negative values (as well as zero values) could not be statistically evaluated using gamma and lognormal distributions, which are the two most commonly used statistical data transformation methods for evaluating environmental data.

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Memorandum – Uncensored Data Analysis

Remedial Investigation, Feasibility Study, Proposed Plan and Decision Document

Camp Hero, Montauk, New York

AECOM has conducted preliminary statistical calculations on the impacts of using uncensored data to background threshold values (BTVs). Sediment data was used for these calculations as the detection frequency pattern for metals is quite similar between the different media (see the fourth tab "Background Detection Rates" of the Excel file); thus, we selected sediment data as the test run to demonstrate the uncensored data effect. In general, most metals follow one these two detection frequency patterns:

- 100% detected (i.e., no censored data; all data were reported as detects, including "J" values and detects above the limit of quantitation [LOQ]), or

- 100% below the limit of quantitation [LOQ] (i.e., all data were either "J" values or censored values, or both)

If a metal background data set follows one of the above detection frequency patterns, then the use of uncensored data will not affect the BTV calculation. As shown in the Excel file, only very few metals will be affected if uncensored data were to be used.

Discussion Items Related to Impacts to BTVs:

1. **Table 1** summarizes the current draft BTVs calculated for the background sediment data set using censored data collected during the Phase III investigation. There was a total of 25 metals and essential nutrients, and of which, some of them showed significant differences between revetted and non-revetted areas, and thus, two BTVs were derived for these analytes. As such, there was a total of 28 background data sets and BTVs.
2. Of these 28 background data sets, 18 of them were 100% detected (i.e., no nondetect results), and thus, there were no uncensored data for them. Two addition data sets were over 85% detected, so the impact to BTVs of using uncensored data would be limited to one or two out of 30 values. Please see the "Background Detection Rates" tab columns "T" through "Y" in the attached Excel spreadsheet as well as Table 1. Specifically, for the sediment background data sets of beryllium (97% detected) and selenium (93% detected), the BTVs changed from 1.303 mg/kg to 1.359 mg/kg, and from 3.195 mg/kg to 3.755 mg/kg, respectively, from using censored data versus using uncensored data. A review of the background sediment data for both the censored and uncensored data for selenium and beryllium resulted in the following (actual data is provided in the "BTV Comparison" tab of the attached Excel spreadsheet:

Constituent	# of results exceeding the censored data BTV	# of results exceeding the uncensored data BTV
Beryllium	17 out of 125 results	16 out of 125 results
Selenium	4 out of 125 results	2 out of 125 results

   Based on the results from these two constituents, the use of the uncensored data BTV would result in one to two locations being screened out related to background.

3. Three data sets (antimony, mercury, and silver) were not detected above the (LOQ) for the sediment background data set, and therefore, the BTVs would set to the LOQ, and the use of uncensored data would not have any impact on the BTV.
4. Of the five remaining data sets, where the detection frequency is between 33% and 73%, the uncensored data were used to calculate a second set of sediment BTVs, to compare to the original BTVs using censored data. Two data sets (Chromium VI of both revetted and non-

revetted areas) contained uncensored data which had many zero values. As such, two commonly used distributional assumptions, gamma and lognormal, could not be employed and their BTVs were rendered to the non-parametric assumption, for which the BTV was set to the highest value and the potential benefits of using statistical parametric models (i.e., assessing the entire data set as a defined, continuous distribution) were not available. For the three remaining data sets (cadmium revetted and non-revetted, and thallium), the BTVs derived from censored and uncensored data were within the same order of magnitude and were different from each other as follows:

- Thallium – uncensored upper tolerance limit (UTL) was 9% higher than with the censored data.
- Cadmium (non-revetted) – uncensored UTL was 41% higher than with the censored data.
- Cadmium (revetted) – uncensored UTL was 5% higher than with the censored data.

It should be noted that over 90% of the data for these three data sets were reported below the LOQ.

Table 1: Uncensored Sediment Data Background Threshold Value Analysis

Use Censored Data										**Use Uncensored Data**			
Analyte	**Location**	**No. of Samples (n)**	**Percent Detects (%)**	**Percent NDs (%)**	**Percent Results < LOQ (%)**	**Max Detect (mg/kg)**	**Goodness-of-Fit Test Results (5% Significance Level)**	**Upper Tolerance Limit (UTL) (mg/kg)**	**UTL Method**	**No. of Zero or Negative Values**	**Goodness-of-Fit Test Results (5% Significance Level)**	**Upper Tolerance Limit (UTL) (mg/kg)**	**Notes**
Metals													
aluminum	all	30	100%	0%	0%	17300	gamma	18860	95% WH Approx. Gamma UTL with 95% Coverage	0			100% Detected
antimony	all	30	20%	80%	100%	0.57	normal	<0.294 - <2.24	Sample LOQ	1			All Samples < LOQ
arsenic	all	30	100%	0%	47%	20.9	lognormal	10.13	95% UTL with 95% Coverage	0			100% Detected
barium	all	30	100%	0%	0%	112	gamma	107.8	95% WH Approx. Gamma UTL with 95% Coverage	0			100% Detected
beryllium	all	30	97%	3%	57%	1.2	gamma	1.303	95% Approx. Gamma UTL with 95% Coverage (KM, WH)	0	Gamma	1.359	>85% Detected
cadmium	not revetted	15	67%	33%	93%	0.3125	non-parametric	0.313	95% UTL with 95% Coverage	0	Gamma	0.528	
cadmium	revetted	15	73%	27%	93%	0.983	gamma	1.115	95% Approx. Gamma UTL with 95% Coverage (KM, WH)	0	Gamma	1.365	
chromium	all	30	100%	0%	0%	19.4	gamma	20.09	95% WH Approx. Gamma UTL with 95% Coverage	0			100% Detected
chromium(iii), insoluble salts	all	30	100%	0%	0%	19.4	gamma	19.23	95% WH Approx. Gamma UTL with 95% Coverage	0			100% Detected
chromium(vi)	not revetted	15	33%	67%	73%	1.1	normal	1.277	95% UTL 95% Coverage (KM)	10	Non-parametric	1.1	Many zero values
chromium(vi)	revetted	15	33%	67%	67%	3.5	normal	3.322	95% UTL 95% Coverage (KM)	10	Non-parametric	3.5	Many zero values
cobalt	all	30	100%	0%	7%	5.86	normal	5.292	95% UTL with 95% Coverage	0			100% Detected
copper	all	30	100%	0%	3%	21.1	lognormal	33.48	95% UTL with 95% Coverage	0			100% Detected
iron (fe)	all	30	100%	0%	0%	27500	gamma	18145	95% WH Approx. Gamma UTL with 95% Coverage	0			100% Detected
lead	all	30	100%	0%	0%	49.45	lognormal	62.78	95% UTL with 95% Coverage	0			100% Detected
manganese (mn)	all	30	100%	0%	0%	147	lognormal	192.3	95% UTL with 95% Coverage	0			100% Detected
mercury	all	30	50%	50%	100%	0.21	lognormal	<0.109 - <0.579	Sample LOQ	1			All Samples < LOQ
nickel	all	30	100%	0%	10%	13.4	gamma	13.66	95% WH Approx. Gamma UTL with 95% Coverage	0			100% Detected
selenium	all	30	93%	7%	90%	1.77	lognormal	3.195	95% KM UTL (Lognormal) 95% Coverage	0	Lognormal	3.755	>85% Detected
silver	all	30	33%	67%	100%	0.171	normal	<0.147 - <1.12	Sample LOQ	0			All Samples < LOQ
thallium	all	30	67%	33%	90%	0.571	lognormal	0.338	95% KM UTL (Lognormal) 95% Coverage	0	Gamma	0.37	
vanadium	all	30	100%	0%	0%	34.9	gamma	40.6	95% WH Approx. Gamma UTL with 95% Coverage	0			100% Detected
zinc	all	30	100%	0%	17%	181.5	lognormal	122.3	95% UTL with 95% Coverage	0			100% Detected
Essential Nutrients													
calcium (ca)	all	30	100%	0%	0%	4525	lognormal	3514	95% UTL with 95% Coverage	0			100% Detected
magnesium (mg)	all	30	100%	0%	0%	3160	gamma	2621	95% WH Approx. Gamma UTL with 95% Coverage	0			100% Detected
potassium (k)	all	30	100%	0%	0%	2190	gamma	1453	95% WH Approx. Gamma UTL with 95% Coverage	0			100% Detected
sodium (na)	not revetted	15	100%	0%	20%	202	normal	262	95% UTL with 95% Coverage	0			100% Detected
sodium (na)	revetted	15	100%	0%	27%	718	gamma	1033	95% WH Approx. Gamma UTL with 95% Coverage	0			100% Detected

Appendix C5

Additional Characterization of PAHs

TABLE OF CONTENTS

LIST OF ATTACHMENTS

TABLES

FIGURES

ACRONYMS AND ABBREVIATIONS

AN	anthracene
AOC	Area of Concern
AST	aboveground storage tank
BaP	benzo(a)pyrene
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COPC	chemical of potential concern
DERP	Defense Environmental Restoration Program
DU	decision unit
EMCX	Environmental and Munitions Center of Expertise
EPC	exposure point concentration
ERA	Ecological Risk Assessment
FL	fluoranthene
FUDS	Formerly Used Defense Site
HHRA	Human Health Risk Assessment
HI	hazard index
HMW	high molecular weight
LMW	low molecular weight
LNAPL	light non-aqueous phase liquid
LOD	limit of detection
LOQ	limit of quantitation
mg/kg	milligram per kilogram
ND	non-detect
NYSOPRHP	New York State Office of Parks, Recreation and Historic Preservation
PAH	polycyclic aromatic hydrocarbon
PAST	PAleontological Statistics
PH	phenanthrene
PSE	preliminary screening evaluation
PY	pyrene

RI	Remedial Investigation
SEA	stream exposure area
UCL	upper confidence limit
UCM	unresolved complex mixture
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
UST	underground storage tank
WDS	waste disposal system

EXECUTIVE SUMMARY

Additional characterization of polycyclic aromatic hydrocarbons (PAHs) was performed for PAHs that may pose potential risks to human and ecological receptors based on the risk assessments conducted as part of the Camp Hero Remedial Investigation (RI). The RI was completed under the Defense Environmental Restoration Program (DERP) for Formerly Used Defense Sites (FUDS) for Hazardous, Toxic, and Radioactive Waste, Project Number C02NY002403. The work was conducted under the DERP FUDS program and is compliant with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process, as amended by the Superfund Amendments and Reauthorization Act of 1986. The risk assessments indicated that PAHs may pose potential risks to human and ecological receptors in surface soil at decision units (DUs) DU11 and DU12 and in sediment at stream exposure areas (SEAs) SEA03 and SEA08. Further evaluation was conducted and presented in this Appendix to verify whether the PAH concentrations in surface soil and sediment were indicative of CERCLA release[1]. This evaluation was conducted in coordination with the United States Army Corps of Engineers (USACE) New England District, New York District, and Environmental and Munitions Center of Expertise (EMCX).

The additional characterization of PAHs was conducted as part of the uncertainty evaluation process of the human health risk assessment (HHRA) and ecological risk assessment (ERA). The evaluation was based on multiple lines of evidence. For all areas, these lines of evidence included reviewing the spatial distribution of PAHs, the site history, and the risk assessment assumptions. As needed, additional lines of evidence included conducting background comparisons based on a refined classification of revetments for sediment locations, calculating relevant PAH ratios, using statistical methods that included scatterplots, box-and-whisker plots, and cross-plots to evaluate/compare the proportions of PAHs based on petrogenic and pyrogenic sources, and conducting a visual review of laboratory chromatograms.

The results of this evaluation indicated that PAHs in surface soil at DU11 were influenced by elevated concentrations of PAHs in a single surface soil sample. Based on the distribution of the data and other site-specific uncertainties identified in the HHRA and ERA, benzo(a)pyrene and other PAHs in surface soil of DU11 were not retained for further evaluation in the HHRA and ERA. As another line of evidence, the ratios of several key PAHs for the referenced DU11 surface soil sample exhibit a pyrogenic signature, which indicates that it is not a CERCLA related release. The results

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[1] A CERCLA release can be defined broadly to include a situation where a hazardous substance escapes into the environment from its normal container. A CERCLA release, as used in the context of this RI, means any Department of Defense activities that may have resulted in "spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing into the environment (including the abandonment or discarding of barrels, containers, and other closed receptacles containing any hazardous substance or pollutant or contaminant)" (CERCLA § 101(22)).

of this evaluation also indicated that PAHs in surface soil at DU12 and in sediment at SEA03 and SEA08 could not be attributed to a CERCLA release.

At DU12, the lines of evidence indicated that PAHs in surface soil could not be attributed to a CERCLA release. The elevated PAH concentrations at DU12 were likely attributed to non-point sources such as vehicle exhaust and emissions, weathering of asphalt roads and tires, coal tar (potentially used as roadway seal coating), and ongoing road maintenance (i.e., Coast Artillery Road runs through the middle of DU12). The statistical and graphical review of PAH ratios and the laboratory chromatograms indicated that the PAHs were attributed to pyrogenic sources.

At SEA03 and SEA08, the lines of evidence indicated that PAHs in sediment could not be attributed to a CERCLA release. A statistical background comparison confirmed that the PAHs in the revetted portions of SEA03 and SEA08 were likely associated with the presence of the revetments. In addition, the statistical evaluation of PAH ratios for the SEA03 and SEA08 samples and the background samples showed that all datasets were dominated by pyrogenic PAHs and likely to be influenced by urban background contributions rather than point sources.

1.0 INTRODUCTION

Camp Hero is a Formerly Used Defense Site (FUDS) undergoing a Remedial Investigation (RI) that is being submitted on behalf of the United States Army Corps of Engineers (USACE) for the former Camp Hero (the site) located in Montauk, New York. This RI was completed under the Defense Environmental Restoration Program (DERP) for Formerly Used Defense Sites (FUDS) for Hazardous, Toxic, and Radioactive Waste, Project Number C02NY002403. Work conducted under the DERP FUDS program is compliant with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process, as amended by the Superfund Amendments and Reauthorization Act of 1986. The primary objective of RI was to determine the nature and extent of potential impacts in site media from former military operations, and to subsequently quantify whether unacceptable risks are posed to human or ecological receptors associated with these impacts. The RI program for Camp Hero is being conducted by the AECOM–Tidewater Joint Venture, in coordination with the USACE New England District, New York District, and the Environmental and Munitions Center of Expertise (EMCX).

Camp Hero State Park is located on the eastern tip of the south fork of Long Island, New York, approximately 5 miles east of the village of Montauk. The former Camp Hero was established in early 1942 as a Coastal Defense Installation, and the facility changed ownership within the military multiple times over the course of the following decades. Site lands were transferred to state, local, and other federal agencies between 1974 and 1984, and the facility was permanently closed in 1982. The area is now used as Camp Hero State Park, which is owned by the State of New York and operated under the jurisdiction of the New York State Office of Parks, Recreation and Historic Preservation.

Former Department of Defense activities at Camp Hero may have resulted in contaminated material or an environmental release from these materials. Three phases (Phase I, Phase II, and Phase III) of field investigation were conducted to evaluate potential environmental impacts. Prior to the Phase I investigation, a historical records review identified 47 Areas of Concern (AOCs) at Camp Hero. The AOCs included former waste disposal areas, former coal storage areas, abandoned drum locations, portions of an abandoned sitewide sanitary waste disposal system (WDS), possible and former aboveground storage tanks (ASTs) and underground storage tanks (USTs), and a Motor Pool building, among others. The AOCs were investigated during the Phase I and II field investigations at Camp Hero. A preliminary screening evaluation was completed after Phase II to determine which AOCs required further assessment. AOCs warranting further assessment were grouped into 18 decision units (DUs) and eight stream exposure areas (SEAs) for the Phase III RI field investigation.

This appendix documents the additional characterization of PAHs evaluation that was conducted to support the risk assessment uncertainty evaluations. The risk assessments conducted as part of the Camp Hero RI identified the potential for risk due to exposure to PAHs at DU11, DU12, SEA03, and SEA08. Therefore, further evaluations were conducted to assess whether the PAH concentrations in surface soil and sediment at these areas could be attributed to non-CERCLA sources.

1.1 Scope and Objectives

The primary objective of the additional PAH characterization was to determine whether PAH concentrations in surface soil at DU11 and DU12 and sediment at SEA03 and SEA08 could be attributed to non-CERCLA sources. Potential risks to human or ecological receptors were identified due to exposure to PAHs in these areas. As detailed in the human health risk assessment (HHRA; Appendix M of the RI Report) and ecological risk assessment (ERA; Appendix N of the RI Report), PAHs deemed to be attributed to non-CERCLA sources based on this evaluation were eliminated from further evaluation.

1.2 Appendix Organization

This appendix is organized into the following sections:

- Section 1.0: Introduction – Describes the purpose of the Additional Characterization of PAHs, including the scope and objectives.

- Section 2.0: Uncertainty Assessment Summary – Briefly summarizes the key issues identified in the uncertainty assessments of the HHRA and ERA that pertain to PAHs in surface soil at DU11 and DU12 and sediment at SEA03 and SEA08.

- Section 3.0: General Approach and Rationale –Provides a description of the general approach and rationale of the methods used to characterize PAHs in surface soil at DU11 and DU12 and sediment at SEA03 and SEA08.

- Section 4.0: Data Handling – Describes the background and site datasets used in the Additional Characterization of PAHs and how they were used to perform the evaluation. This section includes the processes used to handle duplicates and censored data.

- Section 5.0: Additional Background Comparison for Sediment – Describes additional background comparisons using hypothesis testing and box-and-whisker plots for SEA03 and SEA08, based on the sample-by-sample designation of revetted and non-revetted locations.

- Section 6.0: Approaches for PAH Source Classification – Describes the methodology for calculation of PAH ratios and the statistical methods used to evaluate the PAH ratios, including scatterplots, cross-plots, and proportions of PAHs based on petrogenic and pyrogenic sources. A brief discussion of the results is also included.

- Section 7.0: Evaluation of PAH Chromatograms – Describes the visual review of laboratory chromatograms for selected DU12 samples.
- Section 8.0: Results and Discussion – Summarizes the outcome of the Additional Characterization of PAHs for each DU/SEA.

The following attachments are included in this evaluation:

- **Attachment A** contains the references for the Additional Characterization of PAHs.
- **Attachment B** contains the statistical results for the Additional Background Comparison for Sediment.
- **Attachment C** contains the box-and-whisker plots for the Additional Background Comparison for Sediment.
- **Attachment D** contains the PAleontological STatistics (PAST), Version 3.13, statistical output files for the Additional Background Comparison for Sediment (Hammer, 2016; Hammer et al., 2001).
- **Attachment E** contains the scatterplots, with linear regression lines, of phenanthrene versus anthracene and fluoranthene versus pyrene, for surface soil and sediment. These plots were included as a line of evidence in the PAH source classification evaluation.
- **Attachment F** contains the box-and-whisker plots of phenanthrene to anthracene (PH/AN) and fluoranthene to pyrene (FL/PY) ratios, with statistical comparison test results, for surface soil and sediment. These plots were included as a line of evidence in the PAH source classification evaluation.
- **Attachment G** contains the cross-plots of the PH/AN and FL/PY ratios for surface soil and sediment. These plots were included as a line of evidence in the PAH source classification evaluation.
- **Attachment H** contains the PAH chromatograms generated for select DU12 surface soil samples which were evaluation for petrogenic and pyrogenic source signatures. A chromatogram for one DU01 sample, which was expected to have petrogenic source impacts, was included for comparison purposes.

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2.0 UNCERTAINTY ASSESSMENT SUMMARY

This Section briefly summarizes the key issues identified in the uncertainty assessments of the HHRA and ERA that pertain to PAHs in surface soil at DU11 and DU12 and sediment at SEA03 and SEA08.

