FINAL REPORT

Validation of Streamlined Mobile Lab-Based Real Time PFAS Analytical Methods

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The objectives of this project were to demonstrate the application of three real-time mobile laboratory methods for the analysis of per and poly-perfluoroalkyl substances (PFAS), including standard Department of Defense (DoD) Quality Systems Manual (QSM) approach, an accelerated liquid chromatography tandem mass spectroscopy (LC/MS/MS) method (accelerated method) for quantitative screening, and a methylene blue active substances (MBAS) semi-quantitative screening approach. The mobile laboratory methods were applied using high resolution site characterization methods and a stratigraphic flux to map PFAS migration pathways using a relative flux heat map and evaluate source strength using soil to groundwater concentration ratios, lysimeter pore water sampling, and synthetic precipitate leaching procedures (SPLP) at the demonstration site.

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ACRONYMS AND ABBREVIATIONS

% Difference	Percent Difference
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
6-2FTS	6:2 polyfluorotelomer sulfate
8-2FTS	8:2 polyfluorotelomer sulfate
AFCEC	Air Force Civil Engineer Center
AFFF	aqueous film-forming foam
AOI	Areas of Interest
BAA	Broad Agency Announcement
bgs	below ground surface
Br-PFHxS	Branched-Perfluorohexanesulfonic acid
CCV	continuing calibration verification
COI	Contaminants of Interest
CSM	conceptual site model
DoD	Department of Defense
DQOs	data quality objectives
EIS	extraction internal standard
ELAP	Environmental Laboratory Accreditation Program
Est K	estimated hydraulic conductivity
ESTCP	Environmental Security Technology Certification Program
EVS	Earth Volumetric Studio
f_{oc}	organic carbon content
ft/day	feet per day
FTS	polyfluorotelomer sulfate
GAAF	Grayling Army Airfield
HAL	Health Advisory Limit
HDPE	high-density polyethylene
HPT	hydraulic profiling tool
HRSC	high-resolution site characterization
IQR	Interquartile Range
K	hydraulic conductivity
LC	liquid chromatography
LC/MS/MS	liquid chromatography tandem mass spectroscopy

LCL	lower confidence limit
LCS	laboratory control sample
LCSD	laboratory control sample duplicate
LOQ	limit of quantitation
LS	lysimeter
M/T	current mass discharge
M2PFTeDA	Perfluoro-N [1,2-13C2] Tetradecanoic Acid
M8PFOS	Sodium perfluoro-1-[13C8] Octanesulfonate
MATES	Maneuver Area Training Equipment Site
MBAS	methylene blue active substances
MCL	maximum contaminant level
MDEQ, now EGLE	Michigan Department of Environmental Quality
MDL	method detection limit
MDMVA	Michigan Department of Military and Veteran Affairs
MIP	membrane interface probe
mL	milliliters
MPFDoA	Perfluoro-N-[1,2-13C2] Dodecanoic Acid
MPFBA	Perfluoro-N-[13C4] Butanoic Acid
MRM	multiple reaction monitoring
MS	matrix spike
MS/MS	tandem mass spectrometer
MSD	matrix spike duplicate
NAPLs	non-aqueous phase liquids
ng/kg	nanograms per kilogram
ng/L	nanograms per liter
OLS	Ordinary Least Squares
OSD	Office of the Secretary of Defense
PA	preliminary assessment
Pace	Pace Analytical
PCE	tetrachloroethylene
PFAS	per- and polyfluoroalkyl substances
PFBA	perfluorobutanoic acid
PFBS	perfluorobutane sulfonate
PFHpA	Perfluoroheptanoic acid
PFHpS	perfluoroheptanesulfonic acid
PFHxA	Perfluorohexanoic acid
PFHxS	Perfluorohexanesulfonic acid
PFNA	Perfluorononanoic acid
PFNS	Perfluorononanesulfonate
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonate
PFPeA	perfluoro-n-pentanoic acid

PFPeS	Perfluoropentanesulfonic acid
PFTeDA	Perfluorotetradecanoic acid
PFTrDA	Perfluorotridecanoic acid
ppt	parts per trillion
PS	primary source
PVC	polyvinyl chloride
Q/P	flow divided by pressure
QA/QC	Quality Assurance/Quality Control
QSM	Quality Systems Manual
RI	remedial investigation
RL	reporting limit
RPD	relative percent difference
SI	site inspection
SOP	standard operating procedure
SPE	solid-phase extraction
SPLP	synthetic precipitate leaching procedures
TAT	turnaround time
TCE	trichloroethylene
TGI	Technical Guidance Instruction
TOF	total organic fluorine
TOP	total oxidizable precursor
TOST	two one-sided t-test
Total PFHxS	Total Perfluorohexanesulfonic acid
T-PFOS	Technical product (branched) perfluorooctane sulfonate
UCL	upper confidence limit
UPLC	ultra-performance liquid chromatography
USEPA	United States Environmental Protection Agency
UVOST	ultraviolet optical screening test
VAP	vertical aquifer profiling
WAX	Waters Oasis® weak anion exchange
$\gamma_{\text{Soil-GW}}$	soil-to-groundwater concentration ratio

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- Arcadis: Kristen Hasbrouck, Alex Villhauer, Catherine Coffey, Erika Houtz, Jay Erickson, and Gaston Leone
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- Cascade Drilling
- Camp Grayling: Patricia Lyman, Jonathan Edgerly, Steven Gragert, and Bonnie Packer
- AECOM: Amanda Martin and Claire Mitchell

Thank you all for your efforts and support.

ABSTRACT

INTRODUCTION AND OBJECTIVES

The objectives of this project were to demonstrate the application of three real-time mobile laboratory methods for the analysis of per and poly-perfluoroalkyl substances (PFAS), including standard Department of Defense (DoD) Quality Systems Manual (QSM) approach, an accelerated liquid chromatography tandem mass spectroscopy (LC/MS/MS) method (accelerated method) for quantitative screening, and a methylene blue active substances (MBAS) semi-quantitative screening approach. The mobile laboratory methods were applied using high resolution site characterization methods and a stratigraphic flux to map PFAS migration pathways using a relative flux heat map and evaluate source strength using soil to groundwater concentration ratios, lysimeter pore water sampling, and synthetic precipitate leaching procedures (SPLP) at the demonstration site.

TECHNOLOGY DESCRIPTION

The mobile lab currently holds DoD Environmental Laboratory Accreditation Program (ELAP) certification for soil and groundwater analyses, compliant with DoD QSM 5.3. In addition, Pace developed an accelerated method to increase the daily sample testing capacity and used an indicator list of PFAS to streamline the analysis, which enables testing of 20 to 25 soil and groundwater samples per day. Lastly, the MBAS screening technique was evaluated to determine if the method was sensitive and selective enough to provide utility in prescreening samples for the mobile lab and source area screening. The results were combined using a TRIAD approach for adaptive high-resolution site characterization based on the stratigraphic flux approach developed under AFCEC BAA 927. The field methods also included the comparison of lysimeter pore water sampling with SPLP testing on vadose zone soils to evaluate source strength and mass loading.

PERFORMANCE AND COST ASSESSMENT

The PFAS mobile lab builds on decades of mobile lab application for chlorinated solvents and petroleum hydrocarbons by providing near real-time analysis of PFAS compounds. The PFAS mobile lab is currently the only tool capable of providing compound-specific selectivity over a range of concentrations (down to part per trillion levels) to enable source characterization and delineation of PFAS in soil and groundwater. The mobile lab successfully performed the DoD-compliant approach, analyzing up to 15 samples per day, and meeting the majority of the performance metrics at a cost comparable to rush turnaround by fixed labs. The accelerated method can analyze up to 25 samples per day with an indicator list of 13 PFAS compounds. Results showed that the accelerated method provides reliable results that are comparable to the DoD-compliant method at costs that are much less than rush turnaround by fixed labs. The MBAS screening method did not demonstrate the selectivity or sensitivity needed to reliably screen source soil and groundwater samples; the method exhibited significant bias that was attributed to interference. The mobile lab can support Remedial Investigations (RI) activities by providing adaptive high-resolution site characterization of PFAS releases. A collaborative approach combining the accelerated method for adaptive characterization for interim decisions and fixed lab DoD-compliant method for final decisions provides the greatest flexibility for implementation and achieving lowest overall project costs.

IMPLEMENTATION ISSUES:

The project team encountered various challenges while using the on-site DoD-compliant method that impacted laboratory operations and throughput, including 1) excessive sediment in water samples causing delays and likely matrix effects, 2) a significant number of EIS failures, which led to extended reporting times and rework, and 3) calibration associated with switching between matrices. The primary challenge encountered while using the accelerated LC/MS/MS method was the background contamination present in the materials and solvents, which increased reporting limits. Several of these challenges were addressed in the field to optimize the analytical program and the analytical team has recommended modifications to the analytical procedures that should further improve the methods.

Validation of Streamlined Mobile Lab-Based Real Time PFAS Analytical Methods

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EXECUTIVE SUMMARY

INTRODUCTION

The objectives of this project were to demonstrate the application of three real-time mobile laboratory methods for per- and polyfluoroalkyl substances (PFAS) including a Department of Defense (DoD) Quality Systems Manual (QSM)-compliant liquid chromatography tandem mass spectroscopy (LC/MS/MS) method, an accelerated LC/MS/MS method for quantitative screening, and methylene blue active substances (MBAS) assay for semi-quantitative screening at source areas. The mobile lab methods were evaluated using high-resolution site characterization field techniques and stratigraphic flux to map PFAS migration pathways at the site. The team used a relative flux heat map and evaluated source strength using soil to groundwater concentration ratios, lysimeter pore water sampling, and synthetic precipitate leaching procedures (SPLP).

It is increasingly recognized that contaminant mass flux and discharge may represent the most appropriate measure of plume strength and potential migration risk. Application of the PFAS mobile lab approach supports development of a flux-based conceptual site model (CSM) in real time and enables implementation of more cost-effective remedies by ranking and prioritizing sources and focusing remedial efforts primarily on long-term mass discharge reduction. The PFAS mobile lab and stratigraphic flux approach are well suited to remedial investigation (RI) activities for which accelerated timelines are needed to address potential sources of drinking water impacts as well as developing holistic remedial strategies at DoD sites involving multiple sources of PFAS impacts.

OBJECTIVES

The purpose and scope of this demonstration were to validate the application of real-time mobile laboratory methods for characterization of PFAS sources and associated groundwater plumes. The specific objectives of this project were to demonstrate application of:

1. Definitive on-site PFAS analyses: solid-phase extraction (SPE) with LC/MS/MS – provided by a DoD Environmental Laboratory Accreditation Program (ELAP)-certified lab in the field using DoD QSM 5.3 protocol for 24 PFAS compounds which provides definitive results. While not an analytical method, the term "**DoD ELAP *Method***" is used herein for simplicity.

2. An accelerated LC/MS/MS method focusing on quantitation of a limited number of target PFAS compounds based on site-specific data as indicators of PFAS plume distribution. This method is referred to as the **Accelerated Method**, which provides quantitative screening results.

3. **MBAS assay** to evaluate relative amounts of total anionic PFAS and to determine its utility as a pre-LC/MS/MS screening tool to protect the instrumentation.

4. Systematic combination of methods to adaptively and accurately resolve PFAS impacts.

TECHNOLOGY DESCRIPTION

The PFAS mobile lab builds on decades of mobile lab application for chlorinated solvents and petroleum hydrocarbons by providing near real-time analysis of PFAS compounds. The PFAS mobile lab is the only tool capable of providing compound-specific selectivity over a range of concentrations (down to part per trillion levels) to enable source characterization and delineation of PFAS in soil and groundwater. The mobile lab is currently DoD ELAP-certified for soil and groundwater analyses by DoD QSM 5.3. Pace developed the Accelerated LC/MS/MS Method to increase the daily sample testing throughput and used a site-specific list of target PFAS compounds to streamline the analysis, which enables testing of up to 25 soil and groundwater samples per day. The MBAS screening technique was evaluated to determine if the method was sensitive and selective enough to provide utility in prescreening samples for the mobile lab and determine its utility for source area screening. The results were combined using a TRIAD approach for adaptive high-resolution site characterization based on the stratigraphic flux approach developed under Air Force Civil Engineer Center (AFCEC) Broad Agency Announcement (BAA) 927.

Field Application Results

The demonstration was conducted at the Grayling Army Airfield (GAAF) at Camp Grayling in the north-central portion of Michigan's Lower Peninsula (**Figure 1-1**). The site was selected based on its shallow depth to water, applicability of direct-push technology for application of cost-effective characterization, and synergy with Camp Grayling's ongoing remedial investigation. The team mobilized to the site and completed an on-site characterization between October 17 and November 19, 2019. Implementation included adaptive high-frequency soil and groundwater sampling in the source areas (Buildings 1160 and 1194/95) and on transects downgradient progressing toward the southeast site perimeter and boring VAP-27. The initial layout of borings, including borings designated as "primary" and "adaptive," is shown on **Figure 5-1**. The components of the investigation were as follows:

- Three primary source borings installed immediately downgradient of each of the two potential source areas (Building 1160 and Building 1194/95). The primary source borings were used as a snapshot of PFAS concentrations at each source before commencement of the downgradient flux transect sampling.
- Three adaptive flux transects spaced downgradient of the two potential source areas and upgradient of the highest PFAS concentration identified at the site perimeter during previous site characterization (VAP-27).
- Six secondary source borings completed near Building 1160 to provide greater resolution of source area impacts including the installation of four lysimeters and SPLP sampling to characterize pore-water and contaminant loading in the source vadose zone.

The VAP boring locations and sample intervals were based in part on the results of the hydraulic profiling tool (HPT) borings as well as the analytical data from the mobile laboratory. The analytical data were loaded daily into the EVS 3D model to provide reference for additional work. The data from Transect 1 were used to identify a broad area of impact and focus Transect 2 on the Building 1160 source area. Transect 3, although extended based on the mobile laboratory results, did not continue far enough southwest to capture the plume originating near Building 1160 before winter weather set in and forced suspension of the investigation.

Following completion of the downgradient transects and the confirmation of Building 1160 as a primary source area, six additional borings were completed at Building 1160 to refine the source characterization. At each additional boring, an HPT was advanced to approximately 60 feet below ground surface (bgs) to log estimated hydraulic conductivity (Est K). In an adjacent borehole, a soil boring was completed, and soil samples were collected at nominal 2-foot intervals including the capillary fringe, at the water table, and just below the water table. In addition, up to seven vertical aquifer profile (VAP) groundwater samples were collected underneath the Building 1160 source area to evaluate the vertical distribution groundwater impacts.

Four ceramic cup suction lysimeters were installed via hand auger on November 26, 2019 adjacent to borings SS-4, SS-5, and SS-6, west of Building 1160 (**Figure 5-2**). Lysimeters were placed below the locations of the highest soil analytical results and below the frost line. Lysimeter intakes were installed at depth of approximately 10 feet bgs; above the water table but below the highest concentrations of PFAS observed in vadose zone soil. The initial sampling attempt was made on December 20, 2019, during which three of the four lysimeters (LS-2, LS-3, and LS-4) were dry. The remaining lysimeter (LS-1) only yielded a partial sample volume. Arcadis performed the manufacturer's specified reconditioning procedure and attempted to sample the lysimeters again on June 1, 2020 with identical results. After repeated attempts to collect a sample, the lysimeters were pulled and re-installed on August 26 through 27, 2020. After the lysimeters were allowed to equilibrate, a sprinkler was used to simulate a rainfall event on August 2 and facilitate pore-water sample collection. During the lysimeter installation, additional soil samples were collected for SPLP analysis in comparison with the lysimeter pore-water and soil to groundwater ratios.

Evaluate DoD ELAP Method in the Field

DoD ELAP Method Throughput: Over 5 weeks (23 days of laboratory operation), the laboratory analyzed and reported 201 groundwater samples and 47 soil samples. This represents 71 percent of the total number of samples collected by the field team; the balance of the samples was analyzed after the field program ended. Laboratory throughput increased from an average of six samples per day at the beginning of the program to more than 16 samples per day by the end of the project, falling short of the goal of 20 samples per day. Nonetheless, the mobile lab facilitated next-day results for prioritized samples, which enabled adaptive characterization in the field. In-field improvements related to the management of sediment in water samples, increased sample preparation capacity and sample prioritization led to a capacity of 10 to 15 samples per day.

DoD ELAP Method Analytical Costs: The cost to provide DoD ELAP services in the field is approximately \$5,500 per day. A 10-day project with a \$3,500 mobilization would be \$58,500, which equates to 100 to 150 samples over 10 days, or between \$390 and \$585 per sample. Current fixed lab pricing is approximately \$200 for 15-day turnaround time (TAT), with a 100 to 150 percent surcharge for 48 hr. rush analysis, or \$400 to \$500 per sample. This implies that the mobile lab compares favorably with fixed lab pricing, especially considering that actual results can be available next day with the mobile lab compared to 72 hrs. with shipping at a fixed lab.

DoD ELAP Method - Quality Assurance/Quality Control (QA/QC): The data quality objectives for this definitive work were set to satisfy DoD's QSM 5.3, Table B-15. The laboratory was able to largely satisfy these data quality objectives (DQOs) with several exceptions, discussed in more detail in the report and called out in the narratives of the laboratory reports.

A detailed review of the QA/QC data for the final dataset indicates that the analytical work was conducted largely in control: an average of 96.4 percent pass rate for all water QC and an average of 95.3 percent pass rate for soil QC tests, both using the tolerances set forth for this work (See **Table 6-3**). A significant number of extraction internal standard (EIS) recovery issues were encountered with this method that created significant rework, almost all of which was done after the field program ended. Overall, a percent pass rate of 89.1 percent was observed for the EIS recoveries, with the bulk of the issues being associated with several early and late eluting EIS compounds.

> **Duplicates: Water** – To assess both field sampling and analytical precision, 12 field duplicate water samples were collected as part of this work. Excluding an outlier result, the relative percent differences (RPDs) for all of the average RPDs for waters never exceeded 16 percent, indicating excellent sampling and analytical precision. **Soil** - Four field duplicate soil samples were collected as part of this work. These duplicate samples were collected in the field and were placed directly into two separate sample jars; no homogenization of the soil was conducted before the samples were placed into the jars. Only one of the field duplicate samples met the RPD criteria of </=50 percent; in this pair, the average RPD was determined to be 29 percent. It is believed that lack of sampling precision (or sample representativeness) contributed to the poor precision between these soil field duplicates; the following note on soils demonstrates this matter.

Special Note on Soils: At the time of the field demonstration, Pace had not yet received DoD ELAP accreditation for its soil method. To comply with DoD's guidance, soil samples were sent off site for analyses at a DoD ELAP-accredited laboratory. These soils were homogenized in the laboratory before creating the split samples for the off-site laboratory. To evaluate the accuracy of the on-site lab, the following statistical equivalence measures were evaluated: R^2, slope, and RPD for each analyte. The correlation (as R^2) between all of the detect pairs for all analytes is 0.976, and the slope was 1.24, indicating a slight positive bias to the on-site lab work. The average RPD for the entire compound dataset was 36 percent, which is well below the typical goal of 50 percent for soils. Although there were no performance goals established for this off-site testing for soils, the metrics used for comparing the two datasets strongly suggest that there is adequate comparability between the two methods. Further, the data also speak to the analytical precision of the on-site DoD ELAP method and reveals the difficulties with obtaining representative soil samples that can achieve the RPD goal of 50 percent.

DOD ELAP Method Implementation Issues: The primary challenges included: 1) excessive sediment in water samples causing delays and likely matrix effects; 2) a significant number of EIS failures, which led to extended reporting times and rework; and 3) calibration associated with switching between soil and water matrices. These challenges were minimized in the field to optimize the analytical program, as shown by increased analytical throughput during the latter stages of the field program. Several areas for future improvement of the analytical techniques were identified throughout this work and are summarized in **Section 6.5** of the report.

Evaluation of Accelerated Method

The Accelerated Method analyses were conducted over 13 days of analytical work between January 14 and March 4, 2020. The Accelerated Method was developed as a screening-level method with the goal of meeting the QA/QC objectives identified in the Demonstration Plan. The method is summarized below and described in detail in **Section 6.2.1**.

Accelerated Method - Water Analytical Procedure: For groundwater samples, small volumes (3 to 5 mL) were collected in 15 mL centrifuge tubes. All samples and QC were spiked with EIS, and all samples were stabilized by addition of methanol to achieve 70 percent methanol and 30 percent sample ratio to stabilize the PFAS (i.e., PFAS were no longer prone to stratification or adhering to the sample container walls). Samples were then prepared further for in-line solid phase extraction (SPE) followed by analyses via LC/MS/MS.

Accelerated Method - Soil Analytical Procedure: The soil extracts from the DoD ELAP method analyses were analyzed after the field program ended in the same mobile lab using the Accelerated Method. The analyses were conducted using the modified in-line SPE and liquid chromatography (LC) programs to allow for shorter run times. It is worth noting that the Accelerated Method's in-line SPE and LC program also uses isotope dilution calibration and extracted internal standards for soil and does not differ significantly from the DoD ELAP Method from a procedure and equipment perspective.

SELECTION OF GRAYLING SITE-SPECIFIC ACCELERATED METHOD ANALYTE LIST

The analyte list for the Accelerated Method was intended to be focused on a limited number of site-specific PFAS compounds such as perfluorooctane sulfonate (PFOS)/perfluorooctanoic acid (PFOA) and several others. An assessment of the dataset derived from the DoD ELAP Method results indicated that the following compounds adequately represent the makeup of the PFAS: PFOS, PFOA, perfluorobutane sulfonate (PFBS), perfluorobutanoic acid (PFBA), perfluorohexane sulfonate (PFHxS), perfluorohexanoic acid (PFHxA), perfluorononanoic acid (PFNA), perfluoroheptanoic acid (PFHpA), perfluoro-n-pentanoic acid (PFPeA), perfluoroheptanesulfonic acid (PFHpS), perfluoropentanesulfonic acid (PFPeS), 8:2 polyfluorotelomer sulfate (8-2FTS), and 6:2 polyfluorotelomer sulfate (6-2FTS). The PFAS analytes are categorized as "Primary PFAS compounds" and "Secondary PFAS compounds" based on the Office of the Secretary of Defense memorandum (OSD 2019) prescribing screening levels for PFOA, PFOS, and PFBS – these are considered Primary PFAS compounds. The remainder of the list are not. This convention is used throughout the report to simplify comparisons between the DoD ELAP Method and the Accelerated Method.

Accelerated Method Throughput: The laboratory analyzed 234 water samples and 89 soil samples (for a total of 323 samples) over 13 days of laboratory work. This equates to 24.8 samples per day. Based on this productivity, it is reasonable to expect the laboratory to turn around results for a group (four to eight samples) of priority samples within the same day and all samples for a given day (up to approximately 25) being reported by mid-morning of the next day. Use of a shorter analyte list including PFOA, PFOS, and PFBS would likely increase the throughput of the laboratory.

Accelerated Method Analytical Costs: The cost to provide the Accelerated Method services in the field is approximately \$5,500 per day with a capacity of 20 to 25 soil and water samples per day. A 10-day project with a \$3,500 mobilization would be \$58,500, which equates to 200 to 250 samples over 10 days, or between \$283 and \$226 per sample. Current fixed lab pricing is approximately \$200 for 15-day TAT, with a 100 to 150 percent surcharge for 48 hr. rush analysis, or \$400 to \$500 per sample. This implies that the mobile lab compares favorably with fixed lab pricing, especially considering that actual results can be available next day with the mobile lab compared to 72 hrs. with shipping at a fixed lab.

Accelerated Method, QA/QC Performance: As a screening-level technology, the Accelerated Method was conducted using less stringent DQOs than those used for the DoD ELAP Method and only reported an abbreviated list of 13 compounds. Based on the QA/QC performance for both the water and soil analyses, the method demonstrated a high degree of precision and accuracy and could likely be deployed as a definitive technology in the future. The average percent pass rates for all QC testing were 90.9 percent and 95.2 percent for waters and soils, respectively. Much fewer EIS recovery issues were encountered with this method than compared to the DoD ELAP Method; a percent pass rate of 99.7 percent was achieved for the EIS recoveries. Like the DoD ELAP Method, the lowest performing QC metric was the matrix spike (MS)/matrix spike duplicate (MSD) recoveries for PFOS in soil, at approximately 40 percent for both methods.

Duplicates: Waters - All 12 water duplicates compared very well with their respective parent samples. The RPDs for all of the average RPDs never exceeded 13, indicating excellent sampling and analytical precision. **Soils** - Overall, and similar to the DoD field duplicate assessment, there appears to be significantly less correlation between the parent and field duplicate compared to the water analyses. None of the pairs achieved an average RPD of </=50. It is believed that sampling precision is likely a factor here as well as a laboratory sample handling error that led to very poor correlation between a parent and duplicate pair.

Comparison of DoD ELAP and Accelerated Methods

Two tiers of statistical analyses were completed to compare Accelerated Method to the "gold standard" DoD ELAP Method. The base level of statistics was prescribed in the demonstration plan objectives and included certain goals for Ordinary Least Squares (OLS) regression with calculation of R^2 (>/=0.90) and slope (between 0.8 and 1.2) and average RPD </= 30 and 50 percent for water and soil, respectively. An advanced statistical evaluation was also completed to further evaluate the reliability, accuracy, and statistical equivalence of the Accelerated Method compared to the DoD ELAP Method. The advanced level statistical work did not have any prescribed performance goals and, for some of the metrics, is considered to have a more stringent level of standards that were used to assess the Accelerated Method's performance.

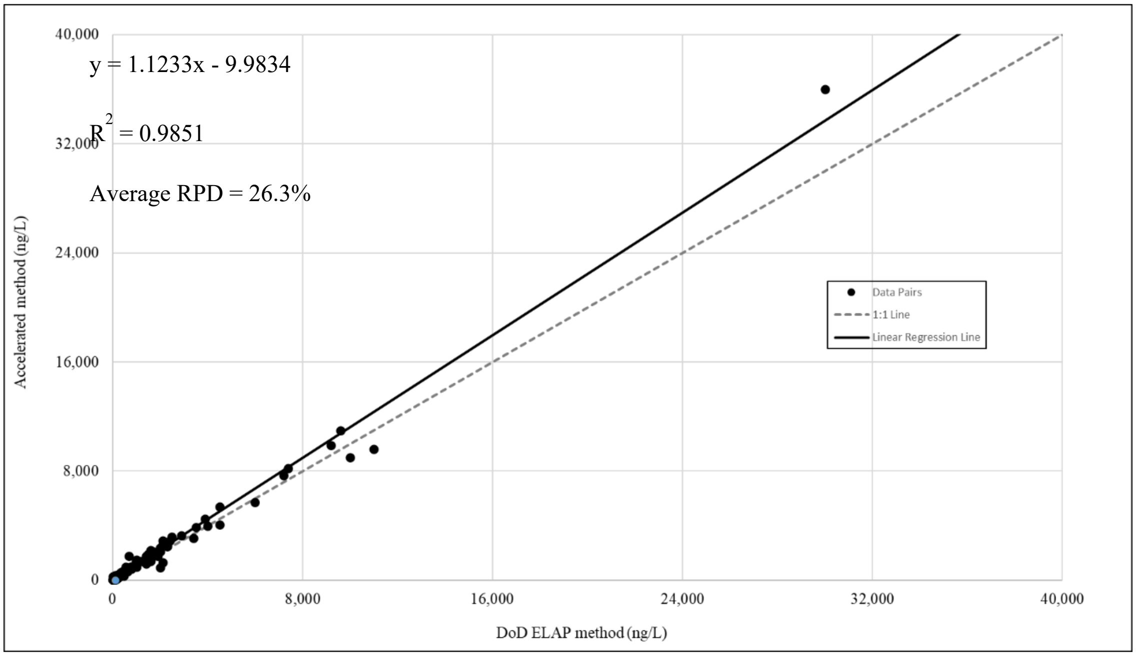
A total of 17 PFAS compounds were analyzed including branched and linear isomers of PFOS and PFHxS; PFBA did not yield sufficient correlation, so it was eliminated from the statistical analyses. Statistical analyses were grouped based on the Primary PFAS compounds and Secondary PFAS compounds. Statistical outlier evaluations identified three groundwater samples and two soil samples. The base level statistics were completed with and without outliers for all agreed detect pairs. PFBS and PFPeS did not have enough pairs for several of the soils metrics in the soils analyses. The advanced level statistics used only data pairs for which both methods detected the compound.

BASE LEVEL STATISTICAL EVALUATION

Groundwater Primary PFAS Compounds: The Accelerated Method data correlated well with the DoD ELAP Method for the Primary PFAS compounds. The following is a summary of the findings:

- The overall average RPD for all five compounds was 30.8 with the two water sample outliers removed. Note that this average is for all five compounds and is not weighted by the number of detectable pairs.
- With outliers included, nine of the 15 (60 percent) individual metrics (three [RPD, slope, and R^2] for each of the five compounds) achieved the performance goals with the dataset that included the outliers.
- Removing the outliers improved the comparisons such that 11 of the 15 (73 percent) individual metrics were achieved. Specific details are as follow:
    - R^2 of </= 0.9 was achieved for Primary PFAS compounds, except for PFBS, which achieved R^2 of 0.67.
    - All of the slope measurements were within the 0.8 to 1.2 goal, indicating no significant bias.
    - RPD of </= 30 was not achieved for three of the five compounds including PFOA (37.2), T-PFOS (33.6), and PFBS (33.7). The RPDs for total PFOS and PFOS were both below 30.
    - In summary, none of the performance data from the five compounds deviated dramatically from the stated goals. An example scatter plot (**ES-1**) for Total PFOS (with listing of R^2, slope and RPD) is offered below to illustrate the correlation between the two methods for this compound.

Figure ES-1. Total PFOS in Groundwater – Outliers Removed



Soil Primary PFAS Compounds: The Accelerated Method data correlated well with the DoD ELAP Method for the Primary PFAS compounds. The following observations were documented regarding the results of these data:

- The overall average for the RPD for all five compounds was 26.1 with the two soil outlier samples removed. Note that this average is for all five compounds and is not weighted by the number of detectable pairs.
- Eight of the 12 (75 percent) individual metrics (three for each of the four compounds, PFBS did not have sufficient data) achieved the performance goals with the dataset that included the outliers.
- Removing the outliers improved the comparisons such that all 12 individual metrics were achieved.
- In summary, the performance data for all five compounds met the stated goals.

Groundwater Secondary PFAS Compounds: The Accelerated Method data correlated less with the DoD ELAP Method compared to the Primary PFAS compounds. The following observations were documented regarding the results of these data:

- The overall average for the RPD for all 11 compounds was 25.1 with the two water outlier samples removed. Note that this average is for all 11 compounds and is not weighted by the number of detectable pairs.
- Eighteen of the 33 (55 percent) individual metrics (three for each of the 11 compounds) achieved the performance goals with the dataset that included the outliers.
- Removing the outliers improved the comparisons such that 27 of the 33 (82 percent) individual metrics were achieved. Specific details are as follow:
  - R^2 of </= 0.9 was not achieved for PFHpS (0.85), Br-PFHxS (0.88), PFNA (0.74), and PFPeS (0.77).
  - All of the slope measurements were within the 0.8 to 1.2 goal, indicating no significant bias.
  - RPD of </= 30 was not achieved for PFHpA (41.9) and PFPeA (31.1).
- In summary, none of the performance data for the 11 compounds deviated dramatically from the stated goals.

Soil Secondary PFAS Compounds: The Accelerated Method data correlated less with the DoD ELAP Method compared to the Primary PFAS compounds. The following observations were documented regarding the results of these data:

- The overall average for the RPD for all 11 compounds was 35.2 with the two soil outlier samples removed. Note that this average is for all 11 compounds and is not weighted by the number of detectable pairs.
- Seven of the 30 (23 percent) available metrics (three for each of the 10 compounds; PFPeS did not have sufficient data) achieved the performance goals with the dataset that included the outliers.
- Removing the two outliers improved the correlations such that 18 of the 30 (60 percent) of the metrics met the goals. Specific details are as follow:
  - R2 of </= 0.9 was not achieved for PFHpA (0.23), PFHpS (0.84), PFHxA (0.81), Br-PFHxS (0.89), and PFPeA (0.04).
  - Slopes between 0.8 and 1.2 were not achieved for PFHpA (0.22), PFHpS (2.2), PFHxA (0.62), and PFPeA (0.05).

  - RPD of </= 50 was not achieved for PFHpA (77.9), PFHxA (50.1), and PFPeA (75.9).
- In summary, PFHpA, PFPeA, and PFHpS represent the three compounds that deviated significantly from the stated performance goals.

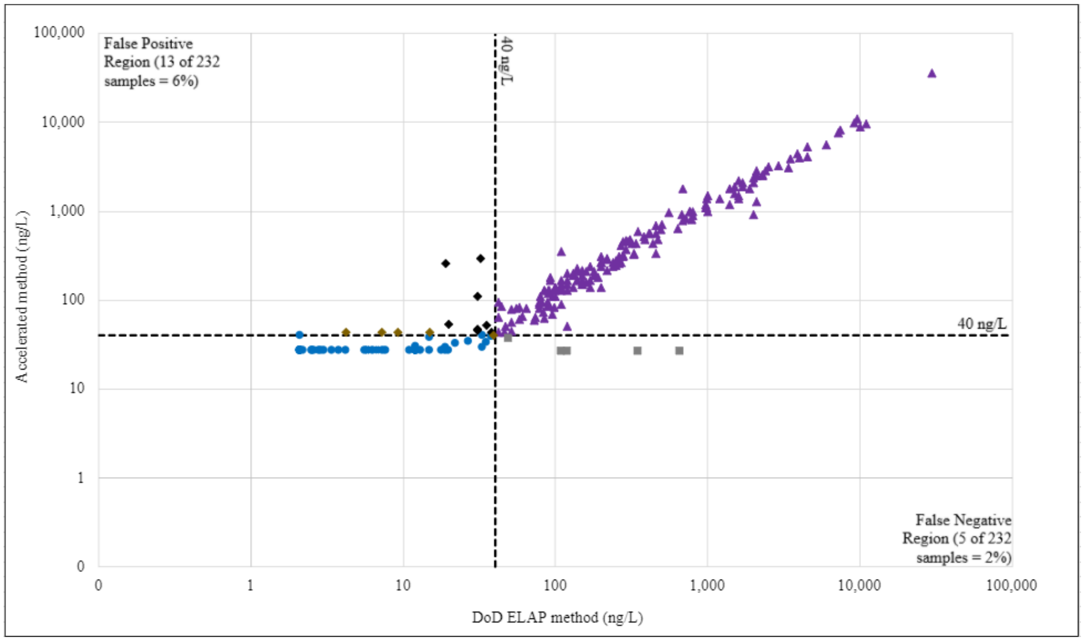
In aggregate, the Accelerated Method correlated well with the DoD ELAP Method, except for several Secondary PFAS compounds. The Accelerated Method provides adequate accuracy and precision for use as a screening method for making field-based intermediate decisions. Where the specific goals were not met, they were in most instances only marginally exceeded. Exceptions to this, which are limited to the Secondary PFAS compounds, included PFBA and several compounds (PFHpA, PFPeA and PFHpS) in soil that exhibited significant exceedances with respect to the performance goals. Knowing these limitations, the DQOs for a given project should be set according to the performance of this method so that there is an adequate level of confidence present for the project-specific decisions.

ADVANCED LEVEL STATISTICAL EVALUATION

The following discussion provides an overview of the results. Detailed discussions for the Primary PFAS compounds are presented in **Sections 7.5** and **7.6**. Detailed results for the Secondary PFAS compounds are presented in **Appendix M**.

Reliability: From the practical standpoint, the single most important issue is whether field personnel will correctly decide whether the soil concentration of a specific compound is within or above an acceptable level. This test estimates the proportion of measurements for which the Accelerated Method would make the correct field decision for a given compound. Where it was determined that a different decision would have been made using the Accelerated Method, these cases were grouped into either false positive or false negative findings. The reliability proportions are summarized in **Tables 7-5** and **7-6** and graphed on **Figures 7-3** and **7-4** for Primary and Secondary PFAS compounds, respectively. An example plot illustrating the reliability for total PFOS is shown on **Figure ES-2**.

Figure ES-2. Total PFOS Reliability Based on Action/No Action at 40 ng/L



Reliable field decisions can be made using the Accelerated Method for the evaluation of PFAS in groundwater and soil. For the Primary PFAS compounds, the Accelerated Method led to the same field decision as the DoD ELAP Method for 90 percent of the data pairs or more for each of the five Primary PFAS compounds in groundwater based on the data analyzed in this study with a lower confidence limit (LCL) of 85 percent or higher. In soil, there were no data pairs for which the Accelerated Method and the DoD ELAP Method differed in a field decision. The Accelerated Method was reliable in making field decisions for at least 90 percent of the data pairs for nine of the 11 Secondary PFAS compounds in groundwater. The two exceptions were PFHxA (89 percent) and PFPeA (87 percent).