2.1 DU11

The HHRA and ERA identified the following key points for PAHs in surface soil at DU11:

- The Camp Hero background evaluation (Appendix L1 of the RI Report) identified concentrations of PAHs [e.g., benzo(a)pyrene, total low molecular weight (LMW) PAHs, and total high molecular weight (HMW) PAHs] in surface soil as being above background concentrations.

- The surface soil exposure point concentrations (EPCs) for PAHs used in the risk assessments were influenced by elevated concentrations in a single surface soil sample from location DU11-S003. As an example, the benzo(a)pyrene concentration in the surface soil sample from DU11-S003 is 180 mg/kg and the remaining surface soil detections for benzo(a)pyrene ranged from 0.031 mg/kg to 1.7 mg/kg (**Figure 1**). The benzo(a)pyrene EPC [based on the upper confidence limit (UCL) of the mean concentration] was 123.3 milligrams per kilogram (mg/kg), which is well above the majority of the measured concentrations.

The HHRA identified the following key points:

- DU11 is a wooded area with dense vegetation that is generally inaccessible to the public. The New York State Office of Parks, Recreation and Historic Preservation (NYSOPRHP) has no plans for developing areas at or near DU11 for future camping grounds or hiking trails.

- Benzo(a)pyrene in surface soil was identified as a risk driver for the future on-site construction worker at DU11; however, the likelihood of an on-site construction worker spending 125 days out of the year for 8 hours each day at the DU11-S003 sample location would be quite low. Since NYSOPRHP has no plans for future development at DU11, the future on-site construction worker scenario is unlikely.

- The HHRA also examined the Phase I biased subsurface soil data because the future on-site construction worker is more apt to be exposed to total soil (0 to 10 feet below ground surface) while excavating the area for future land redevelopment. The Phase I biased subsurface soil sample concentrations of benzo(a)pyrene ranged from 0.00071 mg/kg to 7 mg/kg. The preliminary screening evaluation (PSE) did not identify any subsurface soil chemicals of potential concern (COPCs) for DU11 and therefore subsurface soil was not evaluated in the Phase III investigation.

- The maximum subsurface soil concentration of 7 mg/kg benzo(a)pyrene was used to estimate risk to the on-site construction worker in combination with groundwater and sediment media at DU11; the cumulative non-cancer hazard index (HI) was 0.3 which was below the United States Environmental Protection Agency (USEPA) threshold of 1.

- Also, chronic toxicity values for benzo(a)pyrene were used to estimate non-cancer health effects because subchronic toxicity values were not available.

- The HHRA uncertainty assessment concluded, based on the lines of evidence presented above, that the non-cancer cumulative HI of 3 for the future on-site construction worker at DU11 was likely overestimated.

The ERA identified the following key points:

- The potential for risks to plants, soil invertebrates, birds, and mammals due to exposure to PAHs in DU11 surface soil was identified in the ERA based on risk calculations conducted using the EPC.

- A review of the surface soil PAH data in DU11 indicates that the PAH EPCs are driven by a single location with a total PAH concentration of 3,100 mg/kg (DU11-S003) with the remaining 15 samples at or below 20 mg/kg for total PAHs.

- These results indicate that, although the EPCs for some individual PAHs and PAHs totals exceed the available soil invertebrate or plant criteria, actual impacts to lower trophic level receptors such as invertebrates and plants would be limited to a small geographic area, and community-level impacts are unlikely.

- Similarly, adverse impacts to foraging birds and mammals in DU11 are likely to be overestimated by the EPC, and adverse effects on wildlife populations are unlikely.

Based on the points identified above, benzo(a)pyrene and other PAHs in surface soil at DU11 were not carried forward for further characterization in this appendix.

2.2 DU12

The HHRA and ERA identified the following key points for PAHs in surface soil at DU12:

- The Camp Hero background evaluation (Appendix L1 of the RI Report) identified concentrations of benzo(a)pyrene, total benzo(a)pyrene (BaP) PAHs, total LMW PAHs, and total HMW PAHs in surface soil as being above background concentrations.

- Three of the 16 surface soil benzo(a)pyrene concentrations at DU12 were above 100 mg/kg (ranging from 110 mg/kg to 150 mg/kg) at sample locations DU12-S001, DU12-S004, and DU12-S008. The remaining surface soil sample results ranged from 0.043 mg/kg to 77 mg/kg (**Figure 2**). Concentrations of total LMW PAHs and total HMW PAHs were each above 100 mg/kg in six locations (DU12-S001, DU12-S002, DU12-S003, DU12-S004, DU12-S005, and DU12-S008). These stations are located in the northern half of the DU.

- Coast Artillery Road runs through the middle of DU12. The southern portion of DU12 has a concrete foundation and the northern portion of DU12 contains a park maintenance area with piled brush (partially fenced but usually open).

- As shown in **Figure 2**, a former Fueling Station (former Building 36) was previously located to the northwest of DU12. The historical records associated with the former Fueling Station were reviewed during the records review phase of the RI. The USTs associated with the former Building 36 (USTs 24A, 24B, and 25) had an associated NYSDEC spill report, 93-09098, dated 25 October 1993. The spill report was closed later in 1993 with a NYSDEC-Region 1 Tank Removal Report. The USTs/the former fueling station was not investigated during the Phase I RI field program as an AOC because no further action was required by NYSDEC (there were no COCs above regulatory action levels). Although the fueling station was not specifically investigated in this RI, a potential fuel release from the station was considered as a possible source for the high concentrations of PAHs detected within DU12 near the former fueling station. However, the PAH source evaluation conducted as part of this additional characterization of PAHs (refer to Section 6.0) indicated the PAHs at DU12 were likely pyrogenic in source, which indicates the source is likely not related to a fuel spill from former Building 36.

- Given the lack of other potential point-sources within DU12 and the proximity of the roadway to the most elevated PAH concentrations, the most likely sources of PAHs in surface soil at DU12 are expected to be vehicle exhaust and emissions, coal tar (potentially used as roadway seal coating), weathering of asphalt roads and tires, and ongoing asphalt road maintenance. Also, the soil boring logs for DU12 (Appendix I of the RI Report) indicate evidence of demolished asphalt parking lot materials (black coloring, concrete fragments, tar, and pulverized brick).

The HHRA identified the following key points:

- Benzo(a)pyrene and total BaP PAHs were the primary risk drivers for the on-site current recreational user scenario. The HHRA assumed that the adult and child recreational user would spend 100 days per year for 26 years at DU12 for recreational activities (e.g., camping, hiking, wading in streams, etc.). The results are likely biased high because NYSOPRHP has no plans for developing areas near or at DU12 for future camping grounds or hiking trails so the recreational user is less likely to spend much time there.

The ERA identified the following key points:

- The potential for risks to plants, soil invertebrates, birds, and mammals due to exposure to PAHs in DU12 surface soil was identified in the ERA. Although there are several uncertainties associated with screening values and risks may be overestimated, potential risks to ecological receptors in DU12 could not be ruled out.

Since benzo(a)pyrene, total BaP PAHs, total LMW PAHs, and total HMW PAHs were identified as risk drivers in the risk assessments, PAHs in surface soil at DU12 were further evaluated in this appendix to determine whether they may be attributed to non-CERCLA releases.

2.3 SEA03 and SEA08

The HHRA and ERA identified the following key points for PAHs in sediment at SEA03 (**Figure 3**) and SEA08 (**Figure 4**):

- The Camp Hero background evaluation (Appendix L1 of the RI Report) identified concentrations of benzo(a)pyrene, total BaP PAHs, total LMW PAHs, total HMW PAHs, and total PAHs in sediment from both SEA03 and SEA08 as being above background concentrations.

- The HHRA identified total BaP PAHs and total PAHs as sediment COPCs for SEA03 and SEA08.

- The ERA identified the potential for risks to the benthic invertebrate community due to exposure to PAHs in sediment at both SEA03 and SEA08.

- Many of the primary and intermittent streams throughout the park are channelized with narrow, wooden stream revetments along the sides of the streambeds, which appear to have been installed to control surface water flow across the facility (i.e., revetted). SEA03 and SEA08 sediment DUs were originally classified as non-revetted for the purposes of statistical comparisons based on field observations of revetments in only a subset of the sampling locations (i.e., revetments were not observed at the majority of the stations). Given that these SEAs contain both revetted and non-revetted locations, comparisons to the non-revetted background dataset as part of the COPC selection process may be overly conservative.

- Since both of these SEAs were at least partially composed of revetted segments, an additional review of maps and site photographs (Appendix H of the RI Report) was conducted as part of

> the characterization of potential risks and uncertainties to assess whether PAH concentrations might be related to the presence of revetments in portions of these SEAs. This review showed evidence of revetments for some locations not originally classified as revetted by the field team. In some cases, photographs indicated that wood from revetments was present alongside the SEA03 stream channel indicating that portions of the revetments had been removed, and in SEA08, the water depth at the time of sampling limited the visibility of the revetments in portions of the stream known to be revetted. The review indicated that two additional SEA03 stations (CH-SWSD071 and CH-SWSD072) and four additional SEA08 stations (CH-SWSD146 through CH-SWSD149) could be classified as revetted.

The sediment PAHs in SEA03 and SEA08 were further evaluated in this appendix. In particular, the background evaluation for SEA03 and SEA08 sediment data was revisited since the review described above found that the number of revetted stations in SEA03 and SEA08 was higher than originally designated. These updated revetment determinations were considered in the statistical background comparisons presented in Section 5.0. Additional PAH source evaluations for SEA03 and SEA08 are provided in Section 6.0.

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3.0 GENERAL APPROACH AND RATIONALE

Several lines of evidence were considered to further characterize the PAHs in surface soil at DU12 and sediment at SEA03 and SEA08. These include statistical and graphical evaluations as well as a review of chromatograms provided by the analytical laboratory. The general approaches for these evaluations are described below.

3.1 Additional Background Comparison for Sediment

The background evaluation conducted to support the COPC selection process in the risk assessments (Appendix L1 of the RI Report) compared SEA03 and SEA08 concentrations against the non-revetted background sediment dataset. However, both of these SEAs were at least partially composed of revetted segments, so the comparison to the non-revetted background sediment dataset was a conservative approach. As indicated in Section 2.3, an additional review of maps and site photographs identified additional revetted stations in each SEA. Therefore, the sediment background evaluations were conducted again as part of this evaluation to account for the updated number of revetted stations.

Additional statistical background comparisons were performed based on hypothesis testing, for which the "subset" of samples from each SEA which were identified as revetted were compared to the revetted background, and the "subset" identified as non-revetted were compared to the non-revetted background. The rationale for this additional comparison was that the revetted and non-revetted background PAH concentrations were significantly different.

The background evaluations are presented in Section 5.0.

3.2 Approaches to Evaluate PAH Sources using PAH Ratios and Proportions

The PAH concentrations for surface soil at DU12 and sediment at two SEAs (SEA03 and SEA08) appeared to be elevated relative to the background datasets (Appendix L1 of the RI Report). However, as pointed out by many environmental literature sources, the occurrence of PAHs in soil and sediment may be attributed non-site-related and non-point sources (e.g., atmospheric deposition, roadway runoff), as well as incomplete capturing of urban background levels. Therefore, it is prudent to identify the sources of PAHs at the site. The term "urban background" refers to the variety of non-point sources of PAHs within urban environments, particularly due to incomplete combustion of fuels and other organic matter, such as motor exhaust and wood smoke.

As noted by the Navy "Guidance for Environmental Background Analysis, Volume II: Sediment, NFESC, UG-2054-ENV" (Battelle Memorial Institute et al. 2003):

> *Sources of PAHs in urban sediments can be separated into several categories. Petrogenic PAHs are hydrocarbons formed by the geochemical alteration of organic*

> *matter at moderate temperature (50-150°C) and pressure over very long (i.e., geologic) timescales. These PAHs enter urban environments from anthropogenic sources such as petroleum (crude oil or fuels) spills/leaks, coal-fired power plants, and municipal sewage treatment plants. Pyrogenic PAHs form when fuels and other organic matter are incompletely or inefficiently combusted or pyrolyzed at moderate to high temperatures (>400°C) over very short time intervals.*

Although not all approaches suggested by the Navy's guidance are available for this project, the calculation of PAH ratios (i.e., ratios of phenanthrene to anthracene (PH/AN) and fluoranthene to pyrene (FL/PY)), are useful for differentiating between PAH assemblages containing primarily pyrogenic or petrogenic PAHs.

In addition to the PAH ratios noted above, the 16 non-alkylated (parent) PAHs could be classified as petrogenic or pyrogenic sources based upon the fundamental features of source materials and the expected weathering they endure upon release into the environment. With this simple classification or allocation technique, the proportions of petrogenic and pyrogenic sources could be used to reveal whether the materials were influenced mostly by urban background or point-source releases.

These evaluations are presented in Section 6.0.

3.3 Evaluation of PAH Chromatogram Patterns

In addition to the use of PAH ratios to identify petrogenic and pyrogenic sources, the chromatograms provided by the analytical laboratory were reviewed to further assess the distribution of PAHs within selected samples. This visual pattern recognition approach can be useful for assessing whether particular samples appear to be similar to a potential PAH source based on comparisons to known source samples, if available, or chromatogram patterns identified in the literature.

This visual evaluation was conducted to further evaluate potential PAH sources at DU12 and is presented in Section 7.0.

4.0 DATA HANDLING

This section describes the background and site PAH datasets and how they were handled in the statistical analysis and PAH ratio calculations conducted as part of the additional PAH characterization.

4.1 Background and Site PAH Datasets

During the Camp Hero RI, 16 non-alkylated PAHs of principal environmental concern on the USEPA Priority Pollutant List were analyzed: acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, and pyrene; plus 1-methylnaphthalene and 2-methylnaphthalene. These 18 PAHs made up the total PAH summation, based on the Kaplan-Meier method.

The aforementioned PAHs were analyzed in surface soil and sediment for both background and site-related impacts. For each medium, the site was divided into a number of DUs or SEAs and areas designated for background data collection. Because some SEAs contained wooden revetments that may have contributed chemicals to the sediment in the vicinity, the background sampling locations for sediment were sub-divided into revetted and non-revetted sections. The sample sizes for each location group included in this evaluation are shown in **Table 1**. The revetted station counts for SEA03 and SEA08 in **Table 1** reflect the re-evaluation of stations described in Section 2.3.

Table 1
Sample Size by Media and Location Group

Media	Area	Location Group	No. of Samples	Total No. of Samples
Surface Soil	Background	Background	30	**46**
	Site	DU12: WDS Manhole Area 1	16	
Sediment	Background	Background (Non-Revetted)	15	**59**
	Background	Background (Revetted)	15	
	Site	SEA03: Near DU10 and DU11 Revetted (n=7) Non-Revetted (n=7)	14	
	Site	SEA08: Near DU08 Revetted (n=9) Non-Revetted (n=6)	15	

In general, the sample sizes associated with each DU/SEA and the background were considered to be sufficient (roughly 15 to 20 samples, or more) for the statistical evaluations presented in this Appendix, with the exception of revetted and non-revetted subsets for SEA03 and SEA08.

4.2 Data Handling and Processing

The data handling procedures used in this Appendix were identical to those used for the hypothesis testing conducted as part of the background evaluation (Appendix L1 of the RI Report). When a sample consisted of a normal/duplicate pair, the following data processing was performed to ensure reasonable data independence:

- When both are detected, take the average of field and duplicate.
- When both are non-detects (NDs), take the sample with lower Limit of Detection (LOD).
- When one is detected and one is ND, take the detected result.

Also, if a dataset contained non-detects or J-flagged values, similar to the data handling procedures for hypothesis testing, the estimated J-flagged value was used "as-is" (a detected value) if it was above the LOD and below the Limit of Quantitation (LOQ). For a J-flagged value below the LOD, it was reset to be a censored (i.e., ND) value as <LOD. Non-detect ("U") was also censored at the LOD (i.e., <LOD). A censored value is a condition of which a measurement or observation is only partially known, and in this case, censoring occurred when a value was outside the (lower) range of a measuring instrument with sufficient confidence and was denoted with a less-than (<) sign.

Since the total PAH concentration was a calculated (summed) value using the Kaplan-Meier method (as detailed in Appendix C1), if there were one or more detected individual PAHs for a given sample, the (summed) total PAH concentration was considered to be a detected value (i.e., non-censored). All calculated (summed) PAH values presented in this evaluation are considered to be detected values because there were at least one or more detected individual PAH concentrations.

5.0 ADDITIONAL BACKGROUND COMPARISON FOR SEDIMENT

As described in Section 2.3, SEA03 and SEA08 each included both revetted and non-revetted segments. These SEAs were originally classified as non-revetted because the field observations identified more non-revetted sampling locations than revetted locations. Therefore, the background comparisons conducted as part of the COPC selection process compared data from these SEAs against data from the non-revetted background dataset. PAHs were retained in both SEA03 and SEA08 based on comparisons to the non-revetted background dataset (i.e., comparisons to BTVs and hypothesis testing).

As noted in Section 2.3, further review of maps and photographs identified additional locations that could be classified as revetted in both SEAs. In addition, a review of the total PAH data indicated that PAH concentrations in sediment appeared to be higher in revetted locations than in non-revetted locations. This observation is true for both the SEA03 and SEA08 data (**Table 2**) as well as the background sediment data (**Table 3**).

Therefore, an additional statistical background comparison was performed as another level of comparison for the mean total PAH concentrations. In this comparison, total PAH concentrations in the subset of samples from each SEA identified as revetted were compared to the revetted background sample dataset, and total PAH concentrations in the subset of samples identified as non-revetted were compared to the non-revetted background sample dataset. The rationale for the additional comparison was that the revetted and non-revetted background PAH concentrations were significantly different, indicating a potential difference due to the presence of the wooden revetments within a stream channel; the revetted background PAH concentrations were generally much higher (Appendix L1 of the RI Report). If the entire SEA03 and SEA08 datasets were compared to the non-revetted background (as was done during the COPC selection process as a conservative approach), it would be concluded that these two SEAs had significantly higher PAH concentrations than the background, because part of each SEA was revetted and the elevated PAH concentrations could be attributed to the revetments.

5.1 Approach and Methodology

The comparison of two independent datasets was used for this evaluation. This method was used to compare the investigation area (i.e., revetted or non-revetted subsets of each SEA) to the corresponding revetted or non-revetted background area to determine if total PAH concentrations were present at levels significantly greater than the respective background levels. This population-to-population comparison evaluated whether the mean site values were statistically greater than the mean background values. This statistical analysis was performed separately for each SEA and for each revetted/non-revetted subset.

Table 2
Total PAH Concentrations in SEA03 and SEA08 Sediment

Location	Total PAHs (mg/kg)	Revetted or Non-Revetted
SEA03		
CH-SWSD066	71	Revetted
CH-SWSD069	41	Revetted
CH-SWSD070	32	Revetted
CH-SWSD067	30	Revetted
CH-SWSD068	22	Revetted
CH-SWSD071	18	Revetted (1)
CH-SWSD072	2	Revetted (1)
CH-SWSD079	1.6	Non-Revetted
CH-SWSD077	1.2	Non-Revetted
CH-SWSD078	0.85	Non-Revetted
CH-SWSD076	0.43	Non-Revetted
CH-SWSD073	0.4	Non-Revetted
CH-SWSD074	0.14	Non-Revetted
CH-SWSD075	0.13	Non-Revetted
SEA08		
CH-SWSD146	61	Revetted (1)
CH-SWSD147	34	Revetted (1)
CH-SWSD149	29	Revetted (1)
CH-SWSD142	24	Revetted
CH-SWSD144	22	Revetted
CH-SWSD145	18	Revetted
CH-SWSD143	15	Revetted
CH-SWSD148	15	Revetted (1)
CH-SWSD141	13	Revetted
CH-SWSD150	4.1	Non-Revetted
CH-SWSD155	2	Non-Revetted
CH-SWSD153	1.2	Non-Revetted
CH-SWSD154	1.2	Non-Revetted
CH-SWSD152	0.76	Non-Revetted
CH-SWSD151	0.57	Non-Revetted

1 – Originally classified as a non-revetted location.