Accuracy, Equivalence, and Correlation: Whereas the reliability analysis shows the proportion of correct decisions that would be made in the field, and the accuracy analysis gives the proportion of how often the two tests come within a certain margin of one another, statistical equivalence is a measure of how interchangeable the two methods are with each other. Statistical equivalence can be expressed in more than one way: how well a function could be derived to relate the two methods, the margins between the two methods, and how well the Accelerated Method reproduces the DoD ELAP Method.

Statistical equivalence was tested using four methods including Passing-Bablok, Bland-Altman, TOST, and Lin's Concordance Correlation Coefficient. Deming's orthogonal regression was also attempted, but the applicability criteria for running the test were rarely met. In almost all cases, the tests showed better accuracy and equivalence when statistical outliers were excluded. The proportion of accurate data pairs reveals how many of the analyses exhibit acceptable agreement (**Tables 7-7** and **7-8**). The Passing-Bablok regression shows the bias of the Accelerated Method with regard to the 1:1 (45°) line of agreement. Bland-Altman and TOST show the measure of agreement, the margin based on two different criteria, upper and lower limits of agreement, and the satisfaction of two hypotheses regarding the means of two parameters. Lin's Concordance Correlation Coefficient examines how well the Accelerated Method reproduces the results of the DoD ELAP Method. The results for these four tests of equivalence are summarized in **Tables 7-9** and **7-10** for groundwater and soil, respectively.

Percent difference is used for accuracy when one method is considered the "true" measure. The accuracy of the Accelerated Method was better in soil than in groundwater for the Primary PFAS compounds. However, only PFOS and total PFOS in soil exhibited a rate of 90 percent or more sample pairs matching at +/- 30 percent on a percent difference basis. Only for total PFHxS was the Accelerated Method able to match the DoD ELAP Method for waters within a percent difference of +/- 30 percent for more than 85 percent of the portion of data pairs, and no compound achieved 90 percent.

The results of the Bland-Altman and TOST tests should be interpreted in terms of whether the margins of agreement or equivalence are acceptable. Lin's Concordance Correlation Coefficient was strong for all of the Primary PFAS compounds in soil and groundwater, except for PFBS in groundwater, where the correlation was only moderate. Of the Primary PFAS compounds, Passing-Bablok only found statistical equivalence for PFOS and total PFOS, and only in soil.

The TOST statistical equivalence margins were +/- 40 ng/L or less for Secondary PFAS compounds in groundwater. Lin's Concordance Correlation Coefficient was 0.8122 or higher for all of the datasets with the outliers removed and was 0.9 of higher for eight of the 11 Secondary PFAS compounds. The Passing-Bablok regression found evidence to conclude that the two methods were not equal for most of the compounds, usually due to a high bias. The details of the statistical tests are provided in the tables in **Appendix K**. Although the measures of statistical equivalence were not met for the Accelerated Method, the high sample portions of reliable outcomes indicate that the method appears to be satisfactory for the analysis of the Secondary PFAS compounds in groundwater.

Accelerated Method Implementation Issues: The primary limitation for this method in its use as a screening technology is the elevated detection limit for water analyses. The reporting limit (RL) used for this work was set to approximately 20 nanograms per liter (ng/L). Although the instrument is adequately sensitive to meet lower detection limits that would reach single-digit parts per trillion (ppt) levels for water, the elevated RL was due to background contamination associated with the in-line SPE materials and some of the related solvents. Since the time of this work, Pace has purchased solvents from other vendors and has devised a plan to reduce the effect of background contamination.

Evaluation of Methylene Blue Anionic Substance Screening Method

MBAS test kits were obtained from Chemetrics Corporation for measuring anionic surfactants within the range of 100 to 3,000 micrograms per liter (µg/L) in water samples and 150 to 3,500 micrograms per kilogram (µg/kg) in soil. Due to the relatively high detection limits of this method, this technique was intended to be used on samples collected at and/or near a high strength source area with some evaluation in the downgradient zones that exhibited significant PFAS concentrations.

Over 9 days, the laboratory analyzed and reported 68 groundwater and 22 soil samples. In general, the MBAS method was determined to be an unreliable method for screening water and soils for anionic PFAS. This was due mainly to the presence of a positive interference, the source of which is not fully understood at this time. The data derived from this method were poorly correlated with the anionic PFAS levels found using the DoD ELAP Method and were typically at least one order of magnitude higher than the DoD ELAP Method results.

MBAS Method Throughput and Cost: The actual cost for these MBAS analyses was $26,482. This cost includes all of the labor and expenses to research and set up the method, mobilize, and demobilize to/from the site, and conduct 10 days of analyses. Given that 90 samples were reported as part of this work, this equates to $294 per sample. As stated above, the throughput for the MBAS work was not optimal; if the team was able to analyze 48 samples per day (or 480 samples total), the cost per sample would have been significantly lower at approximately $55/sample.

Recommendations: the MBAS Method does not appear at this time to be a viable screening tool for anionic PFAS, whether it be for determining source zone locations and/or for helping a LC/MS/MS laboratory determine how to dilute potentially "hot" samples. This is especially true at sites where the levels are lower than 100 µg/L, and the groundwater and soil anion chemistry is not well understood.

Stratigraphic Flux and Source Loading

For the GAAF, the high-resolution permeability data collected with the HPT (Est K) and the concentration data collected with VAP borings were evaluated using the 3D model EVS to facilitate mass flux evaluation. Once assembled in a 3D model, the interpolated data fields for conductivity and concentration are multiplied together, along with horizontal groundwater gradient, to produce a heat map that illustrates an estimate of mass flux on 2D cross-sections. The three transects at GAAF were modeled independently to provide a 3D evaluation of mass flux along successive planes within the aquifer. This approach provides insight to mass movement, plume maturity, plume morphology, and allows for future evaluation of remedy approach, location, and design.

Mass Flux: The Accelerated Method versions of the mass flux cross-sections are provided as **Figures 8-1** through **8-6**. Visual comparison of these results with the DoD ELAP Method results (**Figures 5-10** through **5-15**) enables one to determine whether the interpretation and field decisions would be the same and provides another measure of the utility of the accelerated method. The standard and accelerated cross-sections are similar and show little difference in overall interpretation of mass distribution and mass flux with a few notable differences:

- Transect 2: Significant differences are noted at Boring F2-6 that create a different interpretation of the PFOS plume morphology and mass flux. Using the DoD ELAP Method, the PFOS concentrations at the 27- to 31- and 33- to 37-foot intervals are 660 and 210 ng/L (respectively), whereas using the Accelerated Method, the results are <27 and 2,500 ng/L. This result creates a vertically bifurcated plume at this interval where the DoD ELAP Method data suggest a consistent core. The PFAS results for the 33- to 37-foot interval using the Accelerated Method where noted as a statistical outlier as described further in **Section 7.3.1**.

- Transect 3: The total PFOS result from the Accelerated Method at F3_4_25-29 is 1,800 ng/L compared to 690 ng/L from the DoD ELAP Method, which results in a vertically bifurcated plume on the accelerated result (**Figure 5-12**). Also note that, within the same boring, the DoD ELAP Method detected higher concentrations at depth (350 and 110 ng/L) versus the <27 ng/L at both intervals reported using the Accelerated Method, which leads to less lateral extent of the yellow concentration band.

Overall, this result shows that using the additional throughput and shorter TATs of the Accelerated Method does not substantially change the outcome of the investigation. The general shape and magnitude of core PFOS concentrations are quite similar. The increased throughput using the Accelerated Method is better suited and more cost-effective for adaptive PFAS investigations.

Mass Discharge: The nodal data from the mass flux model were summed to estimate a total mass discharge along each transect. The analysis assumes an equidistant grid cell spacing in the model, transects perpendicular to groundwater flow, and an average hydraulic gradient of 0.005 ft/ft from available groundwater flow measurements. **Table ES-1** summarizes the estimated mass discharge for total PFOS and PFOA using the DoD ELAP and Accelerated Methods.

Table ES-1 indicates that the PFOS mass discharge is greatest on Transect 1, which is also the longest transect and spans sections of both groundwater plumes. The lowest PFOS mass discharge is along Transect 3, which is the furthest from the source areas, covers the smallest cross-section area, and does not intersect the core of the plume from the Building 1160 source. Of note, although Transects 2 and 3 are similar cross-sectional areas, and Transect 2 intersects both plumes, the PFOA mass discharge is higher at Transect 3 located furthest downgradient. The increasing concentrations of PFOA with distance are likely due to the higher relative mobility of PFOA compared to PFOS. The PFOA distribution supports the conclusion of a mature plume with the highest concentrations shifted downgradient of a largely depleted source area (i.e., Building 1160). As noted above, this conclusion is also supported by the age of the source area (at least 30 years) and source sampling that shows an order of magnitude lower concentration of PFAS in groundwater/pore-water than observed downgradient at Transects 1 and 2.

Table ES-1: Mass Discharge Estimates Comparison – DoD ELAP and Accelerated Methods

			GW Discharge for Cross Sectional Area	Total Mass Discharge for Cross Sectional Area			
				Total PFOS		PFOA	
	GW Gradient	Cross Sectional Area		DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method
Location	ft/ft	ft^2	gpm	mg/day	mg/day	mg/day	mg/day
Transect 1	0.005	43,543	78.87	229	221	14	13
Transect 1		28,312	51.57	126	124	6	4
Transect 1		23,604	35.46	81	98	10	11
Building 1160 Source Area		4,549	8.60	61	71	1.1	0.6

Source Mass Loading: the source mass loading was estimated using the average the average total PFOS results from lysimeter pore-water sampling following a simulated rainfall event (See **Figure 5-6**). Applying mean average recharge from precipitation across a 5,000-square-foot area leads to a Building 1160 source area mass loading of total PFOS of 0.4 gram/year or 1.1 mg/day. The mass discharge from the Building 1160 source area on Transect 2 is estimated to be approximately 61 mg/day, substantially higher than the source loading estimate. This is also consistent with the order of magnitude increase in groundwater concentration moving downgradient of the source area and suggests two potential interpretations:

1. The source area is depleted of PFOS mass relative to the initial loading provided to the aquifer during and immediately following release. This is consistent with the age of the release (>30 years) and sandy soils that promote flushing of the vadose zone.

2. The source is larger than assumed, and/or at higher concentration than estimated based on the four borings completed in the presumed release area. Tracing the apparent core of the plume originating near Building 1160 back to the source area (**Figure 5-1**) suggests that additional PFAS mass may be present west of the area investigated.

Comparison of Source Strength: Three measures of source strength were evaluated and compared for this study. While lysimeter pore-water data are thought to be most representative of leaching conditions in the vadose zone, we also compared soil to water concentration ratios and SPLP from close intervals to the lysimeter intakes. The data shown on **Figure 5-6** were used to tabulate the results in **Table ES-2**.

Table ES-2: Summary of Total PFOS Partitioning Ratios

Partitioning Ratios – PFOS DoD ELAP Method			
Sample	**Collocated Soil to SPLP (max)**	**Collocated Soil to Pore-Water**	**Max Soil to Groundwater**
LS-1R (SS-6)	17	14	267
LS-3R [LS-4R] (SS-5)	25	38	475
LS-2R (SS-4)	26	531	36

As shown in **Table ES-2**, the ratios derived for SPLP and lysimeter data are similar and range from 14 to 38, except for LS-2R. At location LS-2R, the pore-water concentration was very low relative to the collocated soil and may be anomalous. The ratios of maximum soil concentration to shallow groundwater are higher and reflect the seasonal and intermittent nature of vadose zone source mass loading and dilution due to (relatively) clean groundwater flowing into the source area from upgradient. LS-2R is located on the downgradient side of the Building 1160 source area, and groundwater concentrations are higher relative to collocated soil samples.

Recommendations for Application of Analytical Methods at Remedial Investigations

DoD ELAP Method: Given the relatively low throughput and higher cost per sample associated with the mobile laboratory's DoD ELAP Method, the following characteristics of projects would benefit most from this analytical program: sample production less than 15 per day, DQOs that require definitive analytical data, and fast TATs. The fast TATs will help to accelerate project tasks and minimize project costs related to expensive deep drilling or remediation operations. The balance is the relatively high unit sample cost versus the cost of equipment standby. In these examples, it is assumed that next-day results, as opposed to a 3-day turnaround time at a fixed lab, will allow project work to progress more efficiently and with minimized down time. Examples of these projects are provided in the report.

Accelerated Method: Given the relatively high throughput and lower cost of this screening method, the following are characteristics of projects that would benefit most from this analytical program: high sample production (up to 25 per day), DQOs that will allow for a screening level of analyses to support intermediate decisions and fast TATs to enable the streamlining of sampling activities. As with the DoD ELAP analytical program, the benefit of streamlining and compressing project schedules is that it can greatly reduce project costs. Examples of these projects are provided in the report.

Cost and Performance Compared to Fix Laboratory Analyses

To illustrate how these analytical techniques would be best used for a given project, the following three modes of analyses are considered for completing a hypothetical adaptive characterization at an aqueous film-forming foam (AFFF)-related investigation:

1. All fixed lab services with DoD ELAP Method and quick TAT analyses
2. All mobile lab with definitive DoD ELAP Method analyses
3. Collaborative approach - Accelerated method screening/DoD ELAP Method fixed lab confirmation analyses.

The forgoing examples illustrate the total costs and cost per sample for completing an adaptive high-resolution site characterization (HRSC) project using the three scenarios. Full details of this evaluation are included in the report. A summary of this hypothetical project is offered below.

Scenario #1 - All Fixed-Lab Definitive Analyses. Total estimated cost is $322,000, and the analytical cost per sample is $514. Project duration is 16 days. This is the most expensive of the three approaches and, due to the longer TATs of the fixed lab (expected to be 3 days), it would be more difficult to conduct an efficient adaptive work strategy for the entire project.

Scenario # 2 - All Definitive Mobile Lab Analyses. Total estimated cost is $291,000, and the analytical cost per sample is $450. Project duration is 31 days. This is less expensive than Scenario #1 but requires a longer project duration. As mentioned above, the mobile lab in definitive analyses mode is more suited to sampling projects for which the sampling load is fewer than 15 samples per day and the decisions being made at the site are final in nature.

Scenario #3 – Collaborative Approach. Total estimated cost is $234,000, and the analytical cost per sample is $292. Project duration is 16 days. This collaborative dataset approach provides the lowest cost solution for conducting an adaptive HRSC investigation. It provides equal sampling coverage to those of the other two scenarios and with sufficient definitive data to address the compliance requirements for the site. Because this approach can provide data much faster, the collaborate approach facilitates the most adaptive result. Based on a $88k cost difference between Scenarios 1 and 3, this approach could facilitate more than 6 extra days of sampling, or 550 samples total – 38 percent more than Scenario 1 at the same total cost.

In summary, for the given set of project conditions, Scenario #3 – Collaborative Approach will likely provide the best value for conducting this type of investigation. Each project will have its own unique set of conditions; therefore, it is strongly recommended that the project planning phases include an exercise such as this to ensure that the most appropriate analytical program is used. Considering the scale of RIs at DoD facilities, the collaborative approach is best suited to enable the real-time, adaptive characterization while also providing definitive data required for risk assessment, delineation, and final decision-making. The collaborative approach is planned for further evaluation at four Air Force Phase I PFAS RIs, which are designed to delineate AFFF-related impacts, evaluate source strength, and enable earlier decision-making regarding source treatment and hydraulic containment strategies.

1.0 INTRODUCTION

This Final Report (report) summarizes implementation and results of the Environmental Security Technology Certification Program (ESTCP) Project ER19-B3-5203, which provides validation of streamlined mobile lab-based, real-time, per-and polyfluoroalkyl substances (PFAS) analytical methods, and the application of these methods for adaptive site characterization at the Army National Guard Grayling Army Airfield (GAAF; the site) in Grayling, Michigan. This report documents the results of three real-time mobile laboratory analytical methods:

- Department of Defense (DoD) Quality Standards Manual (DoD QSM) compliant method, herein referred to as DoD Environmental Laboratory Accreditation Program (ELAP) Method;
- Accelerated Method; and
- Methylene Blue Anionic Substance (MBAS) Screening Method.

This report compares the three methods, summarizes the mobile laboratory application at the GAAF site, and describes the resulting flux-based conceptual site model (CSM). The report closes with a summary of the key lessons learned from the demonstration, recommendations for future research, and recommendations for use of the mobile lab at other DoD PFAS sites.

1.1 OBJECTIVES OF THE DEMONSTRATION

The purpose and scope of this demonstration were to validate the application of real-time mobile laboratory methods for characterization of PFAS sources and associated groundwater plumes. The specific objectives of this project were to demonstrate application of:

1. Standard quantitative on-site PFAS analyses: solid-phase extraction (SPE) with liquid chromatography with tandem mass spectrometry (LC/MS/MS) – provided by a DoD-accredited lab in the field using DoD's QSM 5.3 protocol for 24 PFAS compounds. This method is referred to as the DoD ELAP Method, which provides definitive results.
2. An accelerated LC/MS/MS method focusing on quantitation of a limited number of site-specific PFAS compounds: perfluorooctane sulfonate [PFOS], perfluorooctanoic acid [PFOA], perfluorobutane sulfonate [PFBS], perfluorohexane sulfonate [PFHxS], perfluorohexanoic acid [PFHxA], perfluoroheptanoic acid [PFHpA], perfluoro-n-pentanoic acid [PFPeA], perfluoroheptanesulfonic acid [PFHpS], perfluoropentanesulfonic acid [PFPeS] perfluorobutyrate [PFBA], 8:2 polyfluorotelomer sulfate [FTS], 6:2 FTS, based on site-specific data as indicators of PFAS plume distribution. This method is referred to as the Accelerated Method, which provides screening results.
3. MBAS assay to evaluate relative amounts of total anionic PFAS and determine its utility as a pre-LC/MS/MS screening tool to protect the instrumentation.
4. Systematic combination of methods to adaptively and accurately resolve PFAS impacts.

The overarching goal for the analytical chemistry work was to demonstrate that PFAS laboratory methods can be applied in the field to provide near real-time characterization, allowing adaptive delineation and development of flux-based CSMs, as has been the case for chlorinated solvents and 1,4-dioxane.

The mobile laboratory was deployed to support an adaptive stratigraphic flux investigation for the southeast portion of the GAAF (**Figure 1-1**). The investigation focused on the downgradient area associated with two identified aqueous film-forming foam (AFFF) sources identified at Buildings 1160 and 1195. The stratigraphic flux approach for site characterization was developed, in part, with the Air Force Civil Engineering Center (AFCEC; Arcadis 2017, Curry et al. 2020) and combines real-time, high-resolution measurements of stratigraphy and permeability with high-frequency soil and groundwater sampling to focus on characterizing source strength, contaminant leaching, and downgradient mass movement.

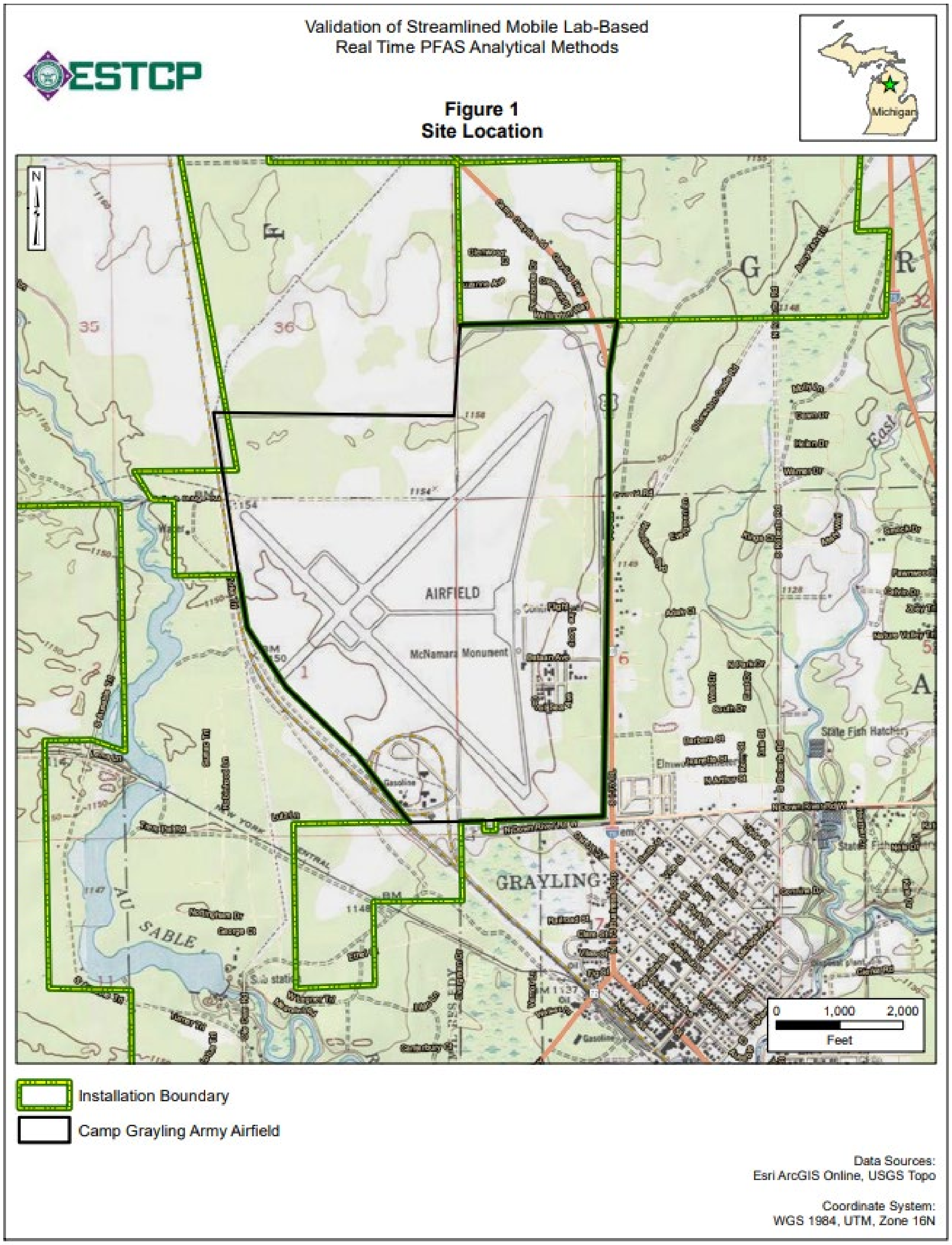


Figure 1-1. Site Location

1.2 REGULATORY DRIVERS

It is increasingly recognized that contaminant mass flux and discharge may represent the most appropriate measure of plume strength and potential migration risk. Application of the PFAS mobile lab approach supports development of a flux-based CSM in real time and enables implementation of more cost-effective remedies by ranking and prioritizing sources and focusing remedial efforts primarily on long-term mass discharge reduction. The PFAS mobile lab and stratigraphic flux approach are well suited to remedial investigations (RIs) where accelerated timelines are needed to address potential sources of drinking water impacts as well as developing holistic remedial strategies at DoD sites involving multiple sources of PFAS impacts.

2.0 TECHNOLOGY

The technologies proposed for this project involve the application of an Environmental Laboratory Accreditation Program (ELAP)-certified mobile lab, development and verification of an accelerated LC/MS/MS screening method, and a semi-quantitative screening approach using MBAS with permeability profiling tools to develop a flux-based CSM at an AFFF source. Real-time PFAS analysis using a mobile lab that is ELAP-certified under DoD QSM 5.3 will provide quantitative results for soil and groundwater sampling (DoD target analyte list) as part of a dynamic, adaptive work strategy consistent with the United States Environmental Protection Agency's (USEPA's) Triad program.

2.1 PFAS MOBILE LABORATORY

Three different analytical programs were deployed to evaluate the efficacy of using a combination of analytical methods to provide timely analytical data and to cost-effectively delineate source areas and related groundwater plumes:

1. On-site PFAS analyses using an SPE sample preparation step followed by analyses via LC/MS/MS procedures. This program was deployed using a definitive level of data quality objectives (DQOs). The program was designed to comply with DoD's QSM 5.3 protocol for 24 PFAS compounds as listed on Table B-15. Pace's DoD ELAP accredited mobile laboratory was deployed to the site and housed all instrumentation needed for these analyses.
2. Off-site PFAS analyses using an SPE sample preparation step followed by analyses via LC/MS/MS procedures according to the standard operating procedure (SOP) titled "Accelerated Method." This program was deployed using a screening level of DQOs and followed a less rigorous quality assurance (QA)/quality control (QC) protocol than that of the definitive analytical work. These analyses were conducted within Pace's mobile lab at their fixed-base facility.
3. On-site total anionic PFAS analyses via an MBAS assay. This program was deployed using a screening level of DQOs. The MBAS assay is a colorimetric test method that uses methylene blue to detect the presence of anionic surfactants (such as a detergent or foaming agent) in a sample of water. These analyses were performed on site within a construction trailer.

2.2 FIELD APPLICATION – STRATIGRAPHIC FLUX

Stratigraphic flux enables development of quantitative, flux-based CSMs that are founded in sequence stratigraphy, high-resolution hydraulic conductivity, and contaminant distribution measurements. The result is a three-dimensional graphical analysis that defines contaminant transport pathways and plume maturity using a hydrofacies classification system that quantifies transport potential in aquifers using relative mass flux as the primary metric. This concept was recently demonstrated and validated through an AFCEC Broad Agency Announcement (BAA) project (BAA 967). The purpose of the BAA project was to develop a method for improving CSMs and remedy performance at complex sites.

The work at the GAAF consisted of source area characterization and a series of adaptive downgradient transects. Each transect was composed of prescriptive borings to broadly track the plume. Subsequently, based on the mobile lab data, adaptive borings were completed to refine the plume characterization. Initial layout of boring locations is shown on **Figure 2-1**.

All the soil, groundwater, and permeability data were evaluated using the Earth Volumetric Studio (EVS; Ctech, Inc.) 3D visualization software daily during the investigation to help facilitate real-time decision-making and the adaptive scope of work. The stratigraphic flux approach combines quantitative concentration data (obtained from vertical aquifer profiling [VAP] sampling) with high-resolution stratigraphy and permeability estimates using a 3D model that illustrates the migration pathways based on the relative mass flux heat map. Model results are provided as **Appendix A**.

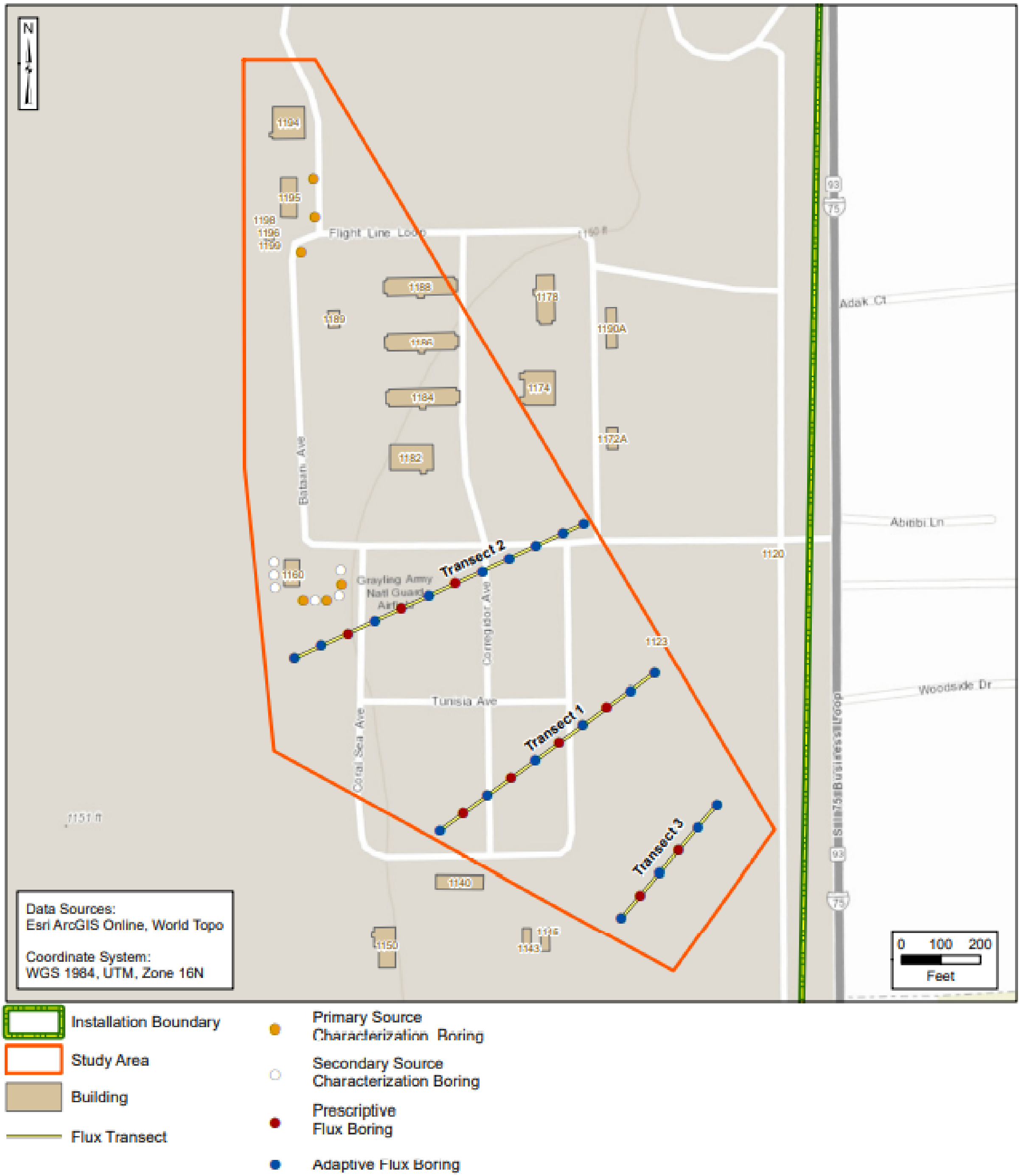


Figure 2-1. Summary of Proposed Scope of Work

The source area, vadose zone, and saturated lower permeability strata were targeted with soil sampling to confirm the locations and strength of source areas, potential mass storage within the capillary fringe, and storage in low-permeability segments of the aquifer, respectively. At one source area, lysimeter and leach testing were completed to indicate a measure of vadose source strength. Pore-water samples obtained from lysimeters were used to estimate source mass loading and current source strength as a basis of comparison to current downgradient mass transport and discharge. These results were compared with synthetic precipitate leaching procedure (SPLP) tests on vadose zone soils as well as ratios of vadose zone soil concentrations to groundwater concentrations. The estimate of source strength can be used to rank and prioritize source treatment during future evaluations.

3.0 PERFORMANCE OBJECTIVES

To address the four objectives established in Section 1.1, groundwater and soil samples were collected and analyzed using the three different analytical methods. The performance objectives and a determination of whether the objectives were met are summarized in **Table 3-1** below.

The parameters used to evaluate accuracy and precision for the two screening methods include standard linear regression analyses, with correlations coefficients and slope being the specific variable being evaluated, along with relative percent difference (RPD). This set of parameters is referred to as the "base level" throughout the remainder of this report. Additionally, an "advanced level" of statistics (that were not outlined in the demonstration plan) was also evaluated to look closer at the reliability, accuracy, and statistical equivalence of the Accelerated Method to the DoD ELAP Method. Intra-laboratory performance evaluations, covering variables such as compliance to stated data quality objectives, throughput, turnaround times (TATs), and cost, are presented in **Section 6**. The base level and advance statistics are further discussed in **Section 7**. The compounds evaluated as part of the Accelerated Method were evaluated by grouping the Primary and Secondary PFAS compounds to facilitate review.

The other remaining set of goals covered in **Table 3-1** were set up to evaluate the utility of using the screening methods in combination with the definitive DoD ELAP Method to lower project costs and conduct PFAS site work more efficiently. Recommendations regarding best use of these analytical techniques for PFAS site work are offered in **Section 9**.

Table 3-1. Base Level Performance Objectives from Demonstration Plan

Performance Objective	Data Requirements	Success Criteria	Success Criteria Achieved
Conduct DoD ELAP Method in the field	QA/QC Data, laboratory throughput and TATs.	Compliance to DoD QSM v. 5.3, laboratory throughput "up to" 20 samples per day, TAT within 24 hours.	**Compliance to DoD QSM v. 5.3:** Yes, with exceptions described in text. **Laboratory Throughput:** No, throughput of 20 samples per day not achieved. **Throughput was low (<10/day) during startup of program and was as high as 17/day during latter portion of program.** **TAT within 24 hours:** No, TAT of 24 hours for all samples was not achieved. However, by end of program, high-priority sample results were available with 24 hours, and most of the prioritized sample results **were delivered to the project team within 48 hours. Due to backlog, low priority samples not analyzed until after the field program ended.**
Accelerated LC/MS/MS Method validation	PFAS results compared to DoD ELAP Method results	**Accuracy:** Statistical correspondence among methods: average RPD between methods: </= 30 for waters and </= 50 for soils and R2 on regression analyses > 0.90 for both soil and water with slope of regressions within 0.20 to indicate no significant bias. **Precision:** RPD on field/lab duplicates and matrix spike (MS)/matrix spike duplicates (MSD) pairs </= 30 for waters and </= 50 for soils.	**Accuracy for Primary PFAS compounds, with outliers removed:** Yes, for water and soil R2 and slope, with exception of one compound (PFBS in water). Yes, for water and soil RPD, except for marginal exceedances for PFOA, T-PFOS, and PFBS. **Accuracy for Secondary PFAS compounds, with outliers removed:** Yes, for R^2 and slope for water, with marginal exceedances for PFHpS, Br-PFHxS, PFNA, and PFPeS. Yes, for RPD for water, with marginal exceedances for PFHpA and PFPeA. No for R^2 and slope for soil, three compounds (PFHpA, PFPeA, and PFHpS) were present at significant exceedances, and two compounds (PFHxA and Br-PFHxS) were present at marginal exceedances. **Precision for All Compounds as per MS/MSD Pairs:** Yes, for water, with exceptions: 80% pass rate. Yes, for soil: 100% pass rate **Precision for All Compounds as per Field Duplicates:** Yes, for water: 100% of average RPDs for samples were less than 30. No for soil: only 25% of average RPDs for samples were less than 50. Alternate "split" soils results achieved RPDs less than 50.
MBAS screening method validation	PFAS concentrations by DOD QSM 5.3 and total PFAS by MBAS	**Accuracy** Statistical correspondence among methods: average RPD between methods </= 50 for both water and soil and R2 on regression analyses > 0.75 with slope of regressions within 30 to indicate no significant bias. **Precision** RPD on field duplicates </= 50 for both soil and water. Dilution Factors for LC/MS/MS methods: did the MBAS data assist lab staff in diluting samples appropriately to prevent significant overloading of instrument?	**Accuracy:** No - Accuracy was not met for any of the metrics for this test. **Precision as per MS/MSD Pairs** Yes, for soil and water: 100% of MS/MSD pairs achieved RPD of less than 50. **Precision as per Field Duplicates:** Yes, for soil and water: 100% of field duplicate pairs achieved RPD of less than 50.
Laboratory cost reduction	On-site lab costs (presented as cost per sample) and market rates for 24 hr. TAT from fixed laboratory	On-site lab per sample costs are equal to or less than the 24 hr. TAT laboratory fees. Note that 24 hr. TAT is not a realistic option for fixed labs today based on capacity issues. Other factors to be considered in costs analyses are: 1) reduced drilling/sampling costs due to adaptive/streamlined work strategy and 2) increased productivity of sampling team(s) due to decreased sample administration (i.e., packaging and shipping) needs.	**No – Actual DoD ELAP Method Price per sample greater than fixed lab 48 hr. TAT cost.** Actual Cost = $707/sample. Includes low production rates at beginning of program. Projected Cost Estimated between $395-$585/sample for 10 to 15 samples per day. Projected pricing is within range of typical fixed lab pricing for 48 hr. TATs. Note that 24 hr. **TATs are not commonly available.** **Yes – Actual Accelerated Method price per sample less than fixed lab 48 hr. TAT cost** Actual Costs = $243/sample Projected Cost Estimated between $226-283/sample Pricing is lower than typical fixed lab pricing for 48 hr. TATs. **Scenarios describing various project scopes and related savings when using DoD ELAP and Accelerated Methods are offered in Section 9.**
Adaptively and accurately define PFAS impacts	PFAS concentrations by three methods	Demonstrate utility of combined approach to improve efficiency and cost-effectiveness of characterization	Based on the laboratory throughput and costing information, using a screening method (Accelerated Method) in conjunction with fixed lab definitive analyses, it is possible to lower project costs and shorten project duration. **A hypothetical project that illustrates this is offered in Section 9.3.**

4.0 SITE CHARACTERISTICS

4.1 GRAYLING ARMY AIRFIELD SITE LOCATION AND HISTORY

Camp Grayling is located approximately 200 miles northwest of Detroit, Michigan in the north-central portion of the Lower Peninsula, and approximately 80 miles south of Michigan's Lower Peninsula. It is the primary training facility for the Michigan National Guard and is the Army National Guard's largest facility. The facility occupies 147,000 acres and is divided into North and South Post operational areas; however, the focus of this study is on the GAAF (**Figure 1-1**). GAAF is located within the North Post of Camp Grayling and has been operational since 1942.