Table 3
Total PAH Concentrations in Background Sediment

Location	Total PAHs (mg/kg)
Background - Revetted	
CH-SWSD030	37
CH-SWSD018	35
CH-SWSD028	30
CH-SWSD016	23
CH-SWSD017	20
CH-SWSD021	19
CH-SWSD020	18
CH-SWSD019	17
CH-SWSD029	17
CH-SWSD027	16
CH-SWSD026	14
CH-SWSD025	12
CH-SWSD023	9.4
CH-SWSD024	7.8
CH-SWSD022	1.5
Background – Non-Revetted	
CH-SWSD014	15
CH-SWSD010	7.6
CH-SWSD015	1.1
CH-SWSD002	0.32
CH-SWSD009	0.27
CH-SWSD001	0.091
CH-SWSD012	0.054
CH-SWSD013	0.047
CH-SWSD007	0.045
CH-SWSD004	0.04
CH-SWSD005	0.03
CH-SWSD011	0.03
CH-SWSD008	0.026
CH-SWSD003	0.023
CH-SWSD006	0.016

The USEPA ProUCL Version 5.1 statistical software (USEPA, 2016) and PAST Version 3.13 data analysis software (Hammer, 2016; Hammer et al., 2001) were used to conduct the statistical analysis of the background and site data. The details of hypothesis testing methodology and selecting the appropriate statistical tests are presented in Section 4.2 of Appendix L1.

5.2 Population Comparison Results

The ERA identified the potential for risks to the benthic invertebrate community due to exposure to PAHs in sediment at both SEA03 and SEA08. Based on a review of the PAH data in these SEAs (**Table 2**), it appeared that the elevated PAH concentrations could be explained by the presence of revetments within portions of the stream channels.

Therefore, total PAHs required further statistical comparison with the background data and the following four comparisons were made:

- Background Non-Revetted vs. SEA03 Non-Revetted
- Background Revetted vs. SEA03 Revetted
- Background Non-Revetted vs. SEA08 Non-Revetted
- Background Revetted vs. SEA08 Revetted

The detailed statistical results are summarized in Attachment B, the corresponding box-and-whisker plots are presented in Attachment C, and the statistical outputs from the PAST software are provided in Attachment D.

As shown in Attachment B, for the comparison between the "background revetted" dataset and the "SEA03 revetted" dataset, the parametric t-Test was used to compare the means because both datasets could be assumed to be normally distributed. For the other three comparisons, only one of the two datasets could not be assumed to follow a normal distribution, and thus, the non-parametric permutation test was used.

The one-sided *p*-values of all four comparison tests were more than 0.05, indicating that the site total PAH concentrations of each of the four subset SEA areas were not significantly different from the respective background, at 95% confidence level. The corresponding box-and-whisker plots shown in Attachment C also indicated that the "boxes" of background and site for each comparison were largely overlapped and the site "boxes" did not appear to be any higher than the background "boxes."

Given these statistical and graphical results, it was concluded that total PAH concentrations in sediment at SEA03 and SEA08 were not significantly higher than the background.

6.0 EVALUATION OF PAH RATIOS AND PROPORTIONS

As discussed in Section 3.2, the occurrence of PAHs in soil and sediment may be attributed to non-site-related and non-point sources, or commonly denoted as "urban background." Most commonly these "urban background" contributions are associated with the incomplete combustion of fuels and other organic matter. Numerous ratios among individual PAH analytes can be plotted to reveal outliers or clusters or patterns of samples that may be considered to be attributed to the urban background population.

Since only the 16 non-alkylated (parent) PAHs were available for this project, the ratios of phenanthrene to anthracene (PH/AN) and fluoranthene to pyrene (FL/PY) were assessed in this section, as suggested by the Navy "Guidance for Environmental Background Analysis, Volume II: Sediment, NFESC, UG-2054-ENV" (Battelle Memorial Institute et al., 2003). These ratios depended upon the thermal stability of related isomers and were useful for differentiating between PAH assemblages containing primarily pyrogenic or petrogenic PAHs.

In addition to the aforementioned PAH ratios, a simple pyrogenic/petrogenic source classification technique for each individual PAH analyte was also suggested by the Navy guidance to assess whether the materials were mostly influenced by urban background based on the proportions of pyrogenic and petrogenic sources. This assessment is presented in Section 6.4.

Pyrogenic PAHs typically occur when fuels and other organic matter were incompletely or inefficiently combusted or pyrolyzed at moderate to high temperatures over a short time, such as motor exhaust, wood smoke, and coal tar. These pyrogenic PAHs may travel over long distances as particles from combustion-related sources. Petrogenic PAHs are formed by the geochemical alteration of organic matter at moderate temperature and pressured over long geologic timescales. These petrogenic PAHs typically entered urban environments from anthropogenic sources, such as petroleum (crude oil or refined products such as fuels) related spills/leaks (Battelle Memorial Institute, et al., 2003).

6.1 Calculation of Selected PAH Ratios

Analytical data for phenanthrene, anthracene, fluoranthene, and pyrene were extracted from the project database after the data handling and processing procedures described Section 4.0. The PAH ratios, phenanthrene to anthracene (PH/AN) and fluoranthene to pyrene (FL/PY), were then calculated for each sample in each area of interest (background surface soil, DU01 LNAPL impacted subsurface soil, DU11 surface soil sample from location DU11-S003, DU12 surface soil, background sediment, SEA03 sediment, and SEA08 sediment). The summary statistics for these two PAH ratios, by area of interest, are shown in **Table 4**.

Table 4
Summary Statistics for the PAH Ratio Data Groups

	Background Surface Soil	DU01 LNAPL Impacted Subsurface Soil	DU11 Surface Soil DU11-S003	DU12 Surface Soil	Background Sediment Revetted	Background Sediment Non-revetted	SEA03 Sediment	SEA08 Sediment
Ratio of PH/AN								
Min	1.00	0.94	2.79	2.24	1.19	1.00	0.41	1.82
Max	11.43	15.00	2.79	5.50	10.00	6.27	5.50	11.72
Average	4.42	7.64	2.79	3.59	3.13	2.50	2.68	4.68
Median	4.12	7.09	2.79	3.40	2.68	1.27	2.85	4.50
Ratio of FL/PY								
Min	0.98	0.33	1.44	0.80	0.88	0.65	0.67	0.59
Max	1.36	3.21	1.44	1.35	1.67	1.28	1.55	1.38
Average	1.11	0.72	1.44	1.18	1.18	1.02	1.16	1.14
Median	1.06	0.49	1.44	1.25	1.20	1.00	1.16	1.20
Sample Count	30	17	1	16	15	15	14	15

As noted in the Navy guidance (Battelle Memorial Institute, et al., 2003):

> *Anthracene and fluoranthene are thermodynamically less stable than their respective isomers, phenanthrene and pyrene (Baumard et al., 1998). Anthracene and fluoranthene are produced during rapid, high temperature pyrosynthesis, but are less favored to persist during the slow organic diagenesis leading to the generation of fossil fuels. Thus, as shown in Table A-3, the P0/AN[2] ratios of pyrogenic PAH assemblages usually are less than 5, whereas petrogenic ratios usually are greater than 5. The FL/PY ratios usually approach or exceed 1 in pyrogenic assemblages and usually are substantially less than 1 in petrogenic PAH assemblages (Table A-3).*

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[2] Note that the Navy guidance uses the abbreviation P0 for phenanthrene. This appendix uses PH for phenanthrene.

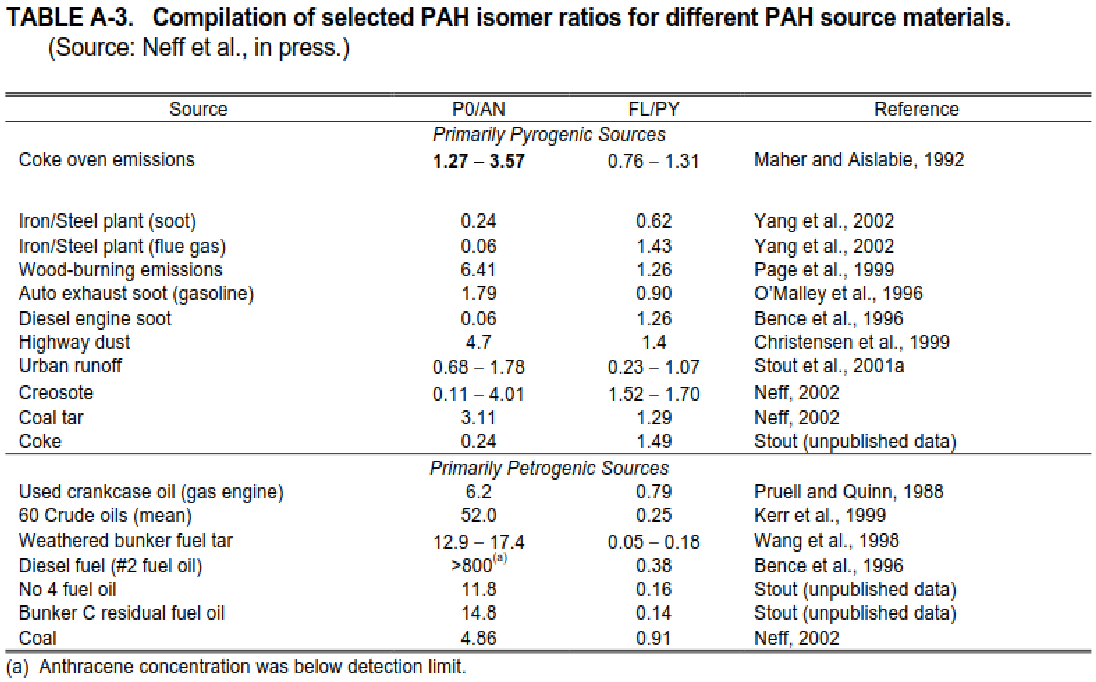

TABLE A-3. Compilation of selected PAH isomer ratios for different PAH source materials.
(Source: Neff et al., in press.)

Source	P0/AN	FL/PY	Reference
	Primarily Pyrogenic Sources		
Coke oven emissions	**1.27 – 3.57**	0.76 – 1.31	Maher and Aislabie, 1992
Iron/Steel plant (soot)	0.24	0.62	Yang et al., 2002
Iron/Steel plant (flue gas)	0.06	1.43	Yang et al., 2002
Wood-burning emissions	6.41	1.26	Page et al., 1999
Auto exhaust soot (gasoline)	1.79	0.90	O'Malley et al., 1996
Diesel engine soot	0.06	1.26	Bence et al., 1996
Highway dust	4.7	1.4	Christensen et al., 1999
Urban runoff	0.68 – 1.78	0.23 – 1.07	Stout et al., 2001a
Creosote	0.11 – 4.01	1.52 – 1.70	Neff, 2002
Coal tar	3.11	1.29	Neff, 2002
Coke	0.24	1.49	Stout (unpublished data)
	Primarily Petrogenic Sources		
Used crankcase oil (gas engine)	6.2	0.79	Pruell and Quinn, 1988
60 Crude oils (mean)	52.0	0.25	Kerr et al., 1999
Weathered bunker fuel tar	12.9 – 17.4	0.05 – 0.18	Wang et al., 1998
Diesel fuel (#2 fuel oil)	>800[a]	0.38	Bence et al., 1996
No 4 fuel oil	11.8	0.16	Stout (unpublished data)
Bunker C residual fuel oil	14.8	0.14	Stout (unpublished data)
Coal	4.86	0.91	Neff, 2002

(a) Anthracene concentration was below detection limit.

The majority of the calculated ratios for background locations, DU12 surface soil, and sediment from SEA03 and SEA08 (**Table 4**) indicated that a pyrogenic source was likely the origin of the PAHs. As indicated in Table A-3 from the Navy guidance (Battelle Memorial Institute, et al., 2003), these ratios can be used to identify potential PAH source materials. Although this approach is not a definitive forensics characterization based on multiple lines of evidence, it may be useful to broadly identify potential sources, recognizing that the soil and sediment samples likely include a mix of PAH contributions from different sources. The PAH ratios for selected subsurface soils with LNAPL impacts at DU01 are included in Table 4 to provide an example of a petrogenic signature.

For DU11, the PAH ratios for surface soil at location DU11-S003 represent a pyrogenic signature indicating that PAHs at this location are not a result of a CERCLA related release. This provides an additional line of evidence, beyond those presented in Section 2.1, that PAHs in DU11 do not warrant further consideration in the risk assessments.

For DU12 surface soil samples, the PH/AN ratio ranged from 2.24 to 5.50 and the FL/PY ratio ranged from 0.80 to 1.35. According to the Navy guidance and additional references for PAH source identification (Neff et al. 2005), potential sources of PAHs within the range of these calculated ratios may include a mix of coal tar (often used as roadway seal coating), diesel and gas exhaust/soot, highway dust, wood burning emissions, and urban runoff.

For SEA03 sediment samples, the PH/AN ratio ranged from 0.41 to 5.50 and the FL/PY ratio ranged from 0.67 to 1.55. The range of PAH ratios for sediment at SEA03 were similar to those in surface soil at DU12, but had a slightly lower range for PH/AN, indicating a potentially more pyrogenic mix of sources. Based on the Navy guidance and Neff et al. (2005), potential sources of PAHs within the range of the calculated ratios may include a mix of coal tar, creosote, diesel and gas exhaust/soot, highway dust, wood burning emissions, and urban runoff.

For SEA08 sediment samples, the PH/AN ratio ranged from 1.82 to 11.72 and the FL/PY ratio ranged from 0.59 to 1.38. The larger range of PAH ratios in sediment at SEA08 could potentially indicate a larger mix of sources; however, the majority of the calculated ratios fell within the pyrogenic range. SEA08 is located at the terminus of the Camp Hero surface water drainage system and receives storm water discharge from the entire eastern half of Camp Hero. PAHs likely migrate into streams throughout Camp Hero and are then transported through the drainage system to SEA08, prior to discharge to the Atlantic Ocean, which may explain the large range of the calculated ratios at SEA08 compared to DU12 and SEA03. Based on the Navy guidance and Neff et al. (2005), potential sources of PAHs within the range of the calculated ratios for the majority of the sample locations at SEA08 may include a mix of wood burning emissions, coal tar, creosote, diesel and gas exhaust/soot, and highway dust. For the datapoints from SEA08 that fell outside of the pyrogenic range, potential sources could include motor oil, fuel oil, or road paving asphalt.

More often than not, in urban environments, no single anthropogenic source accounts for all of the PAHs contributed to the local soil and sediment. Petrogenic and pyrogenic PAHs from discrete point sources are mixed with PAHs derived from nonpoint urban background sources. Defining the contribution of PAHs is challenging because no two reference datasets or study areas are the same. Instead, recognizing and unmixing PAH source signatures in sediments is best achieved through reviewing multiple lines of evidence. The following sections describe other analytical approaches that provided additional lines of evidence in the PAH source characterization.

6.2 Scatterplots, Box-and-Whisker Plots, and Comparison of PAH Ratios

Attachment E presents the scatterplots (with linear regression lines) of phenanthrene versus anthracene, as well as fluoranthene versus pyrene, separately for surface soil (background + DU12) and sediment (background + SEA03 + SEA08). The background data are plotted in solid black circles, whereas the site data are plotted in red triangles. With the exception of PH/AN sediment (Background+SEA03+SEA08) with an R^2 of 0.58, very high correlations were observed for each pair of PAH analytes, for both media, with the R^2 of some regressions indicated a near perfect linear fit. This is an indication these pairs of analytes were presented in the environment "hand-in-hand," suggesting the PAH sources were affecting both background and site in the same or similar manner. Atmospheric deposition of PAHs is a common non-point source of PAHs that may affect a large area in a similar manner.

Attachment F presents the side-by-side box-and-whisker plots of phenanthrene to anthracene (PH/AN) and fluoranthene to pyrene (FL/PY) ratios, separately for surface soil (background + DU12) and sediment (revetted background + non-revetted background + SEA03 + SEA08). In general, both PAH ratios were very similar between background and site, as evident by the "boxes" of background and site of each plot being largely overlapped and the site "boxes" did not appear to be any higher than the background "boxes."

Below each box-and-whisker plot, the results of Wilcoxon Rank Sums Test or Kruskal-Wallis Tests (followed by non-parametric multiple comparisons) were shown. The results of these statistical tests largely indicated that there were no significant differences of these two PAH ratios between the background and site areas. This is another line of evidence suggesting that the PAH sources were likely the same for both the background and site areas, as a different pattern of PAH ratios would have likely been observed if the PAHs were site-related.

6.3 Cross-Plots of PAH Ratios

The Navy guidance (Battelle Memorial Institute, et al., 2003) also suggests that both ratios (PH/AN and FL/PY) should be used together (i.e., simultaneously) to differentiate between PAH sources, given the variability in PAH ratios among the different sources and lack of alkylated PAHs data.

Attachment G presents the cross-plots of the PH/AN (y-axis) and FL/PY (x-axis) ratios for each media (surface soil and sediment), respectively, with different symbols to represent samples from background area(s) and DU and SEA(s) in question. As shown in both cross-plots, there were no discernable or clear differences between the patterns of background and DU/SEA data. More importantly, both background and DU/SEA data did not indicate the PAH sources were petrogenic (PH/AN > 5 and FL/PL < 1) for the vast majority of samples, but rather, most (background and DU and SEA) data were pointing towards likely pyrogenic origin of PAHs. One notable exception is that one datapoint from sediment at SEA08 falls within the petrogenic range on the plot of FL/PY vs. PH/AN. As described above, SEA08 is located at the terminus of the Camp Hero surface water drainage system and receives storm water discharge from the entire eastern half of Camp Hero. PAHs likely migrate into streams throughout Camp Hero and are then transported through the drainage system to SEA08. Therefore, SEA08 is subject to a larger range of PAH sources, which may include occasional inputs from petrogenic sources (motor oil, for example).

Overall, the cross-plots are another line of evidence suggesting that the vast majority of observed PAH concentrations in soil at DU12 and sediment at SEA03 and SEA08 were likely due to urban background contributions.

6.4 Proportion of PAHs based on Petrogenic/Pyrogenic Classification

For this evaluation, it may be useful to quantify the proportion of PAHs derived from petrogenic and pyrogenic sources. Using this approach, each PAH analyte was assigned to either a petrogenic, pyrogenic, or mixed category. As noted by the Navy guidance (Battelle Memorial Institute, et al., 2003):

> *These classifications are based upon the fundamental features of petrogenic and pyrogenic source materials and the expected weathering they endure upon release into the environment. For instance, most low molecular weight (2- and 3-ring) and alkylated PAHs are assigned to petrogenic source materials, whereas most high molecular weight (4- to 6-ring) and nonalkylated parent PAHs are assigned to pyrogenic sources.*

It was also noted that some PAHs, such as phenanthrene, could be originated from both petrogenic and pyrogenic sources and were considered to have mixed sources. For this evaluation, 50% of phenanthrene concentrations were allocated to be petrogenic and 50% pyrogenic.

Analytical data for the 16 non-alkylated (parent) PAHs were extracted from the project database after the data handling and processing procedures described in Section 4.0. The percentages of petrogenic and pyrogenic PAH concentrations were then calculated for each sample in each area of interest (background surface soil, DU12 surface soil, background sediment, SEA03 sediment, and SEA08 sediment), with or without non-detect and censored data. Using this simple PAH classification approach, the summary statistics (average) of these percentages are presented below (**Table 5**).