GAAF is located immediately west and northwest of the City of Grayling, at the intersection of Interstate 75 (I-75) and North Down River Road West, between the North and South Posts, and occupies 923 acres of state and federally owned property. The site has two runways, and facility access is restricted by controlled gates. The site has support buildings and facilities along its eastern boundary including the control tower, barracks, vehicle storage, and the Camp Grayling Fire Department. The former location of the Camp Grayling Maneuver Area Training Equipment Site (MATES) is on the southwestern portion of the airfield, which is now known as the Former Bulk Fuel Storage Area. The former MATES was historically served by railroad tracks running along the western boundary of the airfield (AECOM 2019).

The predominant land use outside the camp boundaries is public lands, primarily forested. Private lands and residences abut portions of the site including the City of Grayling, located southeast of GAAF. Seasonal and permanent residences are present along the banks of the Au Sable River and Lake Margrethe, and both waterbodies are used for recreation. Recreation on both the Au Sable River and Lake Margrethe includes swimming, canoeing, and fishing. The City of Grayling and Grayling Township are zoned light and heavy industrial. Reasonably anticipated future land use is not expected to change from the current land use described above (AECOM 2018).

4.1.1 Site Geology and Hydrogeology

The geology at Camp Grayling consists of unconsolidated glacial sediments underlain by bedrock from the Coldwater and Michigan Formations. Glacial sediments, consisting of sand and gravel outwash plains, lacustrine clay, and glacial till, are reported to extend to at least 600 feet below ground surface (bgs). Fluvial deposits associated with the Au Sable River are also present within the site (AECOM 2018). Soil borings completed to a depth of 60 feet bgs at GAAF exhibit soils consisting of well graded sand and gravels with discontinuous silty sand layers (AECOM 2018). Lenses of clay are also encountered in the southeast corner of the GAAF near the study area.

Regional and local groundwater flow appears to generally follow surface water drainage patterns. Regional groundwater divides most likely correlate to the major surface water divides for the Manistee, Au Sable, and Muskegon Rivers. The site is located between the mainstem and East Branch of the Au Sable River. Groundwater occurs at depths of approximately 6 to 15 feet bgs as an unconfined sandy aquifer. A groundwater potentiometric surface map, shown on **Figure 4-1**, suggests that apparent groundwater flow within the GAAF is southerly, turning southeasterly in the southeast portion of the site towards the East Branch of the Au Sable River.

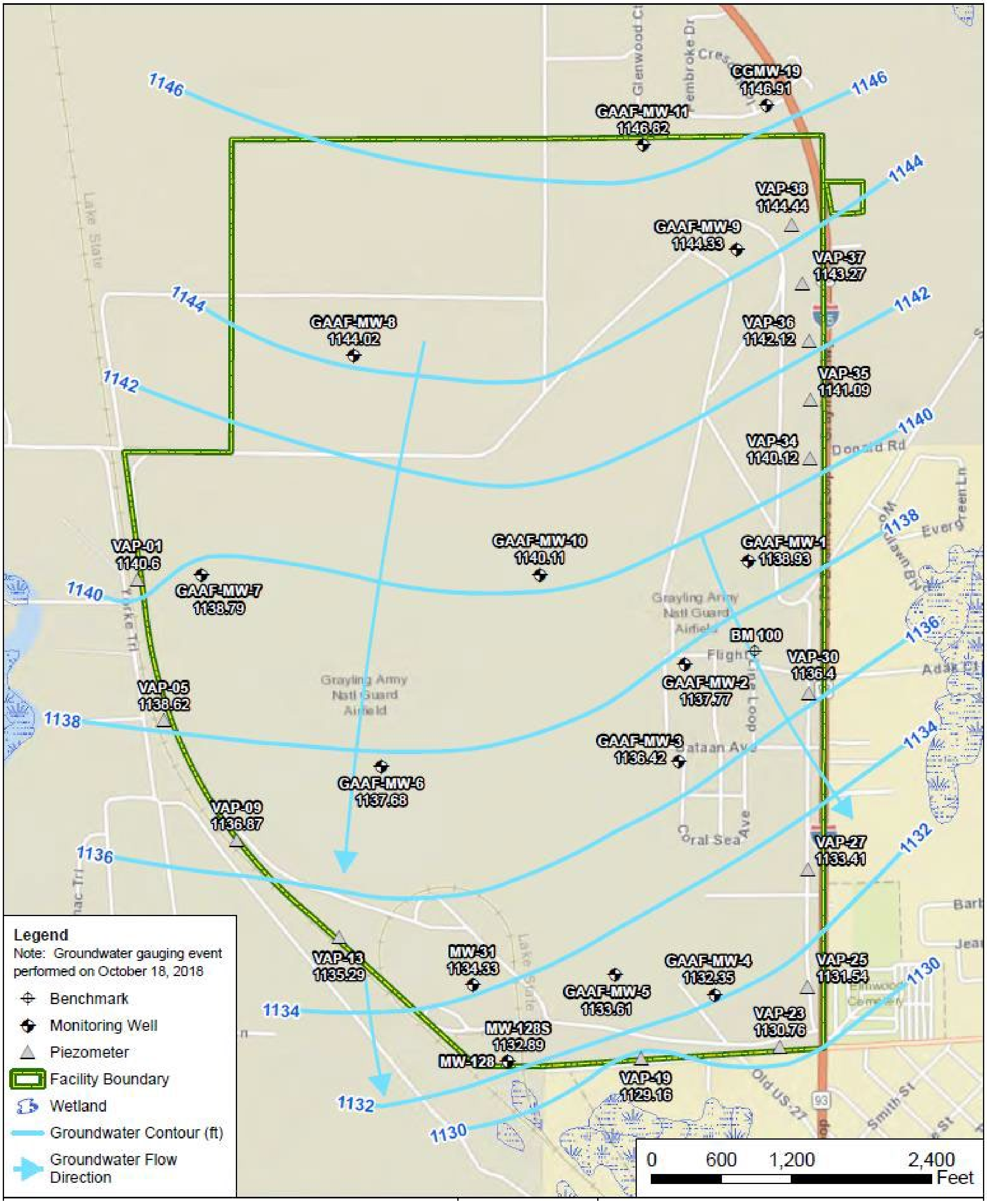


Figure 4-1. GAAF Groundwater Elevation Contour Map

ESTCP Grayling Army Airfield. Grayling, Michigan

Source: AECOM, Site Inspection Report, Camp Grayling Army Airfield, Michigan

4.1.2 Previous PFAS Characterization

The Michigan Department of Military and Veteran Affairs (MDMVA) conducted a PFAS investigation in 2017 in the area of the Former Bulk Fuel Storage Area. This area (formerly referred to as the MATES) has an inactive groundwater pump-and-treatment system (air stripper) to remediate a tetrachloroethylene (PCE) and trichloroethylene (TCE) plume and includes a network of monitoring wells associated with the remediation system. The PFAS investigation was conducted in the area of the inactive treatment system and along the site boundary. Based on VAP groundwater samples collected along the site boundary, the sum of PFOS and PFOA concentrations detected in VAP samples exceeded the USEPA Health Advisory Limit (HAL) of 70 nanograms per liter (ng/L) at several locations along the site boundary (AMEC Foster Wheeler 2017). The locations of PFAS detections and exceedances of the USEPA HAL are shown on **Figure 4-2**. VAP groundwater results show PFOS and PFOA concentrations exceeding the USEPA HAL at six locations spanning the southern portion of the eastern site perimeter with the highest concentrations focused at VAP-27 (PFOS/PFOA: 2,650 ng/L) and with concentrations an order of magnitude lower to the north and south of VAP-27 (AMEC Foster Wheeler 2017).

- In 2017, the Michigan Department of Environmental Quality (MDEQ, now EGLE) began residential drinking water well sampling. As of August 2019, the sampling has identified 17 residential wells with PFAS concentrations that exceed the then combined criteria for PFOS or PFOA of 70 ng/L.
- In 2018, AECOM conducted a preliminary assessment (PA) to identify and assess potential PFAS release areas at Camp Grayling including the GAAF. Five Areas of Interest (AOIs) were identified for GAAF during the PA where PFOS/PFOA, in the form of AFFF, had been used or had been historically released (AECOM 2018).

Of the five AOIs identified at GAAF, AOI 1, located on the eastern portion of GAAF, was selected for this demonstration based on its proximity to the higher concentrations identified off post and the location of soil boring VAS-27. This boring yielded the highest PFAS groundwater sample observed at the site boundary (AMEC Foster Wheeler 2017). Within AOI 1, the following areas with AFFF releases were identified:

- Building 1194 Ramp/Building 1195 – The ramp area, adjacent to the south side of Building 1194 and north of Building 1195, was identified as a routine parking area for fire trucks during the 1970s and 1980s. It is reported that the fire truck AFFF holding tanks had leaked approximately 80 gallons a day while parked (AECOM 2018).
- Building 1160 – Identified as a former fire training area by former firefighters during interviews (AECOM 2018). AFFF holding tanks may have been parked in this area during training exercises in the 1970s and 1980s as well, similar to the Building 1194 ramp area.

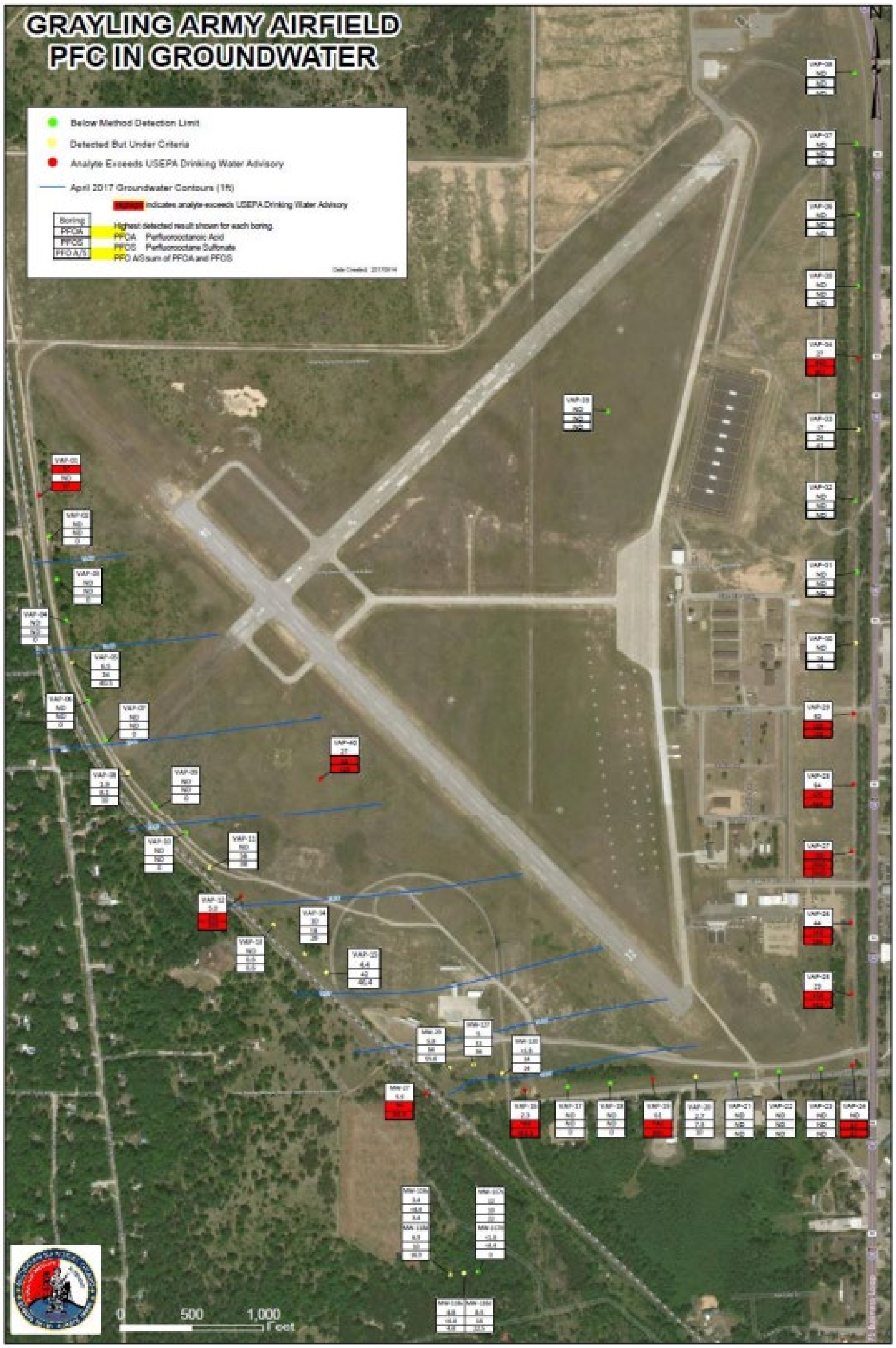


Figure 4-2. GAAF Perimeter Groundwater Sampling Results

ESTCP Grayling Army Airfield. Grayling, Michigan

Source: AMEC Foster Wheeler. 2017. PFCs Investigation – Camp Grayling Airfield, Grayling, Michigan. September

In 2018, a site inspection (SI) was conducted to assess the AOIs identified in the PA. Preliminary results for the southeast portion of the site upgradient of VAP-27 identified PFOS concentrations of 27.4 micrograms per kilogram (µg/kg) and 73.5 µg/kg in vadose zone soil samples collected on the west side of Building 1160 as well as a PFOS concentration of 344 ng/L in groundwater on the east side of Building 1160 (AECOM 2019). Relatively low concentrations of PFOS (1.98 to 12.5 µg/kg) were detected in soil on the east side of Building 1194; however, groundwater samples from this area were non-detect (AECOM 2019).

The ESTCP study area was selected, based on the previous investigation results, to encompass an area upgradient of the highest concentrations of PFOS/PFOA detected along the site perimeter. As outlined above, this area includes two potential source areas: Building 1160 and Building 1194/95. Of the two potential sources, Building 1160 was suspected to be the dominant source contributing to groundwater impacts at the site boundary based on PFAS concentrations detected in soil and groundwater during the SI.

5.0 FIELD APPLICATION RESULTS

The mobile laboratory was validated, and the technology applied at GAAF in accordance with the September 2019 Site Demonstration Memorandum (Arcadis 2019b). Implementation included adaptive high-frequency soil and groundwater sampling in the source areas (Buildings 1160 and 1194/95) and on transects downgradient progressing toward the southeast site perimeter and boring VAP-27. The initial layout of borings, including borings designated as "primary" and "adaptive," is shown on **Figure 2-1**.

The demonstration took place between October 17 and November 15, 2019. High-resolution permeability estimates were obtained using the Geoprobe® hydraulic profiling tool (HPT). To validate the HPT results, the HPT results were compared to soil descriptions; the estimated hydraulic conductivity (Est K) from HPT was compared to the hydraulic conductivity derived from soil grain-size analysis. The final locations of the source areas and scope of work for each boring are shown on **Figure 5-1**. The components of the investigation were as follows:

- Three primary source borings installed immediately downgradient of each of the two potential source areas (Building 1160 and Building 1194/95). The primary source borings were used to provide a snapshot of PFAS concentrations at each source before commencement of the downgradient flux transect sampling.

- Three adaptive flux transects spaced downgradient of the two potential source areas and upgradient of the highest PFAS concentration identified at the site perimeter during previous site characterization (VAP-27).

- Six secondary source borings completed near Building 1160 to provide greater resolution of source area impacts including the installation of four lysimeters and SPLP sampling to characterize pore-water and contaminant loading in the source vadose zone.

Of the two potential sources, Building 1160 was the primary target of the investigation based on PFAS concentrations detected during the SI and the proximity to the downgradient transects. Building 1194/95 was held in reserve in case the mobile lab data suggested that the Building 1160 area was not a significant source of PFAS.

Of the PFAS detected at the site, PFOS is the dominant contaminant of concern in both soil and groundwater at GAAF and was generally detected at concentrations one to three orders of magnitude above PFOA and other PFAS concentrations. Rather than focus on delineation, the objectives of the field demonstration were to define source strength (primarily associated with Building 1160) and identify the primary zones of mass flux downgradient of the source areas along the three HPT/VAP transects.

Table 5-1. Comparison of the Estimated Hydraulic Conductivity from Grain Size Distribution and the Hydraulic Profiling Tool

Sample Location	Depth (ft bgs)	Soil Type	Est. K from Grain Size Distribution (ft/day)			Est. K from HPT (ft/day)		
			Min	Max	Geometric Mean	Min	Max	Geometric Mean
SB-F1-3	26-27	Moderately well sorted sand low in fines	70.90	368.60	152.30	55	70	63
SB-F1-3	44-45	Well sorted sand with trace silt	47.80	127.43	82.05	67	72	69
SB-F1-3	51-52	Poorly sorted gravelly sand low in fines	75.56	1,412.34	344.39	86	98	93
SB-F3-2	19-20	Gravelly sand low in fines	103.28	529.23	231.50	69	78	74
SB-F3-2	27-28	Poorly sorted gravelly sand	118.18	643.60	253.12	76	80	77
SB-F3-2	52-53	Uniform sand with trace fines	35.96	182.51	91.37	37	60	45
SB-F3-2	56-58	Silty clay with trace sand	0.00	0.16	0.03	0.10	0.10	0.10
SB-SS-3	25-30	Moderately well sorted gravelly sand low in fines	74.97	613.55	164.96	47	110	80
SB-SS-3	30-35	Well sorted sand with little silt	44.75	252.00	90.09	56	70	62
SB-SS-3	50-55	Well sorted sand with little gravel and silt	79.36	491.93	172.21	56	100	74
SB-SS-4	1-2	Moderately well sorted sand with some silt	0.03	165.55	13.35	NA	NA	NA
SB-SS-4	4-5	Well sorted sand with little silt	48.10	269.69	95.01	NA	NA	NA
SB-SS-4	10-15	Moderately well sorted sand with some silt and fines	9.71	241.93	43.50	NA	NA	NA
SB-SS-6	2-3	Moderately well sorted sand with some fines	0.49	258.60	31.89	NA	NA	NA
SB-SS-6	5-10	Moderately well sorted sand with little fines and trace gravel	70.47	355.05	153.64	NA	NA	NA
SB-SS-6	10-15	Well sorted sand with trace fines	66.50	297.34	162.76	NA	NA	NA

ft bgs = feet below ground surfaceft/day = foot per day
HPT = hydraulic profiling toolK = conductivity
NA = not applicable

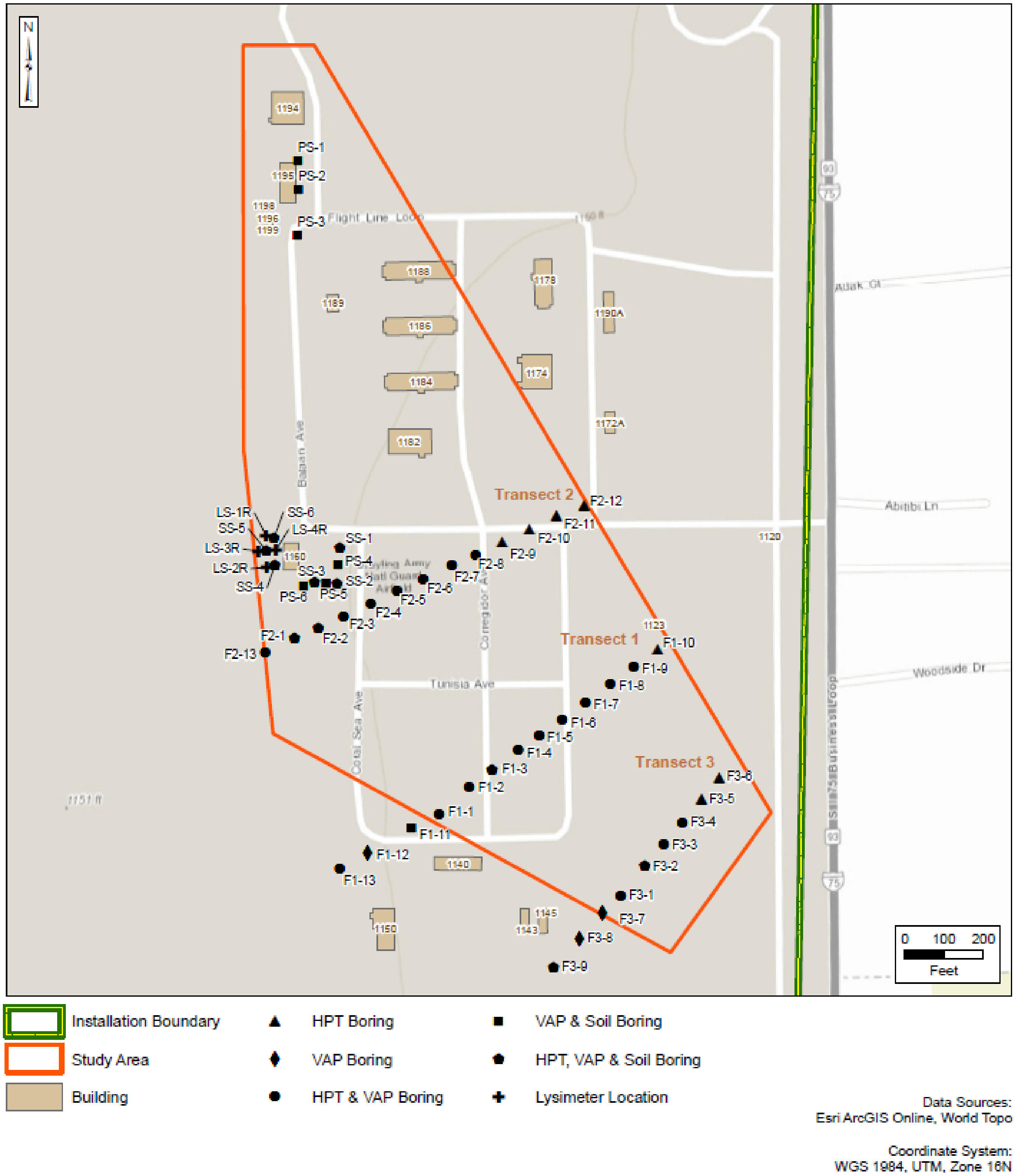


Figure 5-1. Final Boring Location and Completed Scope of Work

5.1 ADAPTIVE APPROACH AND WORKFLOW

The downgradient transects were completed in sequence (i.e., Transect 1, Transect 2, Transect 3). Transect 1 was located at the mid-point between Transect 2 (closest to the source area) and Transect 3 (furthest downgradient). The locations of the transects are illustrated on **Figure 5-1**.

The HPT borings were completed at each location first. More HPT borings were completed per day than VAP borings. As the HPT rig was out in front of the VAP sampling, it was also out in front of the analytical results driving the adaptive work. As a result, the HPT was completed at all primary and adaptive locations, as well as some additional locations southeast of the original study (**Figure 5-1**) area, before it demobilized from the site.

The VAP boring locations and sample intervals were based in part on the results of the HPT borings as well as the analytical data from the mobile laboratory. The analytical data were loaded daily into the EVS 3D model to provide reference for additional work. The data from Transect 1 were used to identify a broad area of impact and focus Transect 2 on the Building 1160 source area. Transect 3, although extended based on the mobile laboratory results, did not continue far enough southwest to capture the plume originating near Building 1160 before winter weather set in and forced suspension of the investigation.

The results of the groundwater analysis were also used to select addition soil sampling locations along the core of the plume originating near Building 1160 and the lower permeability soil encountered on Transect 3, as described below in **Section 5.4.1**.

During the field activities, a total of seven equipment blanks were collected to verify PFAS-free sampling materials:

- VAP sampling screen – one equipment blank sample was collected by pouring PFAS-free water over the clean VAP SP16 screen tooling.
- Soil sampling acetate liners – one sample was collected by pouring PFAS-free water through a clean unused acetate liner.
- Sample tubing – five samples were collected by pumping PFAS-free water through a 2 ft length of clean unused tubing and silicone pump tubing. One blank was collected for each 1,000-foot roll of tubing used.

Equipment blank samples were submitted to the mobile lab and analyzed for PFAS compounds using the DoD ELAP Method. PFAS were not detected in the equipment blanks, suggesting that the decontamination procedures for the VAP sampling device were effective, and that no PFAS were introduced through the sampling materials used. Analytical results for equipment blanks are included as part of **Appendix B**.

Additional detail regarding the specific sampling methodology is provided as **Appendix C**, including:

- Technical Guidance Instruction (TGI) – Vertical Aquifer Profiling (VAP)
- TGI – Geoprobe® HPT
- TGI – Soil Drilling and Sample Collection
- PFAS Field Sampling Guidance
- Soilmoisture Equipment Company - 1920f1 Pressure-Vacuum Soil Water Samplers (i.e., lysimeter operation manual)

5.2 HYDROSTRATIGRAPHY

HPT sampling was completed at both primary and adaptive boring locations before soil and groundwater sampling to define the hydrostratigraphy and provide a basis for VAP groundwater sampling intervals. The HPT provides a continuous profile of relative soil permeability at the centimeter scale. The HPT profiles can be used to infer hydrofacies and interpolation hydrostratigraphy between soundings. The HPT is advanced through an unconsolidated aquifer using a standard direct-push drilling rig. It is attached to the end of a drill string and enables a continuous metered injection of small volumes of water (typically between 200 to 300 milliliters per minute) during advancement of the probe. At the same time, the fluid backpressure due to injection into the formation, as well as the flow rate, are measured and logged at a high frequency. After correcting for atmospheric and hydrostatic pressure effects, the Est K is derived by recognizing that hydraulic conductivity (K) is proportional to flow divided by pressure (Q/P). The Est K analysis includes an empirical correction, developed by Geoprobe® based on comparison of the Q/P data, to collocated slug test data (McCall 2011).

The HPT is sensitive to a range of K spanning two to three orders of magnitude (~0.1 to 75 feet per day [ft/day]). Hydraulic conductivities above or below this range are reflected as minimum or maximum pressure responses. At the high end, Est K is primarily limited by the sensitivity of the pressure sensor and/or frictional losses within the tool. Above 75 ft/day, very small changes in pressure can result in very large changes in Est K (McCall and Christy 2020).

The HPT also includes a dipole that logs the electrical conductivity of the soil to assist with correlating stratigraphy between HPT borings. Elevated electrical conductivity readings correlate with higher-pressure (lower-permeability) zones showing good correlation to finer-grained zones with silt and clay content. Some higher electrical conductivity readings were also observed in the shallow aquifer near roadways and parking lots (e.g., F2-3, F2-8), likely associated with salting during winter months.

Following completion of HPT borings on Transect 1 in the center of the study area, HPT borings were completed for the primary and adaptive locations along Transects 2 and 3. Near the end of the field effort, additional HPT borings were completed adaptively off the southwest end of the transects (collocated with VAP borings) to help define the southern extent of the plume associated with the Building 1160 source area. The locations of the completed HPT borings are shown on **Figure 5-1**. The HPT logs are provided as part of **Appendix D**.

The HPT soundings were advanced to a depth of approximately 60 feet or to boring refusal. Most of the borings refused out before reaching the 60-foot mark due to the increasing silt content and density of the formation. Groundwater is unconfined and was encountered at depths of 10 to 15 feet bgs. The Est K typically ranges from 50 to 75 ft/day through the upper 60 feet of aquifer. The interpolated data are shown in grayscale on several of the attached 2D and 3D figures. The HPT data illustrate alternating sequences of slightly higher- and lower-permeability intervals that mark shifting conditions associated with glacial retreat and outwash. Isolated, discontinuous seams of lower-permeability (i.e., < 2.5 ft/day) silty sands were also encountered on all three transects. At Transect 3, near the southeast perimeter of the GAAF, thicker layers of silty clays were encountered at a depth of approximately 40 feet with Est K of less than 0.1 ft/day. Comparison borings that include soil description were collocated with HPT. Soil boring logs are provided as part of **Appendix D**. **Table 5-1** below provides a summary of the collocated HPT and soil boring logs.

Table 5-2. Summary of Collocated HPT and Soil Borings

HPT Boring	Soil Boring
HPT-F1-3	SB-F1-3
HPT-F3-2	SB-F3-2
HPT-SS-1	SB-SS-1
HPT-SS-2	SB-SS-2
HPT-SS-3	SB-SS-3
HPT-SS-4	SB-SS-4
HPT-SS-5	SB-SS-5
HPT-SS-6	SB-SS-6

Soil samples were collected from the comparison soil borings and submitted for grain-size and hydrometer testing. The soil borings and grain-size results show a poor to well sorted sandy aquifer that consists primarily of fine to medium sand with zones of finer-grained sand and traces of silt, as well as coarser zones that can include up to 25 percent coarse sand to coarse gravel. The soil boring log completed on Transect 3 (SB-F3-2) shows a finer-grained silty sand below 50 feet bgs, transitioning to a high-plasticity clay at 54 feet bgs. Hydrometer analysis of the clay indicates 65 percent clay and 30 percent silt. Grain-size analytical reports are included as **Appendix E**.

5.2.1 Comparison of Sieve Analysis K Estimates with HPT

Several empirical formulas provide a reliable means of estimating K from grain-size distribution data, provided that the formation does not contain abundant fines that result in cohesive or plastic behavior or include cobble-sized grains (Payne et al. 2008). Grain-size analysis can help bracket the permeability of hydrostratigraphic units and identify order-of-magnitude spatial variations in K.

The sieve data were used to validate the Est K produced by the HPT. The Excel-based program HydroGeoSieveXL (Devlin 2015) was used to process the sieve data and estimate K. The HydroGeoSieveXL program calculates estimated K values from grain-size data using 15 different calculations including Hazen (1892), Slichter (1898), Terzaghi (1925), and others (Devlin 2015).

When executed, HydroGeoSieveXL produces a grain-size distribution curve, a list of input parameters, a histogram of grain-size distribution (e.g., clay, sand, gravel), and a summary of calculated K for each method. Output from HydroGeoSieveXL for each sample is included in **Appendix F**. Not all K results are relevant for a given soil type, as the soil characteristics may not meet the requirements for a specific calculation. Relevant results are highlighted on the HydroGeoSieveXL output summary and are used in the final statistical evaluation.

Of the 15 equations used by HydroGeoSieveXL program, Hazen (1892) was not used, as the grain-size sieve analysis did not meet the criteria necessary to complete the calculations. The remaining 14 equations were used at least once during the HydroGeoSieveXL evaluation. Some of the equations used have limitations for input criteria that introduce strong bias to the results if the grain-size distribution deviates from a given range (Delvin 2015). Therefore, based on a review of boring log descriptions and grain-size analysis, K values calculated with the following equations were excluded from the final statistical analysis:

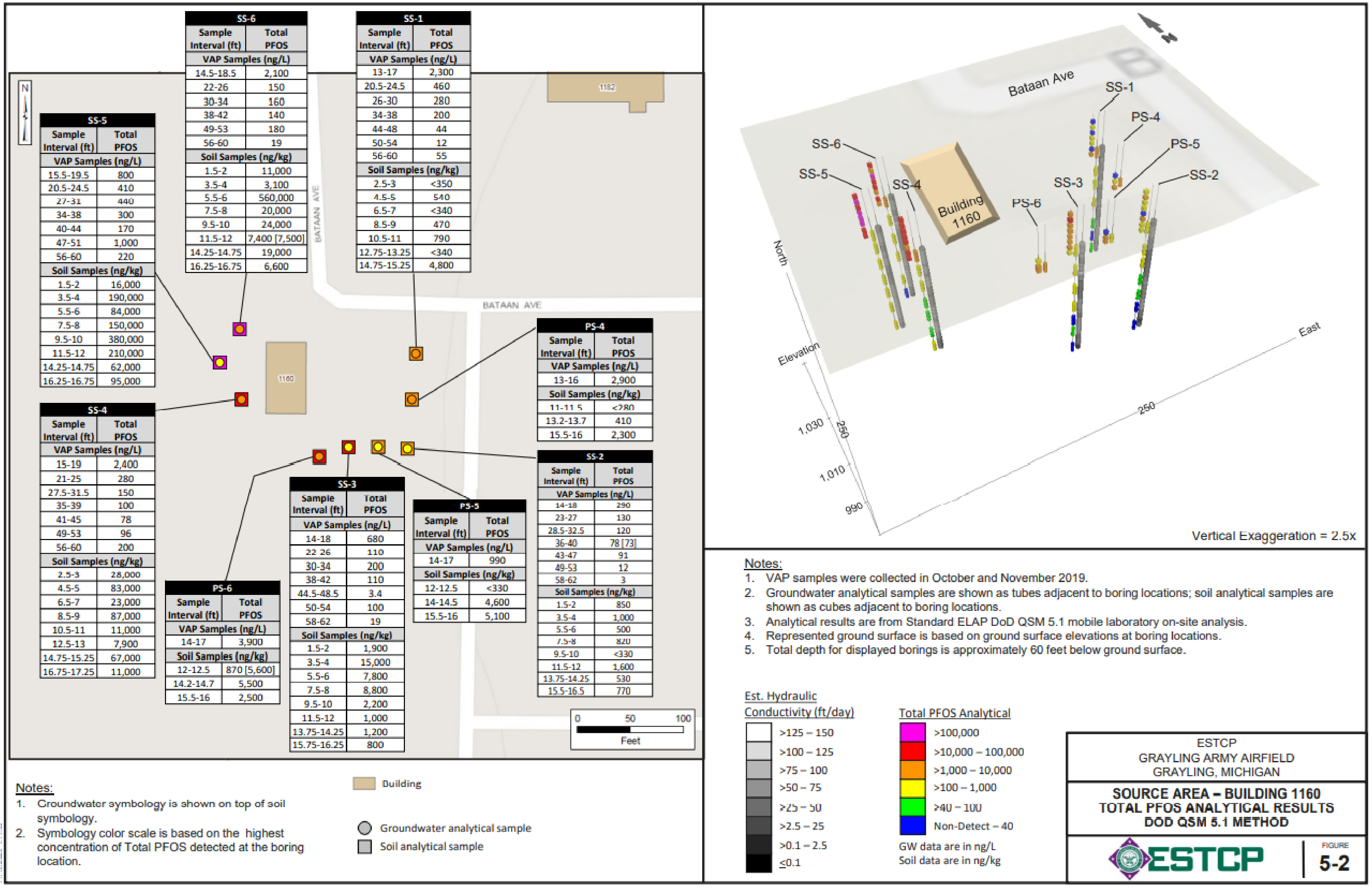
- Hazen simplified (Freeze and Cherry 1979) – Excluded if the sample was not well sorted
- Kozeny (1953) – Excluded if the sample did not consist predominately of course sand
- Zunker (1930) – Excluded if the sample contained a fraction with a grain size greater than 0.0025 millimeters (mm)
- Zamarin (1928) - Excluded if the sample contained a fraction with a grain size greater than 0.00025 mm.

Overall, the variations in K estimated from the grain-size distribution trend higher than the HPT Est K by a factor of 1 to 3. The geometric mean values from the HydrogeoSieveXL evaluation suggest that the silty clays encountered on Transect 3 exhibit hydraulic conductivities of 0.03 ft/day or less, whereas for well sorted sands and gravelly sands, K may be as high as 200 ft/day or more. A comparison of the estimated K from sieve analysis and the Est K from HPT is provided as **Table 5-2**. Within the range of the HPT tool (0.1 to 75 ft/day), the sieve data correlate well to HPT Est K. Where Est K was observed at >75 ft/day, the actual K may higher by a factor of 2 or more. For intervals within the range of the HPT, the geometric mean of the HPT results tends to agree best with the low-end (minimum) K derived from the algorithms included in the HydroGeoSieveXL analysis, suggesting that the geometric mean of the HydroGeoSieveXL analysis may be biased high, or conversely, that HPT may be biased low.

5.3 SOURCE CHARACTERIZATION

Soils at the capillary fringe and water, as well as low-permeability saturated soils, can act as reservoirs for PFAS mass. Soil samples were collected from source area borings to evaluate source strength (vadose zone, capillary fringe, and shallow saturated zones), as well as at key downgradient locations, to evaluate potential mass storage within the capillary fringe and low-permeability zones. Shallow soil sampling was completed using a Geoprobe Dual Tube® sampling system advanced by a direct-push drilling rig. At depth, heaving sands hampered the Dual Tube® system, and deeper saturated soil samples were collected using a discrete Macro-Core® soil sampling system.

Three primary source area borings were completed immediately downgradient of Buildings 1160 and 1195 before downgradient VAP sampling to provide a snapshot of PFAS concentrations at each area of interest. Boring locations at Building 1160 are shown on **Figures 5-2** and **5-3**, and boring locations for Building 1194/95 are shown on **Figures 5-4** and **5-5**. Each primary source area boring (designated PS-1 through PS-6) was advanced to 20 feet and logged by an Arcadis geologist. One-inch-diameter polyvinyl chloride (PVC) temporary monitoring wells were installed at each primary boring to verify the depth to the water table and facilitate the collection of a water table groundwater sample. Soil samples were collected from the capillary fringe, at the water table, and just below the water table.



SS-6

Sample Interval (ft)	Total PFOS
VAP Samples (ng/L)	
14.5-18.5	2,100
22-26	150
30-34	160
38-42	140
49-53	180
56-60	19
Soil Samples (ng/kg)	
1.5-2	11,000
3.5-4	3,100
5.5-6	560,000
7.5-8	20,000
9.5-10	24,000
11.5-12	7,400 [7,500]
14.25-14.75	19,000
16.25-16.75	6,600

SS-1

Sample Interval (ft)	Total PFOS
VAP Samples (ng/L)	
13-17	2,300
20.5-24.5	460
26-30	280
34-38	200
44-48	44
50-54	12
56-60	55
Soil Samples (ng/kg)	
2.5-3	<350
4.5-5	540
6.5-7	<340
8.5-9	470
10.5-11	790
12.75-13.25	<340
14.75-15.25	4,800

SS-5

Sample Interval (ft)	Total PFOS
VAP Samples (ng/L)	
15.5-19.5	800
20.5-24.5	410
27-31	440
34-38	300
40-44	170
47-51	1,000
56-60	220
Soil Samples (ng/kg)	
1.5-2	16,000
3.5-4	190,000
5.5-6	84,000
7.5-8	150,000
9.5-10	380,000
11.5-12	210,000
14.25-14.75	62,000
16.25-16.75	95,000

PS-4

Sample Interval (ft)	Total PFOS
VAP Samples (ng/L)	
13-16	2,900
Soil Samples (ng/kg)	
11-11.5	<280
13.2-13.7	410
15.5-16	2,300

SS-4

Sample Interval (ft)	Total PFOS
VAP Samples (ng/L)	
15-19	2,400
21-25	280
27.5-31.5	150
35-39	100
41-45	78
49-53	96
56-60	200
Soil Samples (ng/kg)	
2.5-3	28,000
4.5-5	83,000
6.5-7	23,000
8.5-9	87,000
10.5-11	11,000
12.5-13	7,900
14.75-15.25	67,000
16.75-17.25	11,000

SS-2

Sample Interval (ft)	Total PFOS
VAP Samples (ng/L)	
14-18	290
23-27	130
28.5-32.5	120
36-40	78 [73]
43-47	91
49-53	12
58-62	3
Soil Samples (ng/kg)	
1.5-2	850
3.5-4	1,000
5.5-6	500
7.5-8	820
9.5-10	<330
11.5-12	1,600
13.75-14.25	530
15.5-16.5	770

SS-3

Sample Interval (ft)	Total PFOS
VAP Samples (ng/L)	
14-18	680
22-26	110
30-34	200
38-42	110
44.5-48.5	3.4
50-54	100
58-62	19
Soil Samples (ng/kg)	
1.5-2	1,900
3.5-4	15,000
5.5-6	7,800
7.5-8	8,800
9.5-10	2,200
11.5-12	1,000
13.75-14.25	1,200
15.75-16.25	800

PS-5

Sample Interval (ft)	Total PFOS
VAP Samples (ng/L)	
14-17	990
Soil Samples (ng/kg)	
12-12.5	<330
14-14.5	4,600
15.5-16	5,100

PS-6

Sample Interval (ft)	Total PFOS
VAP Samples (ng/L)	
14-17	3,900
Soil Samples (ng/kg)	
12-12.5	870 [5,600]
14.2-14.7	5,500
15.5-16	2,500

Notes:

1. Groundwater symbology is shown on top of soil symbology.
2. Symbology color scale is based on the highest concentration of Total PFOS detected at the boring location.

▨ Building

○ Groundwater analytical sample

☐ Soil analytical sample

Notes:

1. VAP samples were collected in October and November 2019.
2. Groundwater analytical samples are shown as tubes adjacent to boring locations; soil analytical samples are shown as cubes adjacent to boring locations.
3. Analytical results are from Standard ELAP DoD QSM 5.1 mobile laboratory on-site analysis.
4. Represented ground surface is based on ground surface elevations at boring locations.
5. Total depth for displayed borings is approximately 60 feet below ground surface.

Est. Hydraulic Conductivity (ft/day)

- >125 – 150
- >100 – 125
- >75 – 100
- >50 – 75
- >25 – 50
- >2.5 – 25
- >0.1 – 2.5
- ≤0.1

Total PFOS Analytical

- >100,000
- >10,000 – 100,000
- >1,000 – 10,000
- >100 – 1,000
- >40 – 100
- Non-Detect – 40

GW data are in ng/L
Soil data are in ng/kg

ESTCP
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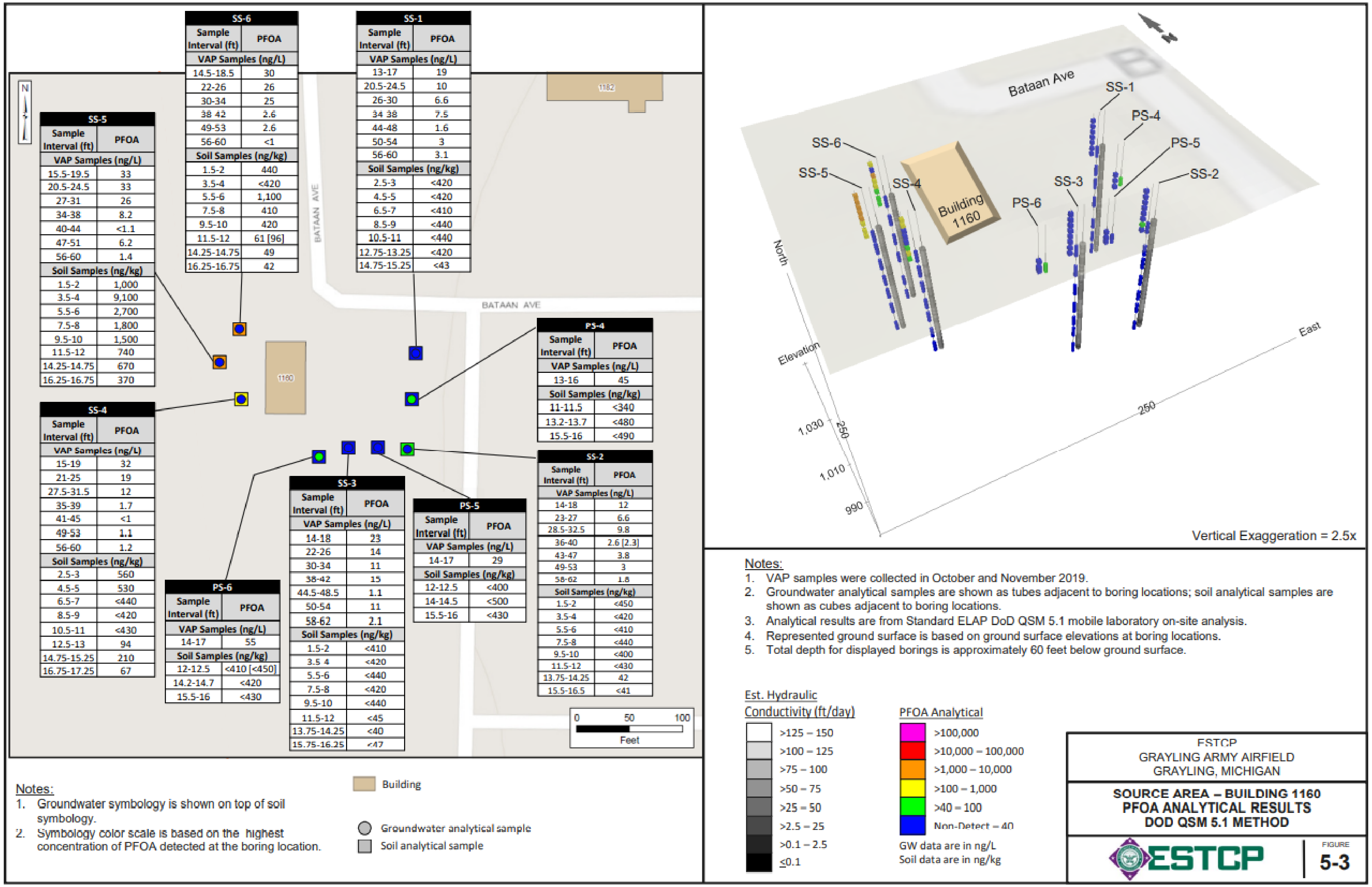
GRAYLING, MICHIGAN

SOURCE AREA – BUILDING 1160
TOTAL PFOS ANALYTICAL RESULTS
DOD QSM 5.1 METHOD

ESTCP

FIGURE
5-2

Figure 5-2. Source Area – Building 1160 Total PFOS Analytical Results DoD QSM 5.3 Method



SS-6

Sample Interval (ft)	PFOA
VAP Samples (ng/L)	
14.5-18.5	30
22-26	26
30-34	25
38 42	2.6
49-53	2.6
56-60	<1
Soil Samples (ng/kg)	
1.5-2	440
3.5-4	<420
5.5-6	1,100
7.5-8	410
9.5-10	420
11.5-12	61 [96]
14.25-14.75	49
16.25-16.75	42

SS-1

Sample Interval (ft)	PFOA
VAP Samples (ng/L)	
13-17	19
20.5-24.5	10
26-30	6.6
34 38	7.5
44-48	1.6
50-54	3
56-60	3.1
Soil Samples (ng/kg)	
2.5-3	<420
4.5-5	<420
6.5-7	<410
8.5-9	<440
10.5-11	<440
12.75-13.25	<420
14.75-15.25	<43

SS-5

Sample Interval (ft)	PFOA
VAP Samples (ng/L)	
15.5-19.5	33
20.5-24.5	33
27-31	26
34-38	8.2
40-44	<1.1
47-51	6.2
56-60	1.4
Soil Samples (ng/kg)	
1.5-2	1,000
3.5-4	9,100
5.5-6	2,700
7.5-8	1,800
9.5-10	1,500
11.5-12	740
14.25-14.75	670
16.25-16.75	370

PS-4

Sample Interval (ft)	PFOA
VAP Samples (ng/L)	
13-16	45
Soil Samples (ng/kg)	
11-11.5	<340
13.2-13.7	<480
15.5-16	<490

SS-4

Sample Interval (ft)	PFOA
VAP Samples (ng/L)	
15-19	32
21-25	19
27.5-31.5	12
35-39	1.7
41-45	<1
49-53	1.1
56-60	1.2
Soil Samples (ng/kg)	
2.5-3	560
4.5-5	530
6.5-7	<440
8.5-9	<420
10.5-11	<430
12.5-13	94
14.75-15.25	210
16.75-17.25	67

SS-3

Sample Interval (ft)	PFOA
VAP Samples (ng/L)	
14-18	23
22-26	14
30-34	11
38-42	15
44.5-48.5	1.1
50-54	11
58-62	2.1
Soil Samples (ng/kg)	
1.5-2	<410
3.5 4	<420
5.5-6	<440
7.5-8	<420
9.5-10	<440
11.5-12	<45
13.75-14.25	<40
15.75-16.25	<47

PS-5

Sample Interval (ft)	PFOA
VAP Samples (ng/L)	
14-17	29
Soil Samples (ng/kg)	
12-12.5	<400
14-14.5	<500
15.5-16	<430

SS-2

Sample Interval (ft)	PFOA
VAP Samples (ng/L)	
14-18	12
23-27	6.6
28.5-32.5	9.8
36-40	2.6 [2.3]
43-47	3.8
49-53	3
58-62	1.8
Soil Samples (ng/kg)	
1.5-2	<450
3.5-4	<420
5.5-6	<410
7.5-8	<440
9.5-10	<400
11.5-12	<430
13.75-14.25	42
15.5-16.5	<41

PS-6

Sample Interval (ft)	PFOA
VAP Samples (ng/L)	
14-17	55
Soil Samples (ng/kg)	
12-12.5	<410 [<450]
14.2-14.7	<420
15.5-16	<430

Notes:

1. Groundwater symbology is shown on top of soil symbology.
2. Symbology color scale is based on the highest concentration of PFOA detected at the boring location.

▨ Building

○ Groundwater analytical sample

□ Soil analytical sample

Notes:

1. VAP samples were collected in October and November 2019.
2. Groundwater analytical samples are shown as tubes adjacent to boring locations; soil analytical samples are shown as cubes adjacent to boring locations.
3. Analytical results are from Standard ELAP DoD QSM 5.1 mobile laboratory on-site analysis.
4. Represented ground surface is based on ground surface elevations at boring locations.
5. Total depth for displayed borings is approximately 60 feet below ground surface.

Est. Hydraulic Conductivity (ft/day)

- >125 – 150
- >100 – 125
- >75 – 100
- >50 – 75
- >25 – 50
- >2.5 – 25
- >0.1 – 2.5
- ≤0.1

PFOA Analytical

- >100,000
- >10,000 – 100,000
- >1,000 – 10,000
- >100 – 1,000
- >40 – 100
- Non-Detect – 40

GW data are in ng/L
Soil data are in ng/kg

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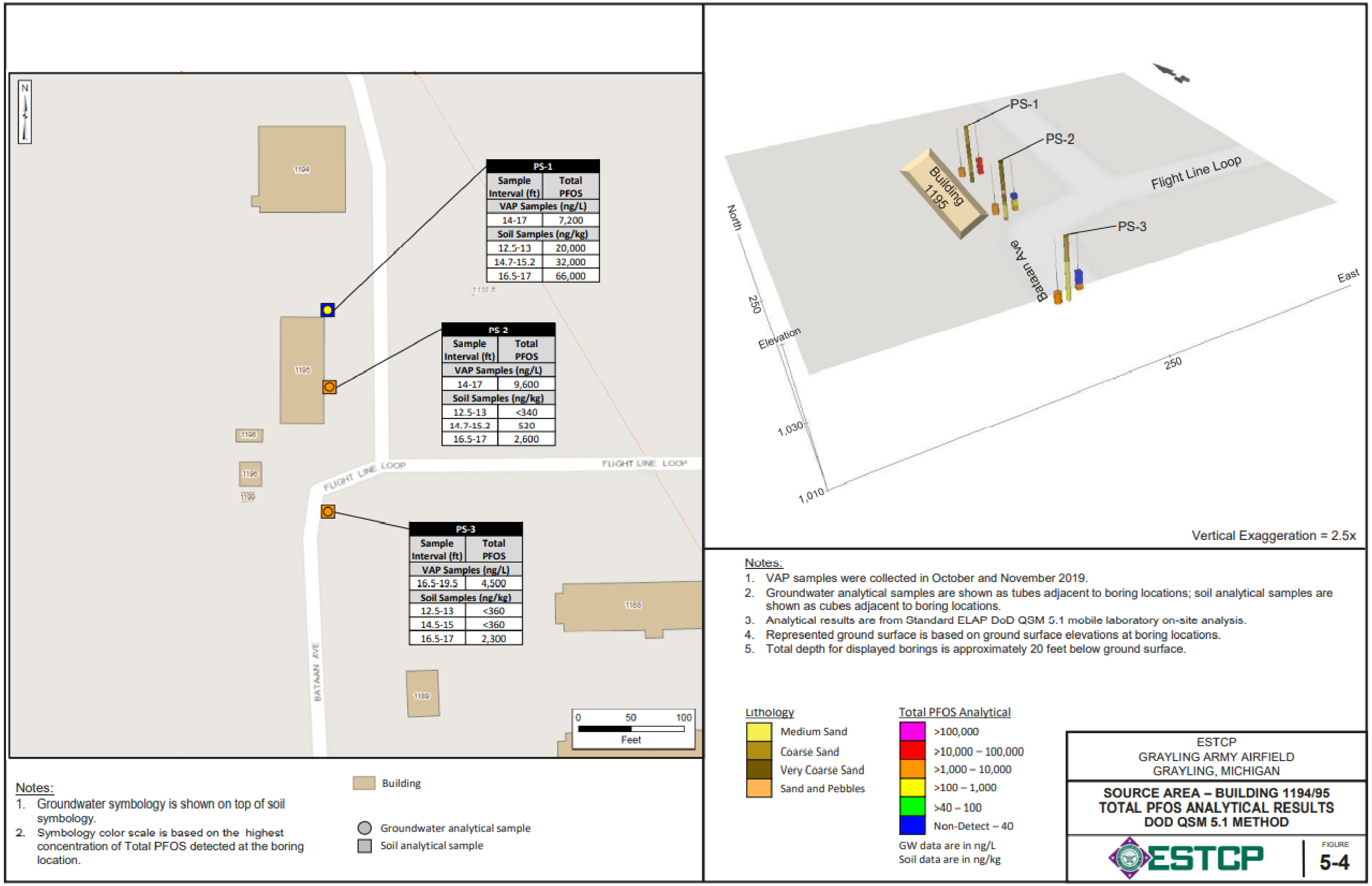
SOURCE AREA – BUILDING 1160
PFOA ANALYTICAL RESULTS
DOD QSM 5.1 METHOD

ESTCP

FIGURE
5-3

Figure 5-3. **Source Area – Building 1160 PFOA Analytical Results DoD QSM 5.1 Method**



PS-1

Sample Interval (ft)	Total PFOS
VAP Samples (ng/L)	
14-17	7,200
Soil Samples (ng/kg)	
12.5-13	20,000
14.7-15.2	32,000
16.5-17	66,000

PS 2

Sample Interval (ft)	Total PFOS
VAP Samples (ng/L)	
14-17	9,600
Soil Samples (ng/kg)	
12.5-13	<340
14.7-15.2	520
16.5-17	2,600

PS-3

Sample Interval (ft)	Total PFOS
VAP Samples (ng/L)	
16.5-19.5	4,500
Soil Samples (ng/kg)	
12.5-13	<360
14.5-15	<360
16.5-17	2,300

Notes:
1. Groundwater symbology is shown on top of soil symbology.
2. Symbology color scale is based on the highest concentration of Total PFOS detected at the boring location.

Notes:
1. VAP samples were collected in October and November 2019.
2. Groundwater analytical samples are shown as tubes adjacent to boring locations; soil analytical samples are shown as cubes adjacent to boring locations.
3. Analytical results are from Standard ELAP DoD QSM 5.1 mobile laboratory on-site analysis.
4. Represented ground surface is based on ground surface elevations at boring locations.
5. Total depth for displayed borings is approximately 20 feet below ground surface.

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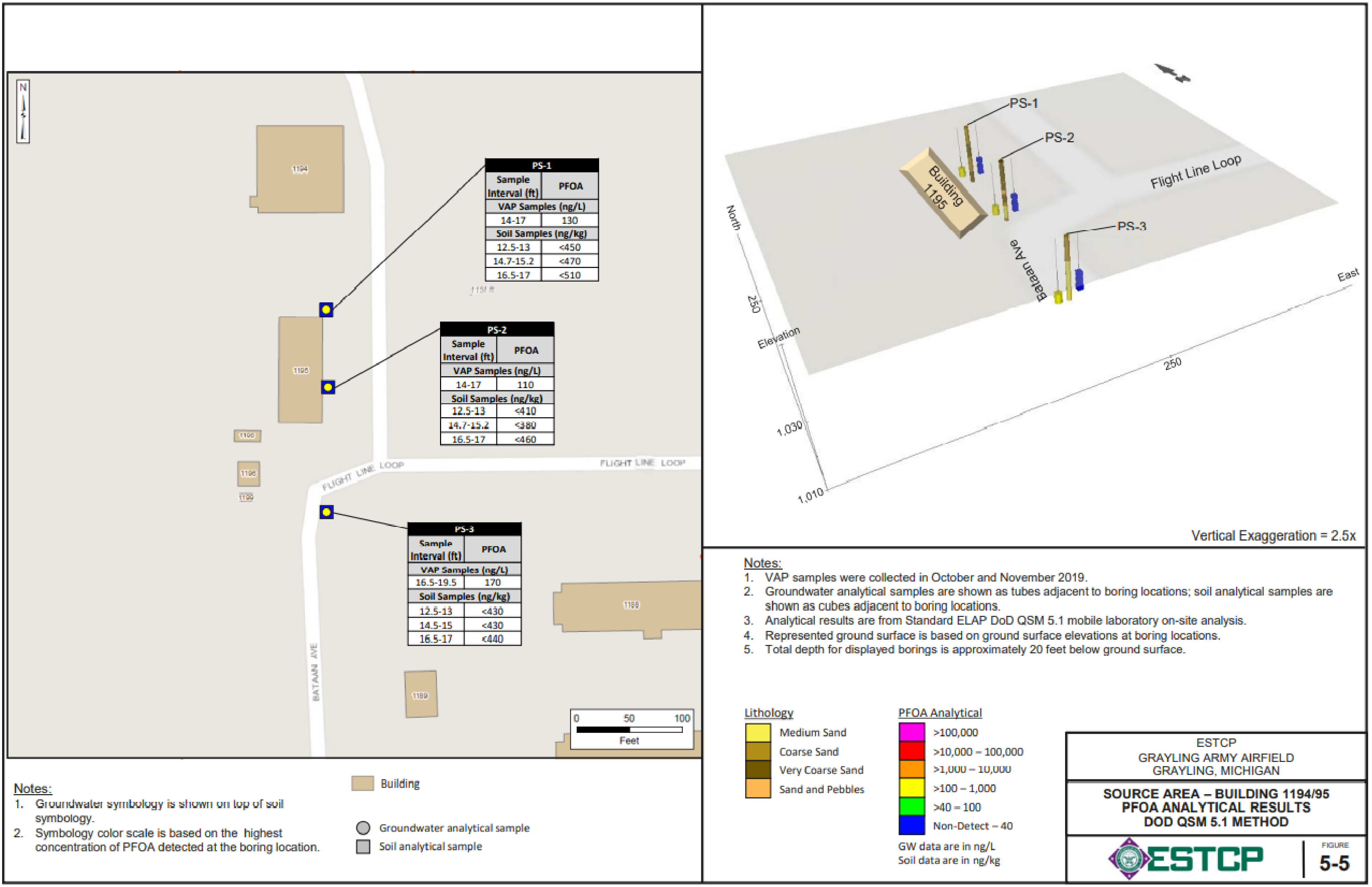
GRAYLING, MICHIGAN

SOURCE AREA – BUILDING 1194/95
TOTAL PFOS ANALYTICAL RESULTS
DOD QSM 5.1 METHOD

FIGURE
5-4

Figure 5-4. Source Area – Building 1194/95 Total PFOS Analytical Results DoD QSM 5.1 Method



PS-1

Sample Interval (ft)	PFOA
VAP Samples (ng/L)	
14-17	130
Soil Samples (ng/kg)	
12.5-13	<450
14.7-15.2	<470
16.5-17	<510

PS-2

Sample Interval (ft)	PFOA
VAP Samples (ng/L)	
14-17	110
Soil Samples (ng/kg)	
12.5-13	<410
14.7-15.2	<380
16.5-17	<460

PS-3

Sample Interval (ft)	PFOA
VAP Samples (ng/L)	
16.5-19.5	170
Soil Samples (ng/kg)	
12.5-13	<430
14.5-15	<430
16.5-17	<440

Notes:

1. Groundwater symbology is shown on top of soil symbology.
2. Symbology color scale is based on the highest concentration of PFOA detected at the boring location.

Notes:

1. VAP samples were collected in October and November 2019.
2. Groundwater analytical samples are shown as tubes adjacent to boring locations; soil analytical samples are shown as cubes adjacent to boring locations.
3. Analytical results are from Standard ELAP DoD QSM 5.1 mobile laboratory on-site analysis.
4. Represented ground surface is based on ground surface elevations at boring locations.
5. Total depth for displayed borings is approximately 20 feet below ground surface.

Figure 5-5. Source Area – Building 1194/95 PFOA Analytical Results DoD QSM 5.1 Method

The results of the primary borings were used, in conjunction with the VAP sampling results, to select the source for more detailed soil sampling and source strength assessments. Based on the mobile laboratory results, the focus of the investigation shifted to Building 1160 for the detailed source evaluation. In general, the proximity of Building 1160 provided a clearer correlation of source concentration to downgradient mass flux. Only the primary borings were completed at Building 1194/95. PFAS impacts were evaluated using the DoD ELAP Method analytical results and fixed-lab splits for QA/QC on soils (**Appendix B**). Subsequent analyses were completed on all samples using the Accelerated Method (**Appendix G**) and select samples for MBAS screening evaluation (**Appendix H**).

Following completion of the downgradient transects and the confirmation of Building 1160 as a primary source area, six additional borings were completed at Building 1160 to refine the source characterization. At each additional boring, an HPT was advanced to approximately 60 feet bgs to log Est K. In an adjacent borehole, a soil boring was completed, and soil samples were collected at nominal 2-foot intervals including the capillary fringe, at the water table, and just below the water table. In addition, up to seven VAP groundwater samples were collected underneath the Building 1160 source area to evaluate the vertical distribution groundwater impacts. The distribution of PFOS and PFOA impacts at Building 1160, as well as Building 1194/95, are shown on **Figures 5-2** and **5-3** and **Figures 5-4** and **5-5**, respectively. Groundwater analytical data are summarized in **Tables 5-3** (Primary PFAS compounds) and **5-4** (Secondary PFAS compounds), and soil analytical data are summarized in **Tables 5-5** and **5-6**. The complete summary of soil and groundwater data is tabulated in Appendix I for all compounds.

Soil and groundwater sample results are presented based on the DoD ELAP Method in the following discussion. Comparisons of the method results are presented in **Section 7**.

Table 5-3. Groundwater Analytical Results for the PFAS Mobile Lab-Based Real-Time Method Pilot Study Primary Constituents of Interest

Location ID	Arcadis Sample ID	Collection Date	Start Depth (ft)	End Depth (ft)	PRIMARY CONSTITUENTS OF INTEREST									
					PFOA		PFOS		T-PFOS		Total PFOS		PFBS	
					DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method
TRANSECT 1														
VAP-F1-1	VAP-F1-1_12-16	10/29/2019	12	16	8.3	< 17	67	86	40	53	110	140	2.5	< 17
	VAP-F1-1_22-26	10/29/2019	22	26	32	33	660	800	310	320	970	1100	11	21
	VAP-F1-1_28.5-32.5	10/29/2019	28.5	32.5	18	18	200	270	75	150	270	420	17	< 17
	VAP-F1-1_36-40	10/29/2019	36	40	19	27	160	200	65	87	220	290	20	19
	VAP-F1-1_42.5-46.5	10/29/2019	42.5	46.5	12	21	23	180	8.9	120	32	300	9.4	21
	VAP-F1-1_49.5-53.5	10/29/2019	49.5	53.5	8.3	< 17	78	< 17	45	< 11	120	< 27	2.6	< 17
	VAP-F1-1_56-60	10/29/2019	56	60	< 1	< 17	3.3	< 17	2.9	< 11	6.3	< 27	< 1.3	< 17
VAP-F1-2	VAP-F1-2_12-16	10/22/2019	12	16	3.7	< 31	67	130	25	45	92	170	1.3	< 31
	VAP-F1-2_19-23	10/22/2019	19	23	28 [31]	41 [55]	1000 [1100]	910 [920]	390 [470]	330 [360]	1400 [1600]	1200 [1300]	4.6 [4.5]	< 33 [< 36]
	VAP-F1-2_26-30	10/22/2019	26	30	47	47	1300	800	840	490	2100	1300	8.7	< 33
	VAP-F1-2_33-37	10/23/2019	33	37	9.3	< 33	210	230	120	120	330	340	5.3	< 33
	VAP-F1-2_40-44	10/23/2019	40	44	12	< 34	320	250	140	96	460	340	12	< 34
	VAP-F1-2_47-51	10/23/2019	47	51	8	< 33	84	37	37	15	120	52	< 2.7	< 33
	VAP-F1-2_56-60	10/23/2019	56	60	3.6	< 33	31	< 33	20	16	51	45	< 1.4	< 33
VAP-F1-3	VAP-F1-3_11-15	10/29/2019	11	15	29	37	120	180	160	280	280	460	3.5	< 17
	VAP-F1-3_19-23	10/30/2019	19	23	44	57	3800	3900	2200	1900	6000	5700	13	20
	VAP-F1-3_28-32	10/30/2019	28	32	13	< 17	230	390	120	220	350	600	4	< 17
	VAP-F1-3_34-38	10/30/2019	34	38	13	< 17	120	160	74	110	200	270	2.2	< 17
	VAP-F1-3_42-46	10/30/2019	42	46	8.8	< 17	85	130	46	75	130	200	< 1.4	< 17
	VAP-F1-3_48-52	10/30/2019	48	52	< 1.1	< 17	10	< 17	5	< 11	15	< 27	< 1.4	< 17
	VAP-F1-3_56-60	10/30/2019	56	60	< 5.1	< 17	9.6	17	3.8	< 11	13	< 27	< 6.6	< 17
VAP-F1-4	VAP-F1-4_12.5-16.5	10/22/2019	12.5	16.5	3.4	< 33	9.8	< 33	5	< 11	15	< 44	< 1.7	< 33
	VAP-F1-4_20-24	10/23/2019	20	24	11	< 33	66	60	82	92	150	150	6.1	< 33
	VAP-F1-4_27-31	10/23/2019	27	31	32	39	120	150	220	290	340	440	3.9	< 33
	VAP-F1-4_34-38	10/23/2019	34	38	38	61	140	170	240	360	380	530	3.7	< 33
	VAP-F1-4_41-45	10/23/2019	41	45	7.6	< 33	< 1.2	< 33	3.9	< 11	4.2	< 44	< 1.3	< 33
	VAP-F1-4_49-53	10/23/2019	49	53	< 1.1	< 33	3	< 33	4.2	< 11	7.2	< 44	< 1.5	< 33
	VAP-F1-4_54.5-58.5	10/23/2019	54.5	58.5	3.2	< 33	3.5	< 33	5.6	< 11	9.2	< 44	< 1.6	< 33
VAP-F1-5	VAP-F1-5_12-16	10/29/2019	12	16	< 0.93	< 16	6.9	< 16	5.4	< 10	12	< 27	< 1.2	< 16
	VAP-F1-5_20-24	10/29/2019	20	24	60	64	2000	1900	1400	1200	3400	3100	< 1.3	< 17
	VAP-F1-5_26-30	10/29/2019	26	30	210	250	6600	6100	4300	3500	11000	9600	14	< 17
	VAP-F1-5_33-37	10/29/2019	33	37	130	200	4800	5900	2500	2300	7400	8200	8.8	18
	VAP-F1-5_40-44	10/29/2019	40	44	48	79	500	620	260	390	760	1000	3.6	< 17
	VAP-F1-5_47-51	10/29/2019	47	51	11	17	180	210	80	100	260	310	< 1.4	< 16
	VAP-F1-5_56-60	10/29/2019	56	60	19	31	440	520	250	280	690	800	1.4	< 17
VAP-F1-6	VAP-F1-6_9-13	10/22/2019	9	13	3.7	< 30	23	< 30	10	9.5	33	< 40	< 1.5	< 30
	VAP-F1-6_16-20	10/22/2019	16	20	13	34	11	< 31	29	15	39	< 41	1.4	< 31
	VAP-F1-6_23-27	10/22/2019	23	27	590	560	700	690	1200	1100	1900	1800	37	48
	VAP-F1-6_28.5-32.5	10/22/2019	28.5	32.5	370	390	810	910	1200	1200	2000	2100	49	76
	VAP-F1-6_36-40	10/22/2019	36	40	320	300	680	660	910	780	1600	1400	44	51
	VAP-F1-6_42.5-46.5	10/22/2019	42.5	46.5	42	65	78	83	74	67	150	150	6.8	< 31
	VAP-F1-6_49.5-53.5	10/22/2019	49.5	53.5	93	76	37	32	59	38	96	70	4.8	< 30
VAP-F1-7	VAP-F1-7_12-16	10/30/2019	12	16	36	50	74	66	49	68	120	130	4.2	< 17
	VAP-F1-7_20-24	10/30/2019	20	24	23	26	120	100	140	170	270	270	7.7	< 16
	VAP-F1-7_27.5-31.5	10/30/2019	27.5	31.5	100	130	1100	1200	960	1300	2100	2500	29	30
	VAP-F1-7_32.5-36.5	10/30/2019	32.5	36.5	130	130	680	800	750	1000	1400	1800	33	27
	VAP-F1-7_39.5-43.5	10/30/2019	39.5	43.5	8	< 16	36	49	54	85	90	130	2.6	< 16
	VAP-F1-7_48-52	10/30/2019	48	52	2.4	< 17	6.4	17	5.7	14	12	30	< 1.2	< 17
	VAP-F1-7_54-58	10/30/2019	54	58	4.6	< 17	18	18	21	26	38	44	< 1.3	< 17
VAP-F1-8	VAP-F1-8_13.5-17.5	10/24/2019	13.5	17.5	3	< 33	66	58	17	16	83	74	2.2	< 33
	VAP-F1-8_22-26	10/24/2019	22	26	35	55	80	86	160	190	240	270	10	< 33
	VAP-F1-8_28-32	10/24/2019	28	32	190	93	910	380	1100	540	2000	920	22	< 33
	VAP-F1-8_37.5-41.5	10/24/2019	37.5	41.5	85	95	220	220	280	390	490	620	6.9	< 33
	VAP-F1-8_46-50	10/24/2019	46	50	6.2	< 33	18	< 33	28	20	46	< 44	< 1.3	< 33
	VAP-F1-8_52.5-56.5	10/24/2019	52.5	56.5	3.6	< 33	8.9	< 33	11	32	20	54	< 1.4	< 33