Table 5
Summary Statistics for the Percentages of Petrogenic and Pyrogenic PAHs

Area	No. of Samples	All Data		No NDs or Censored Data	
		Average Percent Petrogenic	Average Percent Pyrogenic	Average Percent Petrogenic	Average Percent Pyrogenic
Background Surface Soil	30	18%	82%	21%	79%
DU12 Surface Soil	16	10%	90%	10%	90%
Background Sediment Revetted	15	15%	85%	15%	85%
Background Sediment Non-revetted	15	23%	77%	26%	74%
SEA03 Sediment	14	10%	90%	7%	93%
SEA08 Sediment	15	23%	77%	23%	77%

As shown in **Table 5**, this simple PAH classification and allocation technique demonstrated both background and DU/SEA areas were likely influenced by urban background sources. The calculations indicated that approximately 20% of the PAHs detected in these samples were derived from petrogenic sources and 80% from pyrogenic sources, and these percentages in general had little variations from sample to sample. This proportion is typical of urban background conditions in many areas (Battelle Memorial Institute, et al., 2003). In addition, the datasets did not identify an "excess" of the petrogenic or pyrogenic fraction at a given area which could be indicative of a point source of PAHs super-imposed on the urban background. This is another line of evidence suggesting that the PAH sources (pyrogenic) were likely the same for both the background and site areas, as the proportions of petrogenic and pyrogenic would likely be different if the PAHs were related to a release from the site.

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7.0 EVALUATION OF PAH CHROMATOGRAM PATTERNS

The chromatograms provided by the analytical laboratory were reviewed to further assess the distribution of PAHs within selected soil samples from DU12. This visual pattern recognition approach was used to assess whether PAH results from surface soil samples driving the identification of risks in DU12 were petrogenic or pyrogenic and whether they were similar to a known petrogenic source. The chromatograms for the samples requested were analyzed by EPA Method SW8270D. Method SW8270D via selected ion mass spectrometry was not used due to the high concentrations of PAHs.

7.1 Approach and Methodology

Total ion chromatograms provided by the analytical laboratory (Eurofins Lancaster Laboratories Environmental, LLC) were reviewed to identify the sources of the parent PAHs detected in DU12 soil as either petrogenic or pyrogenic based on comparisons to chromatogram examples provided in Navy guidance (Battelle Memorial Institute, et al., 2003). Chromatograms for the surface soil samples at DU12 with the highest total PAH concentrations were reviewed as part of this evaluation, including samples DU12-S001-00-01, DU12-S002-00-01, DU12-S003-00-01, DU12-S004-00-01, DU12-S005-00-01, and DU12-S008-00-01. Additionally, one subsurface soil sample from DU01 (203-SB15-28) near light non-aqueous phase liquid (LNAPL) impacts (a known petrogenic source) was reviewed for comparison and verification of the evaluation method. The PAH chromatograms are presented in Attachment H.

7.2 Chromatogram Evaluation Results

The visual review of the chromatogram for subsurface soil sample 203-SB15-28 from DU01 shows a clearly petrogenic pattern, as expected for a sample collected from an area near LNAPL impacts. The regularly spaced largest peaks marked ‘A’ by the lab are a series of normal alkanes typically present in mid-range distillate fuels. The Unresolved Complex Mixture (UCM) hump with a maximum near the fluorene retention time is also a typical feature of petroleum distillates. The alkane positions relative to the marked PAHs suggest that this may be weathered diesel fuel/fuel oil #2. Note that the identified PAHs marked on the chromatogram are minor components of the total pattern, as expected for any purely petrogenic source.

The chromatograms for the selected surface soil samples from DU12 (DU12-S001-00-01, DU12-S002-00-01, DU12-S003-00-01, DU12-S004-00-01, DU12-S005-00-01, and DU12-S008-00-01) are all very similar and show clearly pyrogenic patterns. The largest peaks in each pattern are identified as 2 to 6 ring parent PAHs, and the pattern is dominated by phenanthrene, fluoranthene, and pyrene in each case. The weak UCM shown in these chromatograms maximizes late in the run by retention time, in the 5 to 6 ring PAH region, and is probably attributable to unresolved alkylated PAHs and possibly asphalt related hydrocarbons. This pattern is consistent with weathered creosote or coal tar products, which are commonly used as seal coats for asphalt pavement surfaces.

As indicated in Section 2.2, Coast Artillery Road runs through the middle of DU12; therefore, asphalt pavement surfacing of the road may explain the PAH concentrations in the surface soil at DU12. Also, the soil boring logs for DU12 (Appendix I of the RI Report) indicate evidence of demolished asphalt parking lot materials (black coloring, concrete fragments, tar, and pulverized brick). These observations further support the findings from the visual review of the DU12 surface soil chromatograms.

8.0 RESULTS AND DISCUSSION

The primary objective of this appendix was to provide an additional evaluation of PAHs in surface soil at DU11 and DU12 and sediment at SEA03 and SEA08 to determine whether they could be attributed to non-CERCLA sources. This evaluation was conducted in coordination with the USACE New England District, New York District, and EMCX. This evaluation included a summary of uncertainties considered in the HHRA and ERA, statistical and graphical evaluations of the PAH data, and a review of selected chromatograms. The results for each DU and SEA are presented below.

8.1 DU11

As described in Section 2.1, surface soil EPCs for PAHs used in the HHRA and ERA were influenced by elevated concentrations in a single surface soil sample from location DU11-S003. Concentrations of PAHs in the remaining 15 samples within the DU were considerably lower. In addition, the PH/AN and FL/PY ratios for the DU11-S0003 surface soil sample exhibit a pyrogenic signature, which indicates that it is not a CERCLA related release. Based the distribution of the data and other HHRA- and ERA-specific uncertainties, benzo(a)pyrene and other PAHs in surface soil at DU11 were not retained for further evaluation in the risk assessments or the RI and were not carried forward for additional PAH characterization in this appendix.

8.2 DU12

Concentrations of PAHs in surface soil were elevated in several locations located in the northern half of the DU. The nearby former fueling station (former Building 36) was considered as a point-source; however, the PAH source characterization indicated that the PAHs at DU12 were pyrogenic. Because a release of fuel would show a petrogenic signature, the former fueling station was eliminated as a potential source of the PAHs at DU12. Given the lack of other known point-sources within DU12 and the proximity of Coast Artillery Road to the most elevated PAH concentrations, the most likely sources of PAHs in surface soil at DU12 are non-point sources such as vehicle exhaust and emissions, coal tar (potentially used as roadway seal coating), weathering of asphalt roads and tires, and ongoing asphalt road maintenance. Soil boring logs for DU12 also indicate evidence of demolished asphalt parking lot materials.

A statistical and graphical review of PAH ratios (PH/AN and FL/PY) showed no significant differences for these PAH ratios between the background dataset and the DU12 surface soil dataset. In addition, a review of the PAH ratio cross-plots and a review of the proportion of pyrogenic and petrogenic PAHs for the DU12 and background samples showed that both the DU12 and background datasets were dominated by pyrogenic PAHs and likely to be influenced by urban background contributions rather than site-related point sources.

This finding is further confirmed by a review of chromatograms from selected DU12 soil samples. This review confirmed that the surface soil PAHs within DU12 were very similar to each other and showed clearly pyrogenic patterns. These surface soil PAH patterns were clearly different from a DU01 sub-surface soil sample (203-SB15-28) that was representative of petrogenic LNAPL impacts.

These lines of evidence indicated that the PAHs present in DU12 surface soil could not be attributed to a CERCLA release.

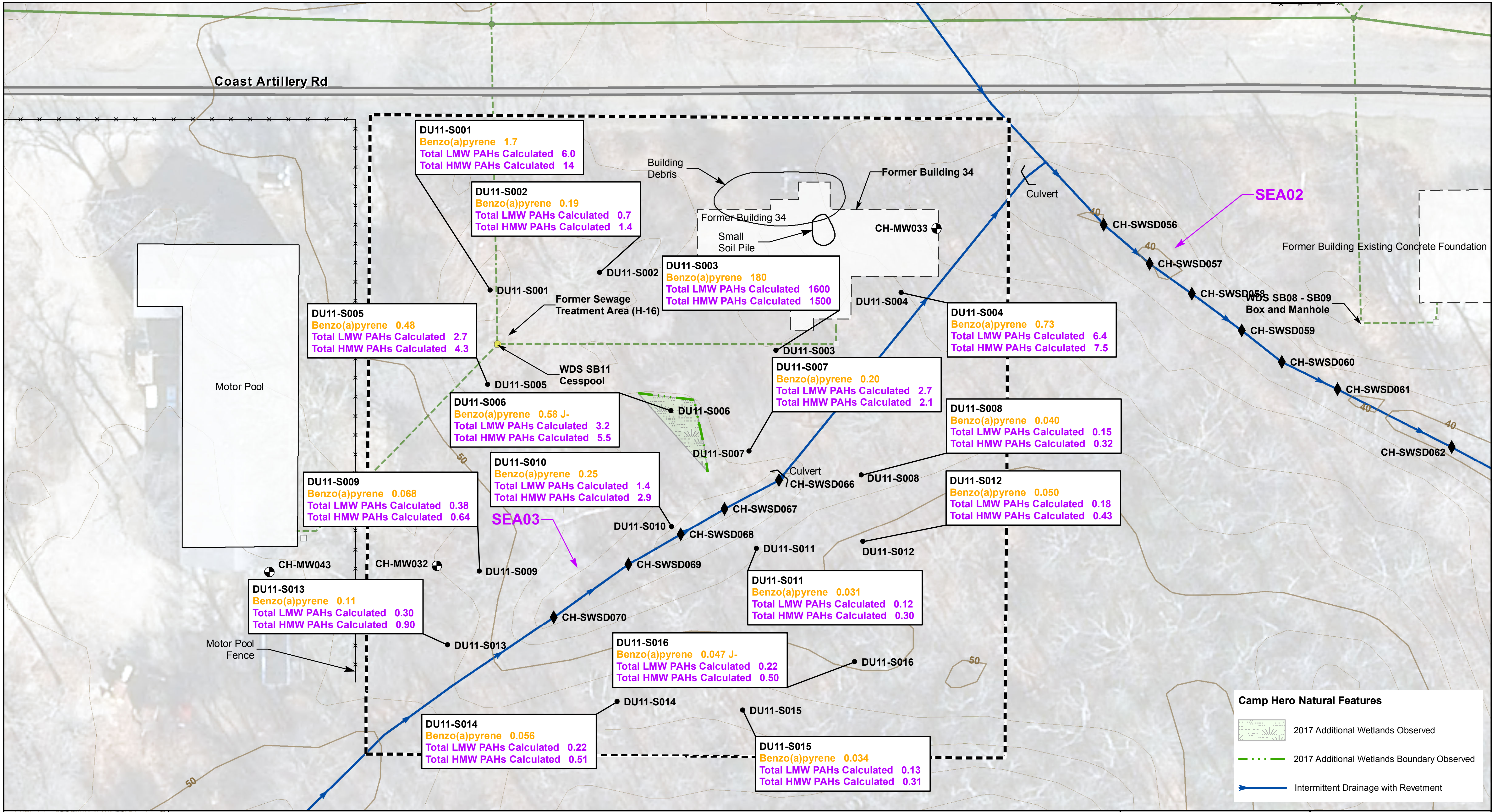
8.3 SEA03 and SEA08

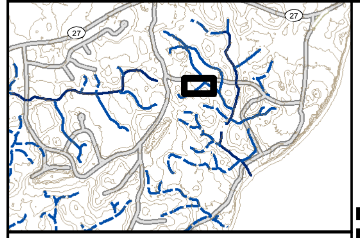
Total PAH concentrations in sediment in both SEA03 and SEA08 appeared to be higher in revetted locations than in non-revetted locations (**Table 2**). A statistical background comparison confirmed that the PAHs in the revetted portions of SEA03 and SEA08 were not significantly higher than the background revetted dataset. A graphical comparison of concentrations confirmed this finding. Therefore, it was likely that the PAHs found in these SEAs were associated with the presence of the revetments.

A statistical and graphical review of PH/AN and FL/PY ratios showed no significant differences for these PAH ratios between the background dataset and the SEA03 and SEA08 sediment datasets. In addition, a review of the PAH ratio cross-plots and a review of the proportion of pyrogenic and petrogenic PAHs within the SEA03 and SEA08 samples and the background samples showed that all datasets were dominated by pyrogenic PAHs and likely to be influenced by urban background contributions rather than point sources.

These lines of evidence indicated that the PAHs present in SEA03 and SEA08 sediment could not be attributed to a CERCLA release.

Figures





MAP LOCATION

Camp Hero Built Features

- ● Phase III Surface Soil Sample Location
- Groundwater Monitoring Well
- ◆ Phase III Surface Water and Sediment Sampling Location
- Decision Unit
- ☐ Existing Building
- Former Building
- Fence

Former Sanitary Sewer System Features

- Primary Sanitary Sewer Line
- Secondary WDS Line
- ● Manhole
- ☐ Box (cleanout or other)
- Cesspool

Topographic Contours

- 10 ft
- 2 ft

Results
Units are in mg/kg.
Orange = PAHs that warranted additional evaluation as part of the HHRA.
Purple = PAHs that warranted additional evaluation as part of the ERA.
HMW = high molecular weight.
LMW = low molecular weight.
PAHs = polycyclic aromatic hydrocarbons.

0 15 30 Feet
1 inch = 30 feet

Note
Wetlands were evaluated only within Decision Units.

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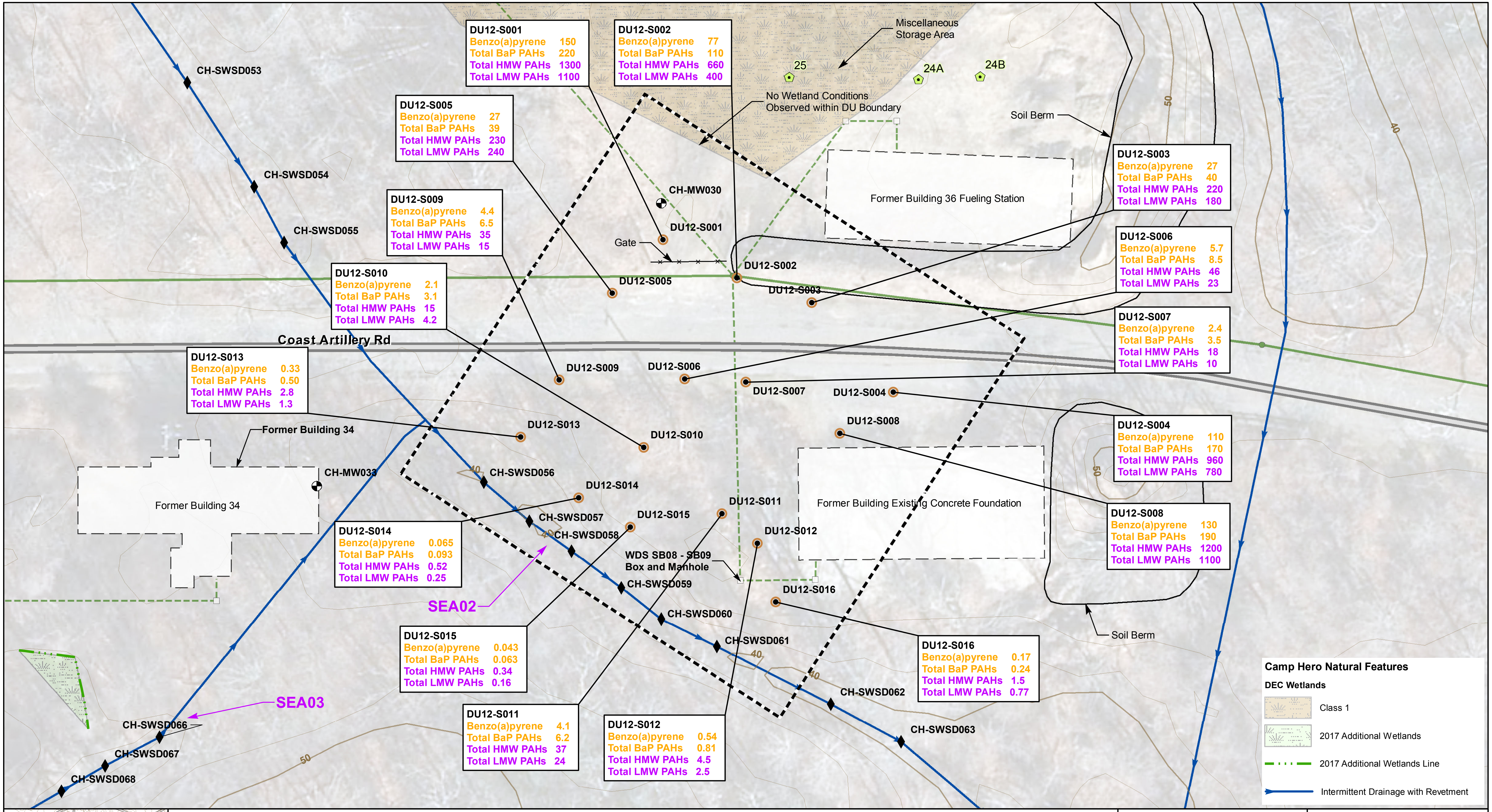
Distribution of PAHs, DU11, H16 Sewage/WDS Septic Area

Camp Hero Remedial Investigation
Montauk, New York

PROJECT NO.	PREPARED BY:	DATE:	
60443903	JB	January 2019	**Figure 1**

10/17/2018 \\USCHL1FP001\Data\Projects\Govt\Projects\USACE\Camp_Hero\GIS\Projects\RI_Report\MXD\Fig_4_11b_Distribution_of_COCs_DU11_H16_Sewage_WDS_Septic_Area.mxd



MAP LOCATION

Camp Hero Built Features

- ● Phase III Surface Soil Sample Location
- ○ Phase III Subsurface Soil Sample Location (1-10 Feet)
- Groundwater Monitoring Well
- ◆ Phase III Surface Water and Sediment Sampling Location

Decision Unit

Storage Tanks

UST (closed)

Former Building

Fence

Former Sanitary Sewer System Features

Primary Sanitary Sewer Line

Secondary WDS Line

● Manhole

Box (cleanout or other)

Topographic Contours

10 ft

2 ft

Results
Units are in mg/kg
Orange = PAHs that warranted additional evaluation as part of the HHRA
Purple = PAHs that warranted additional evaluation as part of the ERA

Note
Wetlands were evaluated only within Decision Units.