Location ID	Arcadis Sample ID	Collection Date	Start Depth (ft)	End Depth (ft)	PRIMARY CONSTITUENTS OF INTEREST									
					PFOA		PFOS		T-PFOS		Total PFOS		PFBS	
					DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method
VAP-F1-9	VAP-F1-9_11-15	10/30/2019	11	15	5.8	< 17	39	41	20	21	58	62	4.5	< 17
	VAP-F1-9_19-23	10/30/2019	19	23	93	100	840	880	690	740	1500	1600	31	22
	VAP-F1-9_27-31	10/30/2019	27	31	89	100	780	970	970	1100	1700	2100	42	39
	VAP-F1-9_32-36	10/30/2019	32	36	140	NA	88	NA	410	NA	500	NA	28	NA
	VAP-F1-9_38-42	10/30/2019	38	42	100	140	640	540	980	930	1600	1500	15	19
	VAP-F1-9_45-49	10/30/2019	45	49	110	150	140	220	410	740	560	970	18	18
VAP-F1-11	VAP-F1-11_12-16	11/8/2019	12	16	3	< 17	23	20	12	12	35	33	< 1.4	< 17
	VAP-F1-11_21-25	11/8/2019	21	25	270	310	19000	22000	11000	14000	30000	36000	46	45
	VAP-F1-11_27-31	11/8/2019	27	31	140	140	4800	5300	4400	4600	9200	9900	11	< 17
	VAP-F1-11_36-40	11/8/2019	36	40	23	36	420	400	360	420	790	820	4.3	< 17
	VAP-F1-11_43-47	11/8/2019	43	47	2	< 17	61	59	43	52	100	110	< 1.3	< 17
	VAP-F1-11_50-54	11/11/2019	50	54	< 1.1	< 17	57	71	27	55	84	130	< 1.4	< 17
	VAP-F1-11_56-60	11/11/2019	56	60	1.5	< 17	65	100	27	74	92	180	7.4	< 17
VAP-F1-12	VAP-F1-12_14-18	11/14/2019	14	18	26	31	< 1.3	< 17	2.4	< 11	2.8	< 27	2.3	< 17
	VAP-F1-12_21-25	11/14/2019	21	25	11	< 17	25	30	17	35	42	65	1.4	< 17
	VAP-F1-12_28-32	11/14/2019	28	32	17	20	48	51	43	38	91	89	< 1.4	< 17
	VAP-F1-12_36-40	11/14/2019	36	40	3.2 [3.1]	< 17 [< 17]	31 [36]	38 [40]	18 [18]	< 11 [19]	49 [53]	38 [59]	< 1.4 [< 1.4]	< 17 [< 17]
	VAP-F1-12_43-47	11/14/2019	43	47	< 1.1	< 17	2.1	< 17	< 0.79	< 10	< 2.1	< 27	< 1.4	< 17
	VAP-F1-12_50-54	11/14/2019	50	54	< 1.1	< 17	< 1.3	< 17	< 0.79	< 11	< 2.1	< 27	< 1.4	< 17
	VAP-F1-12_56-60	11/14/2019	56	60	1.3	< 17	4	< 17	< 0.78	< 11	4.2	< 27	< 1.3	< 17
VAP-F1-13	VAP-F1-13_15-19	11/13/2019	15	19	1.1	< 17	< 1.3	< 17	2.5	< 11	2.9	< 27	1.7	< 17
	VAP-F1-13_22-26	11/13/2019	22	26	31	47	47	55	150	250	200	310	3.7	< 17
	VAP-F1-13_29-33	11/13/2019	29	33	5.2	< 17	21	25	57	57	78	82	< 1.4	< 17
	VAP-F1-13_36-40	11/13/2019	36	40	2.7	< 17	24	26	23	26	47	52	< 1.4	< 17
	VAP-F1-13_43-47	11/14/2019	43	47	< 1.1	< 17	3.9	< 17	3.9	< 11	7.7	< 27	< 1.4	< 17
	VAP-F1-13_50-54	11/14/2019	50	54	< 1.1	< 17	< 1.3	< 17	< 0.79	< 11	< 2.1	< 27	< 1.4	< 17
	VAP-F1-13_56-60	11/14/2019	56	60	< 1.1	< 17	1.5	< 17	1	< 10	2.5	< 27	< 1.4	< 17
TRANSECT 2														
VAP-F2-1	VAP-F2-1_15-19	11/7/2019	15	19	160	2200	22000	24000	8200	9500	30000	34000	53	1800
	VAP-F2-1_22-26	11/7/2019	22	26	24	34	1700	1900	860	1200	2500	3200	2.8	< 17
	VAP-F2-1_28.5-32.5	11/7/2019	28.5	32.5	4.4	< 17	120	140	32	43	150	190	1.4	< 17
	VAP-F2-1_36-40	11/7/2019	36	40	< 1.1	< 17	65	72	16	26	81	98	1.7	< 17
	VAP-F2-1_43-47	11/7/2019	43	47	1.1	< 17	250	320	70	110	320	440	< 1.3	< 17
	VAP-F2-1_51-55	11/7/2019	51	55	< 1.1	< 17	52	62	11	20	64	82	< 1.4	< 17
	VAP-F2-1_56-60	11/7/2019	56	60	1.4	< 17	110	120	27	50	140	170	< 1.4	< 17
VAP-F2-2	VAP-F2-2_14-18	11/1/2019	14	18	22	22	1500	2100	610	780	2100	2900	4.9	< 17
	VAP-F2-2_20-24	11/1/2019	20	24	37	43	1200	1600	420	580	1600	2200	12	19
	VAP-F2-2_28-32	11/1/2019	28	32	26 [26]	31 [33]	100 [98]	110 [110]	59 [48]	59 [61]	160 [150]	160 [170]	17 [17]	20 [< 17]
	VAP-F2-2_35-39	11/1/2019	35	39	27	34	120	130	61	66	180	190	17	18
	VAP-F2-2_41-45	11/1/2019	41	45	7.2	20	91	96	43	49	130	140	2.7	< 17
	VAP-F2-2_48-52	11/1/2019	48	52	3	< 17	22	29	9.3	17	31	46	< 1.4	< 17
	VAP-F2-2_55-59	11/1/2019	55	59	1.7	< 17	5	< 17	1.8	< 10	6.8	< 27	< 1.4	< 17
VAP-F2-3	VAP-F2-3_15-19	10/24/2019	15	19	31	45	760	850	430	560	1200	1400	6.5	< 33
	VAP-F2-3_23-27	10/24/2019	23	27	5.9	< 33	130	100	39	36	170	140	3.6	< 33
	VAP-F2-3_29-33	10/24/2019	29	33	5.8	< 33	76	62	29	29	110	91	7.8	< 33
	VAP-F2-3_38-42	10/24/2019	38	42	13	< 33	80	80	< 0.82	28	80	110	20	< 33
	VAP-F2-3_47-51	10/25/2019	47	51	9.1	< 17	13	< 17	5.1	< 11	18	< 27	1.4	< 17
	VAP-F2-3_56-60	10/25/2019	56	60	5.6	< 17	19	23	8.6	11	27	34	< 1.4	< 17
VAP-F2-4	VAP-F2-4_15-19	11/7/2019	15	19	8.5	< 17	780	900	190	290	970	1200	6.7	< 17
	VAP-F2-4_20-24	11/7/2019	20	24	12	< 17	500	570	260	410	760	990	3.7	< 17
	VAP-F2-4_27-31	11/8/2019	27	31	7.9	24	240	280	150	200	390	490	1.9	< 17
	VAP-F2-4_33-37	11/8/2019	33	37	6.1	17	160	160	86	86	250	250	1.5	< 17
	VAP-F2-4_39.5-43.5	11/8/2019	39.5	43.5	4.1	< 17	130	130	58	56	190	180	1.5	< 17
	VAP-F2-4_48-52	11/8/2019	48	52	< 1.1	< 17	15	22	7	< 11	22	32	< 1.4	< 17
	VAP-F2-4_56-60	11/8/2019	56	60	1.1	< 17	24	34	11	19	35	53	< 1.4	< 17

Location ID	Arcadis Sample ID	Collection Date	Start Depth (ft)	End Depth (ft)	PRIMARY CONSTITUENTS OF INTEREST									
					PFOA		PFOS		T-PFOS		Total PFOS		PFBS	
					DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method
VAP-F2-5	VAP-F2-5_13-17	10/25/2019	13	17	27	33	1000	1200	510	620	1500	1900	7.1	< 17
	VAP-F2-5_22-26	10/25/2019	22	26	21	26	150	110	< 0.79	50	150	160	1.9	< 17
	VAP-F2-5_31-35	10/25/2019	31	35	16	34	99	120	41	56	140	170	2.8	< 17
	VAP-F2-5_38.5-42.5	10/25/2019	38.5	42.5	1.7	< 17	13	20	7	< 11	20	27	< 1.4	< 17
	VAP-F2-5_47.5-51.5	10/25/2019	47.5	51.5	4.7	< 17	56	46	28	17	85	63	< 1.5	< 17
	VAP-F2-5_56-60	10/25/2019	56	60	6.7	< 17	70	60	28	24	98	84	< 2	< 17
VAP-F2-6	VAP-F2-6_13-17	10/31/2019	13	17	6.1	< 17	65	73	42	76	110	150	4.7	< 17
	VAP-F2-6_22-26	10/31/2019	22	26	35	43	390	420	340	410	720	830	3.4	< 17
	VAP-F2-6_27-31	10/31/2019	27	31	39	< 17	390	< 17	270	11	660	< 27	3.5	< 17
	VAP-F2-6_33-37	10/31/2019	33	37	19	1700	100	1700	110	790	210	2500	2.6	1600
	VAP-F2-6_40-44	10/31/2019	40	44	2.3	21	14	110	5.5	150	19	260	< 1.4	< 17
	VAP-F2-6_48-52	10/31/2019	48	52	1.5 [< 1.0]	< 17 [< 17]	< 1.3 [2.8]	21 [< 17]	< 0.79 [3.0]	19 [< 11]	< 2.1 [5.8]	40 [< 27]	< 1.4 [< 1.4]	< 17 [< 17]
	VAP-F2-6_55-59	10/31/2019	55	59	< 1	< 17	1.4	< 17	1.2	< 11	2.5	< 27	< 1.3	< 17
VAP-F2-7	VAP-F2-7_12-16	10/25/2019	12	16	14	< 33	24	< 33	38	39	61	66	26	< 33
	VAP-F2-7_22-26	10/25/2019	22	26	480	510	5100	5300	4900	3800	10000	9000	34	35
	VAP-F2-7_32-36	10/25/2019	32	36	67	67	1500	1700	820	820	2300	2500	3	< 17
	VAP-F2-7_41-45	10/28/2019	41	45	8.3	< 17	70	94	33	39	100	130	< 1.4	< 17
	VAP-F2-7_49-53	10/28/2019	49	53	3.5	< 17	27	50	24	30	51	80	< 1.4	< 17
	VAP-F2-7_56-60	10/28/2019	56	60	16	25	420	410	220	230	640	650	2.3	< 17
VAP-F2-8	VAP-F2-8_11-15	10/30/2019	11	15	1.9	< 17	59	76	31	45	90	120	8	< 17
	VAP-F2-8_20-24	10/30/2019	20	24	330	440	820	970	1200	1400	2000	2400	31	37
	VAP-F2-8_27-31	10/30/2019	27	31	310	390	750	860	920	1000	1700	1900	32	36
	VAP-F2-8_34-38	10/30/2019	34	38	45	58	27	41	58	87	85	130	12	< 17
	VAP-F2-8_42-46	10/30/2019	42	46	9.2	29	13	42	18	71	31	110	< 1.3	< 17
	VAP-F2-8_49-53	10/31/2019	49	53	4.6	< 17	6.5	< 17	8.1	22	15	38	< 1.3	< 17
	VAP-F2-8_56-60	10/31/2019	56	60	1.7 [1.9]	< 17 [< 17]	< 1.2 [< 1.2]	< 17 [< 17]	< 0.78 [< 0.76]	< 10 [< 10]	< 2.1 [< 2]	< 27 [< 27]	< 1.3 [< 1.3]	< 17 [< 17]
VAP-F2-13	VAP-F2-13_15-19	11/12/2019	15	19	8.9	< 17	30	36	21	21	51	57	< 1.4	< 17
	VAP-F2-13_22-26	11/12/2019	22	26	40 [39]	45 [45]	24 [22]	24 [23]	18 [15]	19 [21]	42 [38]	44 [45]	1.9 [2]	< 17 [< 17]
	VAP-F2-13_28-32	11/13/2019	28	32	13	< 17	43	34	31	26	73	60	1.4	< 17
	VAP-F2-13_36-40	11/13/2019	36	40	3.4	17	26	48	16	48	42	96	< 1.4	< 17
	VAP-F2-13_43-47	11/13/2019	43	47	1.2	< 17	3	< 17	< 0.8	< 11	3.8	< 27	< 1.4	< 17
	VAP-F2-13_51-55	11/13/2019	51	55	< 1.1	< 17	< 1.3	< 17	< 0.79	< 11	< 2.1	< 27	< 1.4	< 17
	VAP-F2-13_56-60	11/13/2019	56	60	< 1.1	< 17	1.3	< 17	< 0.81	< 11	< 2.2	< 27	< 1.4	< 17
TRANSECT 3														
VAP-F3-1	VAP-F3-1_9-13	11/11/2019	9	13	1.2	< 17	6.2	< 17	5.7	11	12	< 27	< 1.4	< 17
	VAP-F3-1_15-19	11/15/2019	15	19	3.5	NA	4.9	NA	6.1	NA	11	NA	< 1.4	NA
	VAP-F3-1_21-25	11/15/2019	21	25	9.4	< 17	24	20	64	76	88	96	4.6	< 17
	VAP-F3-1_27-31	11/15/2019	27	31	36	29	57	59	180	190	240	240	4.2	< 17
	VAP-F3-1_37-41	11/15/2019	37	41	36	37	73	80	190	210	260	290	4.2	< 17
	VAP-F3-1_46-50	11/15/2019	46	50	13	< 17	8.8	< 17	30	29	38	39	2.1	< 17
	VAP-F3-1_56-60	11/15/2019	56	60	12	< 17	7.9	< 17	26	21	33	29	< 1.4	< 17
VAP-F3-2	VAP-F3-2_11-15	10/28/2019	11	15	4	19	2.3	< 17	9	< 11	11	< 27	2.8	< 17
	VAP-F3-2_18-22	10/28/2019	18	22	69 [70]	81 [120]	71 [75]	90 [90]	170 [180]	190 [190]	250 [260]	280 [280]	20 [22]	33 [27]
	VAP-F3-2_25-29	10/28/2019	25	29	430	570	1700	2200	1800	1800	3500	3900	46	69
	VAP-F3-2_32-36	10/28/2019	32	36	540	640	2700	3100	1700	2300	4500	5400	41	42
	VAP-F3-2_40-44	10/28/2019	40	44	42	52	290	280	180	190	470	480	< 1.4	20
	VAP-F3-2_47-51	10/29/2019	47	51	320	380	2000	2300	2000	1700	4000	4000	24	23
VAP-F3-3	VAP-F3-3_10-14	11/1/2019	10	14	2.6 [1.6]	< 17 [< 17]	1.8 [1.7]	< 17 [< 17]	4.1 [4.4]	< 11 [< 11]	5.9 [6.1]	< 27 [< 27]	< 1.3 [< 1.4]	< 17 [< 17]
	VAP-F3-3_20-24	11/1/2019	20	24	180	220	56	45	240	330	290	370	31	32
	VAP-F3-3_24.5-28.5	11/4/2019	24.5	28.5	400 [370]	410 [410]	57 [69]	94 [93]	510 [390]	610 [560]	460 [460]	700 [650]	40 [45]	53 [< 17]
	VAP-F3-3_33-37	11/4/2019	33	37	230	230	100	110	320	450	420	560	45	51
	VAP-F3-3_42-46	11/4/2019	42	46	36	46	18	24	40	59	58	84	5	< 17
	VAP-F3-3_48-52	11/4/2019	48	52	12	18	2.9	< 17	9.5	11	12	< 27	2.8	< 17
	VAP-F3-3_55-59	11/4/2019	55	59	21	30	9	< 17	22	33	31	48	2	< 17

Location ID	Arcadis Sample ID	Collection Date	Start Depth (ft)	End Depth (ft)	PRIMARY CONSTITUENTS OF INTEREST									
					PFOA		PFOS		T-PFOS		Total PFOS		PFBS	
					DoD ELAP Method	Accelerate dMethod	DoD ELAP Method	Accelerate dMethod	DoD ELAP Method	Accelerate dMethod	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerate dMethod
VAP-F3-4	VAP-F3-4_11-15	10/30/2019	11	15	< 1	< 17	1.6	< 17	< 0.78	< 11	< 2.1	< 27	< 1.4	< 17
	VAP-F3-4_19-23	10/30/2019	19	23	43	59	36	54	100	160	140	210	25	34
	VAP-F3-4_27-31	10/30/2019	27	31	74	88	62	73	220	240	280	320	25	27
	VAP-F3-4_35-39	10/30/2019	35	39	41	120	340	920	360	910	690	1800	17	47
	VAP-F3-4_42-46	10/30/2019	42	46	68	75	450	750	550	800	1000	1500	10	< 17
	VAP-F3-4_56-60	10/30/2019	56	60	6.6	< 17	51	70	73	98	120	170	< 1.5	< 17
VAP-F3-7	VAP-F3-7_9-13	11/11/2019	9	13	< 1	< 17	1.4	< 17	1.2	< 11	2.6	< 27	< 1.3	< 17
	VAP-F3-7_15-19	11/11/2019	15	19	28	37	46	64	62	64	110	130	6.5	< 17
	VAP-F3-7_21-25	11/11/2019	21	25	58	70	540	590	460	760	990	1400	7.2	< 17
	VAP-F3-7_27-31	11/11/2019	27	31	15	21	290	350	220	370	500	720	3.1	< 17
	VAP-F3-7_37-41	11/11/2019	37	41	9	< 17	76	100	45	95	120	200	2.2	< 17
	VAP-F3-7_46-50	11/11/2019	46	50	< 1	< 17	3.6	< 17	2.3	< 11	5.9	< 27	< 1.3	< 17
	VAP-F3-7_56-60	11/11/2019	56	60	< 1.1	< 17	2.9	< 17	2.8	< 10	5.6	< 27	< 1.4	< 17
VAP-F3-8	VAP-F3-8_11-15	11/15/2019	11	15	1.4	< 17	3.9	< 17	3.5	< 10	7.4	< 27	< 1.4	< 17
	VAP-F3-8_18-22	11/15/2019	18	22	11 [9.1]	< 17 [< 17]	220 [220]	220 [230]	120 [110]	110 [110]	330 [330]	330 [340]	4.1 [4.2]	< 17 [< 17]
	VAP-F3-8_25-29	11/15/2019	25	29	14 [21]	22 [23]	11 [480]	540 [530]	35 [320]	370 [370]	46 [800]	910 [900]	1.9 [8]	< 17 [< 17]
	VAP-F3-8_33-37	11/15/2019	33	37	9.2	< 17	160	170	92	97	260	260	< 1.4	< 17
	VAP-F3-8_41-45	11/15/2019	41	45	3.7	< 17	46	44	29	21	74	65	< 1.4	< 17
	VAP-F3-8_49-53	11/15/2019	49	53	12	< 17	200	< 17	150	< 11	350	< 27	4.2	< 17
	VAP-F3-8_56-60	11/15/2019	56	60	5.2	< 17	65	< 17	48	< 11	110	< 27	< 1.4	39
VAP-F3-9	VAP-F3-9_9-13	11/12/2019	9	13	1	< 17	< 1.3	< 17	< 0.78	< 11	< 2.1	< 27	< 1.4	< 17
	VAP-F3-9_15-19	11/12/2019	15	19	8	< 17	150	200	63	100	220	300	2.9	< 17
	VAP-F3-9_21-25	11/12/2019	21	25	15	19	220	310	84	180	310	490	5.8	< 17
	VAP-F3-9_27-31	11/12/2019	27	31	17	24	100	130	67	110	170	240	3.7	< 17
	VAP-F3-9_37-41	11/12/2019	37	41	9.3	17	130	140	50	71	180	210	5.2	< 17
	VAP-F3-9_46-50	11/12/2019	46	50	2.2	< 17	4.1	< 17	8.3	< 11	12	< 27	22	25
	VAP-F3-9_56-60	11/12/2019	56	60	5.1	< 17	54	52	34	33	88	85	29	22
PRIMARY SOURCE														
VAP-PS-1	VAP-PS-1_14-17	10/21/2019	14	17	130	160	5700	6300	1500	1400	7200	7700	18	41
VAP-PS-2	VAP-PS-2_14-17	10/21/2019	14	17	110	120	7000	8300	2600	2500	9600	11000	47	65
VAP-PS-3	VAP-PS-3_16.5-19.5	10/21/2019	16.5	19.5	170	160	2800	2500	1700	1600	4500	4100	17	< 33
VAP-PS-4	VAP-PS-4_13-16	10/22/2019	13	16	45	73	1800	2100	1100	1200	2900	3300	12	< 35
VAP-PS-5	VAP-PS-5_14-17	10/22/2019	14	17	29	49	670	820	320	320	990	1100	4.7	< 35
VAP-PS-6	VAP-PS-6_14-17	10/22/2019	14	17	55	78	2600	3000	1300	1500	3900	4500	17	< 34
SECONDARY SOURCE														
VAP-SS-1	VAP-SS-1_13-17	11/5/2019	13	17	19	28	1800	1900	450	640	2300	2600	6.3	< 17
	VAP-SS-1_20.5-24.5	11/5/2019	20.5	24.5	10	23	280	330	180	220	460	560	3.8	< 17
	VAP-SS-1_26-30	11/5/2019	26	30	6.6	< 17	190	210	85	110	280	320	2.2	< 17
	VAP-SS-1_34-38	11/5/2019	34	38	7.5	19	140	190	56	83	200	270	< 1.4	17
	VAP-SS-1_44-48	11/5/2019	44	48	1.6	< 17	30	57	14	27	44	85	< 1.4	< 17
	VAP-SS-1_50-54	11/5/2019	50	54	3	< 17	7.5	< 17	4.8	< 11	12	< 27	< 1.4	< 17
	VAP-SS-1_56-60	11/6/2019	56	60	3.1	< 17	41	57	14	26	55	82	< 1.4	< 17
VAP-SS-2	VAP-SS-2_14-18	11/5/2019	14	18	12	25	200	280	94	190	290	470	11	< 17
	VAP-SS-2_23-27	11/5/2019	23	27	6.6	18	91	130	41	57	130	190	< 1.4	< 17
	VAP-SS-2_28.5-32.5	11/5/2019	28.5	32.5	9.8	26	86	100	37	48	120	150	< 1.4	< 17
	VAP-SS-2_36-40	11/5/2019	36	40	2.6 [2.3]	< 17 [< 17]	55 [53]	61 [66]	23 [20]	34 [35]	78 [73]	95 [100]	1.8 [< 1.3]	< 17 [< 17]
	VAP-SS-2_43-47	11/5/2019	43	47	3.8	17	62	88	29	46	91	130	< 1.4	< 17
	VAP-SS-2_49-53	11/5/2019	49	53	3	18	8.6	< 17	3.7	10	12	< 27	< 1.4	< 17
	VAP-SS-2_58-62	11/5/2019	58	62	1.8	< 17	1.6	< 17	1.5	< 11	3	< 27	< 1.4	< 17
VAP-SS-3	VAP-SS-3_14-18	11/6/2019	14	18	23	36	530	680	150	240	680	930	7.2	< 17
	VAP-SS-3_22-26	11/6/2019	22	26	14	19	85	270	28	92	110	360	20	< 17
	VAP-SS-3_30-34	11/6/2019	30	34	11	32	150	100	49	42	200	140	6.7	24
	VAP-SS-3_38-42	11/6/2019	38	42	15	29	83	120	27	46	110	170	28	31
	VAP-SS-3_44.5-48.5	11/6/2019	44.5	48.5	1.1	< 17	1.7	< 17	1.7	< 11	3.4	< 27	< 1.4	< 17
	VAP-SS-3_50-54	11/6/2019	50	54	11	24	76	110	24	37	100	140	13	20
	VAP-SS-3_58-62	11/6/2019	58	62	2.1	< 17	15	22	3.6	< 11	19	29	1.9	< 17

Location ID	Arcadis Sample ID	Collection Date	Start Depth (ft)	End Depth (ft)	PRIMARY CONSTITUENTS OF INTEREST									
					PFOA		PFOS		T-PFOS		Total PFOS		PFBS	
					DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	AcceleratedMethod
VAP-SS-4	VAP-SS-4_15-19	11/6/2019	15	19	32	42	1800	2200	530	700	2400	2900	6.5	17
	VAP-SS-4_21-25	11/6/2019	21	25	19	22	120	120	160	190	280	310	8.7	19
	VAP-SS-4_27.5-31.5	11/6/2019	27.5	31.5	12	< 17	100	110	48	64	150	170	11	< 17
	VAP-SS-4_35-39	11/6/2019	35	39	1.7	< 17	82	100	22	40	100	140	< 1.4	< 17
	VAP-SS-4_41-45	11/7/2019	41	45	< 1	< 17	66	76	13	15	78	91	< 1.3	< 17
	VAP-SS-4_49-53	11/7/2019	49	53	1.1	< 17	80	93	16	22	96	110	< 1.4	< 17
	VAP-SS-4_56-60	11/7/2019	56	60	1.2	< 17	170	200	29	40	200	240	< 1.5	< 17
VAP-SS-5	VAP-SS-5_15.5-19.5	11/6/2019	15.5	19.5	33	49	490	600	310	420	800	1000	11	< 17
	VAP-SS-5_20.5-24.5	11/6/2019	20.5	24.5	33	43	170	190	240	380	410	570	14	21
	VAP-SS-5_27-31	11/6/2019	27	31	26	33	210	180	230	250	440	440	13	23
	VAP-SS-5_34-38	11/6/2019	34	38	8.2	< 17	220	320	84	140	300	460	8.7	< 17
	VAP-SS-5_40-44	11/6/2019	40	44	< 1.1	< 17	140	140	28	35	170	170	< 1.4	< 17
	VAP-SS-5_47-51	11/7/2019	47	51	6.2	< 17	900	870	140	130	1000	990	< 1.4	< 17
	VAP-SS-5_56-60	11/7/2019	56	60	1.4	< 17	190	190	31	36	220	220	< 1.4	< 17
VAP-SS-6	VAP-SS-6_14.5-18.5	11/7/2019	14.5	18.5	30	36	1200	1300	820	1300	2100	2600	15	25
	VAP-SS-6_22-26	11/7/2019	22	26	26	32	95	130	54	97	150	220	19	33
	VAP-SS-6_30-34	11/7/2019	30	34	25	29	80	93	81	110	160	210	16	23
	VAP-SS-6_38-42	11/8/2019	38	42	2.6	< 17	100	170	34	65	140	230	2.4	< 17
	VAP-SS-6_49-53	11/8/2019	49	53	2.6	< 17	150	150	37	39	180	190	< 1.4	< 17
	VAP-SS-6_56-60	11/8/2019	56	60	< 1	< 17	16	18	3.1	< 10	19	< 27	< 1.4	< 17

Abbreviations:

DoD ELAP = Department of Defense Environmental Laboratory Accreditation Programft = feet

NA = not applicable

PFBS = perfluorobutane sulfonatePFOA = perfluorooctanoic acid PFOS = perfluorooctane sulfonate

Notes:

1. Groundwater analytical results are in units nanograms per liter (ng/L).
2. Method Detection Limits (MDLs) are shown for DoD ELAP Method non-detects and Limits of Quantitation (LOQ) are shown for Accelerated Method non-detects.
3. Accelerated Method data are unavailable for Arcadis Sample IDs VAP-F1-9_32-36 and VAP-F3-1_15-19 due to sample handling errors at the laboratory.
4. Field duplicate analytical results are presented in brackets.

Table 5-4. Groundwater Analytical Results for the PFAS Mobile Lab-Based Real Time Method Pilot Study Secondary Constituents of Interest

Location ID	Arcadis Sample ID	Collection Date	Start Depth (ft)	End Depth (ft)	SECONDARY CONSTITUENTS OF INTEREST											
					6-2FTS		8-2FTS		PFHpA		PFHpS		PFHxA		PFHxS	
					DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method
TRANSECT 1																
VAP-F1-1	VAP-F1-1_12-16	10/29/2019	12	16	0.78	< 17	< 1.4	< 17	4.9	< 17	6	< 17	11	19	71	75
	VAP-F1-1_22-26	10/29/2019	22	26	0.79	< 17	< 1.4	< 17	14	17	22	28	26	35	380	410
	VAP-F1-1_28.5-32.5	10/29/2019	28.5	32.5	< 0.76	< 17	< 1.5	< 17	11	< 17	< 2.9	< 17	24	33	150	190
	VAP-F1-1_36-40	10/29/2019	36	40	< 0.77	< 17	< 1.5	< 17	13	< 17	4.1	< 17	23	34	160	180
	VAP-F1-1_42.5-46.5	10/29/2019	42.5	46.5	8.8	< 17	9.7	< 17	12	< 17	12	< 17	13	34	17	190
	VAP-F1-1_49.5-53.5	10/29/2019	49.5	53.5	< 0.77	< 17	< 1.5	< 17	4.6	< 17	6	< 17	11	< 17	66	< 17
	VAP-F1-1_56-60	10/29/2019	56	60	< 0.73	< 17	< 1.4	< 17	< 3.4	< 17	< 2.8	< 17	< 1.3	< 17	< 1.4	< 17
VAP-F1-2	VAP-F1-2_12-16	10/22/2019	12	16	< 0.75	< 31	< 1.4	< 31	< 3.5	< 31	< 2.9	< 31	7.6	< 31	78	89
	VAP-F1-2_19-23	10/22/2019	19	23	< 1 [< 1.1]	< 33 [< 36]	< 1.9 [< 2.1]	< 33 [< 36]	16 [19]	< 33 [< 36]	22 [26]	< 33 [< 36]	36 [38]	34 [37]	460 [500]	400 [400]
	VAP-F1-2_26-30	10/22/2019	26	30	< 1.2	< 33	< 2.3	< 33	32	< 33	50	< 33	58	42	880	550
	VAP-F1-2_33-37	10/23/2019	33	37	< 0.78	< 33	< 1.5	< 33	12	< 33	5.4	< 33	35	36	110	100
	VAP-F1-2_40-44	10/23/2019	40	44	< 1.3	< 34	< 2.4	< 34	13	< 34	8	< 34	46	38	83	69
	VAP-F1-2_47-51	10/23/2019	47	51	< 1.5	< 33	< 2.9	< 33	< 7	< 33	< 5.7	< 33	8.6	< 33	40	< 33
	VAP-F1-2_56-60	10/23/2019	56	60	< 0.77	< 33	< 1.5	< 33	< 3.6	< 33	< 2.9	< 33	3.9	< 33	23	< 33
VAP-F1-3	VAP-F1-3_11-15	10/29/2019	11	15	< 0.74	< 17	1.6	< 17	16	26	12	< 17	19	30	130	170
	VAP-F1-3_19-23	10/30/2019	19	23	46	48	2.5	< 17	18	25	88	81	57	69	720	700
	VAP-F1-3_28-32	10/30/2019	28	32	< 0.73	< 17	< 1.4	< 17	11	21	6	< 17	19	24	87	100
	VAP-F1-3_34-38	10/30/2019	34	38	< 0.78	< 17	< 1.5	< 17	11	22	4.5	< 17	15	18	89	86
	VAP-F1-3_42-46	10/30/2019	42	46	< 0.79	< 17	< 1.5	< 17	7.3	< 17	< 3	< 17	8.5	< 17	43	43
	VAP-F1-3_48-52	10/30/2019	48	52	< 0.78	< 17	< 1.5	< 17	< 3.6	< 17	< 3	< 17	1.7	< 17	11	17
	VAP-F1-3_56-60	10/30/2019	56	60	< 3.7	< 17	< 7.1	< 17	< 17	< 17	< 14	< 17	< 6.6	< 17	13	< 17
VAP-F1-4	VAP-F1-4_12.5-16.5	10/22/2019	12.5	16.5	< 0.95	< 33	< 1.8	< 33	< 4.4	< 33	< 3.7	< 33	< 1.7	< 33	10	< 33
	VAP-F1-4_20-24	10/23/2019	20	24	< 0.9	< 33	< 1.7	< 33	6.4	< 33	5.2	< 33	11	< 33	66	58
	VAP-F1-4_27-31	10/23/2019	27	31	< 0.73	< 33	< 1.4	< 33	25	36	16	< 33	36	< 33	160	180
	VAP-F1-4_34-38	10/23/2019	34	38	0.87	< 33	< 1.4	< 33	27	38	17	< 33	38	40	170	160
	VAP-F1-4_41-45	10/23/2019	41	45	< 0.72	< 33	< 1.4	< 33	13	< 33	< 2.8	< 33	15	< 33	32	< 33
	VAP-F1-4_49-53	10/23/2019	49	53	< 0.81	< 33	< 1.6	< 33	< 3.8	< 33	< 3.1	< 33	2.7	< 33	8.5	< 33
	VAP-F1-4_54.5-58.5	10/23/2019	54.5	58.5	< 0.88	< 33	< 1.7	< 33	< 4.1	< 33	< 3.4	< 33	1.8	< 33	8.6	< 33
VAP-F1-5	VAP-F1-5_12-16	10/29/2019	12	16	< 0.68	< 16	< 1.3	< 16	< 3.2	< 16	< 2.6	< 16	< 1.2	< 16	7.4	< 16
	VAP-F1-5_20-24	10/29/2019	20	24	190	< 17	19	33	60	71	31	26	< 1.3	87	190	220
	VAP-F1-5_26-30	10/29/2019	26	30	2000	1700	100	110	230	250	85	110	250	310	640	770
	VAP-F1-5_33-37	10/29/2019	33	37	1000	1500	120	180	130	200	52	81	160	230	440	610
	VAP-F1-5_40-44	10/29/2019	40	44	130	180	8.9	19	52	70	7.6	< 17	63	93	110	150
	VAP-F1-5_47-51	10/29/2019	47	51	22	25	3.2	< 16	13	< 16	< 3	< 16	17	26	14	21
	VAP-F1-5_56-60	10/29/2019	56	60	110	150	12	24	17	33	5.5	< 17	21	34	51	66
VAP-F1-6	VAP-F1-6_9-13	10/22/2019	9	13	< 0.84	< 30	< 1.6	< 30	< 3.9	< 30	< 3.2	< 30	2.4	< 30	3	< 30
	VAP-F1-6_16-20	10/22/2019	16	20	9.9	< 31	< 1.3	< 31	5.1	< 31	3.2	< 31	5.4	< 31	23	< 31
	VAP-F1-6_23-27	10/22/2019	23	27	970	880	7.7	< 32	290	270	170	140	380	370	1200	1000
	VAP-F1-6_28.5-32.5	10/22/2019	28.5	32.5	1100	1200	5.7	< 35	250	240	120	130	470	530	960	1000
	VAP-F1-6_36-40	10/22/2019	36	40	1600	1400	7.2	< 30	220	200	94	75	440	410	900	850
	VAP-F1-6_42.5-46.5	10/22/2019	42.5	46.5	65	71	< 1.4	< 31	45	39	6.2	< 31	88	92	130	140
	VAP-F1-6_49.5-53.5	10/22/2019	49.5	53.5	88	< 31	< 2.3	< 31	15	< 30	4.8	< 30	26	< 30	59	35
VAP-F1-7	VAP-F1-7_12-16	10/30/2019	12	16	22	20	15	25	65	70	< 2.7	< 17	49	61	37	44
	VAP-F1-7_20-24	10/30/2019	20	24	83	77	3.8	< 16	13	17	13	< 16	40	48	100	99
	VAP-F1-7_27.5-31.5	10/30/2019	27.5	31.5	260	300	18	32	82	88	74	95	200	230	480	520
	VAP-F1-7_32.5-36.5	10/30/2019	32.5	36.5	210	270	2.6	< 16	76	94	69	82	190	180	590	610
	VAP-F1-7_39.5-43.5	10/30/2019	39.5	43.5	0.9	< 16	< 1.4	< 16	6.5	< 16	5.1	< 16	18	23	57	51
	VAP-F1-7_48-52	10/30/2019	48	52	< 0.69	< 17	< 1.3	< 17	< 3.2	< 17	< 2.6	< 17	2.7	< 17	6	< 17
	VAP-F1-7_54-58	10/30/2019	54	58	2.4	< 17	< 1.4	< 17	< 3.3	< 17	< 2.7	< 17	5.4	< 17	13	22
VAP-F1-8	VAP-F1-8_13.5-17.5	10/24/2019	13.5	17.5	< 0.8	< 33	< 1.5	< 33	< 3.7	< 33	< 3.1	< 33	8.8	< 33	21	< 33
	VAP-F1-8_22-26	10/24/2019	22	26	5.2	< 33	< 1.5	< 33	23	< 33	24	< 33	53	56	250	250
	VAP-F1-8_28-32	10/24/2019	28	32	150	64	< 3.2	< 33	130	69	100	50	350	150	1200	520
	VAP-F1-8_37.5-41.5	10/24/2019	37.5	41.5	110	100	< 1.4	< 33	46	54	82	60	130	140	450	440
	VAP-F1-8_46-50	10/24/2019	46	50	4.6	< 33	< 1.5	< 33	4.1	< 33	4.3	< 33	8.8	< 33	42	< 33
	VAP-F1-8_52.5-56.5	10/24/2019	52.5	56.5	2.8	< 33	< 1.5	< 33	< 3.5	< 33	< 2.9	< 33	4.5	< 33	19	41
VAP-F1-9	VAP-F1-9_11-15	10/30/2019	11	15	< 0.7	< 17	< 1.3	< 17	3.9	20	< 2.7	< 17	8.7	< 17	28	23
	VAP-F1-9_19-23	10/30/2019	19	23	49	40	< 1.4	< 17	45	61	60	74	85	87	730	660
	VAP-F1-9_27-31	10/30/2019	27	31	54	55	< 1.5	< 17	57	87	64	74	200	210	720	710
	VAP-F1-9_32-36	10/30/2019	32	36	69	NA	< 1.5	NA	69	NA	130	NA	230	NA	1000	NA
	VAP-F1-9_38-42	10/30/2019	38	42	170	250	< 1.3	< 17	49	76	98	140	150	200	580	770
	VAP-F1-9_45-49	10/30/2019	45	49	75	110	< 1.4	< 16	40	63	95	140	150	200	600	820
VAP-F1-11	VAP-F1-11_12-16	11/8/2019	12	16	< 0.79	< 17	< 1.5	< 17	< 3.7	< 17	< 3	< 17	2.6	< 17	17	19

Location ID	Arcadis Sample ID	Collection Date	Start Depth (ft)	End Depth (ft)	SECONDARY CONSTITUENTS OF INTEREST											
					6-2FTS		8-2FTS		PFHpA		PFHpS		PFHxA		PFHxS	
					DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method
	VAP-F1-11_21-25	11/8/2019	21	25	110	120	18	22	95	95	270	360	390	420	2000	2100
	VAP-F1-11_27-31	11/8/2019	27	31	54	55	3.6	< 17	33	41	150	150	85	84	740	740
	VAP-F1-11_36-40	11/8/2019	36	40	3.7	< 17	1.9	< 17	12	22	18	< 17	19	22	120	95
	VAP-F1-11_43-47	11/8/2019	43	47	< 0.74	< 17	< 1.4	< 17	< 3.5	< 17	< 2.9	< 17	3.4	< 17	10	< 17
	VAP-F1-11_50-54	11/11/2019	50	54	< 0.79	< 17	< 1.5	< 17	< 3.7	< 17	< 3	< 17	< 1.4	< 17	3.6	< 17
	VAP-F1-11_56-60	11/11/2019	56	60	< 0.8	< 17	< 1.5	< 17	< 3.7	< 17	< 3.1	< 17	2.3	< 17	6.4	< 17
VAP-F1-12	VAP-F1-12_14-18	11/14/2019	14	18	< 0.78	< 17	< 1.5	< 17	14	20	< 3	< 17	10	< 67	7.1	< 17
	VAP-F1-12_21-25	11/14/2019	21	25	< 0.79	< 17	< 1.5	< 17	56	66	< 3	< 17	56	< 67	23	22
	VAP-F1-12_28-32	11/14/2019	28	32	< 0.77	< 17	< 1.5	< 17	73	77	< 3	< 17	110	97	28	25
	VAP-F1-12_36-40	11/14/2019	36	40	< 0.79 [< 0.79]	< 17 [< 17]	< 1.5 [< 1.5]	< 17 [< 17]	< 3.7 [< 3.7]	< 17 [< 17]	< 3 [< 3]	< 17 [< 17]	3.3 [2.8]	< 17 [< 17]	28 [33]	35 [31]
	VAP-F1-12_43-47	11/14/2019	43	47	< 0.77	< 17	< 1.5	< 17	< 3.6	< 17	< 2.9	< 17	< 1.4	< 17	1.5	< 17
	VAP-F1-12_50-54	11/14/2019	50	54	< 0.77	< 17	< 1.5	< 17	< 3.6	< 17	< 3	< 17	< 1.4	< 17	2.2	< 17
	VAP-F1-12_56-60	11/14/2019	56	60	< 0.76	< 17	< 1.4	< 17	< 3.5	< 17	< 2.9	< 17	2.4	< 17	3.9	< 17
VAP-F1-13	VAP-F1-13_15-19	11/13/2019	15	19	< 0.77	< 17	< 1.5	< 17	< 3.6	< 17	< 3	< 17	< 1.4	< 17	47	45
	VAP-F1-13_22-26	11/13/2019	22	26	< 0.77	< 17	< 1.5	< 17	9.9	20	56	63	25	< 67	380	500
	VAP-F1-13_29-33	11/13/2019	29	33	< 0.78	< 17	< 1.5	< 17	< 3.6	< 17	8.3	< 17	4	< 17	32	39
	VAP-F1-13_36-40	11/13/2019	36	40	< 0.77	< 17	< 1.5	< 17	< 3.6	< 17	< 3	< 17	4.1	< 17	16	19
	VAP-F1-13_43-47	11/14/2019	43	47	< 0.79	< 17	< 1.5	< 17	< 3.7	< 17	< 3	< 17	< 1.4	< 67	4.6	< 17
	VAP-F1-13_50-54	11/14/2019	50	54	< 0.77	< 17	< 1.5	< 17	< 3.6	< 17	< 3	< 17	< 1.4	< 67	< 1.5	< 17
	VAP-F1-13_56-60	11/14/2019	56	60	< 0.78	< 17	< 1.5	< 17	< 3.6	< 17	< 3	< 17	< 1.4	< 67	1.9	< 17
TRANSECT 2																
VAP-F2-1	VAP-F2-1_15-19	11/7/2019	15	19	60	1900	20	1800	46	2100	190	1900	92	1900	830	2200
	VAP-F2-1_22-26	11/7/2019	22	26	5	< 17	2.6	< 17	15	24	28	29	21	21	170	180
	VAP-F2-1_28.5-32.5	11/7/2019	28.5	32.5	0.89	< 17	18	19	4.7	< 17	< 3	< 17	4.9	< 17	24	25
	VAP-F2-1_36-40	11/7/2019	36	40	< 0.81	< 17	4.1	< 17	< 3.8	< 17	< 3.1	< 17	1.5	< 17	14	20
	VAP-F2-1_43-47	11/7/2019	43	47	2.7	< 17	50	52	< 3.5	< 17	< 2.9	< 17	3.5	< 17	5.4	< 17
	VAP-F2-1_51-55	11/7/2019	51	55	0.82	< 17	3.8	< 17	< 3.8	< 17	< 3.1	< 17	2.7	< 17	2.4	< 17
	VAP-F2-1_56-60	11/7/2019	56	60	< 0.77	< 17	4.5	< 17	< 3.6	< 17	< 2.9	< 17	2.5	< 67	3.4	< 17
VAP-F2-2	VAP-F2-2_14-18	11/1/2019	14	18	0.85	< 17	2.4	< 17	14	24	25	31	17	23	350	390
	VAP-F2-2_20-24	11/1/2019	20	24	2.6	< 17	37	39	40	41	22	22	68	81	310	300
	VAP-F2-2_28-32	11/1/2019	28	32	< 0.76 [1.8]	< 17 [< 17]	< 1.5 [< 1.5]	< 17 [< 17]	14 [14]	29 [29]	9.1 [8.2]	< 17 [< 17]	26 [25]	29 [32]	220 [220]	220 [230]
	VAP-F2-2_35-39	11/1/2019	35	39	< 0.75	< 17	< 1.4	< 17	15	28	11	< 17	30	31	240	42
	VAP-F2-2_41-45	11/1/2019	41	45	< 0.76	< 17	< 1.5	< 17	3.5	24	2.9	< 17	8.3	< 17	73	62
	VAP-F2-2_48-52	11/1/2019	48	52	< 0.77	< 17	< 1.5	< 17	< 3.6	< 17	< 3	< 17	2.9	< 17	17	< 17
	VAP-F2-2_55-59	11/1/2019	55	59	< 0.76	< 17	< 1.5	< 17	< 3.5	< 17	< 2.9	< 17	1.4	< 17	8.3	< 17
VAP-F2-3	VAP-F2-3_15-19	10/24/2019	15	19	18	< 33	3.1	< 33	23	33	45	34	53	57	250	220
	VAP-F2-3_23-27	10/24/2019	23	27	< 0.92	< 33	< 1.8	< 33	4.7	< 33	< 3.5	< 33	9.9	< 33	55	41
	VAP-F2-3_29-33	10/24/2019	29	33	< 0.88	< 33	< 1.7	< 33	5.5	< 33	< 3.4	< 33	10	< 33	69	54
	VAP-F2-3_38-42	10/24/2019	38	42	< 0.8	< 33	< 1.5	< 33	11	< 33	< 3.1	< 33	23	< 33	120	120
	VAP-F2-3_47-51	10/25/2019	47	51	< 0.79	< 17	< 1.5	< 17	6.7	< 17	< 3	< 17	6.4	< 17	8.9	< 17
	VAP-F2-3_56-60	10/25/2019	56	60	< 0.78	< 17	< 1.5	< 17	4.2	< 17	< 3	< 17	4.7	< 17	14	19
VAP-F2-4	VAP-F2-4_15-19	11/7/2019	15	19	< 0.74	< 17	< 1.4	< 17	4.7	< 17	7.1	< 17	6.8	< 67	150	140
	VAP-F2-4_20-24	11/7/2019	20	24	< 0.75	< 17	< 1.4	< 17	5.6	< 17	16	< 17	10	< 67	110	95
	VAP-F2-4_27-31	11/8/2019	27	31	< 0.79	< 17	3.8	< 17	5.9	24	8.9	< 17	16	17	69	65
	VAP-F2-4_33-37	11/8/2019	33	37	< 0.77	< 17	< 1.5	< 17	7.2	25	3.2	< 17	18	19	55	49
	VAP-F2-4_39.5-43.5	11/8/2019	39.5	43.5	< 0.8	< 17	5.8	< 17	5.4	< 17	< 3.1	< 17	17	17	41	33
	VAP-F2-4_48-52	11/8/2019	48	52	< 0.77	< 17	< 1.5	< 17	< 3.6	< 17	< 3	< 17	1.5	< 17	8.9	< 17
	VAP-F2-4_56-60	11/8/2019	56	60	< 0.78	< 17	< 1.5	< 17	< 3.6	< 17	< 3	< 17	< 1.4	< 17	5.3	< 17
VAP-F2-5	VAP-F2-5_13-17	10/25/2019	13	17	< 0.75	< 17	< 1.4	< 17	35	41	13	18	26	39	170	200
	VAP-F2-5_22-26	10/25/2019	22	26	25	< 17	4.5	< 17	22	24	3.1	< 17	25	30	68	69
	VAP-F2-5_31-35	10/25/2019	31	35	1.2	< 17	< 1.5	< 17	19	24	< 2.9	< 17	23	23	54	58
	VAP-F2-5_38.5-42.5	10/25/2019	38.5	42.5	0.98	< 17	< 1.5	< 17	< 3.7	23	< 3.1	< 17	3.1	< 17	10	18
	VAP-F2-5_47.5-51.5	10/25/2019	47.5	51.5	1.3	< 17	< 1.6	< 17	4.9	< 17	< 3.2	< 17	6.4	< 17	18	22
	VAP-F2-5_56-60	10/25/2019	56	60	2.9	< 17	< 2.2	< 17	< 5.3	< 17	< 4.4	< 17	7.7	< 17	23	28
VAP-F2-6	VAP-F2-6_13-17	10/31/2019	13	17	< 0.76	< 17	< 1.5	< 17	3.9	< 17	< 2.9	< 17	7.9	< 17	35	40
	VAP-F2-6_22-26	10/31/2019	22	26	2.8	< 17	< 1.4	< 17	34	51	11	< 17	39	43	240	250
	VAP-F2-6_27-31	10/31/2019	27	31	2.5	< 17	< 1.5	< 17	34	< 17	13	< 17	35	< 17	210	< 17
	VAP-F2-6_33-37	10/31/2019	33	37	< 0.73	1800	< 1.4	1800	21	1700	3.4	1600	28	1800	140	1500
	VAP-F2-6_40-44	10/31/2019	40	44	< 0.79	< 17	< 1.5	< 17	< 3.7	27	< 3	< 17	2.2	27	4.8	140
	VAP-F2-6_48-52	10/31/2019	48	52	< 0.77 [< 0.77]	< 17 [< 17]	< 1.5 [< 1.5]	< 17 [< 17]	< 3.6 [< 3.6]	< 17 [< 17]	< 3 [< 2.9]	< 17 [< 17]	< 1.4 [< 1.4]	< 17 [< 17]	4.6 [3.9]	< 17 [< 17]
	VAP-F2-6_55-59	10/31/2019	55	59	< 0.73	< 17	< 1.4	< 17	< 3.4	< 17	< 2.8	< 17	< 1.3	< 17	1.7	< 17
VAP-F2-7	VAP-F2-7_12-16	10/25/2019	12	16	17	< 33	< 1.4	< 33	16	< 33	< 2.7	< 33	45	58	170	190
	VAP-F2-7_22-26	10/25/2019	22	26	3400	3500	200	210	300	330	150	130	510	520	1100	1000
	VAP-F2-7_32-36	10/25/2019	32	36	590	620	77	76	38	44	26	26	52	62	180	180
	VAP-F2-7_41-45	10/28/2019	41	45	13	17	2.8	< 17	15	27	< 3	< 17	21	29	17	29
	VAP-F2-7_49-53	10/28/2019	49	53	13	18	< 1.5	< 17	< 3.6	< 17	< 3	< 17	3.1	< 17	7.2	21

Location ID	Arcadis Sample ID	Collection Date	Start Depth (ft)	End Depth (ft)	SECONDARY CONSTITUENTS OF INTEREST											
					6-2FTS		8-2FTS		PFHpA		PFHpS		PFHxA		PFHxS	
					DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method
	VAP-F2-7_56-60	10/28/2019	56	60	120	130	18	18	19	18	5.8	< 17	42	61	45	60
VAP-F2-8	VAP-F2-8_11-15	10/30/2019	11	15	< 0.72	< 17	< 1.4	< 17	4.1	18	< 2.8	< 17	21	32	40	57
	VAP-F2-8_20-24	10/30/2019	20	24	180	220	< 1.3	< 17	180	270	87	150	200	280	950	1300
	VAP-F2-8_27-31	10/30/2019	27	31	430	510	< 1.4	< 16	180	290	78	140	280	320	1300	1200
	VAP-F2-8_34-38	10/30/2019	34	38	35	28	< 1.3	< 17	49	77	9	< 17	77	92	230	200
	VAP-F2-8_42-46	10/30/2019	42	46	4.6	17	< 1.4	< 17	< 3.3	24	< 2.7	< 17	4.8	21	16	45
	VAP-F2-8_49-53	10/31/2019	49	53	3.8	< 17	< 1.4	< 17	< 3.5	< 17	< 2.9	< 17	5.1	< 17	15	27
	VAP-F2-8_56-60	10/31/2019	56	60	< 0.76 [< 0.74]	< 17 [< 17]	< 1.4 [< 1.4]	< 17 [< 17]	< 3.5 [< 3.5]	< 17 [< 17]	< 2.9 [< 2.8]	< 17 [< 17]	< 1.3 [< 1.3]	< 17 [< 17]	< 1.4 [1.5]	< 17 [< 17]
VAP-F2-13	VAP-F2-13_15-19	11/12/2019	15	19	< 0.78	< 17	< 1.5	< 17	15	23	< 3	< 17	19	22	17	20
	VAP-F2-13_22-26	11/12/2019	22	26	< 0.76 [< 0.77]	< 17 [< 17]	< 1.5 [< 1.5]	< 17 [< 17]	17 [16]	26 [25]	< 2.9 [< 3]	< 17 [< 17]	13 [17]	18 [< 17]	110 [120]	130 [120]
	VAP-F2-13_28-32	11/13/2019	28	32	< 0.79	< 17	< 1.5	< 17	5.8	< 17	< 3	< 17	5.6	< 67	51	25
	VAP-F2-13_36-40	11/13/2019	36	40	< 0.77	< 17	< 1.5	< 17	< 3.6	< 17	< 2.9	< 17	3.8	< 67	21	60
	VAP-F2-13_43-47	11/13/2019	43	47	< 0.78	< 17	< 1.5	< 17	< 3.6	< 17	< 3	< 17	< 1.4	< 67	5.9	< 17
	VAP-F2-13_51-55	11/13/2019	51	55	< 0.77	< 17	< 1.5	< 17	< 3.6	< 17	< 2.9	< 17	1.8	< 67	1.9	< 17
	VAP-F2-13_56-60	11/13/2019	56	60	< 0.79	< 17	< 1.5	< 17	< 3.7	< 17	< 3	< 17	< 1.4	< 67	< 1.5	< 17
TRANSECT 3																
VAP-F3-1	VAP-F3-1_9-13	11/11/2019	9	13	< 0.76	< 17	< 1.5	< 17	< 3.6	< 17	< 2.9	< 17	2.7	< 67	13	< 17
	VAP-F3-1_15-19	11/15/2019	15	19	< 0.77	NA	< 1.5	NA	< 3.6	NA	< 3	NA	6.6	NA	12	NA
	VAP-F3-1_21-25	11/15/2019	21	25	< 0.75	< 17	< 1.4	< 17	4.4	< 17	< 2.9	< 17	5.4	< 17	47	42
	VAP-F3-1_27-31	11/15/2019	27	31	< 0.79	< 17	< 1.5	< 17	24	26	12	< 17	31	34	140	130
	VAP-F3-1_37-41	11/15/2019	37	41	< 0.78	< 17	< 1.5	< 17	26	31	13	< 17	34	37	150	150
	VAP-F3-1_46-50	11/15/2019	46	50	< 0.77	< 17	< 1.5	< 17	15	21	< 3	< 17	17	19	49	45
	VAP-F3-1_56-60	11/15/2019	56	60	< 0.78	< 17	< 1.5	< 17	14	19	< 3	< 17	17	19	42	34
VAP-F3-2	VAP-F3-2_11-15	10/28/2019	11	15	8	< 17	< 1.5	< 17	< 3.6	< 17	< 3	< 17	15	< 17	13	< 17
	VAP-F3-2_18-22	10/28/2019	18	22	260 [250]	280 [290]	1.5 [2.6]	< 17 [< 17]	65 [67]	80 [54]	23 [19]	25 [34]	190 [190]	230 [230]	190 [180]	230 [210]
	VAP-F3-2_25-29	10/28/2019	25	29	4200	4400	22	26	330	330	140	230	520	630	1000	1200
	VAP-F3-2_32-36	10/28/2019	32	36	4600	4800	47	42	470	390	140	200	640	780	1300	1600
	VAP-F3-2_40-44	10/28/2019	40	44	270	250	10	< 17	55	54	14	18	120	160	130	150
	VAP-F3-2_47-51	10/29/2019	47	51	2500	3200	31	41	270	350	110	100	370	490	920	1100
VAP-F3-3	VAP-F3-3_10-14	11/1/2019	10	14	< 0.76 [3.2]	< 17 [< 17]	< 1.5 [< 1.5]	< 17 [< 17]	< 3.5 [< 3.6]	< 17 [< 17]	< 2.9 [< 3]	< 17 [< 17]	< 1.3 [< 1.4]	< 17 [< 17]	4.5 [4.2]	< 17 [< 17]
	VAP-F3-3_20-24	11/1/2019	20	24	17	17	< 1.5	< 17	68	90	58	72	80	86	500	550
	VAP-F3-3_24.5-28.5	11/4/2019	24.5	28.5	220 [230]	260 [270]	< 1.5 [< 1.4]	< 17 [< 17]	210 [220]	230 [250]	110 [100]	120 [120]	310 [340]	390 [360]	1100 [1200]	1300 [1200]
	VAP-F3-3_33-37	11/4/2019	33	37	180	190	< 1.4	< 17	160	170	75	87	320	340	850	930
	VAP-F3-3_42-46	11/4/2019	42	46	5.6	< 17	< 1.5	< 17	19	35	10	< 17	41	48	120	130
	VAP-F3-3_48-52	11/4/2019	48	52	4.1	< 17	< 1.4	< 17	8.5	22	< 2.8	< 17	21	20	50	40
	VAP-F3-3_55-59	11/4/2019	55	59	15	< 17	< 1.5	< 17	9.3	24	4.9	< 17	19	18	52	48
VAP-F3-4	VAP-F3-4_11-15	10/30/2019	11	15	5.3	< 17	< 1.5	< 17	< 3.5	< 17	< 2.9	< 17	< 1.4	< 17	< 1.5	< 17
	VAP-F3-4_19-23	10/30/2019	19	23	76	91	< 1.5	< 17	32	48	18	17	130	180	220	280
	VAP-F3-4_27-31	10/30/2019	27	31	280	300	1.8	< 17	49	58	36	39	170	200	360	350
	VAP-F3-4_35-39	10/30/2019	35	39	120	300	2.1	< 17	63	200	18	50	130	380	340	960
	VAP-F3-4_42-46	10/30/2019	42	46	170	210	4.5	< 17	47	84	54	56	120	150	450	490
	VAP-F3-4_56-60	10/30/2019	56	60	10	< 17	< 1.6	< 17	< 3.9	17	4.2	< 17	8.2	< 17	39	39
VAP-F3-7	VAP-F3-7_9-13	11/11/2019	9	13	< 0.75	< 17	< 1.4	< 17	< 3.5	< 17	< 2.9	< 17	< 1.3	< 17	1.4	< 17
	VAP-F3-7_15-19	11/11/2019	15	19	< 0.76	< 17	< 1.5	< 17	25	34	6.5	< 17	18	20	160	190
	VAP-F3-7_21-25	11/11/2019	21	25	5.9	< 17	< 1.5	< 17	46	56	31	32	44	52	280	330
	VAP-F3-7_27-31	11/11/2019	27	31	1.5	< 17	< 1.5	< 17	14	19	12	< 17	22	20	120	140
	VAP-F3-7_37-41	11/11/2019	37	41	< 0.74	< 17	< 1.4	< 17	9.4	17	3.7	< 17	14	< 17	61	68
	VAP-F3-7_46-50	11/11/2019	46	50	1.1	< 17	< 1.4	< 17	< 3.5	< 17	< 2.9	< 17	1.7	< 67	8.9	< 17
	VAP-F3-7_56-60	11/11/2019	56	60	< 0.77	< 17	< 1.5	< 17	< 3.6	< 17	< 2.9	< 17	1.8	< 67	8.7	< 17
VAP-F3-8	VAP-F3-8_11-15	11/15/2019	11	15	< 0.78	< 17	< 1.5	< 17	< 3.6	< 17	< 3	< 17	2.4	< 17	5.6	< 17
	VAP-F3-8_18-22	11/15/2019	18	22	< 0.79 [< 0.8]	< 17 [< 17]	< 1.5 [< 1.5]	< 17 [< 17]	8.1 [7.5]	< 17 [< 17]	5.8 [5.6]	< 17 [< 17]	19 [18]	24 [24]	200 [200]	200 [190]
	VAP-F3-8_25-29	11/15/2019	25	29	< 0.83 [< 0.8]	< 17 [< 17]	< 1.6 [< 1.5]	< 17 [< 17]	16 [14]	22 [< 17]	< 3.2 [25]	29 [29]	20 [45]	55 [45]	53 [470]	470 [430]
	VAP-F3-8_33-37	11/15/2019	33	37	1.1	< 17	< 1.5	< 17	10	17	4.4	< 67	32	37	90	81
	VAP-F3-8_41-45	11/15/2019	41	45	< 0.79	< 17	< 1.5	< 17	4.3	< 17	< 3	< 67	13	20	33	28
	VAP-F3-8_49-53	11/15/2019	49	53	< 0.9	< 17	< 1.7	< 17	11	< 17	9.5	< 67	37	< 17	170	< 17
	VAP-F3-8_56-60	11/15/2019	56	60	< 0.78	< 17	< 1.5	< 17	5.1	< 17	< 3	< 67	18	18	50	17
VAP-F3-9	VAP-F3-9_9-13	11/12/2019	9	13	< 0.76	< 17	< 1.5	< 17	< 3.5	< 17	< 2.9	< 17	< 1.4	< 17	2	< 17
	VAP-F3-9_15-19	11/12/2019	15	19	< 0.77	< 17	< 1.5	< 17	8.8	< 17	4	< 17	21	21	92	110
	VAP-F3-9_21-25	11/12/2019	21	25	< 0.79	< 17	< 1.5	< 17	13	22	9.4	< 17	24	22	120	150
	VAP-F3-9_27-31	11/12/2019	27	31	< 0.77	< 17	< 1.5	< 17	19	28	6.9	< 17	35	39	130	150
	VAP-F3-9_37-41	11/12/2019	37	41	< 0.78	< 17	< 1.5	< 17	10	19	8.3	< 17	22	< 67	92	110
	VAP-F3-9_46-50	11/12/2019	46	50	< 0.77	< 17	< 1.5	< 17	4.9	< 17	< 3	< 17	31	33	31	31
	VAP-F3-9_56-60	11/12/2019	56	60	< 0.93	< 17	< 1.8	< 17	13	17	< 3.6	< 17	43	35	110	96
PRIMARY SOURCE																
VAP-PS-1	VAP-PS-1_14-17	10/21/2019	14	17	85	91	180	210	34	38	49	51	62	72	850	940
VAP-PS-2	VAP-PS-2_14-17	10/21/2019	14	17	69	68	110	120	79	77	58	62	160	150	1100	1000

Location ID	Arcadis Sample ID	Collection Date	Start Depth (ft)	End Depth (ft)	SECONDARY CONSTITUENTS OF INTEREST											
					6-2FTS		8-2FTS		PFHpA		PFHpS		PFHxA		PFHxS	
					DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method
VAP-PS-3	VAP-PS-3_16.5-19.5	10/21/2019	16.5	19.5	800	640	73	67	60	52	61	54	150	120	330	290
VAP-PS-4	VAP-PS-4_13-16	10/22/2019	13	16	< 0.7	< 35	< 1.3	< 35	30	< 35	64	82	52	66	710	760
VAP-PS-5	VAP-PS-5_14-17	10/22/2019	14	17	24	< 36	< 1.4	< 36	39	41	14	< 35	49	58	300	320
VAP-PS-6	VAP-PS-6_14-17	10/22/2019	14	17	3.6	< 34	8.3	< 34	25	< 34	55	53	45	54	550	600
SECONDARY SOURCE																
VAP-SS-1	VAP-SS-1_13-17	11/5/2019	13	17	< 0.76	< 17	< 1.5	< 17	9.9	21	21	23	39	45	280	290
	VAP-SS-1_20.5-24.5	11/5/2019	20.5	24.5	< 0.75	< 17	< 1.4	< 17	11	22	6.4	< 17	25	33	88	96
	VAP-SS-1_26-30	11/5/2019	26	30	2.2	< 17	< 1.5	< 17	10	< 17	< 3	< 17	26	28	50	44
	VAP-SS-1_34-38	11/5/2019	34	38	3.8	< 17	< 1.5	< 17	15	29	< 3	< 17	68	72	47	50
	VAP-SS-1_44-48	11/5/2019	44	48	0.92	< 17	< 1.5	< 17	< 3.7	< 17	< 3.1	< 17	7.7	< 17	13	< 17
	VAP-SS-1_50-54	11/5/2019	50	54	< 0.77	< 17	< 1.5	< 17	< 3.6	17	< 2.9	< 17	2.9	< 17	4.2	< 17
	VAP-SS-1_56-60	11/6/2019	56	60	< 0.81	< 17	< 1.6	< 17	< 3.8	17	< 3.1	< 17	5.5	< 17	8.3	< 17
VAP-SS-2	VAP-SS-2_14-18	11/5/2019	14	18	< 0.75	< 17	< 1.4	< 17	10	24	5.6	< 17	26	40	120	150
	VAP-SS-2_23-27	11/5/2019	23	27	< 0.76	< 17	< 1.5	< 17	6.7	23	< 2.9	< 17	21	28	67	63
	VAP-SS-2_28.5-32.5	11/5/2019	28.5	32.5	< 0.76	< 17	< 1.5	< 17	4.5	< 17	< 2.9	< 17	12	20	59	53
	VAP-SS-2_36-40	11/5/2019	36	40	0.98 [< 0.75]	< 17 [< 17]	< 1.4 [< 1.4]	< 17 [< 17]	< 3.5 [< 3.5]	19 [21]	< 2.9 [< 2.9]	< 17 [< 17]	6.2 [6.4]	< 17 [< 17]	43 [41]	40 [46]
	VAP-SS-2_43-47	11/5/2019	43	47	< 0.8	< 17	< 1.5	< 17	< 3.7	20	< 3.1	< 17	7.2	< 17	34	34
	VAP-SS-2_49-53	11/5/2019	49	53	< 0.76	< 17	< 1.5	< 17	< 3.5	< 17	< 2.9	< 17	2.7	< 17	6.9	< 17
	VAP-SS-2_58-62	11/5/2019	58	62	< 0.79	< 17	< 1.5	< 17	< 3.7	< 17	< 3	< 17	1.4	< 17	3.9	< 17
VAP-SS-3	VAP-SS-3_14-18	11/6/2019	14	18	< 0.77	< 17	< 1.5	< 17	11	27	8.8	< 17	16	19	170	180
	VAP-SS-3_22-26	11/6/2019	22	26	< 0.76	< 17	< 1.5	< 17	13	21	< 2.9	< 17	29	20	120	110
	VAP-SS-3_30-34	11/6/2019	30	34	< 0.76	< 17	< 1.5	< 17	9.1	24	< 2.9	< 17	14	39	110	140
	VAP-SS-3_38-42	11/6/2019	38	42	2	< 17	< 1.5	< 17	12	21	< 3	< 17	29	42	110	110
	VAP-SS-3_44.5-48.5	11/6/2019	44.5	48.5	< 0.76	< 17	< 1.5	< 17	< 3.6	< 17	< 2.9	< 17	1.6	< 17	2	< 17
	VAP-SS-3_50-54	11/6/2019	50	54	< 0.78	< 17	< 1.5	< 17	8.3	23	< 3	< 17	18	23	75	84
	VAP-SS-3_58-62	11/6/2019	58	62	< 0.75	< 17	< 1.4	< 17	< 3.5	23	< 2.9	< 17	3	< 17	6.4	< 17
VAP-SS-4	VAP-SS-4_15-19	11/6/2019	15	19	3.3	< 17	44	51	19	28	19	21	28	26	380	470
	VAP-SS-4_21-25	11/6/2019	21	25	< 0.81	< 17	< 1.6	< 17	13	18	13	< 17	24	17	160	170
	VAP-SS-4_27.5-31.5	11/6/2019	27.5	31.5	0.83	< 17	< 1.4	< 17	7	< 17	6.7	< 17	23	20	130	150
	VAP-SS-4_35-39	11/6/2019	35	39	0.92	< 17	2.4	< 17	< 3.6	< 17	< 3	< 17	2.7	< 17	10	< 17
	VAP-SS-4_41-45	11/7/2019	41	45	< 0.75	< 17	4.8	< 17	< 3.5	< 17	< 2.9	< 17	< 1.3	< 17	2	< 17
	VAP-SS-4_49-53	11/7/2019	49	53	1	< 17	4.6	< 17	< 3.7	< 17	< 3	< 17	2	< 17	5.2	< 17
	VAP-SS-4_56-60	11/7/2019	56	60	1.3	< 17	5.9	< 17	< 3.9	< 17	< 3.2	< 17	1.8	< 17	5.1	< 17
VAP-SS-5	VAP-SS-5_15.5-19.5	11/6/2019	15.5	19.5	2.5	< 17	5	< 17	13	27	16	< 17	21	25	280	350
	VAP-SS-5_20.5-24.5	11/6/2019	20.5	24.5	< 0.78	< 17	5.6	< 17	10	20	22	24	22	20	300	310
	VAP-SS-5_27-31	11/6/2019	27	31	1	< 17	4.7	< 17	8.6	18	31	29	23	20	210	200
	VAP-SS-5_34-38	11/6/2019	34	38	< 0.78	< 17	22	32	< 3.6	< 17	7.6	< 17	9.7	< 17	100	120
	VAP-SS-5_40-44	11/6/2019	40	44	< 0.77	< 17	26	27	< 3.6	< 17	< 3	< 17	< 1.4	< 17	7.1	< 17
	VAP-SS-5_47-51	11/7/2019	47	51	4.2	< 17	200	180	< 3.6	< 17	3.3	< 17	16	< 17	12	< 17
	VAP-SS-5_56-60	11/7/2019	56	60	1.2	< 17	40	41	< 3.6	< 17	< 3	< 17	4.4	< 17	5.9	< 17
VAP-SS-6	VAP-SS-6_14.5-18.5	11/7/2019	14.5	18.5	2.1	< 17	11	< 17	40	46	30	27	41	< 67	380	430
	VAP-SS-6_22-26	11/7/2019	22	26	1	< 17	< 1.5	< 17	16	23	4.8	< 17	33	< 67	230	260
	VAP-SS-6_30-34	11/7/2019	30	34	< 0.79	< 17	< 1.5	< 17	15	22	7.9	< 17	29	< 67	230	250
	VAP-SS-6_38-42	11/8/2019	38	42	0.85	< 17	7.3	< 17	< 3.7	< 17	< 3	< 17	3.8	< 17	34	43
	VAP-SS-6_49-53	11/8/2019	49	53	0.98	< 17	< 1.5	17	< 3.7	17	< 3	< 17	3.9	< 17	14	< 17
	VAP-SS-6_56-60	11/8/2019	56	60	< 0.76	< 17	< 1.5	< 17	< 3.6	17	< 2.9	< 17	4.1	< 17	1.8	< 17

Table 5.4. Groundwater Analytical Results for the PFAS Mobile Lab-Based Real Time Method Pilot Study Secondary Constituents of Interest (Continued)

Location ID	Arcadis Sample ID	Collection Date	Start Depth (ft)	End Depth (ft)	SECONDARY CONSTITUENTS OF INTEREST									
					Br-PFHxS		Total PFHxS		PFNA		PFPeA		PFPeS	
					DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method
TRANSECT 1														
VAP-F1-1	VAP-F1-1_12-16	10/29/2019	12	16	14	18	85	93	< 3.4	< 17	6.2	< 17	9.3	< 17
	VAP-F1-1_22-26	10/29/2019	22	26	74	74	450	480	< 3.4	< 17	11	< 17	25	23
	VAP-F1-1_28.5-32	10/29/2019	28.5	32.5	32	39	180	230	< 3.4	< 17	11	20	23	26
	VAP-F1-1_36-40	10/29/2019	36	40	40	44	200	220	< 3.5	< 17	13	25	24	23
	VAP-F1-1_42.5-46	10/29/2019	42.5	46.5	4.5	48	21	240	9.2	< 17	13	18	11	18
	VAP-F1-1_49.5-53	10/29/2019	49.5	53.5	13	< 7.3	79	< 24	< 3.5	< 17	6.2	< 17	9	< 17
	VAP-F1-1_56-60	10/29/2019	56	60	< 0.46	< 7.3	< 1.9	< 24	< 3.3	< 17	< 1.6	< 17	< 1.4	< 17
VAP-F1-2	VAP-F1-2_12-16	10/22/2019	12	16	9.5	12	87	100	< 3.4	< 31	4.6	< 31	3	< 31
	VAP-F1-2_19-23	10/22/2019	19	23	66 [74]	43 [45]	530 [570]	440 [450]	5.9 [6.5]	< 33 [< 36]	21 [23]	< 33 [< 36]	9.9 [12]	< 33 [< 36]
	VAP-F1-2_26-30	10/22/2019	26	30	130	88	1000	640	7.1	< 33	40	34	23	< 33
	VAP-F1-2_33-37	10/23/2019	33	37	19	13	120	110	< 3.5	< 33	38	38	8.2	< 33
	VAP-F1-2_40-44	10/23/2019	40	44	17	13	100	82	< 5.7	< 34	59	53	18	< 34
	VAP-F1-2_47-51	10/23/2019	47	51	6.6	< 7.3	47	< 41	< 6.7	< 33	9.8	< 33	< 2.9	< 33
	VAP-F1-2_56-60	10/23/2019	56	60	3.7	< 7.3	27	< 41	< 3.5	< 33	3.9	< 33	< 1.5	< 33
VAP-F1-3	VAP-F1-3_11-15	10/29/2019	11	15	26	31	160	200	5.1	< 17	18	60	2.7	< 17
	VAP-F1-3_19-23	10/30/2019	19	23	150	140	860	850	10	< 17	25	64	28	34
	VAP-F1-3_28-32	10/30/2019	28	32	14	12	100	110	< 3.3	< 17	14	17	3.7	< 17
	VAP-F1-3_34-38	10/30/2019	34	38	14	18	100	100	< 3.5	< 17	15	22	3.5	< 17
	VAP-F1-3_42-46	10/30/2019	42	46	5.5	< 7.3	49	43	< 3.6	< 17	9	20	< 1.5	< 17
	VAP-F1-3_48-52	10/30/2019	48	52	1.8	< 7.3	13	< 24	< 3.5	< 17	2.9	< 17	< 1.5	< 17
	VAP-F1-3_56-60	10/30/2019	56	60	2.3	< 7.3	15	< 24	< 17	< 17	< 8.1	< 17	< 7.1	< 17
VAP-F1-4	VAP-F1-4_12.5-16	10/22/2019	12.5	16.5	4.3	< 7.3	15	< 41	< 4.3	< 33	< 2.1	< 33	5.4	< 33
	VAP-F1-4_20-24	10/23/2019	20	24	10	12	76	70	< 4.1	< 33	12	< 33	4.2	< 33
	VAP-F1-4_27-31	10/23/2019	27	31	32	28	190	210	10	< 33	33	42	7.8	< 33
	VAP-F1-4_34-38	10/23/2019	34	38	33	26	200	180	12	< 33	36	41	7.3	< 33
	VAP-F1-4_41-45	10/23/2019	41	45	6.5	< 7.3	39	< 41	< 3.3	< 33	17	< 33	1.9	< 33
	VAP-F1-4_49-53	10/23/2019	49	53	1.3	< 7.3	9.8	< 41	< 3.7	< 33	3	< 33	< 1.6	< 33
	VAP-F1-4_54.5-58	10/23/2019	54.5	58.5	1.3	< 7.3	9.9	< 41	< 4	< 33	< 1.9	< 33	< 1.7	< 33
VAP-F1-5	VAP-F1-5_12-16	10/29/2019	12	16	1.3	< 7.2	8.7	< 24	< 3.1	< 16	< 1.5	17	< 1.3	< 16
	VAP-F1-5_20-24	10/29/2019	20	24	35	40	230	260	13	< 17	86	97	< 1.4	< 17
	VAP-F1-5_26-30	10/29/2019	26	30	110	130	750	900	38	45	250	340	27	30
	VAP-F1-5_33-37	10/29/2019	33	37	71	91	510	700	25	36	160	230	19	28
	VAP-F1-5_40-44	10/29/2019	40	44	17	23	130	170	< 3.2	< 17	61	100	4.8	< 17
	VAP-F1-5_47-51	10/29/2019	47	51	3.8	< 7	18	25	< 3.5	< 16	26	32	< 1.5	< 16
	VAP-F1-5_56-60	10/29/2019	56	60	8	14	59	80	3.5	< 17	21	35	1.9	< 17
VAP-F1-6	VAP-F1-6_9-13	10/22/2019	9	13	0.64	< 6.6	3.7	< 37	< 3.8	< 30	2.7	< 30	< 1.6	< 30
	VAP-F1-6_16-20	10/22/2019	16	20	3.1	< 6.9	26	< 38	< 3.1	< 31	4.8	< 31	< 1.3	< 31
	VAP-F1-6_23-27	10/22/2019	23	27	210	170	1400	1200	37	34	410	370	48	44
	VAP-F1-6_28.5-32	10/22/2019	28.5	32.5	170	160	1100	1200	17	< 35	460	550	60	62
	VAP-F1-6_36-40	10/22/2019	36	40	150	140	1100	990	7.9	< 30	410	390	69	62
	VAP-F1-6_42.5-46	10/22/2019	42.5	46.5	29	27	150	170	< 3.3	< 31	81	90	11	< 31
	VAP-F1-6_49.5-53	10/22/2019	49.5	53.5	7.6	7.2	67	42	< 5.5	< 31	25	< 30	3.9	< 30
VAP-F1-7	VAP-F1-7_12-16	10/30/2019	12	16	6.4	8	44	52	6.2	< 17	74	110	2.8	< 17
	VAP-F1-7_20-24	10/30/2019	20	24	16	16	120	120	< 3.1	< 16	61	71	3.4	< 16
	VAP-F1-7_27.5-31	10/30/2019	27.5	31.5	100	120	580	650	27	25	210	270	38	39
	VAP-F1-7_32.5-36	10/30/2019	32.5	36.5	120	120	710	730	22	28	180	200	48	78
	VAP-F1-7_39.5-43	10/30/2019	39.5	43.5	13	11	70	62	< 3.3	< 16	15	24	4.9	< 16
	VAP-F1-7_48-52	10/30/2019	48	52	0.8	< 7.3	6.8	< 24	< 3.1	< 17	< 1.5	< 17	< 1.3	< 17
	VAP-F1-7_54-58	10/30/2019	54	58	2.4	< 7.3	15	< 24	< 3.2	< 17	6.3	< 17	< 1.4	< 17
VAP-F1-8	VAP-F1-8_13.5-17	10/24/2019	13.5	17.5	2.9	< 7.3	24	< 41	< 3.6	< 33	5.1	< 33	1.7	< 33
	VAP-F1-8_22-26	10/24/2019	22	26	36	33	280	280	7.7	< 33	49	45	8.3	< 33
	VAP-F1-8_28-32	10/24/2019	28	32	160	67	1400	590	43	< 33	400	140	39	< 33
	VAP-F1-8_37.5-41	10/24/2019	37.5	41.5	69	58	520	490	7.7	< 33	160	140	20	< 33
	VAP-F1-8_46-50	10/24/2019	46	50	5	< 7.3	48	< 41	< 3.4	< 33	9.4	< 33	1.6	< 33
	VAP-F1-8_52.5-56	10/24/2019	52.5	56.5	2.1	< 7.3	21	47	< 3.4	< 33	4.7	< 33	< 1.5	< 33
VAP-F1-9	VAP-F1-9_11-15	10/30/2019	11	15	3.9	< 7.3	32	29	< 3.2	< 17	4.5	< 17	2.6	< 17
	VAP-F1-9_19-23	10/30/2019	19	23	120	98	860	760	3.5	< 17	66	72	39	37
	VAP-F1-9_27-31	10/30/2019	27	31	130	140	860	850	< 3.5	< 17	150	160	64	71
	VAP-F1-9_32-36	10/30/2019	32	36	170	NA	1200	NA	< 3.5	NA	230	NA	58	NA
	VAP-F1-9_38-42	10/30/2019	38	42	95	98	670	870	< 3.1	< 17	150	200	34	43
	VAP-F1-9_45-49	10/30/2019	45	49	97	130	700	950	< 3.3	< 16	140	210	33	44
VAP-F1-11	VAP-F1-11_12-16	11/8/2019	12	16	1.7	< 7.3	19	< 24	< 3.6	< 17	2.8	< 17	< 1.5	< 31
	VAP-F1-11_21-25	11/8/2019	21	25	340	480	2300	2600	50	47	85	64	140	180
	VAP-F1-11_27-31	11/8/2019	27	31	89	88	830	820	40	37	36	< 67	21	24