N W E S

0 15 30 Feet

1 inch = 30 feet

AECOM

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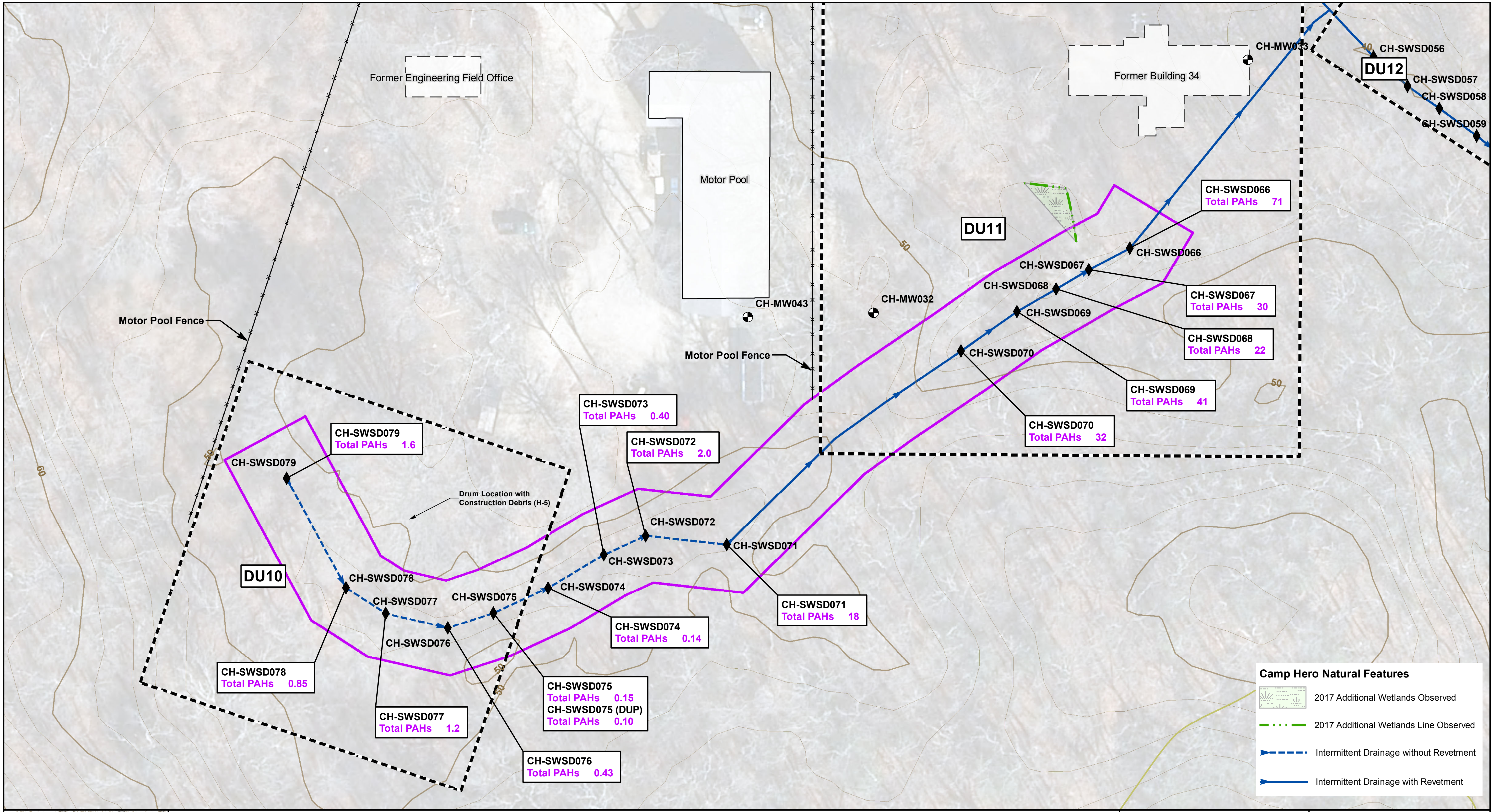
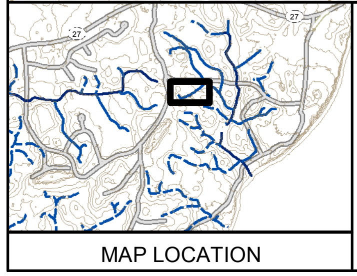
Distribution of PAHs in Surface Soil, DU12, WDS Manhole Area 1

Camp Hero Remedial Investigation
Montauk, New York

PROJECT NO.	PREPARED BY:	DATE:	
60443903	JB	January 2019	Figure 2

7/14/2018 \\USCHL1FP001\Data\Projects\Govt\Projects\USACE\Camp_Hero\GIS\Projects\RI_Report\MXD\Fig_4_12b_Distribution_of_COCs_DU12_WDS_Manhole_Area_1.mxd





MAP LOCATION

Camp Hero Built Features

- ◆ Phase III Surface Water and Sediment Sampling Location
- ◕ Groundwater Monitoring Well
- ▭ Stream Exposure Area
- ⬚ Decision Unit

State Park Trails

- Battery 113 Trail
- Fence

Topographic Contours

- 10 ft
- 2 ft

Results
Units are in mg/kg.
Purple = PAHs that warranted additional evaluation
as part of the ERA

Note
Wetlands were evaluated only within Decision Units.

N
W E
S

0 20 40
Feet
1 inch = 40 feet

AECOM

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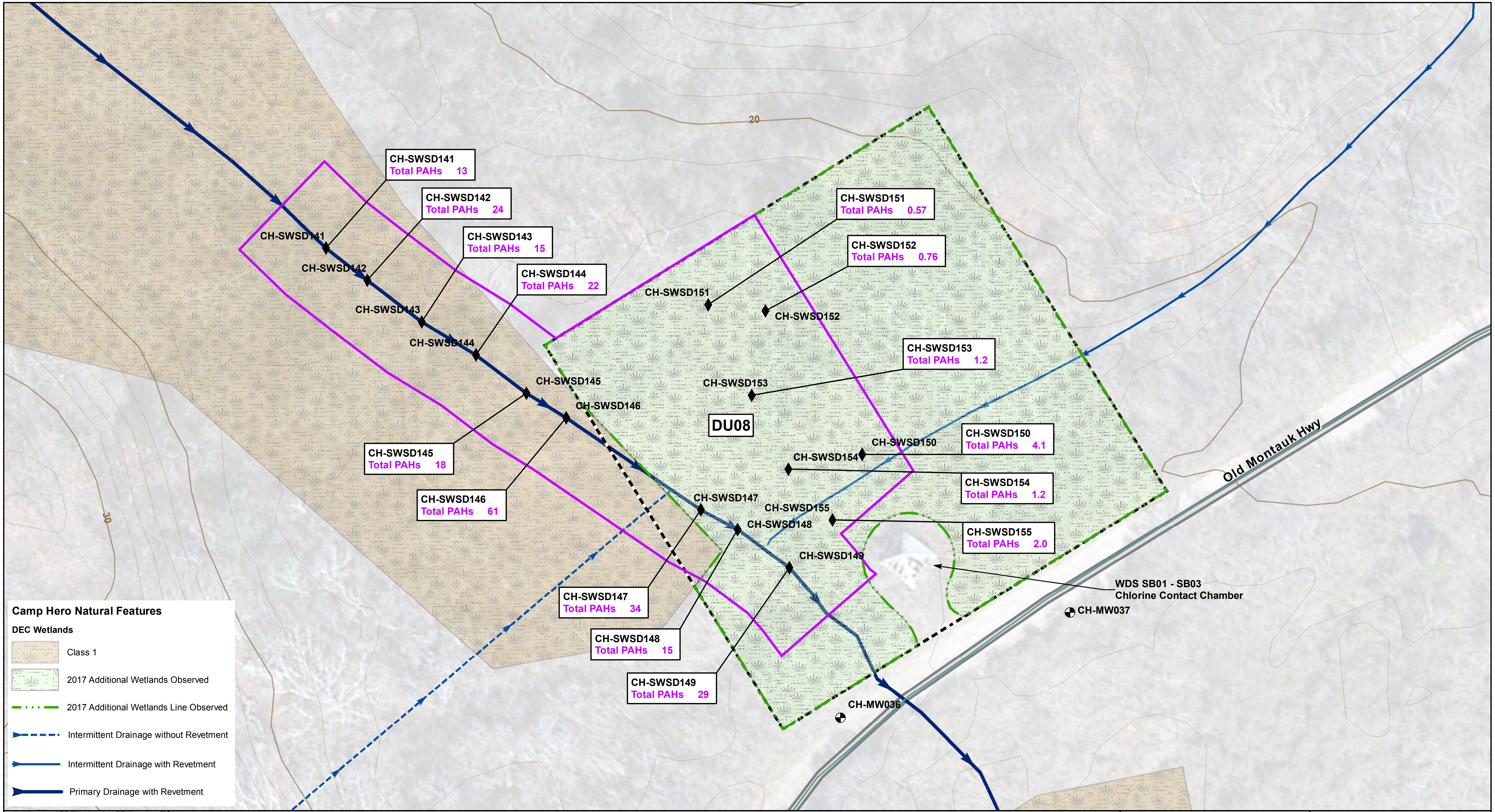
Distribution of Total PAHs in Sediment, SEA03

Camp Hero Remedial Investigation
Montauk, New York

PROJECT NO.	PREPARED BY:	DATE:	
60443903	JB	January 2019	Figure 3

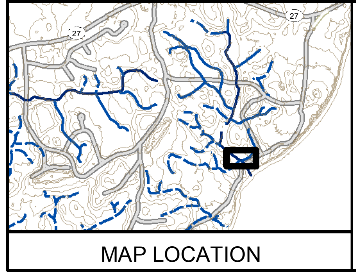
7/14/2018 \\USCHL1FP001\Data\Projects\Govt\Projects\USACE\Camp_Hero\GIS\Projects\RI_Report\MXD\Fig_4_21b_Distribution_of_COCs_SEA03.mxd



Camp Hero Natural Features

DEC Wetlands

- Class 1
- 2017 Additional Wetlands Observed
- 2017 Additional Wetlands Line Observed
- Intermittent Drainage without Revetment
- Intermittent Drainage with Revetment
- Primary Drainage with Revetment



MAP LOCATION

Camp Hero Built Features

- ◆ Phase III Surface Water and Sediment Sampling Location
- ◐ Groundwater Monitoring Well
- Stream Exposure Area
- Decision Unit

State Park Trails

- Paumanok Path

Topographic Contours

- 10 ft
- 2 ft

Results
Units are in mg/kg
Purple = PAHs that warranted additional evaluation as part of the ERA

Note
Wetlands were evaluated only within Decision Units.

N W E S

0 15 30 Feet
1 inch = 30 feet

AECOM

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Arlington, VA 22201
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Distribution of Total PAHs in Sediment, SEA08

Camp Hero Remedial Investigation
Montauk, New York

PROJECT NO.	PREPARED BY:	DATE:	
60443903	JB	January 2019	Figure 4

7/14/2018 \\USCHL1FP001\Data\Projects\Govt\Projects\USACE\Camp_Hero\GIS\Projects\RI_Report\MXD\Fig_4_26b_Distribution_of_COCs_SEA08.mxd

Attachment A

References

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References

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Attachment B

Statistical Results - Additional Background Comparison for Sediment

Attachment B
Statistical Results
Additional Background Comparison for Sediment
Camp Hero, Montauk, New York

						Background					Site					Goodness-of Fit Test		Hypothesis Testing		
Media	Background Name	Site Name	Fraction	Chemical Name	Unit	Total No. of Samples	Detection Rate	No. of Detects	No. of Detects Above LOD	Sample Mean	Total No. of Samples	Detection Rate	No. of Detects	No. of Detects Above LOD	Sample Mean	Background Distribution	Site Distribution	Statistical Test	p-value (1-sided)	Site Higher Than Background?
Sediment	Background Non-Revetted	SEA03 Non-Revetted	T	Total PAHs Calculated	mg/kg	15	100%	15	15	1.65	7	100%	7	7	0.679	-	Normal	Permutation Test	0.611	No
Sediment	Background Revetted	SEA03 Revetted	T	Total PAHs Calculated	mg/kg	15	100%	15	15	18.4	7	100%	7	7	30.9	Normal	Normal	t-Test	0.094	No
Sediment	Background Non-Revetted	SEA08 Non-Revetted	T	Total PAHs Calculated	mg/kg	15	100%	15	15	1.65	6	100%	6	6	1.64	-	Normal	Permutation Test	0.501	No
Sediment	Background Revetted	SEA08 Revetted	T	Total PAHs Calculated	mg/kg	15	100%	15	15	18.4	9	100%	9	9	25.7	Normal	-	Permutation Test	0.085	No

Notes:
- = Not Applicable
LOD = Limit of Detection
mg/kg = milligrams per kilogram
PAH = polycyclic aromatic hydrocarbon
SEA = stream exposure area
T = total fraction

Attachment C

Box-and-Whisker Plots – Additional Background Comparison for Sediment

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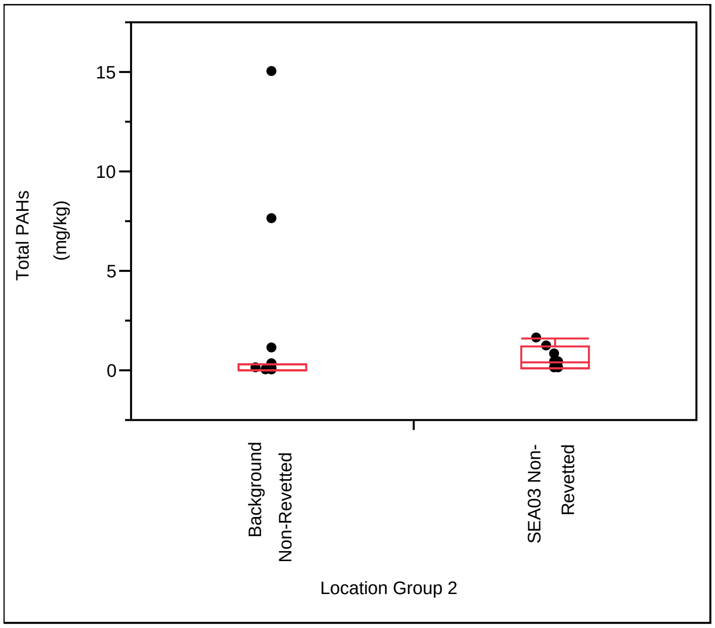
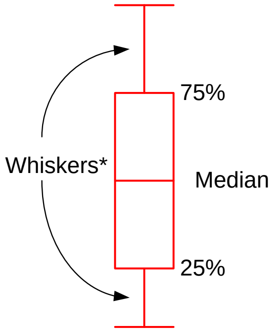
Attachment C
Box-and-Whisker Plots - Additional Background Comparison for Sediment

Sediment - Background Non-Revetted vs. SEA03 Non-Revetted

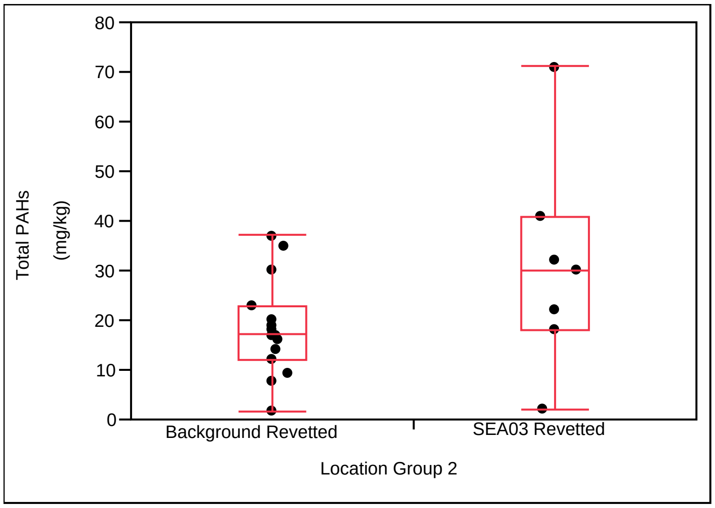


Box-and-Whisker Plot Legend



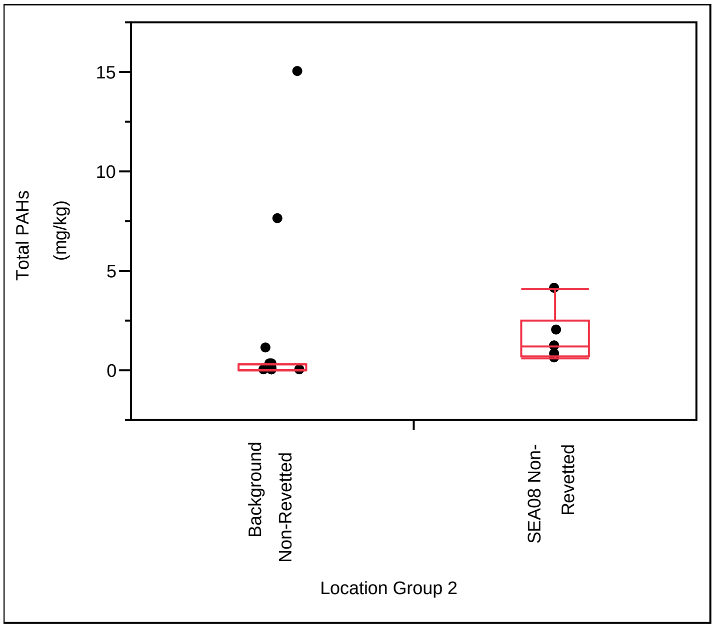
*from the ends of the box to the outermost data point that falls within upper/lower quartile +/- (1.5 × interquartile range)

Sediment - Background Revetted vs. SEA03 Revetted

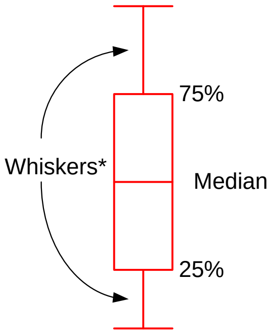


Attachment C
Box-and-Whisker Plots - Additional Background Comparison for Sediment

Sediment - Background Non-Revetted vs. SEA08 Non-Revetted

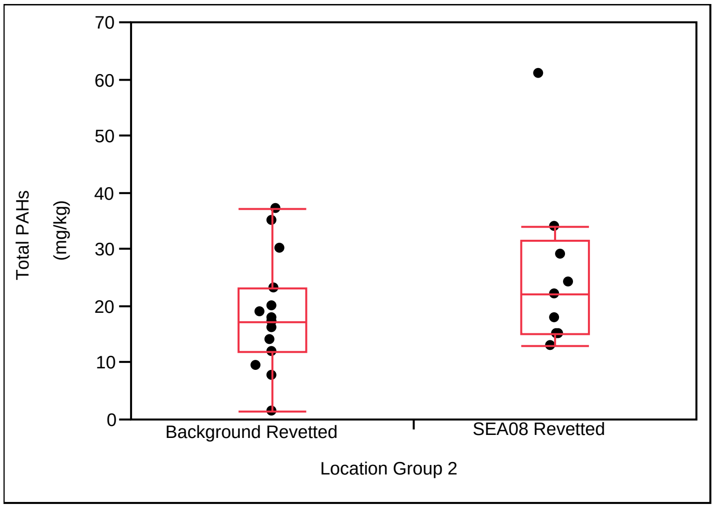


Box-and-Whisker Plot Legend



*from the ends of the box to the outermost data point that falls within upper/lower quartile +/- (1.5 × interquartile range)

Sediment - Background Revetted vs. SEA08 Revetted



Attachment D

PAST Statistical Output Files – Additional Background Comparison for Sediment

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Attachment D
PAST Statistical Output Files - Additional Background Comparison for Sediment

Background Non-Revetted vs. SEA03 Non-Revetted

```
Tests for equal means

Background Non-Revetted            SEA03 Non-Revetted
N:                                                    15 N:                              7
Mean:                                             1.6461 Mean:                     0.67857
95% conf.:                         (-0.66349 3.9558)     95% conf.:     (0.16078 1.1964)
Variance:                                         17.394 Variance:                 0.31345

Difference between means:                        0.96756
95% conf. interval (parametric):   (-2.377 4.3122)
95% conf. interval (bootstrap):    (-1.4119 2.6298)

t :                                              0.60345 p (same mean):            0.55299
Uneq. var. t :                                   0.88165 p (same mean):            0.39183
Monte Carlo permutation:           p (same mean):                  0.7789
Exact permutation:                 p (same mean):                 0.76806

Tests for equal variances

Background Non-Revetted            SEA03 Non-Revetted
N:                                                    15 N:                              7
Variance:                                         17.394 Variance:                 0.31345

F :                                               55.493 p (same var.):           7.31E-05
Monte Carlo permutation:           p (same var.):                   0.389
Exact permutation:                 p (same var.):                 0.39331
```