Location ID	Arcadis Sample ID	Collection Date	Start Depth (ft)	End Depth (ft)	SECONDARY CONSTITUENTS OF INTEREST									
					Br-PFHxS		Total PFHxS		PFNA		PFPeA		PFPeS	
					DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method
	VAP-F1-11_36-40	11/8/2019	36	40	16	15	140	110	4.8	< 17	11	< 67	5.3	< 17
	VAP-F1-11_43-47	11/8/2019	43	47	1.8	< 7.3	12	< 24	< 3.4	< 17	1.9	< 17	< 1.4	< 17
	VAP-F1-11_50-54	11/11/2019	50	54	< 0.5	< 7.3	3.6	< 24	< 3.6	< 17	3.4	< 17	< 1.5	< 17
	VAP-F1-11_56-60	11/11/2019	56	60	< 0.5	< 7.3	6.4	< 24	< 3.6	< 17	11	< 17	< 1.5	< 17
VAP-F1-12	VAP-F1-12_14-18	11/14/2019	14	18	2.5	< 7.3	9.5	< 24	< 3.5	< 17	15	22	3.2	< 17
	VAP-F1-12_21-25	11/14/2019	21	25	3	< 7.3	26	26	5.6	< 17	71	85	< 1.5	< 17
	VAP-F1-12_28-32	11/14/2019	28	32	3.6	< 7.3	32	28	9.7	< 17	180	170	< 1.5	< 17
	VAP-F1-12_36-40	11/14/2019	36	40	5.1 [5.3]	< 7.3 [< 7.3]	33 [38]	35 [38]	< 3.5 [< 3.6]	< 17 [< 17]	3.5 [4.2]	< 17 [< 17]	< 1.5 [< 1.5]	< 17 [< 17]
	VAP-F1-12_43-47	11/14/2019	43	47	< 0.48	< 7.3	< 2	< 24	< 3.5	< 17	< 1.7	< 17	< 1.5	< 17
	VAP-F1-12_50-54	11/14/2019	50	54	< 0.49	< 7.3	2.2	< 24	< 3.5	< 17	< 1.7	< 17	< 1.5	< 17
	VAP-F1-12_56-60	11/14/2019	56	60	< 0.48	< 7.3	4.3	< 24	< 3.4	< 17	3.3	< 17	< 1.4	< 17
VAP-F1-13	VAP-F1-13_15-19	11/13/2019	15	19	6.1	< 7.3	53	51	< 3.5	< 17	< 1.7	< 17	2.4	< 17
	VAP-F1-13_22-26	11/13/2019	22	26	63	67	450	570	5.9	< 17	5.9	< 17	17	23
	VAP-F1-13_29-33	11/13/2019	29	33	4.5	< 7.3	36	44	< 3.5	< 17	3.8	< 17	< 1.5	< 17
	VAP-F1-13_36-40	11/13/2019	36	40	2.5	< 7.3	18	< 24	< 3.5	< 17	4.2	< 17	< 1.5	< 17
	VAP-F1-13_43-47	11/14/2019	43	47	0.56	< 7.3	5.1	< 24	< 3.6	< 17	< 1.7	< 17	< 1.5	< 17
	VAP-F1-13_50-54	11/14/2019	50	54	< 0.49	< 7.3	< 2	< 24	< 3.5	< 17	< 1.7	< 17	< 1.5	< 17
	VAP-F1-13_56-60	11/14/2019	56	60	< 0.49	< 7.3	2.2	< 24	< 3.5	< 17	< 1.7	< 17	< 1.5	< 17
TRANSECT 2														
VAP-F2-1	VAP-F2-1_15-19	11/7/2019	15	19	140	510	980	2700	100	2000	40	1700	41	1900
	VAP-F2-1_22-26	11/7/2019	22	26	30	25	200	210	18	23	10	< 17	6.9	< 17
	VAP-F2-1_28.5-32	11/7/2019	28.5	32.5	3.7	< 7.3	28	30	< 3.5	< 17	3.5	< 17	1.8	< 17
	VAP-F2-1_36-40	11/7/2019	36	40	2	< 7.3	16	< 24	< 3.7	< 17	3.9	< 17	1.6	< 17
	VAP-F2-1_43-47	11/7/2019	43	47	0.62	< 7.3	6	< 24	< 3.4	< 17	3.1	< 17	< 1.4	< 17
	VAP-F2-1_51-55	11/7/2019	51	55	< 0.51	< 7.3	2.4	< 24	< 3.7	< 17	< 1.8	< 17	< 1.6	< 17
	VAP-F2-1_56-60	11/7/2019	56	60	< 0.48	< 7.3	3.4	< 24	< 3.5	< 17	< 1.7	< 17	< 1.5	< 17
VAP-F2-2	VAP-F2-2_14-18	11/1/2019	14	18	76	88	420	480	10	< 17	9.6	< 17	22	< 67
	VAP-F2-2_20-24	11/1/2019	20	24	62	63	370	360	7.5	< 17	56	65	39	< 67
	VAP-F2-2_28-32	11/1/2019	28	32	48 [54]	54 [58]	260 [270]	270 [290]	< 3.4 [< 3.5]	< 17 [< 17]	13 [12]	< 17 [< 17]	28 [29]	18 [26]
	VAP-F2-2_35-39	11/1/2019	35	39	43	49	280	91	< 3.4	< 17	15	< 17	31	31
	VAP-F2-2_41-45	11/1/2019	41	45	13	16	86	78	< 3.4	< 17	4.2	< 17	7.2	< 17
	VAP-F2-2_48-52	11/1/2019	48	52	3.7	< 7.3	20	< 24	< 3.5	< 17	< 1.7	< 17	2.1	< 17
	VAP-F2-2_55-59	11/1/2019	55	59	2.1	< 7.3	10	< 24	< 3.4	< 17	< 1.7	< 17	< 1.5	< 17
VAP-F2-3	VAP-F2-3_15-19	10/24/2019	15	19	42	33	300	250	9.2	< 33	44	44	13	< 33
	VAP-F2-3_23-27	10/24/2019	23	27	13	7.5	67	49	< 4.1	< 33	8	< 33	6.2	< 33
	VAP-F2-3_29-33	10/24/2019	29	33	19	9.7	87	63	< 4	< 33	6.6	< 33	12	< 33
	VAP-F2-3_38-42	10/24/2019	38	42	31	35	150	160	< 3.6	< 33	12	< 33	26	35
	VAP-F2-3_47-51	10/25/2019	47	51	2.2	< 7.3	11	< 24	< 3.6	< 17	10	45	1.7	< 17
	VAP-F2-3_56-60	10/25/2019	56	60	3.9	< 7.3	18	< 24	< 3.5	< 17	6.1	40	3.2	< 17
VAP-F2-4	VAP-F2-4_15-19	11/7/2019	15	19	29	25	170	160	4.5	< 17	4.9	< 17	12	20
	VAP-F2-4_20-24	11/7/2019	20	24	19	11	120	110	< 3.4	< 17	6.1	< 17	5.5	< 17
	VAP-F2-4_27-31	11/8/2019	27	31	11	8.9	79	73	< 3.6	< 17	15	< 17	4.1	< 17
	VAP-F2-4_33-37	11/8/2019	33	37	9	8.4	64	58	< 3.5	< 17	20	< 17	2.3	< 17
	VAP-F2-4_39.5-43	11/8/2019	39.5	43.5	6.8	< 7.3	48	39	< 3.6	< 17	19	< 17	< 1.5	< 17
	VAP-F2-4_48-52	11/8/2019	48	52	1.5	< 7.3	10	< 24	< 3.5	< 17	< 1.7	< 17	< 1.5	< 31
	VAP-F2-4_56-60	11/8/2019	56	60	1.1	< 7.3	6.3	< 24	< 3.5	< 17	1.9	< 17	< 1.5	< 31
VAP-F2-5	VAP-F2-5_13-17	10/25/2019	13	17	27	28	200	230	12	18	20	29	14	< 17
	VAP-F2-5_22-26	10/25/2019	22	26	9.8	8.8	78	78	3.9	< 17	23	60	2.9	< 17
	VAP-F2-5_31-35	10/25/2019	31	35	7.3	< 7.3	61	64	4.5	< 17	24	49	3	< 17
	VAP-F2-5_38.5-42	10/25/2019	38.5	42.5	0.9	< 7.3	11	< 24	< 3.6	< 17	3.7	25	< 1.5	< 17
	VAP-F2-5_47.5-51	10/25/2019	47.5	51.5	4.1	< 7.3	22	< 24	< 3.8	< 17	6.8	19	< 1.6	< 17
	VAP-F2-5_56-60	10/25/2019	56	60	2.9	< 7.3	26	28	< 5.2	< 17	10	26	< 2.2	< 17
VAP-F2-6	VAP-F2-6_13-17	10/31/2019	13	17	6.4	< 7.3	41	47	< 3.4	< 17	11	< 17	3	< 17
	VAP-F2-6_22-26	10/31/2019	22	26	42	37	280	290	11	< 17	54	41	9	< 17
	VAP-F2-6_27-31	10/31/2019	27	31	41	< 7.3	260	< 24	11	< 17	36	< 17	7.9	< 17
	VAP-F2-6_33-37	10/31/2019	33	37	30	380	170	1900	< 3.3	1600	22	1800	5.2	1800
	VAP-F2-6_40-44	10/31/2019	40	44	0.53	26	5.3	170	< 3.5	< 17	2	27	< 1.5	< 17
	VAP-F2-6_48-52	10/31/2019	48	52	1.3 [1.2]	< 7.3 [< 7.3]	5.9 [5]	< 24 [< 24]	< 3.5 [< 3.5]	< 17 [< 17]	< 1.7 [< 1.7]	< 17 [< 17]	< 1.5 [< 1.5]	< 17 [< 17]
	VAP-F2-6_55-59	10/31/2019	55	59	< 0.46	< 7.3	< 1.9	< 24	< 3.3	< 17	< 1.6	< 17	< 1.4	< 17
VAP-F2-7	VAP-F2-7_12-16	10/25/2019	12	16	46	44	210	230	< 3.2	< 33	74	100	25	34
	VAP-F2-7_22-26	10/25/2019	22	26	170	180	1300	1200	44	36	580	560	73	85
	VAP-F2-7_32-36	10/25/2019	32	36	22	24	200	200	9	< 17	54	68	5.3	< 17
	VAP-F2-7_41-45	10/28/2019	41	45	3.9	< 7.3	21	33	< 3.5	< 17	27	55	1.9	< 17
	VAP-F2-7_49-53	10/28/2019	49	53	1.1	< 7.3	8.3	< 24	< 3.5	< 17	4.3	26	< 1.5	< 17
	VAP-F2-7_56-60	10/28/2019	56	60	9.7	10	55	70	< 3.6	< 17	41	75	5.7	< 17
VAP-F2-8	VAP-F2-8_11-15	10/30/2019	11	15	8.9	19	49	76	< 3.2	< 17	8.2	< 17	19	32
	VAP-F2-8_20-24	10/30/2019	20	24	180	250	1100	1500	46	66	200	250	39	51
	VAP-F2-8_27-31	10/30/2019	27	31	240	< 7	1500	1200	18	27	270	290	65	100

Location ID	Arcadis Sample ID	Collection Date	Start Depth (ft)	End Depth (ft)	SECONDARY CONSTITUENTS OF INTEREST									
					Br-PFHxS		Total PFHxS		PFNA		PFPeA		PFPeS	
					DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method
	VAP-F2-8_34-38	10/30/2019	34	38	50	52	280	260	< 3.1	< 17	84	94	18	37
	VAP-F2-8_42-46	10/30/2019	42	46	1.8	< 7.3	18	52	< 3.2	< 17	6.6	20	< 1.4	< 17
	VAP-F2-8_49-53	10/31/2019	49	53	2.7	< 7.3	18	27	< 3.4	< 17	5.5	< 17	1.4	< 17
	VAP-F2-8_56-60	10/31/2019	56	60	< 0.48 [< 0.47]	< 7.3 [< 7.3]	< 2 [< 1.9]	< 24 [< 24]	< 3.4 [< 3.4]	< 17 [< 17]	< 1.7 [< 1.6]	19 [< 17]	< 1.4 [< 1.4]	< 17 [< 17]
VAP-F2-13	VAP-F2-13_15-19	11/12/2019	15	19	2.1	< 7.3	19	< 24	< 3.5	< 17	21	28	< 1.5	< 17
	VAP-F2-13_22-26	11/12/2019	22	26	14 [15]	14 [12]	130 [140]	140 [130]	< 3.5 [3.8]	< 17 [< 17]	13 [18]	25 [27]	3.8 [4]	< 17 [< 17]
	VAP-F2-13_28-32	11/13/2019	28	32	6.4	< 7.3	57	29	< 3.6	< 17	4.3	< 17	2.6	< 17
	VAP-F2-13_36-40	11/13/2019	36	40	2.9	< 7.3	24	66	< 3.5	< 17	3.2	< 17	< 1.5	< 17
	VAP-F2-13_43-47	11/13/2019	43	47	0.98	< 7.3	6.9	< 24	< 3.5	< 17	< 1.7	< 17	< 1.5	< 17
	VAP-F2-13_51-55	11/13/2019	51	55	< 0.48	< 7.3	< 2	< 24	< 3.5	< 17	1.9	< 17	< 1.5	< 17
	VAP-F2-13_56-60	11/13/2019	56	60	< 0.5	< 7.3	< 2.1	< 24	< 3.6	< 17	< 1.7	< 17	< 1.5	< 17
TRANSECT 3														
VAP-F3-1	VAP-F3-1_9-13	11/11/2019	9	13	2.6	< 7.3	16	< 24	< 3.5	< 17	1.8	< 17	< 1.5	< 17
	VAP-F3-1_15-19	11/15/2019	15	19	2.4	NA	14	NA	< 3.5	NA	5	NA	2	NA
	VAP-F3-1_21-25	11/15/2019	21	25	5.5	7.3	53	49	< 3.4	< 17	4.7	< 17	3.4	< 17
	VAP-F3-1_27-31	11/15/2019	27	31	23	18	160	150	4.9	< 17	27	25	6.3	< 17
	VAP-F3-1_37-41	11/15/2019	37	41	25	20	180	170	5.5	< 17	33	38	6.1	< 17
	VAP-F3-1_46-50	11/15/2019	46	50	7.2	< 7.3	57	51	< 3.5	< 17	19	< 17	2.7	< 17
	VAP-F3-1_56-60	11/15/2019	56	60	6.9	< 7.3	49	38	< 3.5	< 17	18	18	2.2	< 17
VAP-F3-2	VAP-F3-2_11-15	10/28/2019	11	15	4	< 7.3	17	< 24	< 3.5	< 17	17	33	3.9	< 17
	VAP-F3-2_18-22	10/28/2019	18	22	41 [37]	50 [45]	230 [220]	280 [260]	< 3.5 [< 3.4]	< 17 [< 17]	250 [250]	380 [360]	19 [20]	24 [21]
	VAP-F3-2_25-29	10/28/2019	25	29	200	190	1200	1400	19	25	640	900	76	76
	VAP-F3-2_32-36	10/28/2019	32	36	260	300	1600	1900	22	28	610	910	95	110
	VAP-F3-2_40-44	10/28/2019	40	44	28	39	160	190	< 3.6	< 17	140	200	14	21
	VAP-F3-2_47-51	10/29/2019	47	51	180	210	1100	1400	14	18	390	480	62	77
VAP-F3-3	VAP-F3-3_10-14	11/1/2019	10	14	< 0.48 [< 0.49]	< 7.3 [< 7.3]	4.5 [4.2]	< 24 [< 24]	< 3.4 [< 3.5]	< 17 [< 17]	< 1.7 [< 1.7]	< 17 [< 17]	< 1.5 [< 1.5]	< 17 [< 31]
	VAP-F3-3_20-24	11/1/2019	20	24	91	100	600	650	12	< 17	88	71	12	< 17
	VAP-F3-3_24.5-28	11/4/2019	24.5	28.5	230 [220]	220 [240]	1400 [1400]	1500 [1500]	18 [19]	22 [21]	350 [350]	380 [370]	58 [58]	68 [57]
	VAP-F3-3_33-37	11/4/2019	33	37	190	210	1000	1100	7.1	< 17	310	340	58	60
	VAP-F3-3_42-46	11/4/2019	42	46	27	30	150	160	< 3.6	< 17	44	42	6.7	< 31
	VAP-F3-3_48-52	11/4/2019	48	52	14	16	63	56	< 3.4	< 17	18	< 17	5.3	< 31
	VAP-F3-3_55-59	11/4/2019	55	59	10	11	62	59	< 3.6	< 17	20	< 17	2.6	< 31
VAP-F3-4	VAP-F3-4_11-15	10/30/2019	11	15	< 0.48	< 7.3	< 2	< 24	< 3.4	< 17	1.7	< 17	< 1.5	< 17
	VAP-F3-4_19-23	10/30/2019	19	23	38	43	260	320	< 3.6	< 17	200	250	9.2	22
	VAP-F3-4_27-31	10/30/2019	27	31	59	45	420	400	4.5	< 17	230	260	12	< 17
	VAP-F3-4_35-39	10/30/2019	35	39	93	250	440	1200	< 3.3	< 17	110	300	43	150
	VAP-F3-4_42-46	10/30/2019	42	46	88	100	540	590	5.5	< 17	120	130	30	32
	VAP-F3-4_56-60	10/30/2019	56	60	6.1	< 7.3	45	39	< 3.8	< 17	11	< 17	2.5	< 17
VAP-F3-7	VAP-F3-7_9-13	11/11/2019	9	13	< 0.48	< 7.3	< 2	< 24	< 3.4	< 17	< 1.7	< 17	< 1.4	< 17
	VAP-F3-7_15-19	11/11/2019	15	19	34	34	190	220	< 3.4	< 17	12	20	3.8	< 17
	VAP-F3-7_21-25	11/11/2019	21	25	52	54	330	390	9.6	< 17	49	65	7.2	< 17
	VAP-F3-7_27-31	11/11/2019	27	31	20	16	140	160	< 3.5	< 17	20	25	3.9	< 17
	VAP-F3-7_37-41	11/11/2019	37	41	9.1	10	70	78	< 3.4	< 17	14	18	2.6	< 17
	VAP-F3-7_46-50	11/11/2019	46	50	1.7	< 7.3	11	< 24	< 3.4	< 17	< 1.6	< 17	< 1.4	< 17
	VAP-F3-7_56-60	11/11/2019	56	60	1.7	< 7.3	10	< 24	< 3.5	< 17	< 1.7	< 17	< 1.5	< 17
VAP-F3-8	VAP-F3-8_11-15	11/15/2019	11	15	< 0.49	< 7.3	5.6	< 24	< 3.5	< 17	< 1.7	< 17	< 1.5	< 17
	VAP-F3-8_18-22	11/15/2019	18	22	36 [37]	31 [29]	240 [240]	230 [220]	< 3.6 [< 3.6]	< 17 [< 17]	15 [14]	< 17 [< 17]	6.6 [6.6]	< 17 [< 17]
	VAP-F3-8_25-29	11/15/2019	25	29	8.9 [97]	80 [66]	62 [560]	550 [500]	< 3.7 [< 3.6]	< 17 [< 17]	22 [36]	44 [42]	3 [21]	21 [23]
	VAP-F3-8_33-37	11/15/2019	33	37	16	7.5	110	88	< 3.5	< 17	34	43	4	< 17
	VAP-F3-8_41-45	11/15/2019	41	45	6.1	< 7.3	39	32	< 3.6	< 17	15	< 17	1.6	< 17
	VAP-F3-8_49-53	11/15/2019	49	53	34	< 7.3	210	< 24	< 4.1	< 17	35	< 17	9.1	< 17
	VAP-F3-8_56-60	11/15/2019	56	60	9.7	< 7.3	60	< 24	< 3.5	< 17	20	22	2.5	< 17
VAP-F3-9	VAP-F3-9_9-13	11/12/2019	9	13	< 0.48	< 7.3	2	< 24	< 3.4	< 17	2.6	< 17	< 1.5	< 17
	VAP-F3-9_15-19	11/12/2019	15	19	21	20	110	130	< 3.5	< 17	11	21	17	20
	VAP-F3-9_21-25	11/12/2019	21	25	19	23	140	180	< 3.6	< 17	14	28	14	21
	VAP-F3-9_27-31	11/12/2019	27	31	25	30	160	180	< 3.5	< 17	27	41	8.4	< 17
	VAP-F3-9_37-41	11/12/2019	37	41	20	21	110	130	< 3.5	< 17	14	< 17	14	< 17
	VAP-F3-9_46-50	11/12/2019	46	50	7	< 7.3	38	37	< 3.5	< 17	22	35	10	< 17
	VAP-F3-9_56-60	11/12/2019	56	60	34	25	150	120	< 4.2	< 17	15	22	48	35
PRIMARY SOURCE														
VAP-PS-1	VAP-PS-1_14-17	10/21/2019	14	17	100	120	950	1100	4.1	< 33	38	53	57	59
VAP-PS-2	VAP-PS-2_14-17	10/21/2019	14	17	230	210	1300	1200	25	< 33	92	100	120	130
VAP-PS-3	VAP-PS-3_16.5-19	10/21/2019	16.5	19.5	58	37	390	320	22	< 33	140	130	16	< 33
VAP-PS-4	VAP-PS-4_13-16	10/22/2019	13	16	130	100	840	860	9.8	< 35	25	35	23	< 35
VAP-PS-5	VAP-PS-5_14-17	10/22/2019	14	17	54	45	350	360	9.1	< 36	35	42	11	< 35
VAP-PS-6	VAP-PS-6_14-17	10/22/2019	14	17	100	85	650	690	11	< 34	22	34	36	< 34
SECONDARY SOURCE														
VAP-SS-1	VAP-SS-1_13-17	11/5/2019	13	17	63	59	340	340	6.3	< 17	21	20	11	< 31

Location ID	Arcadis Sample ID	Collection Date	Start Depth (ft)	End Depth (ft)	SECONDARY CONSTITUENTS OF INTEREST									
					Br-PFHxS		Total PFHxS		PFNA		PFPeA		PFPeS	
					DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method
	VAP-SS-1_20.5-24	11/5/2019	20.5	24.5	19	15	110	110	< 3.4	< 17	27	< 17	6.7	< 31
	VAP-SS-1_26-30	11/5/2019	26	30	9	10	59	54	< 3.6	< 17	29	< 17	3.7	< 31
	VAP-SS-1_34-38	11/5/2019	34	38	9.1	10	56	60	< 3.5	< 17	80	76	3	< 31
	VAP-SS-1_44-48	11/5/2019	44	48	2.5	< 7.3	16	< 24	< 3.6	< 17	8.8	< 17	< 1.5	< 31
	VAP-SS-1_50-54	11/5/2019	50	54	0.92	< 7.3	5.1	< 24	< 3.5	< 17	3	< 67	< 1.5	< 17
	VAP-SS-1_56-60	11/6/2019	56	60	1.8	< 7.3	10	< 24	< 3.7	< 17	8.5	< 67	< 1.6	< 17
VAP-SS-2	VAP-SS-2_14-18	11/5/2019	14	18	24	27	140	180	< 3.4	< 17	19	< 17	9	< 31
	VAP-SS-2_23-27	11/5/2019	23	27	14	15	81	78	< 3.4	< 17	24	< 67	2.2	< 17
	VAP-SS-2_28.5-32	11/5/2019	28.5	32.5	15	14	74	67	< 3.4	< 17	12	< 67	2.2	< 17
	VAP-SS-2_36-40	11/5/2019	36	40	8 [8.6]	11 [12]	51 [49]	51 [58]	< 3.4 [< 3.4]	< 17 [< 17]	3.9 [3.4]	< 67 [< 67]	3.8 [3.6]	< 17 [< 17]
	VAP-SS-2_43-47	11/5/2019	43	47	7.1	10	41	44	< 3.6	< 17	4	< 67	3.7	< 17
	VAP-SS-2_49-53	11/5/2019	49	53	1.1	< 7.3	7.9	< 24	< 3.4	< 17	2.4	< 67	< 1.5	< 17
	VAP-SS-2_58-62	11/5/2019	58	62	1.1	< 7.3	5.1	< 24	< 3.6	< 17	< 1.7	< 67	< 1.5	< 17
VAP-SS-3	VAP-SS-3_14-18	11/6/2019	14	18	39	48	210	230	8.1	< 17	11	< 67	12	18
	VAP-SS-3_22-26	11/6/2019	22	26	44	34	160	140	< 3.4	< 17	17	< 67	35	< 17
	VAP-SS-3_30-34	11/6/2019	30	34	33	46	140	180	< 3.4	< 17	9	< 67	12	46
	VAP-SS-3_38-42	11/6/2019	38	42	41	45	150	160	< 3.5	< 17	18	< 67	42	52
	VAP-SS-3_44.5-48	11/6/2019	44.5	48.5	2.1	< 7.3	4	< 24	< 3.5	< 17	2.2	< 67	< 1.5	< 17
	VAP-SS-3_50-54	11/6/2019	50	54	27	30	100	110	< 3.5	< 17	11	< 67	24	28
	VAP-SS-3_58-62	11/6/2019	58	62	2.2	< 7.3	8.6	< 24	< 3.4	< 17	2.4	< 67	2.9	< 17
VAP-SS-4	VAP-SS-4_15-19	11/6/2019	15	19	55	52	430	520	19	22	19	21	11	< 17
	VAP-SS-4_21-25	11/6/2019	21	25	32	29	190	200	< 3.7	< 17	14	21	14	< 17
	VAP-SS-4_27.5-31	11/6/2019	27.5	31.5	28	33	160	180	< 3.3	< 17	14	17	22	24
	VAP-SS-4_35-39	11/6/2019	35	39	1.4	< 7.3	12	< 24	< 3.5	< 17	11	< 17	< 1.5	< 17
	VAP-SS-4_41-45	11/7/2019	41	45	< 0.47	< 7.3	2	< 24	< 3.4	< 17	< 1.6	< 17	< 1.4	< 17
	VAP-SS-4_49-53	11/7/2019	49	53	1.3	< 7.3	6.4	< 24	< 3.6	< 17	< 1.7	< 17	< 1.5	< 17
	VAP-SS-4_56-60	11/7/2019	56	60	< 0.53	< 7.3	5.1	< 24	< 3.8	< 17	< 1.9	< 17	< 1.6	< 17
VAP-SS-5	VAP-SS-5_15.5-19	11/6/2019	15.5	19.5	49	55	330	400	< 3.5	< 17	12	< 67	19	23
	VAP-SS-5_20.5-24	11/6/2019	20.5	24.5	60	57	360	370	< 3.5	< 17	14	< 17	22	25
	VAP-SS-5_27-31	11/6/2019	27	31	42	42	260	240	< 3.5	< 17	12	18	20	< 17
	VAP-SS-5_34-38	11/6/2019	34	38	23	19	120	140	< 3.5	< 17	6.4	< 17	13	< 17
	VAP-SS-5_40-44	11/6/2019	40	44	1.5	< 7.3	8.6	< 24	< 3.5	< 17	< 1.7	< 17	< 1.5	< 17
	VAP-SS-5_47-51	11/7/2019	47	51	2.4	< 7.3	15	< 24	5.3	< 17	< 1.7	< 17	< 1.5	< 17
	VAP-SS-5_56-60	11/7/2019	56	60	1.2	< 7.3	7.1	< 24	< 3.5	< 17	< 1.7	< 17	< 1.5	< 17
VAP-SS-6	VAP-SS-6_14.5-18	11/7/2019	14.5	18.5	66	70	440	500	4.4	< 17	28	37	29	32
	VAP-SS-6_22-26	11/7/2019	22	26	59	55	290	320	< 3.6	< 17	17	21	39	61
	VAP-SS-6_30-34	11/7/2019	30	34	60	46	290	300	< 3.6	< 17	17	28	33	40
	VAP-SS-6_38-42	11/8/2019	38	42	8.9	11	43	54	< 3.6	< 17	3.4	< 17	5	< 17
	VAP-SS-6_49-53	11/8/2019	49	53	3.4	< 7.3	18	< 24	< 3.6	< 17	1.7	< 17	1.8	17
	VAP-SS-6_56-60	11/8/2019	56	60	< 0.48	< 7.3	< 2	< 24	< 3.5	< 17	< 1.7	< 17	< 1.5	< 17

Abbreviations:

DoD ELAP = Department of Defense Environmental Laboratory Accreditation Program ft = feet

NA = not applicable

PFAS = per- and polyfluoroalkylated substances

Notes:

1. Groundwater analytical results are in units nanograms per liter (ng/L).
2. Method Detection Limits (MDLs) are shown for DoD ELAP Method non-detects and Limits of Quantitation (LOQ) are shown for Accelerated Method non-detects.
3. Accelerated Method data are unavailable for Arcadis Sample IDs VAP-F1-9_32-36 and VAP-F3-1_15-19 due to sample handling errors at laboratory.
4. Field duplicate analytical results are presented in brackets.