Background Revetted vs. SEA03 Revetted

```
Tests for equal means

Background Revetted                SEA03 Revetted
N:                                                    15 N:                              7
Mean:                                             18.447 Mean:                      30.857
95% conf.:                         (13.051 23.843)       95% conf.:     (10.904 50.811)
Variance:                                         94.947 Variance:                  465.48

Difference between means:                          12.41
95% conf. interval (parametric):   (-1.2973 26.118)
95% conf. interval (bootstrap):    (-4.0229 26.879)

t :                                              -1.8885 p (same mean):           0.073545
Uneq. var. t :                                   -1.4543 p (same mean):            0.18821
Monte Carlo permutation:           p (same mean):                  0.0715
Exact permutation:                 p (same mean):                0.069184

Tests for equal variances

Background Revetted                SEA03 Revetted
N:                                                    15 N:                              7
Variance:                                         94.947 Variance:                  465.48

F :                                               4.9025 p (same var.):           0.013486
Monte Carlo permutation:           p (same var.):                  0.1534
Exact permutation:                 p (same var.):                 0.15631
```

Attachment D
PAST Statistical Output Files - Additional Background Comparison for Sediment

Background Non-Revetted vs. SEA08 Non-Revetted

```
Tests for equal means

Background Non-Revetted            SEA08 Non-Revetted
N:                                               15 N:                        6
Mean:                                        1.6461 Mean:                1.6383
95% conf.:                         (-0.66349 3.9558) 95% conf.:   (0.27103 3.0056)
Variance:                                    17.394 Variance:            1.6975

Difference between means:                    0.0078
95% conf. interval (parametric):   (-3.6743 3.6899)
95% conf. interval (bootstrap):    (-2.4455 1.9708)

t :                                       0.0044338 p (same mean):      0.99651
Uneq. var. t :                            0.0064943 p (same mean):      0.99489
Monte Carlo permutation:           p (same mean):            0.9987
Exact permutation:                 p (same mean):           0.99847

Tests for equal variances

Background Non-Revetted            SEA08 Non-Revetted
N:                                               15 N:                        6
Variance:                                    17.394 Variance:            1.6975

F :                                          10.247 p (same var.):      0.01795
Monte Carlo permutation:           p (same var.):            0.4181
Exact permutation:                 p (same var.):           0.41359
```

Background Revetted vs. SEA08 Revetted

```
Tests for equal means

Background Revetted                SEA08 Revetted
N:                                               15 N:                        9
Mean:                                        18.447 Mean:                25.667
95% conf.:                         (13.051 23.843)   95% conf.:   (14.162 37.171)
Variance:                                    94.947 Variance:               224

Difference between means:                      7.22
95% conf. interval (parametric):   (-3.1954 17.635)
95% conf. interval (bootstrap):    (-3.6622 16.489)

t :                                         -1.4376 p (same mean):      0.16461
Uneq. var. t :                              -1.2922 p (same mean):      0.22035
Monte Carlo permutation:           p (same mean):            0.1703
Exact permutation:                 p (same mean):           0.16798

Tests for equal variances

Background Revetted                SEA08 Revetted
N:                                               15 N:                        9
Variance:                                    94.947 Variance:               224

F :                                          2.3592 p (same var.):      0.15318
Monte Carlo permutation:           p (same var.):            0.6527
Exact permutation:                 p (same var.):           0.65504
```

Attachment E

Scatterplots – PAH Source Classification

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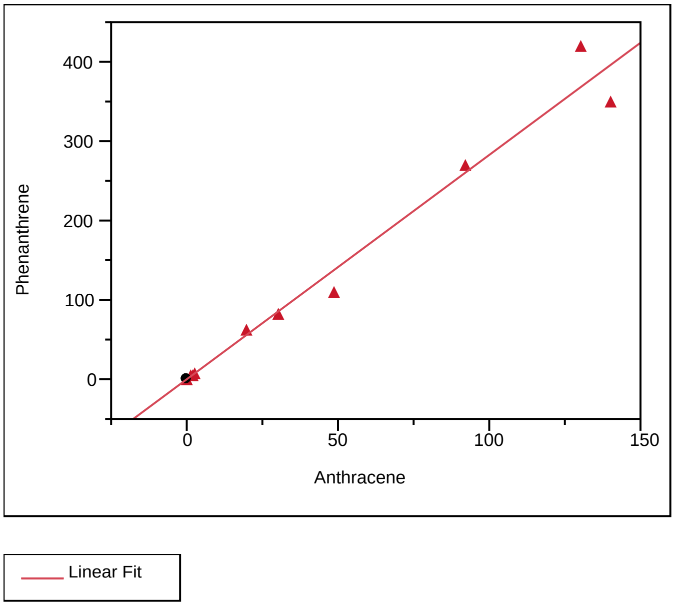
Attachment E
Scatterplots - PAH Source Classification

Surface Soil (Background + DU12)
Bivariate Fit of Phenanthrene By Anthracene



Linear Fit

Phenanthrene = -0.063155 + 2.8272191*Anthracene

Summary of Fit

RSquare	0.983697
RSquare Adj	0.983327
Root Mean Square Error	11.49832
Mean of Response	28.70216
Observations (or Sum Wgts)	46

Analysis of Variance

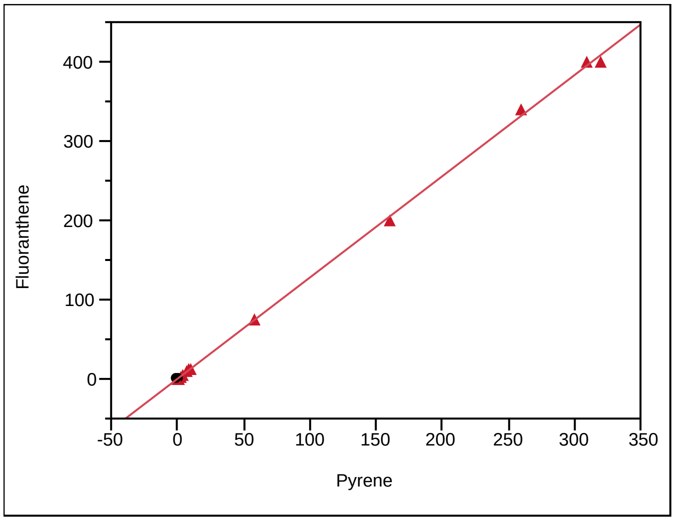
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	351015.78	351016	2654.961
Error	44	5817.30	132	**Prob > F**
C. Total	45	356833.07		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-0.063155	1.784886	-0.04	0.9719
Anthracene	2.8272191	0.054869	51.53	<.0001*

Attachment E
Scatterplots - PAH Source Classification

Surface Soil (Background + DU12)
Bivariate Fit of Fluoranthene By Pyrene



Linear Fit

Linear Fit
Fluoranthene = -0.031167 + 1.2769036*Pyrene

Summary of Fit

RSquare	0.999593
RSquare Adj	0.999583
Root Mean Square Error	2.009368
Mean of Response	33.39488
Observations (or Sum Wgts)	46

Analysis of Variance

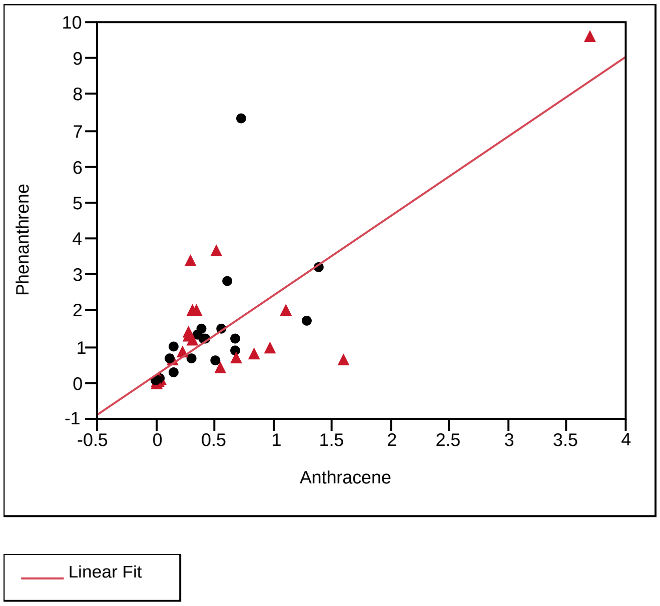
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**
Model	1	435804.82	435805	107937.7
Error	44	177.65	4.03756	**Prob > F**
C. Total	45	435982.47		<.0001*

Parameter Estimates

Term	**Estimate**	**Std Error**	**t Ratio**	**Prob>|t|**
Intercept	-0.031167	0.313248	-0.10	0.9212
Pyrene	1.2769036	0.003887	328.54	<.0001*

Attachment E
Scatterplots - PAH Source Classification

Sediment (Background + SEA03 + SEA08)
Bivariate Fit of Phenanthrene By Anthracene



Linear Fit
Phenanthrene = 0.214724 + 2.2054594*Anthracene

Summary of Fit

RSquare	0.585265
RSquare Adj	0.577989
Root Mean Square Error	1.098352
Mean of Response	1.011859
Observations (or Sum Wgts)	59

Analysis of Variance

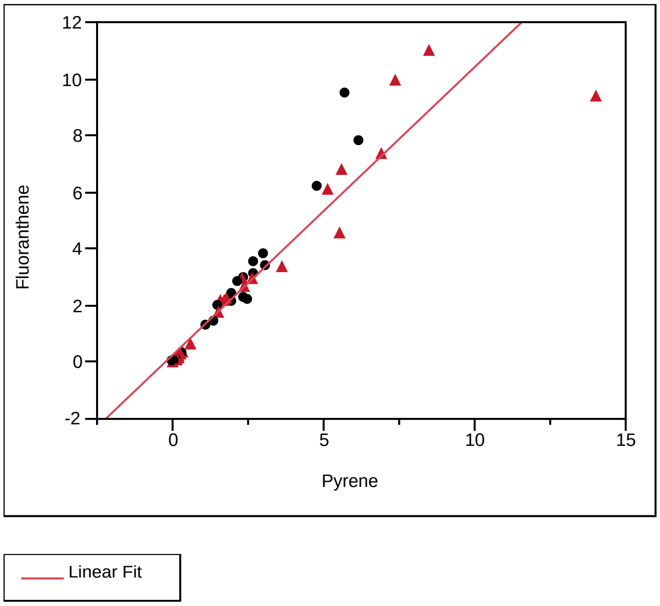
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	97.03760	97.0376	80.4372
Error	57	68.76347	1.2064	**Prob > F**
C. Total	58	165.80107		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.214724	0.168365	1.28	0.2074
Anthracene	2.2054594	0.245907	8.97	<.0001*

Attachment E
Scatterplots - PAH Source Classification

Sediment (Background + SEA03 + SEA08)
Bivariate Fit of Fluoranthene By Pyrene



Linear Fit

Fluoranthene = 0.253319 + 1.0161968*Pyrene

Summary of Fit

RSquare	0.885922
RSquare Adj	0.883921
Root Mean Square Error	0.993575
Mean of Response	2.306188
Observations (or Sum Wgts)	59

Analysis of Variance

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**
Model	1	436.98955	436.990	442.6592
Error	57	56.26993	0.987	**Prob > F**
C. Total	58	493.25948		<.0001*

Parameter Estimates

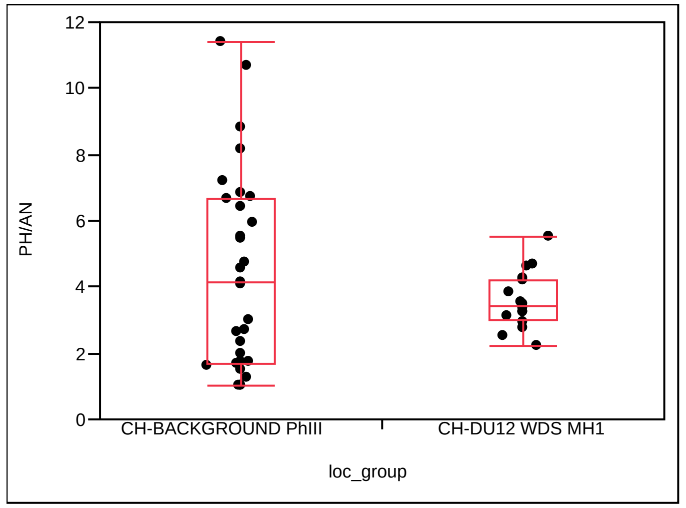
Term	**Estimate**	**Std Error**	**t Ratio**	**Prob>|t|**
Intercept	0.253319	0.162026	1.56	0.1235
Pyrene	1.0161968	0.0483	21.04	<.0001*

Attachment F

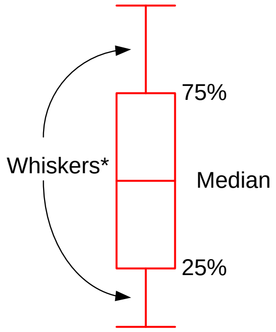
Box-and-Whisker Plots - PAH Source Classification

Attachment F
Box-and-Whisker Plots - PAH Source Classification

Compare DU12 PAH Ratios to Background PAH Ratios (Surface Soil)
<u>One-way Analysis of PH/AN By loc_group Media=Surface Soil</u>



<u>Box-and-Whisker Plot Legend</u>



*from the ends of the box to the outermost data point that falls within upper/lower quartile +/- (1.5 × interquartile range)

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
CH-BACKGROUND PhIII	30	715.000	705.000	23.8333	0.219
CH-DU12 WDS MH1	16	366.000	376.000	22.8750	-0.219

2-Sample Test, Normal Approximation

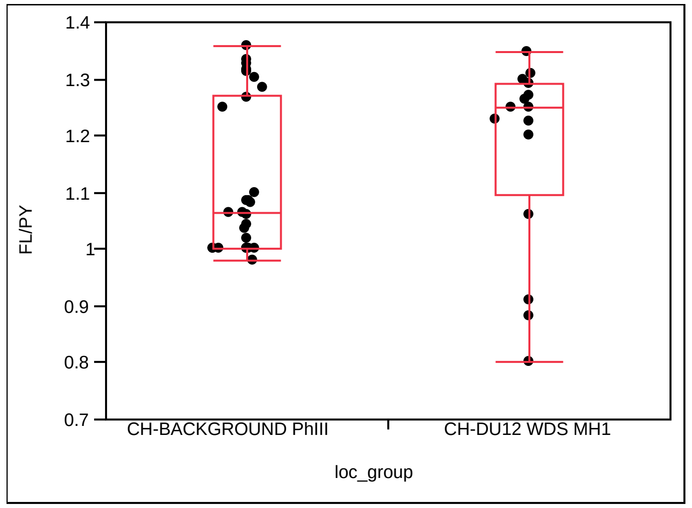
S	Z	Prob>|Z|
366	-0.21913	0.8266

1-way Test, ChiSquare Approximation

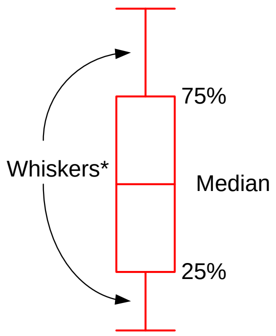
ChiSquare	DF	Prob>ChiSq
0.0532	1	0.8176

Attachment F
Box-and-Whisker Plots - PAH Source Classification

One-way Analysis of FL/PY By loc_group Media=Surface Soil



Box-and-Whisker Plot Legend



*from the ends of the box to the outermost data point that falls within upper/lower quartile +/- (1.5 × interquartile range)

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
CH-BACKGROUND PhIII	30	655.000	705.000	21.8333	-1.146
CH-DU12 WDS MH1	16	426.000	376.000	26.6250	1.146

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
426	1.14602	0.2518

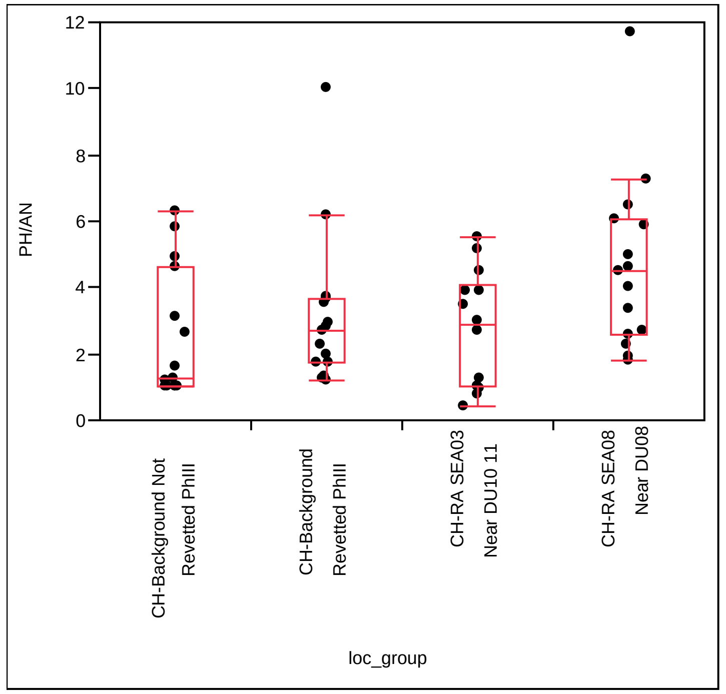
1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
1.3400	1	0.2470

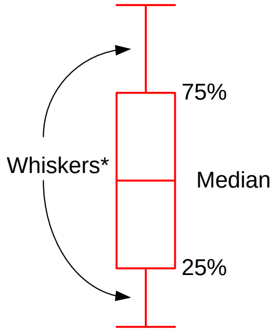
Attachment F
Box-and-Whisker Plots - PAH Source Classification

Compare SEA03 and SEA08 PAH Ratios to Revetted and Non-revetted Background (Sediment)

One-way Analysis of PH/AN By loc_group Media=Sediment



Box-and-Whisker Plot Legend



*from the ends of the box to the outermost data point that falls within upper/lower quartile +/- (1.5 × interquartile range)

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

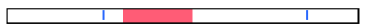
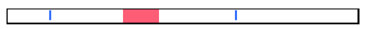
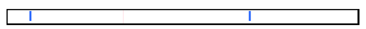
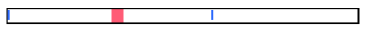
Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
CH-Background Not Revetted PhIII	15	352.000	450.000	23.4667	-1.699
CH-Background Revetted PhIII	15	446.000	450.000	29.7333	-0.061
CH-RA SEA03 Near DU10 11	14	357.000	420.000	25.5000	-1.115
CH-RA SEA08 Near DU08	15	615.000	450.000	41.0000	2.866

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
9.3028	3	0.0255*

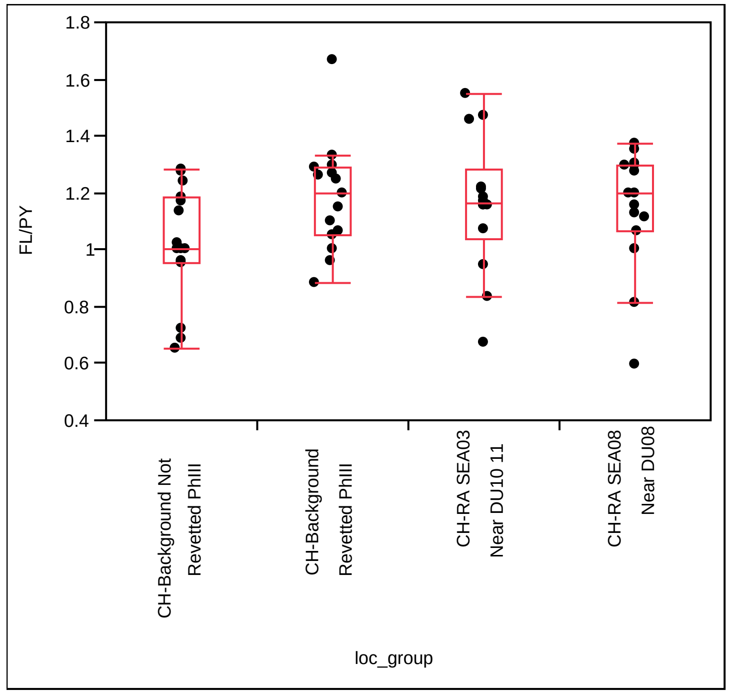
Nonparametric Comparisons For All Pairs Using Steel-Dwass Method

q*	Alpha
2.56903	0.05

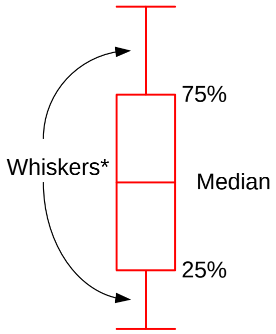
Level	- Level	Score Mean Difference	Std Err Dif	Z	p-Value	Hodges-Lehmann	Lower CL	Upper CL	Difference
CH-RA SEA08 Near DU08	CH-Background Not Revetted PhIII	8.53333	3.207391	2.66052	0.0390*	1.69565	0.05269	4.615686	
CH-RA SEA08 Near DU08	CH-RA SEA03 Near DU10 11	6.83571	3.163770	2.16062	0.1344	1.64429	-0.51843	4.024096	
CH-RA SEA08 Near DU08	CH-Background Revetted PhIII	6.66667	3.214550	2.07390	0.1617	1.40229	-0.37422	3.660915	
CH-Background Revetted PhIII	CH-Background Not Revetted PhIII	4.80000	3.207391	1.49654	0.4395	0.70000	-1.43732	2.246847	
CH-RA SEA03 Near DU10 11	CH-Background Not Revetted PhIII	-0.34524	3.142262	-0.10987	0.9995	0.00000	-1.82963	2.531661	
CH-RA SEA03 Near DU10 11	CH-Background Revetted PhIII	-1.31190	3.163770	-0.41467	0.9760	-0.23836	-2.27232	1.795113	

Attachment F
Box-and-Whisker Plots - PAH Source Classification

One-way Analysis of FL/PY By loc_group Media=Sediment



Box-and-Whisker Plot Legend



*from the ends of the box to the outermost data point that falls within upper/lower quartile +/- (1.5 × interquartile range)

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
CH-Background Not Revetted PhIII	15	320.000	450.000	21.3333	-2.255
CH-Background Revetted PhIII	15	502.500	450.000	33.5000	0.905
CH-RA SEA03 Near DU10 11	14	446.000	420.000	31.8571	0.454
CH-RA SEA08 Near DU08	15	501.500	450.000	33.4333	0.888

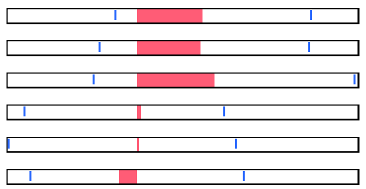
1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
5.2085	3	0.1572

Nonparametric Comparisons For All Pairs Using Steel-Dwass Method

q*	Alpha
2.56903	0.05

Level	- Level	Score Mean Difference	Std Err Dif	Z	p-Value	Hodges-Lehmann	Lower CL	Upper CL	Difference
CH-Background Revetted PhIII	CH-Background Not Revetted PhIII	6.60000	3.210973	2.05545	0.1679	0.129630	-0.041667	0.3461538	
CH-RA SEA08 Near DU08	CH-Background Not Revetted PhIII	6.20000	3.210615	1.93109	0.2150	0.125000	-0.073864	0.3441176	
CH-RA SEA03 Near DU10 11	CH-Background Not Revetted PhIII	4.48810	3.162600	1.41912	0.4873	0.154509	-0.085284	0.4318182	
CH-RA SEA08 Near DU08	CH-Background Revetted PhIII	0.40000	3.213477	0.12448	0.9993	0.008052	-0.222222	0.1750000	
CH-RA SEA08 Near DU08	CH-RA SEA03 Near DU10 11	0.06905	3.163770	0.02182	1.0000	0.003385	-0.254545	0.1975052	
CH-RA SEA03 Near DU10 11	CH-Background Revetted PhIII	-0.75952	3.164159	-0.24004	0.9951	-0.035778	-0.213636	0.2111582	

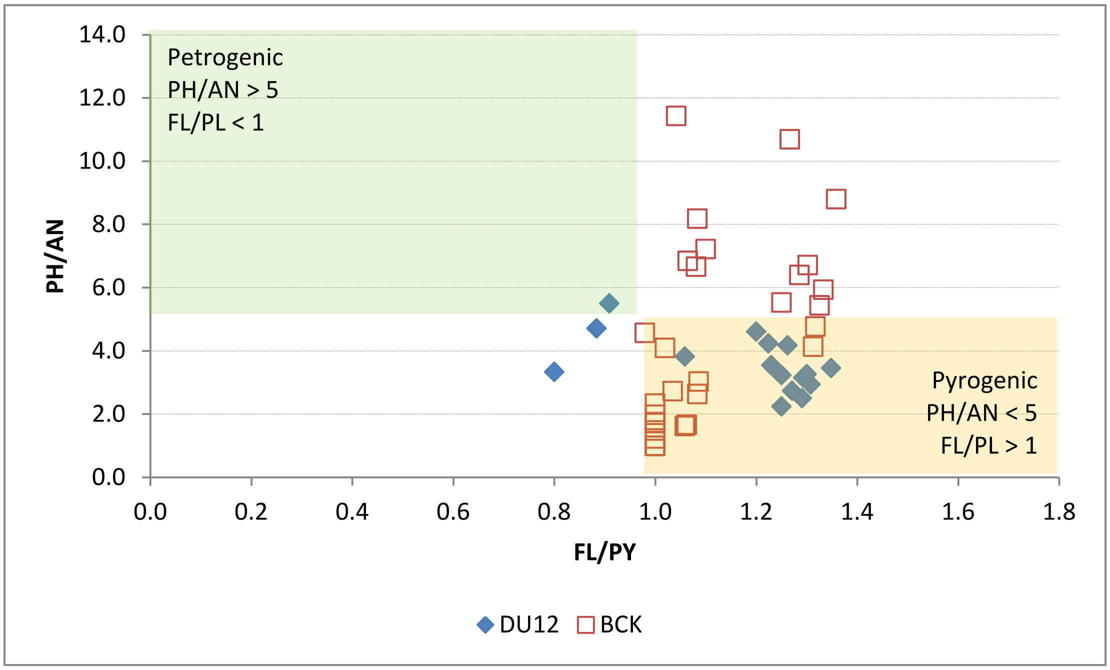


Attachment G

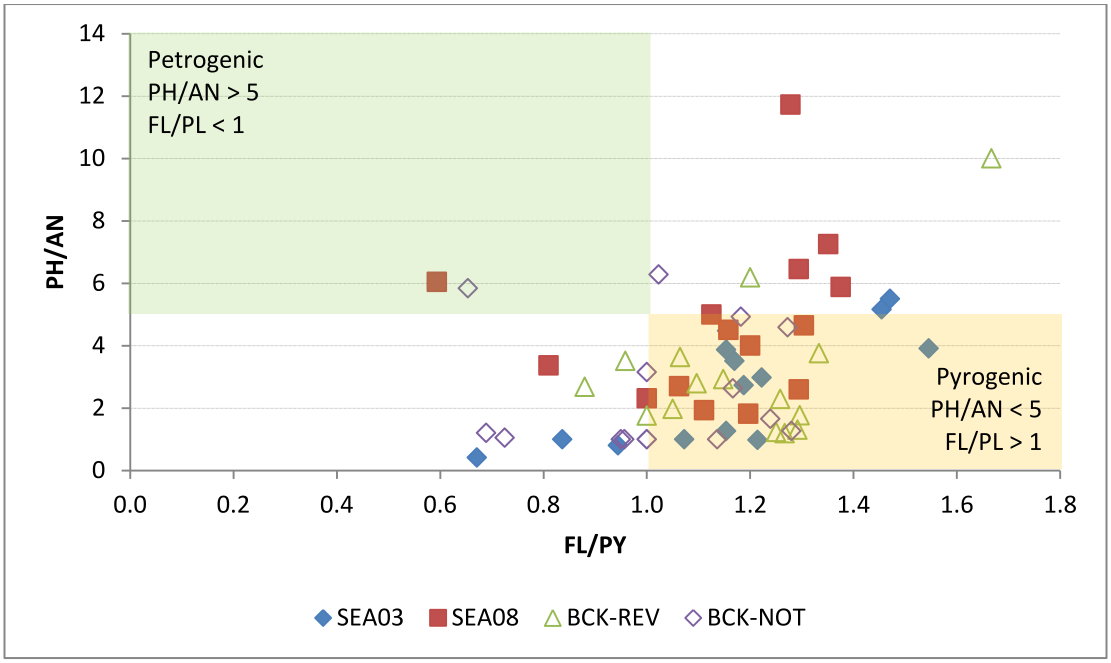
PAH Ratio Crossplots - PAH Source Classification

Attachment G
PAH Ratio Crossplots - PAH Source Classification

Graph of FL/PY vs. PH/AN in Soil (DU12 and Background)



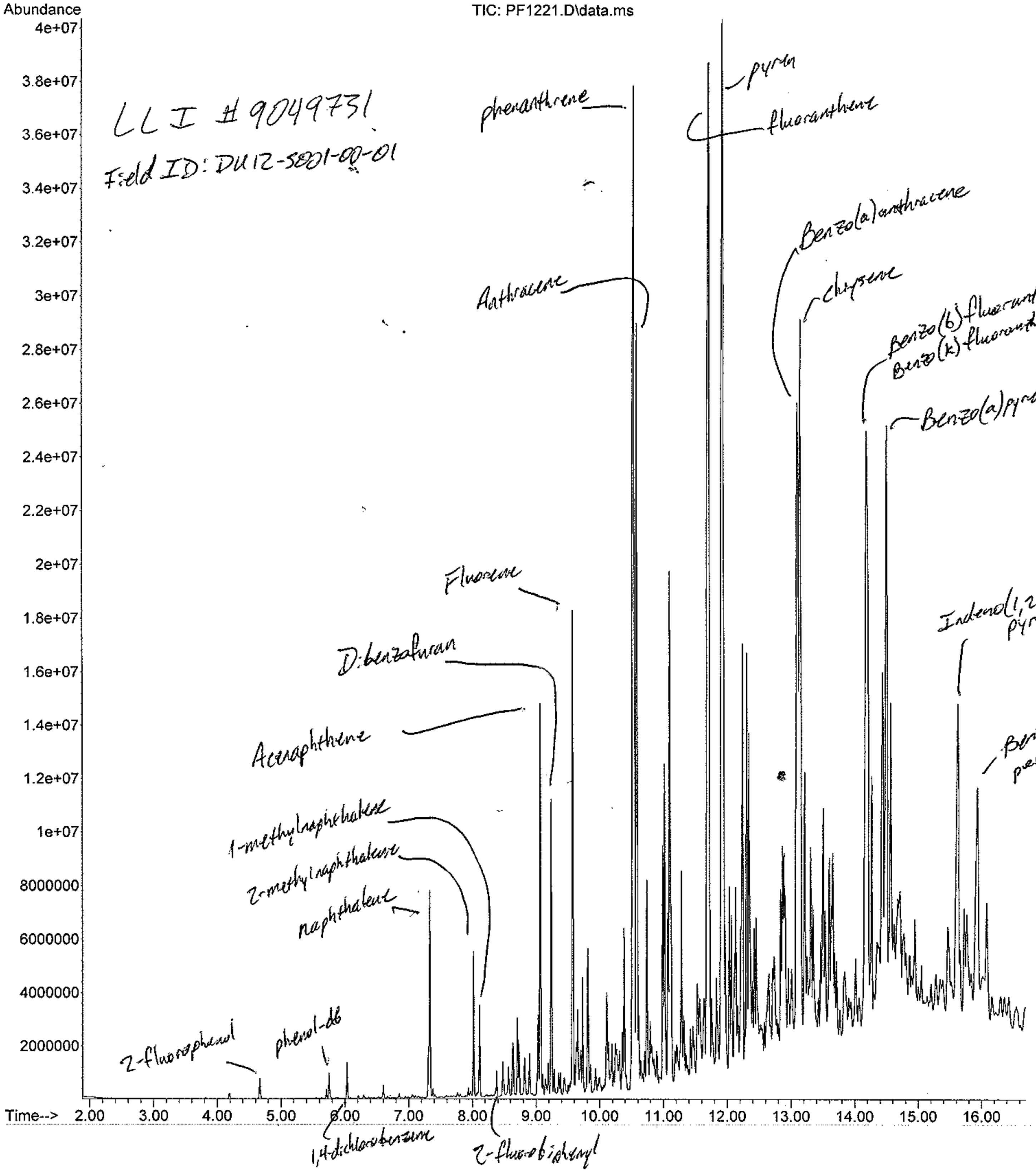
Graph of FL/PY vs. PH/AN in Sediment (SEA03, SEA08, and Background)



Attachment H

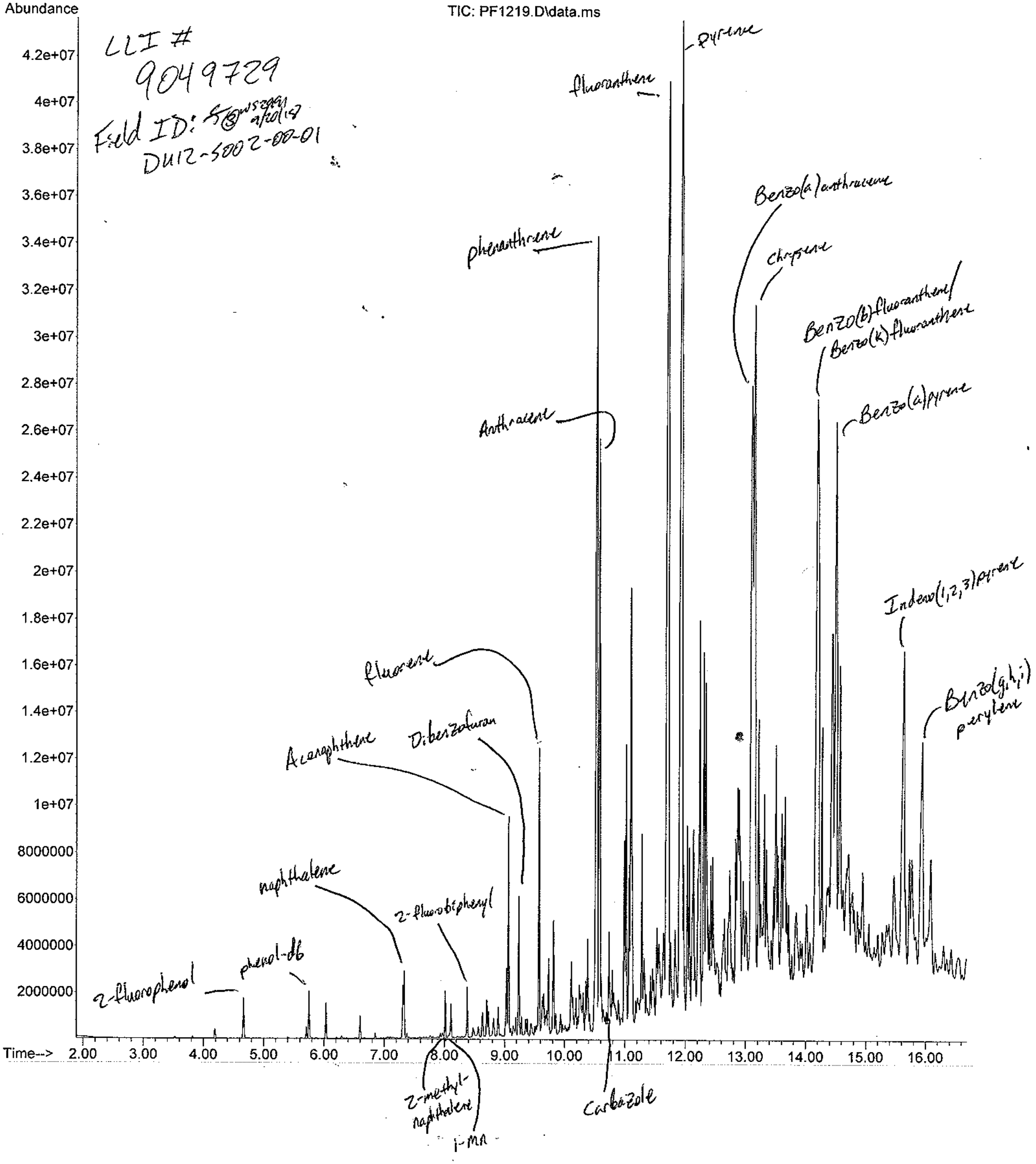
PAH Chromatograms

File   :D:\data\2017data\17jun24\PF1221.D
Operator   : lmh00956
Acquired   : 24 Jun 2017   6:49 pm using AcqMethod M8270D.M
Instrument :   HP23262
Sample Name: A3311;9049731;2;0;SAMPLE;;DOD26;T1
Misc Info : 17172SLJ;24564.sub;30.33;;1000;0;pf1203;10726;
Vial Number: 22



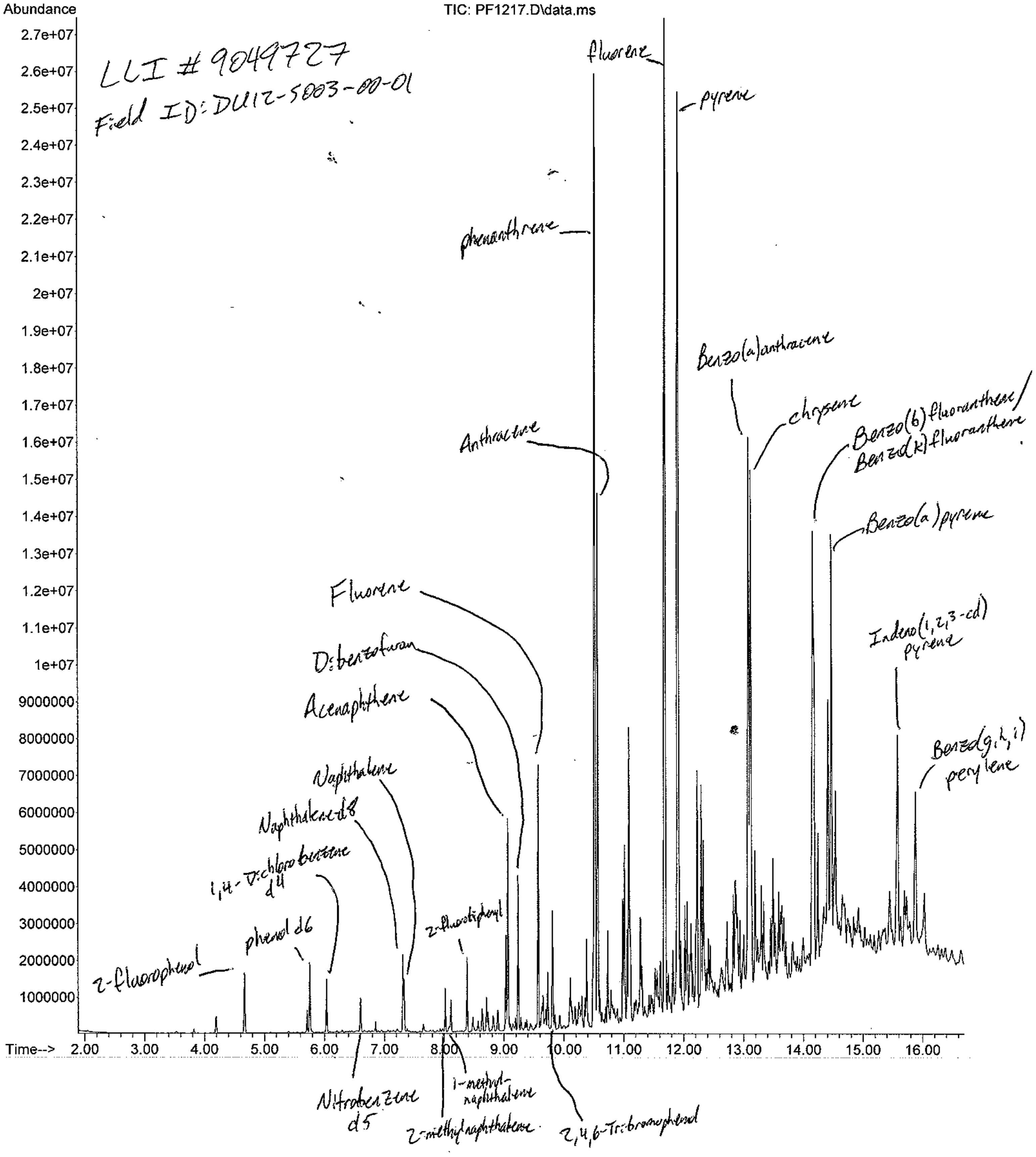
LLI # 9049731
Field ID: DU12-SB01-00-01

File :D:\data\2017data\17jun24\PF1219.D
Operator : lmh00956
Acquired : 24 Jun 2017 5:59 pm using AcqMethod M8270D.M
Instrument : HP23262
Sample Name: A3309;9049729;2;0;SAMPLE;;DOD26;T1
Misc Info : 17172SLJ;24564.sub;30.31;;1000;0;pf1203;10726;
Vial Number: 20



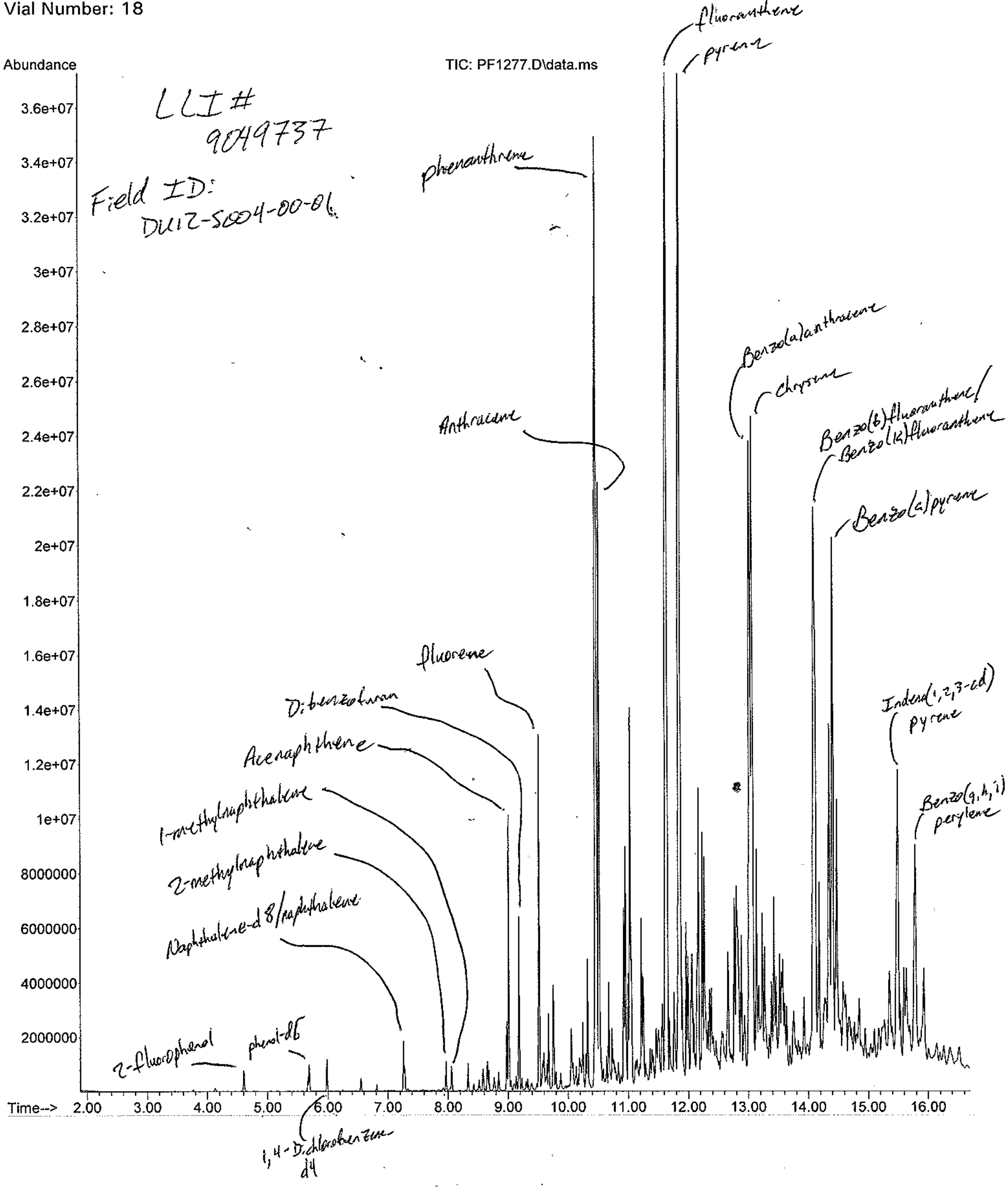
LLI #
9049729
Field ID: ~~5~~ ③ ws2991 9/20/17
DU12-S002-00-01

File   :D:\data\2017data\17jun24\PF1217.D
Operator   : lmh00956
Acquired   : 24 Jun 2017   5:08 pm using AcqMethod M8270D.M
Instrument :   HP23262
Sample Name: A3307;9049727;2;0;SAMPLE;;DOD26;T1
Misc Info : 17172SLJ;24564.sub;30.16;;1000;0;pf1203;10726;
Vial Number: 18



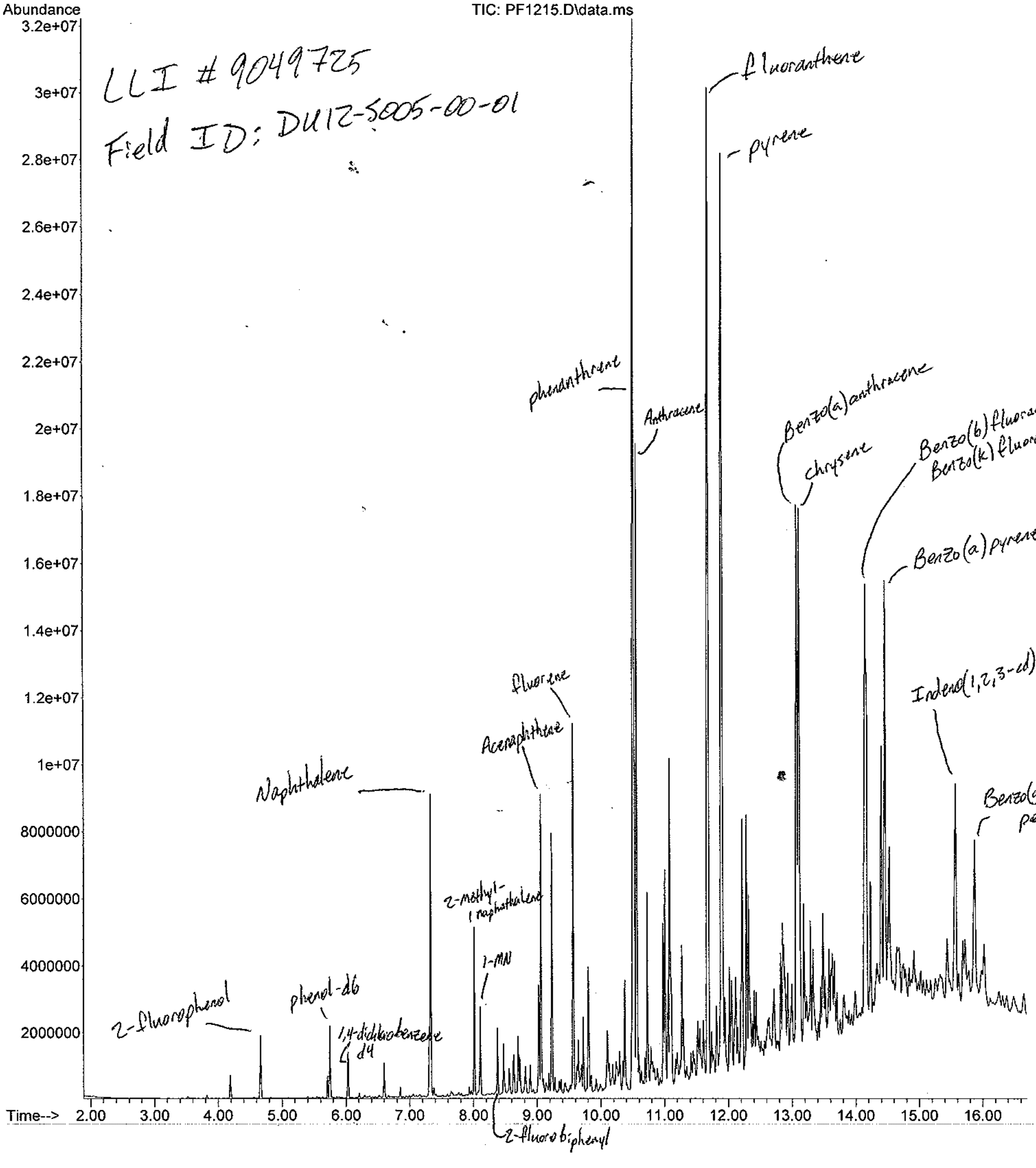
LLI # 9049727
Field ID: DU12-5003-00-01

File   :D:\data\2017data\17jun24a\PF1277.D
Operator   : apb10206
Acquired   : 25 Jun 2017   2:51 am using AcqMethod M8270D.M
Instrument :   HP23262
Sample Name: A3317;9049737;2;0;SAMPLE;;DOD26;T1
Misc Info   : 17172SLJ;24564.sub;30.39;;1000;0;pf1203;10726;
Vial Number: 18



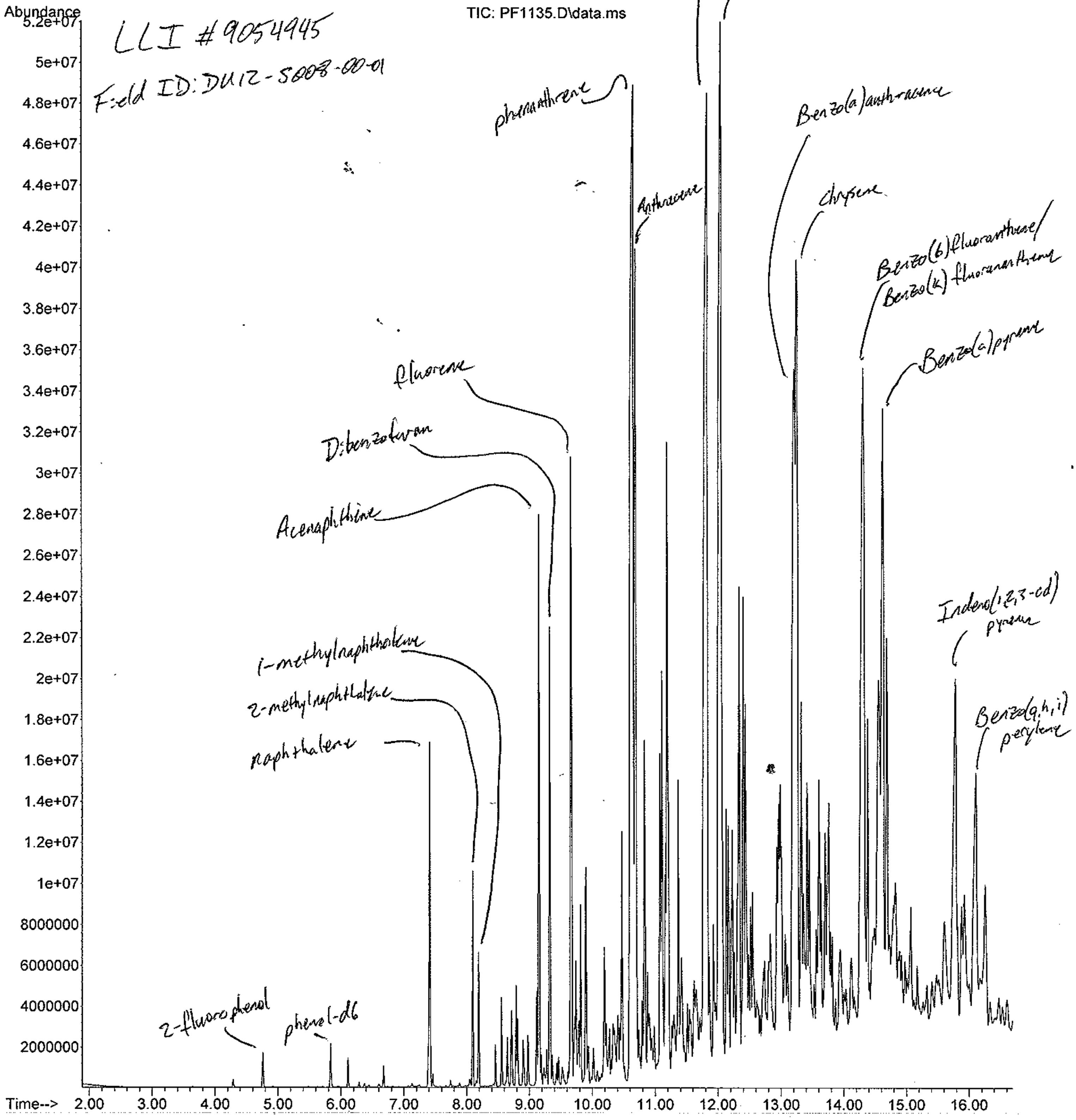
LLI #
9049737
Field ID:
DU12-S004-00-06

File   :D:\data\2017data\17jun24\PF1215.D
Operator   : lmh00956
Acquired   : 24 Jun 2017   4:18 pm using AcqMethod M8270D.M
Instrument :   HP23262
Sample Name: A3305;9049725;2;0;SAMPLE;;DOD26;T1
Misc Info : 17172SLJ;24564.sub;30.48;;1000;0;pf1203;10726;
Vial Number: 16

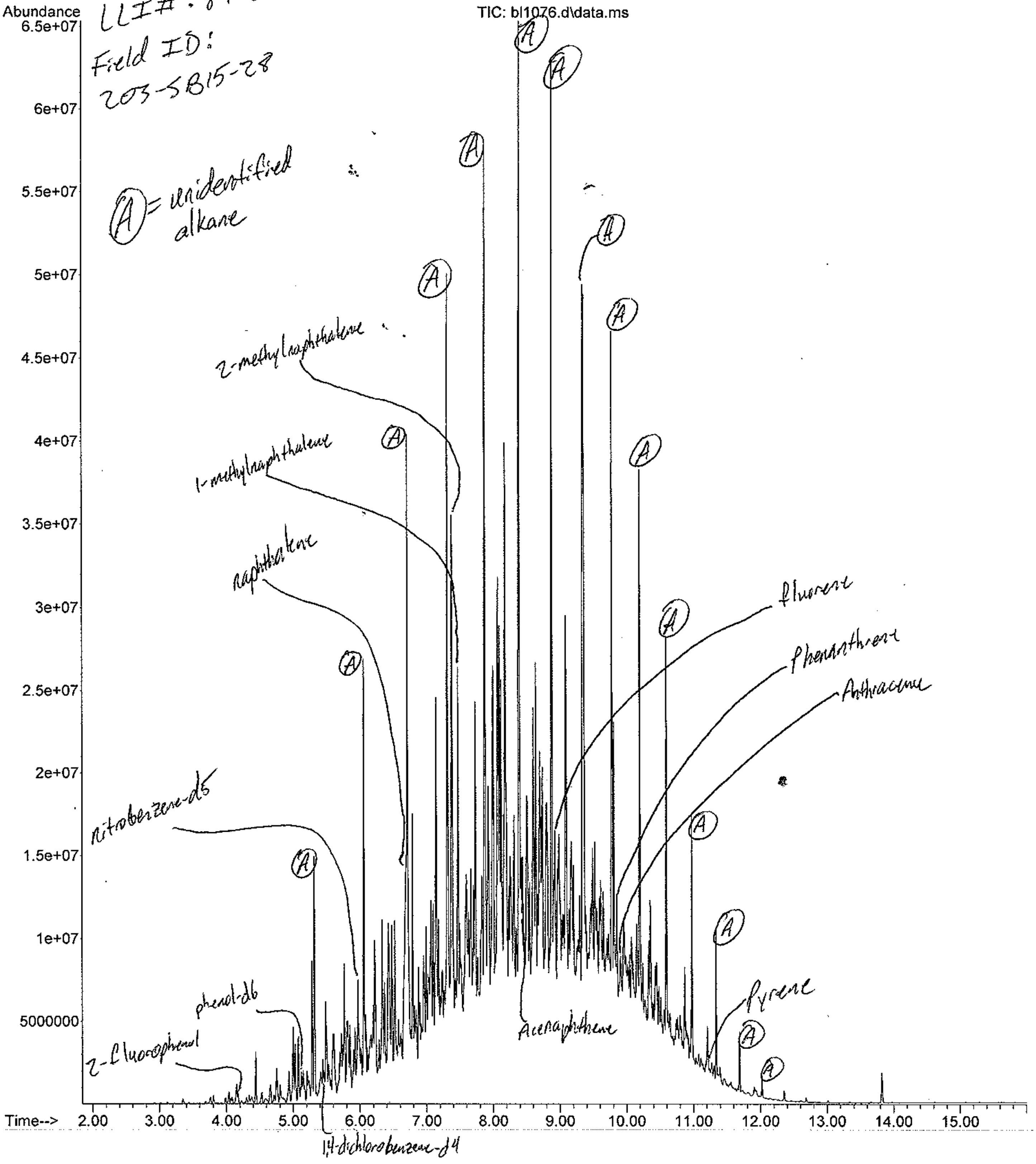

LLI # 9049725
Field ID: DU12-5005-00-01

File :D:\data\2017data\17jun23\PF1135.D
Operator : lmh00956
Acquired : 23 Jun 2017 5:36 pm using AcqMethod M8270D.M
Instrument : HP23262
Sample Name: 33-05;9054945;2;0;SAMPLE;;DOD26;T1
Misc Info : 17173SLH;24564.sub;30.29;;1000;0;pf1113;10726;
Vial Number: 26

LLI #9054945
Field ID: DU12-S008-00-01



File :C:\msdchem\1\data\16dec26\bl1076.d
Operator : lmh00956
Acquired : 26 Dec 2016 8:50 pm using AcqMethod M8270D.M
Instrument : HP18444
Sample Name: AP819;8746414;2;0;SAMPLE;;DOD26;
Misc Info : 16357SLD;22423.sub;30.07;;1000;0;bl1003;10726;
Vial Number: 27



LLI#: 8746414
Field ID:
203-SB15-28

(A) = unidentified alkane

File :C:\msdchem\1\data\16dec27a\bl1225a.d
Operator : apb10206
Acquired : 28 Dec 2016 12:33 am using AcqMethod M8270D.M
Instrument : HP18444
Sample Name: AP819DL;8746414DL;2;0;SAMPLE;;DOD26;
Misc Info : 16357SLD;22423.sub;30.07;;1000;0;bl1003;10726;
Vial Number: 6

LLI #: 8746414 - dilution