Table 5-5. Soil Analytical Results for the PFSA Mobile Lab-Based Real-Time Method Pilot Study Primary Constituents of Interest

Location ID	Arcadis Sample ID	Collection Date	Start Depth (ft)	End Depth (ft)	PRIMARY CONSTITUENTS OF INTEREST									
					PFOA		PFOS		T-PFOS		Total PFOS		PFBS	
					DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method
TRANSECT 1														
SB-F1-3	SB-F1-3_8.5-9	11/13/2019	8.5	9	< 43	< 53	< 28	< 53	< 7.8	< 37	< 36	< 90	< 15	< 53
	SB-F1-3_10.25-10.75	11/13/2019	10.25	10.75	< 49	< 60	46	< 60	22	< 42	68	< 100	< 17	< 60
	SB-F1-3_12-12.5	11/13/2019	12	12.5	< 52	< 64	74	< 64	35	< 45	110	< 110	< 18	< 64
SB-F1-11	SB-F1-11_12.5-13	11/14/2019	12.5	13	< 40	< 48	< 26	< 48	8	< 34	< 33	< 82	< 13	< 48
	SB-F1-11_14.25-14.75	11/14/2019	14.25	14.75	< 43	< 53	< 29	< 53	9.9	< 37	< 36	< 90	< 15	< 53
	SB-F1-11_16-16.5	11/14/2019	16	16.5	< 50	< 61	< 33	< 61	21	< 43	< 42	< 100	< 17	< 61
TRANSECT 2														
SB-F2-1	SB-F2-1_13.5-14	11/14/2019	13.5	14	< 33 [< 49]	< 40 [< 60]	< 22 [< 32]	< 40 [< 60]	18 [< 8.9]	< 28 [< 42]	39 [< 41]	< 68 [< 100]	< 11 [< 17]	< 40 [< 60]
	SB-F2-1_15.25-15.75	11/14/2019	15.25	15.75	73	75	5800	5800	1300	1800	7100	7600	63	< 62
	SB-F2-1_17-18	11/14/2019	17	18	< 430	NA	7100	NA	1600	NA	8800	NA	< 150	NA
SB-F2-2	SB-F2-2_13.5-14	11/14/2019	13.5	14	< 41	< 50	< 27	< 50	< 7.5	< 35	< 34	< 86	< 14	< 50
	SB-F2-2_15-15.5	11/14/2019	15	15.5	< 47	< 57	48	< 57	60	63	110	100	< 16	< 57
	SB-F2-2_17-18	11/14/2019	17	18	51 [< 36]	56 [< 44]	7100 [< 24]	7100 [< 44]	2100 [< 6.5]	2700 [< 31]	9100 [< 30]	9800 [< 74]	< 13 [< 12]	< 48 [< 44]
TRANSECT 3														
SB-F3-2	SB-F3-2_7.5-8	11/14/2019	7.5	8	< 48	< 59	< 32	< 59	< 8.7	< 41	< 40	< 100	< 16	< 59
	SB-F3-2_9.25-9.75	11/14/2019	9.25	9.75	< 51	< 63	< 34	< 63	< 9.3	< 44	< 43	< 110	< 18	< 63
	SB-F3-2_11-11.5	11/14/2019	11	11.5	< 45	< 55	< 30	< 55	< 8.1	< 38	< 37	< 93	< 15	< 55
	SB-F3-2_54.5-55	11/14/2019	54.5	55	< 51	< 62	< 33	< 62	26	< 43	45	< 100	< 17	< 62
	SB-F3-2_56-56.5	11/14/2019	56	56.5	< 67	< 82	< 44	< 82	22	< 57	< 56	< 140	< 23	< 82
	SB-F3-2_59.5-60	11/14/2019	59.5	60	< 57	< 70	< 38	< 70	< 10	< 49	< 47	< 120	< 20	< 70
SB-F3-9	SB-F3-9_8.5-9	11/14/2019	8.5	9	< 45	< 55	< 29	< 55	9.3	< 38	< 37	< 93	< 15	< 55
	SB-F3-9_10.75-11.25	11/14/2019	10.75	11.25	< 37	< 45	< 24	< 45	11	< 32	< 31	< 77	< 13	< 45
	SB-F3-9_12.5-13	11/14/2019	12.5	13	< 47	< 57	< 31	< 57	11	< 40	< 39	< 96	< 16	< 57
PRIMARY SOURCE														
SB-PS-1	SB-PS-1_12.5-13	10/21/2019	12.5	13	< 450	68	16000	17000	3300	4000	20000	21000	< 150	< 54
	SB-PS-1_14.7-15.2	10/21/2019	14.7	15.2	< 470	< 57	29000	23000	3100	3200	32000	27000	< 160	< 57
	SB-PS-1_16.5-17	10/21/2019	16.5	17	< 510	490	38000	38000	28000	26000	66000	64000	< 170	66
SB-PS-2	SB-PS-2_12.5-13	10/21/2019	12.5	13	< 410	54	< 270	1600	< 73	850	< 340	2500	< 140	< 50
	SB-PS-2_14.7-15.2	10/21/2019	14.7	15.2	< 380	98	< 250	170	290	230	520	400	< 130	< 46
	SB-PS-2_16.5-17	10/21/2019	16.5	17	< 460	100	1700	110	830	86	2600	190	< 160	< 56
SB-PS-3	SB-PS-3_12.5-13	10/21/2019	12.5	13	< 430	490	< 280	110	< 78	330	< 360	440	< 150	< 53
	SB-PS-3_14.5-15	10/21/2019	14.5	15	< 430	< 52	< 280	1700	< 77	950	< 360	2600	< 150	< 52
	SB-PS-3_16.5-17	10/21/2019	16.5	17	< 440	< 54	1700	71	650	< 38	2300	100	< 150	< 54
SB-PS-4	SB-PS-4_11-11.5	10/22/2019	11	11.5	< 340	< 41	< 220	160	79	43	< 280	200	< 120	< 41
	SB-PS-4_13.2-13.7	10/22/2019	13.2	13.7	< 480	< 59	320	260	92	65	410	320	< 160	< 59
	SB-PS-4_15.5-16	10/22/2019	15.5	16	< 490	< 59	1600	1500	650	790	2300	2300	< 170	< 59
SB-PS-5	SB-PS-5_12-12.5	10/22/2019	12	12.5	< 400	< 49	< 260	< 49	< 72	< 34	< 330	< 82	< 140	< 49
	SB-PS-5_14-14.5	10/22/2019	14	14.5	< 500	130	3200	3700	1400	2400	4600	6100	< 170	< 61
	SB-PS-5_15.5-16	10/22/2019	15.5	16	< 430	< 53	3800	4500	1400	1800	5100	6200	< 150	< 53
SB-PS-6	SB-PS-6_12-12.5	10/22/2019	12	12.5	< 410 [< 450]	< 50 [72]	670 [4400]	390 [7100]	200 [1200]	160 [3000]	870 [5600]	560 [10000]	< 140 [< 150]	< 50 [< 55]
	SB-PS-6_14.2-14.7	10/22/2019	14.2	14.7	< 420	< 51	3300	2500	2100	1900	5500	4400	< 140	< 51
	SB-PS-6_15.5-16	10/22/2019	15.5	16	< 430	< 53	1900	2000	610	840	2500	2800	< 150	< 53
SECONDARY SOURCE														
SB-SS-1	SB-SS-1_2.5-3	11/4/2019	2.5	3	< 420	< 51	< 280	150	150	42	< 350	190	210	< 51
	SB-SS-1_4.5-5	11/4/2019	4.5	5	< 420	< 51	380	350	160	74	540	420	< 140	79
	SB-SS-1_6.5-7	11/4/2019	6.5	7	< 410	< 50	< 270	210	81	37	< 340	240	< 140	< 50
	SB-SS-1_8.5-9	11/4/2019	8.5	9	< 440	< 53	< 290	280	200	61	470	340	< 150	< 53
	SB-SS-1_10.5-11	11/4/2019	10.5	11	< 440	< 54	580	580	200	130	790	710	390	< 54
	SB-SS-1_12.75-13.25	11/4/2019	12.75	13.25	< 420	< 51	< 270	240	160	57	< 340	290	< 140	< 51
	SB-SS-1_14.75-15.25	11/4/2019	14.75	15.25	< 43	< 53	3700	3700	1200	1500	4800	5200	< 15	< 53
SB-SS-2	SB-SS-2_1.5-2	11/4/2019	1.5	2	< 450	< 55	720	820	130	< 38	850	850	170	< 55
	SB-SS-2_3.5-4	11/4/2019	3.5	4	< 420	83	900	780	150	100	1000	880	290	< 51
	SB-SS-2_5.5-6	11/4/2019	5.5	6	< 410	56	290	300	210	82	500	380	< 140	< 50
	SB-SS-2_7.5-8	11/4/2019	7.5	8	< 440	< 54	580	670	240	210	820	880	230	< 54
	SB-SS-2_9.5-10	11/4/2019	9.5	10	< 400	< 49	< 260	< 49	< 72	< 34	< 330	< 83	< 140	< 49
	SB-SS-2_11.5-12	11/4/2019	11.5	12	< 430	< 52	1300	1300	220	240	1600	1600	< 150	< 52
	SB-SS-2_13.75-14.25	11/4/2019	13.75	14.25	42	46	310	340	230	330	530	660	< 12	< 41
	SB-SS-2_15.5-16.5	11/4/2019	15.5	16.5	< 41	< 50	530	550	250	360	770	920	< 14	< 50
SB-SS-3	SB-SS-3_1.5-2	11/5/2019	1.5	2	< 410	56	1800	1900	160	100	1900	2000	< 140	< 50
	SB-SS-3_3.5-4	11/5/2019	3.5	4	< 420	< 51	14000	13000	1200	2000	15000	15000	< 140	< 51
	SB-SS-3_5.5-6	11/5/2019	5.5	6	< 440	< 54	6300	6500	1500	1900	7800	8400	< 150	< 54
	SB-SS-3_7.5-8	11/5/2019	7.5	8	< 420	84	7000	6800	1800	2500	8800	9300	150	< 51
	SB-SS-3_9.5-10	11/5/2019	9.5	10	< 440	< 54	1600	1300	550	650	2200	2000	< 150	180
	SB-SS-3_11.5-12	11/5/2019	11.5	12	< 45	< 55	750	750	270	370	1000	1100	< 15	< 55
	SB-SS-3_13.75-14.25	11/5/2019	13.75	14.25	< 40	< 49	740	770	410	580	1200	1300	< 14	< 49
	SB-SS-3_15.75-16.25	11/5/2019	15.75	16.25	< 47	< 58	570	590	230	330	800	920	< 16	< 58
SB-SS-4	SB-SS-4_2.5-3	11/5/2019	2.5	3	560	300	26000	24000	2300	2400	28000	26000	< 140	< 51
	SB-SS-4_4.5-5	11/5/2019	4.5	5	530	180	80000	77000	3400	4700	83000	82000	< 150	< 53
	SB-SS-4_6.5-7	11/5/2019	6.5	7	< 440	92	22000	25000	1200	1900	23000	27000	< 150	< 54
	SB-SS-4_8.5-9	11/5/2019	8.5	9	< 420	150	84000	79000	3500	5000	87000	84000	< 140	< 51
	SB-SS-4_10.5-11	11/5/2019	10.5	11	< 430	67	10000	11000	750	860	11000	12000	< 150	< 53
	SB-SS-4_12.5-13	11/5/2019	12.5	13	94	85	7400	7400	530	730	7900	8100	< 18	< 64
	SB-SS-4_14.75-15.25	11/5/2019	14.75	15.25	210	190	54000	58000	13000	13000	67000	72000	< 19	82
	SB-SS-4_16.75-17.25	11/5/2019	16.75	17.25	67	57	11000	12000	< 7.3	3800	11000	15000	< 14	< 49
SB-SS-5	SB-SS-5_1.5-2	11/6/2019	1.5	2	1000	780	13000	15000	2900	3200	16000	18000	< 160	< 57
	SB-SS-5_3.5-4	11/6/2019	3.5	4	9100	920	180000	20000	16000	2900	190000	23000	< 140	< 51
	SB-SS-5_5.5-6	11/6/2019	5.5	6	2700	1900	77000	75000	6900	8100	84000	83000	< 150	< 54
	SB-SS-5_7.5-8	11/6/2019	7.5	8	1800	1800	130000	170000	13000	22000	150000	190000	< 140	< 49
	SB-SS-5_9.5-10	11/6/2019	9.5	10	1500	1300	330000	320000	47000	53000	380000	370000	< 140	< 50
	SB-SS-5_11.5-12	11/6/2019	11.5	12	740	740	160000	140000	43000	40000	210000	180000	< 17	< 61
	SB-SS-5_14.25-14.75	11/6/2019	14.25	14.75	670	670	52000	53000	10000	13000	62000	65000	53	< 68
	SB-SS-5_16.25-16.75	11/6/2019	16.25	16.75	370	380	73000	61000	22000	18000	95000	78000	< 16	< 57
B-SS-6	SB-SS-6_1.5-2	11/7/2019	1.5	2	440	99	9800	9900	860	1100	11000	11000	< 150	< 53
	SB-SS-6_3.5-4	11/7/2019	3.5	4	< 420	64	2600	2500	470	450	3100	2900	< 140	< 52
	SB-SS-6_5.5-6	11/7/2019	5.5	6	1100	96	530000	44000	26000	2600	560000	46000	420	< 52
	SB-SS-6_7.5-8	11/7/2019	7.5	8	410	63	19000	17000	1000	1400	20000	18000	< 140	< 49
	SB-SS-6_9.5-10	11/7/2019	9.5	10	420	87	22000	21000	2000	2800	24000	24000	290	< 51
	SB-SS-6_11.5-12	11/7/2019	11.5	12	61 [96]	84 [92]	6700 [7100]	6700 [7400]	680 [450]	1000 [770]	7400 [7500]	7700 [8200]	< 18 [< 21]	< 63 [< 74]
	SB-SS-6_14.25-14.75	11/7/2019	14.25	14.75	49	66	13000	13000	6000	6500	19000	20000	< 12	< 42
	SB-SS-6_16.25-16.75	11/7/2019	16.25	16.75	42	49	4900	5500	1600	2300	6600	7800	< 13	< 46

Abbreviations:

DoD ELAP = Department of Defense Environmental Laboratory Accreditation Program ft = feet
PFAS = per- and polyfluoroalkylated substances PFBS = perfl;uorobutane sulfonate
PFOA = perfluorooctanic acid PFOS = perfluorooctane sulfonate NA = not applicable

Notes:

1. Soil analytical results are in units nanograms per kilogram (ng/kg).
2. Method Detection Limits (MDLs) are shown for DoD ELAP Method non-detects and Limits of Quantitation (LOQ) are shown for Accelerated Method non-detects.
3. Accelerated Method data are unavailable for Arcadis Sample ID SB-F2-1_17-18 due to sample handling error at the laboratory.
4. Field duplicate analytical results are presented in brackets.

Table 5-6. Soil Analytical Results for the PFSA Mobile Lab-Based Real-Time Method Pilot Study Secondary Constituents of Interest

Location ID	Arcadis Sample ID	Collection Date	Start Depth (ft)	End Depth (ft)	SECONDARY CONSTITUENTS OF INTEREST											
					6-2FTS		8-2FTS		PFHpA		PFHpS		PFHxA		PFHxS	
					DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method
TRANSECT 1																
SB-F1-3	SB-F1-3_8.5-9	11/13/2019	8.5	9	< 31	< 53	< 20	< 53	< 31	< 53	< 20	< 53	19	< 53	< 7.9	< 41
	SB-F1-3_10.25-10.75	11/13/2019	10.25	10.75	< 35	< 60	< 23	< 60	< 35	< 60	< 23	< 60	< 21	< 60	< 9	< 47
	SB-F1-3_12-12.5	11/13/2019	12	12.5	< 37	< 64	< 24	< 64	< 37	< 64	< 24	< 64	< 22	< 64	12	< 50
SB-F1-11	SB-F1-11_12.5-13	11/14/2019	12.5	13	< 28	< 48	< 18	< 48	< 28	< 48	< 18	< 48	< 16	< 48	< 7.2	< 38
	SB-F1-11_14.25-14.75	11/14/2019	14.25	14.75	< 31	< 53	< 20	< 53	< 31	< 53	< 20	< 53	< 18	< 53	< 8	< 41
	SB-F1-11_16-16.5	11/14/2019	16	16.5	< 36	< 61	< 23	< 61	< 36	< 61	< 23	< 61	22	< 61	11	< 48
TRANSECT 2																
SB-F2-1	SB-F2-1_13.5-14	11/14/2019	13.5	14	< 23 [< 35]	< 40 [< 60]	< 15 [< 23]	< 40 [< 60]	< 23 [< 35]	< 40 [< 60]	< 15 [< 23]	< 40 [< 60]	15 [25]	< 40 [< 60]	24 [20]	< 31 [< 47]
	SB-F2-1_15.25-15.75	11/14/2019	15.25	15.75	< 36	< 62	< 23	< 62	53	< 62	< 23	< 62	38	< 62	110	120
	SB-F2-1_17-18	11/14/2019	17	18	< 310	NA	< 200	NA	310	NA	< 200	NA	< 180	NA	90	NA
SB-F2-2	SB-F2-2_13.5-14	11/14/2019	13.5	14	< 29	< 50	< 19	< 50	< 29	< 50	< 19	< 50	< 17	< 50	14	< 39
	SB-F2-2_15-15.5	11/14/2019	15	15.5	< 33	< 57	< 22	< 57	< 33	< 57	< 22	< 57	< 19	< 57	38	48
	SB-F2-2_17-18	11/14/2019	17	18	< 28 [< 25]	< 48 [< 44]	< 18 [< 17]	< 48 [< 44]	36 [< 25]	< 48 [< 44]	54 [< 17]	76 [< 44]	30 [15]	< 48 [< 44]	370 [15]	400 [< 34]
TRANSECT 3																
SB-F3-2	SB-F3-2_7.5-8	11/14/2019	7.5	8	< 34	< 59	< 22	< 59	< 34	< 59	< 22	< 59	< 20	< 59	< 8.8	< 46
	SB-F3-2_9.25-9.75	11/14/2019	9.25	9.75	< 36	< 63	< 24	< 63	< 36	< 63	< 24	< 63	< 21	< 63	< 9.4	< 49
	SB-F3-2_11-11.5	11/14/2019	11	11.5	< 32	< 55	< 21	< 55	< 32	< 55	< 21	< 55	< 19	< 55	< 8.2	< 43
	SB-F3-2_54.5-55	11/14/2019	54.5	55	< 36	< 62	< 23	< 62	< 36	< 62	< 23	< 62	34	< 62	35	< 48
	SB-F3-2_56-56.5	11/14/2019	56	56.5	< 47	< 82	< 31	< 82	< 47	< 82	< 31	< 82	< 28	< 82	< 12	< 64
	SB-F3-2_59.5-60	11/14/2019	59.5	60	< 40	< 70	< 26	< 70	< 40	< 70	< 26	< 70	< 24	< 70	< 10	< 54
SB-F3-9	SB-F3-9_8.5-9	11/14/2019	8.5	9	< 32	< 55	< 21	< 55	< 32	< 55	< 21	< 55	< 19	< 55	< 8.2	< 43
	SB-F3-9_10.75-11.25	11/14/2019	10.75	11.25	< 26	< 45	< 17	< 45	< 26	< 45	< 17	< 45	< 15	< 45	< 6.8	< 35
	SB-F3-9_12.5-13	11/14/2019	12.5	13	< 33	< 57	< 22	< 57	< 33	< 57	< 22	< 57	< 19	< 57	< 8.5	< 44
PRIMARY SOURCE																
SB-PS-1	SB-PS-1_12.5-13	10/21/2019	12.5	13	< 320	65	490	480	< 320	< 54	< 210	78	< 190	< 54	290	340
	SB-PS-1_14.7-15.2	10/21/2019	14.7	15.2	< 330	< 57	870	930	< 330	< 57	< 220	< 57	< 190	< 57	110	74
	SB-PS-1_16.5-17	10/21/2019	16.5	17	6900	6100	720	630	510	190	500	900	710	470	2600	2200
SB-PS-2	SB-PS-2_12.5-13	10/21/2019	12.5	13	< 290	< 50	< 190	< 50	< 290	< 50	< 190	< 50	210	< 50	< 74	230
	SB-PS-2_14.7-15.2	10/21/2019	14.7	15.2	< 270	< 46	< 180	80	270	52	< 180	< 46	< 160	< 46	< 69	89
	SB-PS-2_16.5-17	10/21/2019	16.5	17	< 330	< 56	< 210	< 56	360	< 56	< 210	< 56	< 190	< 56	330	56
SB-PS-3	SB-PS-3_12.5-13	10/21/2019	12.5	13	870	690	< 200	< 53	310	85	< 200	120	210	< 53	540	470
	SB-PS-3_14.5-15	10/21/2019	14.5	15	< 300	130	< 200	59	< 300	< 52	< 200	< 52	< 180	< 52	< 78	45
	SB-PS-3_16.5-17	10/21/2019	16.5	17	< 310	< 54	< 200	< 54	< 310	< 54	< 200	< 54	< 180	< 54	90	< 42
SB-PS-4	SB-PS-4_11-11.5	10/22/2019	11	11.5	< 240	< 41	< 160	< 41	< 240	< 41	< 160	< 41	140	< 41	120	100
	SB-PS-4_13.2-13.7	10/22/2019	13.2	13.7	< 340	< 59	< 220	< 59	< 340	< 59	< 220	< 59	210	< 59	< 88	110
	SB-PS-4_15.5-16	10/22/2019	15.5	16	< 340	< 59	< 230	< 59	< 340	< 59	< 230	< 59	< 200	< 59	140	100
SB-PS-5	SB-PS-5_12-12.5	10/22/2019	12	12.5	< 280	< 49	< 180	< 49	< 280	< 49	< 180	< 49	170	< 49	< 73	< 38
	SB-PS-5_14-14.5	10/22/2019	14	14.5	< 350	130	< 230	< 61	420	< 61	< 230	350	210	< 61	470	580
	SB-PS-5_15.5-16	10/22/2019	15.5	16	< 310	< 53	< 200	< 53	380	< 53	< 200	< 53	< 180	< 53	270	190
SB-PS-6	SB-PS-6_12-12.5	10/22/2019	12	12.5	< 290 [< 320]	< 50 [< 55]	< 190 [< 210]	< 50 [< 55]	< 290 [< 320]	< 50 [< 55]	< 190 [< 210]	< 50 [88]	< 170 [< 190]	< 50 [< 55]	< 76 [290]	< 39 [440]
	SB-PS-6_14.2-14.7	10/22/2019	14.2	14.7	< 300	< 51	< 190	< 51	< 300	< 51	< 190	< 51	< 170	< 51	160	45
	SB-PS-6_15.5-16	10/22/2019	15.5	16	< 310	< 53	< 200	< 53	310	< 53	< 200	< 53	< 180	< 53	< 79	140
SECONDARY SOURCE																
SB-SS-1	SB-SS-1_2.5-3	11/4/2019	2.5	3	< 300	< 51	< 200	< 51	< 300	< 51	< 200	< 51	< 170	< 51	< 77	< 40
	SB-SS-1_4.5-5	11/4/2019	4.5	5	< 300	< 51	< 190	< 51	< 300	< 51	< 190	< 51	< 170	< 51	< 77	40
	SB-SS-1_6.5-7	11/4/2019	6.5	7	< 290	< 50	< 190	< 50	< 290	< 50	< 190	< 50	180	< 50	< 75	39
	SB-SS-1_8.5-9	11/4/2019	8.5	9	< 310	< 53	< 200	< 53	< 310	< 53	< 200	< 53	< 180	< 53	97	55
	SB-SS-1_10.5-11	11/4/2019	10.5	11	< 310	< 54	< 200	< 54	320	< 54	< 200	< 54	180	< 54	160	91
	SB-SS-1_12.75-13.25	11/4/2019	12.75	13.25	< 290	< 51	< 190	< 51	< 290	< 51	< 190	< 51	180	< 51	< 76	60
	SB-SS-1_14.75-15.25	11/4/2019	14.75	15.25	< 31	< 53	< 20	< 53	< 31	< 53	< 20	< 53	34	< 53	220	200
SB-SS-2	SB-SS-2_1.5-2	11/4/2019	1.5	2	< 320	< 55	< 210	< 55	350	< 55	< 210	< 55	210	< 55	< 82	< 43
	SB-SS-2_3.5-4	11/4/2019	3.5	4	< 300	< 51	< 200	< 51	330	< 51	< 200	< 51	210	< 51	< 77	< 40
	SB-SS-2_5.5-6	11/4/2019	5.5	6	< 290	< 50	< 190	< 50	< 290	< 50	< 190	< 50	< 170	< 50	< 76	< 39
	SB-SS-2_7.5-8	11/4/2019	7.5	8	< 310	< 54	< 200	< 54	370	< 54	< 200	< 54	190	< 54	< 80	210
	SB-SS-2_9.5-10	11/4/2019	9.5	10	< 280	< 49	< 180	< 49	< 280	< 49	< 180	< 49	< 170	< 49	< 73	< 38
	SB-SS-2_11.5-12	11/4/2019	11.5	12	< 300	< 52	< 200	< 52	< 300	< 52	< 200	< 52	180	< 52	170	140
	SB-SS-2_13.75-14.25	11/4/2019	13.75	14.25	< 24	< 41	< 16	< 41	24	< 41	28	< 41	47	41	360	360
	SB-SS-2_15.5-16.5	11/4/2019	15.5	16.5	< 29	< 50	< 19	< 50	< 29	< 50	< 19	< 50	28	< 50	110	110
SB-SS-3	SB-SS-3_1.5-2	11/5/2019	1.5	2	< 290	< 50	< 190	< 50	< 290	< 50	< 190	< 50	< 170	< 50	< 75	< 39
	SB-SS-3_3.5-4	11/5/2019	3.5	4	< 300	< 51	< 200	< 51	< 300	< 51	< 200	< 51	190	< 51	79	47
	SB-SS-3_5.5-6	11/5/2019	5.5	6	< 310	< 54	< 200	< 54	< 310	< 54	< 200	< 54	210	< 54	< 81	64
	SB-SS-3_7.5-8	11/5/2019	7.5	8	< 300	< 51	< 200	< 51	310	< 51	< 200	67	210	< 51	230	170
	SB-SS-3_9.5-10	11/5/2019	9.5	10	< 310	< 54	< 210	< 54	320	< 54	< 210	< 54	210	< 54	< 81	140
	SB-SS-3_11.5-12	11/5/2019	11.5	12	< 32	< 55	< 21	< 55	< 32	< 55	< 21	< 55	< 19	< 55	130	140
	SB-SS-3_13.75-14.25	11/5/2019	13.75	14.25	< 28	< 49	< 18	< 49	28	< 49	< 18	< 49	20	< 49	120	120

Location ID	Arcadis Sample ID	Collection Date	Start Depth (ft)	End Depth (ft)	SECONDARY CONSTITUENTS OF INTEREST											
					6-2FTS		8-2FTS		PFHpA		PFHpS		PFHxA		PFHxS	
					DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method
	SB-SS-3_15.75-16.25	11/5/2019	15.75	16.25	< 33	< 58	< 22	< 58	< 33	< 58	< 22	< 58	25	< 58	60	61
SB-SS-4	SB-SS-4_2.5-3	11/5/2019	2.5	3	< 300	72	< 190	120	440	100	330	320	370	200	860	790
	SB-SS-4_4.5-5	11/5/2019	4.5	5	< 310	< 53	750	770	330	< 53	< 200	340	230	< 53	650	590
	SB-SS-4_6.5-7	11/5/2019	6.5	7	< 310	< 54	350	330	380	< 54	< 210	150	190	< 54	760	730
	SB-SS-4_8.5-9	11/5/2019	8.5	9	< 300	< 51	1800	1900	< 300	52	< 200	310	200	< 51	940	990
	SB-SS-4_10.5-11	11/5/2019	10.5	11	< 310	< 53	220	190	< 310	< 53	< 200	< 53	210	< 53	400	350
	SB-SS-4_12.5-13	11/5/2019	12.5	13	53	< 64	180	170	39	< 64	39	< 64	31	< 64	360	380
	SB-SS-4_14.75-15.25	11/5/2019	14.75	15.25	160	180	3800	3500	67	< 68	120	160	54	< 68	610	660
	SB-SS-4_16.75-17.25	11/5/2019	16.75	17.25	48	53	430	370	31	< 49	41	51	23	< 49	330	330
SB-SS-5	SB-SS-5_1.5-2	11/6/2019	1.5	2	< 330	500	3100	4100	570	280	< 220	220	410	280	600	760
	SB-SS-5_3.5-4	11/6/2019	3.5	4	3100	440	65000	6000	1500	150	3000	360	980	83	8900	1300
	SB-SS-5_5.5-6	11/6/2019	5.5	6	500	420	37000	33000	450	100	450	440	300	71	1200	1000
	SB-SS-5_7.5-8	11/6/2019	7.5	8	410	600	69000	77000	350	130	340	1000	240	73	1100	1900
	SB-SS-5_9.5-10	11/6/2019	9.5	10	890	1100	100000	96000	380	160	800	1900	250	160	1200	1300
	SB-SS-5_11.5-12	11/6/2019	11.5	12	1600	1600	9500	9600	150	140	440	760	120	130	1800	1900
	SB-SS-5_14.25-14.75	11/6/2019	14.25	14.75	730	750	3400	3400	210	210	280	380	190	160	1500	1700
	SB-SS-5_16.25-16.75	11/6/2019	16.25	16.75	340	400	6400	6600	81	70	320	460	76	< 57	950	1100
SB-SS-6	SB-SS-6_1.5-2	11/7/2019	1.5	2	< 310	< 53	200	85	370	< 53	< 200	78	240	< 53	480	450
	SB-SS-6_3.5-4	11/7/2019	3.5	4	< 300	< 52	< 200	< 52	310	< 52	< 200	< 52	190	< 52	93	110
	SB-SS-6_5.5-6	11/7/2019	5.5	6	< 300	< 52	270	< 52	400	< 52	1500	190	320	< 52	1300	150
	SB-SS-6_7.5-8	11/7/2019	7.5	8	< 290	< 49	< 190	< 49	300	< 49	< 190	89	< 170	< 49	340	290
	SB-SS-6_9.5-10	11/7/2019	9.5	10	< 300	< 51	230	< 51	320	< 51	< 190	100	190	< 51	490	530
	SB-SS-6_11.5-12	11/7/2019	11.5	12	< 37 [< 43]	< 63 [< 74]	< 24 [< 28]	< 63 [< 74]	< 37 [56]	< 63 [< 74]	37 [< 28]	< 63 [< 74]	31 [53]	< 63 [< 74]	220 [420]	230 [420]
	SB-SS-6_14.25-14.75	11/7/2019	14.25	14.75	< 25	< 42	< 16	< 42	27	< 42	150	150	37	< 42	570	620
	SB-SS-6_16.25-16.75	11/7/2019	16.25	16.75	< 26	< 46	< 17	< 46	49	< 46	36	49	31	< 46	200	190

Table 5.6. Soil Analytical Results for the PFSA Mobile Lab-Based Real-Time Method Pilot Study Secondary Constituents of Interest (Continued)

Location ID	Arcadis Sample ID	Collection Date	Start Depth (ft)	End Depth (ft)	SECONDARY CONSTITUENTS OF INTEREST									
					Br-PFHxS		Total PFHxS		PFNA		PFPeA		PFPeS	
					DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method
TRANSECT 1														
SB-F1-3	SB-F1-3_8.5-9	11/13/2019	8.5	9	< 8.1	< 23	< 16	< 64	< 13	< 53	25	< 53	< 20	< 53
	SB-F1-3_10.25-10.75	11/13/2019	10.25	10.75	< 9.3	< 27	< 18	< 74	20	< 60	39	110	< 23	< 60
	SB-F1-3_12-12.5	11/13/2019	12	12.5	< 9.8	< 28	< 19	< 78	< 15	< 64	< 25	< 64	< 24	< 64
SB-F1-11	SB-F1-11_12.5-13	11/14/2019	12.5	13	< 7.4	< 21	< 14	< 59	< 12	< 48	40	< 48	< 18	< 48
	SB-F1-11_14.25-14.75	11/14/2019	14.25	14.75	< 8.2	< 23	< 16	< 65	< 13	< 53	37	< 53	< 20	< 53
	SB-F1-11_16-16.5	11/14/2019	16	16.5	< 9.5	< 27	< 18	< 75	< 15	< 61	40	< 61	< 23	< 61
TRANSECT 2														
SB-F2-1	SB-F2-1_13.5-14	11/14/2019	13.5	14	< 6.2 [< 9.2]	< 18 [< 26]	24 [20]	< 49 [< 73]	< 9.6 [< 14]	< 40 [< 60]	< 16 [41]	< 40 [< 60]	< 15 [< 23]	< 40 [< 60]
	SB-F2-1_15.25-15.75	11/14/2019	15.25	15.75	< 9.5	< 27	120	120	< 15	< 62	59	< 62	< 23	< 62
	SB-F2-1_17-18	11/14/2019	17	18	< 81	NA	< 160	NA	< 130	NA	< 210	NA	< 200	NA
SB-F2-2	SB-F2-2_13.5-14	11/14/2019	13.5	14	< 7.8	< 22	< 15	< 62	< 12	< 50	< 20	< 50	< 19	< 50
	SB-F2-2_15-15.5	11/14/2019	15	15.5	< 8.8	< 25	38	< 70	< 14	< 57	30	74	< 22	< 57
	SB-F2-2_17-18	11/14/2019	17	18	46 [< 6.7]	51 [< 19]	410 [15]	450 [< 53]	26 [< 11]	< 48 [< 44]	39 [32]	< 48 [< 44]	< 18 [< 17]	< 48 [< 44]
TRANSECT 3														
SB-F3-2	SB-F3-2_7.5-8	11/14/2019	7.5	8	< 9	< 26	< 18	< 72	< 14	< 59	28	< 59	< 22	< 59
	SB-F3-2_9.25-9.75	11/14/2019	9.25	9.75	< 9.7	< 28	< 19	< 76	< 15	< 63	36	< 63	< 24	< 63
	SB-F3-2_11-11.5	11/14/2019	11	11.5	< 8.4	< 24	< 16	< 67	< 13	< 55	< 22	< 55	< 21	< 55
	SB-F3-2_54.5-55	11/14/2019	54.5	55	< 9.5	< 27	35	< 75	< 15	< 62	< 25	93	< 23	< 62
	SB-F3-2_56-56.5	11/14/2019	56	56.5	< 13	< 36	< 25	< 100	< 20	< 82	< 33	120	< 31	< 82
	SB-F3-2_59.5-60	11/14/2019	59.5	60	< 11	< 31	< 21	< 85	< 17	< 70	< 28	< 70	< 26	< 70
SB-F3-9	SB-F3-9_8.5-9	11/14/2019	8.5	9	< 8.4	< 24	< 16	< 67	< 13	< 55	28	< 55	< 21	< 55
	SB-F3-9_10.75-11.25	11/14/2019	10.75	11.25	< 7	< 20	< 14	< 55	< 11	< 45	32	< 45	< 17	< 45
	SB-F3-9_12.5-13	11/14/2019	12.5	13	< 8.7	< 25	< 17	< 69	< 14	< 57	36	< 57	< 22	< 57
PRIMARY SOURCE														
SB-PS-1	SB-PS-1_12.5-13	10/21/2019	12.5	13	< 84	51	290	400	180	< 54	300	< 54	< 210	< 54
	SB-PS-1_14.7-15.2	10/21/2019	14.7	15.2	< 88	< 25	< 170	84	< 140	< 57	620	< 57	< 220	< 57
	SB-PS-1_16.5-17	10/21/2019	16.5	17	370	320	3000	2500	210	< 62	870	300	< 240	120
SB-PS-2	SB-PS-2_12.5-13	10/21/2019	12.5	13	< 76	53	< 150	290	< 120	< 50	< 200	< 50	< 190	< 50
	SB-PS-2_14.7-15.2	10/21/2019	14.7	15.2	< 71	< 20	< 140	89	< 110	< 46	450	< 46	< 180	< 46
	SB-PS-2_16.5-17	10/21/2019	16.5	17	120	< 25	450	< 69	< 130	< 56	590	< 56	< 210	< 56
SB-PS-3	SB-PS-3_12.5-13	10/21/2019	12.5	13	< 81	40	540	510	180	67	460	< 53	< 200	< 53
	SB-PS-3_14.5-15	10/21/2019	14.5	15	< 81	< 23	< 160	< 64	< 130	< 52	710	< 52	< 200	< 52
	SB-PS-3_16.5-17	10/21/2019	16.5	17	< 83	< 24	< 160	< 66	< 130	< 54	270	< 54	< 200	< 54
SB-PS-4	SB-PS-4_11-11.5	10/22/2019	11	11.5	< 63	< 18	180	120	< 99	< 41	560	< 41	< 160	< 41
	SB-PS-4_13.2-13.7	10/22/2019	13.2	13.7	< 90	< 26	< 180	120	< 140	< 59	330	< 59	< 220	< 59
	SB-PS-4_15.5-16	10/22/2019	15.5	16	< 92	82	< 180	190	< 140	< 59	670	< 59	< 230	< 59
SB-PS-5	SB-PS-5_12-12.5	10/22/2019	12	12.5	< 75	< 21	< 150	< 59	150	< 49	350	< 49	< 180	< 49
	SB-PS-5_14-14.5	10/22/2019	14	14.5	< 94	66	470	640	< 150	< 61	800	< 61	< 230	< 61
	SB-PS-5_15.5-16	10/22/2019	15.5	16	< 81	28	270	220	< 130	< 53	570	< 53	< 200	< 53
SB-PS-6	SB-PS-6_12-12.5	10/22/2019	12	12.5	< 78 [< 85]	< 22 [57]	< 150 [290]	< 62 [490]	150 [130]	< 50 [< 55]	550 [390]	< 50 [< 55]	< 190 [< 210]	< 50 [< 55]
	SB-PS-6_14.2-14.7	10/22/2019	14.2	14.7	< 79	< 23	160	< 63	< 120	< 51	610	< 51	< 190	< 51
	SB-PS-6_15.5-16	10/22/2019	15.5	16	< 82	< 23	< 160	150	< 130	< 53	420	< 53	< 200	< 53
SECONDARY SOURCE														
SB-SS-1	SB-SS-1_2.5-3	11/4/2019	2.5	3	< 79	< 23	< 150	< 63	< 120	< 51	1600	< 51	< 200	< 51
	SB-SS-1_4.5-5	11/4/2019	4.5	5	< 79	< 22	< 150	< 62	< 120	< 51	< 200	56	< 190	< 51
	SB-SS-1_6.5-7	11/4/2019	6.5	7	< 77	< 22	< 150	< 61	< 120	< 50	< 200	< 50	< 190	< 50
	SB-SS-1_8.5-9	11/4/2019	8.5	9	< 82	< 23	< 160	73	< 130	< 53	< 210	< 53	< 200	< 53
	SB-SS-1_10.5-11	11/4/2019	10.5	11	< 83	< 24	200	91	< 130	< 54	< 220	< 54	< 200	< 54
	SB-SS-1_12.75-13.25	11/4/2019	12.75	13.25	< 78	< 22	< 150	< 62	< 120	< 51	2500	< 51	< 190	< 51
	SB-SS-1_14.75-15.25	11/4/2019	14.75	15.25	34	33	260	230	24	< 53	36	< 53	< 20	< 53
SB-SS-2	SB-SS-2_1.5-2	11/4/2019	1.5	2	< 84	< 24	< 160	< 67	< 130	< 55	3100	260	< 210	< 55
	SB-SS-2_3.5-4	11/4/2019	3.5	4	< 79	< 23	< 150	< 63	< 120	51	2600	< 51	< 200	< 51
	SB-SS-2_5.5-6	11/4/2019	5.5	6	< 78	< 22	< 150	< 62	< 120	< 50	< 200	< 50	< 190	< 50
	SB-SS-2_7.5-8	11/4/2019	7.5	8	< 83	< 24	< 160	230	< 130	< 54	3000	< 54	< 200	< 54
	SB-SS-2_9.5-10	11/4/2019	9.5	10	< 75	< 21	< 150	< 59	< 120	< 49	< 190	< 49	< 180	< 49
	SB-SS-2_11.5-12	11/4/2019	11.5	12	< 81	< 23	170	140	< 130	< 52	3000	< 52	< 200	< 52
	SB-SS-2_13.75-14.25	11/4/2019	13.75	14.25	55	45	410	400	15	< 41	27	< 41	24	< 41
	SB-SS-2_15.5-16.5	11/4/2019	15.5	16.5	9.2	< 22	120	120	< 12	< 50	47	< 50	< 19	< 50
SB-SS-3	SB-SS-3_1.5-2	11/5/2019	1.5	2	< 77	< 22	< 150	< 61	< 120	< 50	< 200	< 50	< 190	< 50
	SB-SS-3_3.5-4	11/5/2019	3.5	4	< 79	< 23	< 150	< 63	< 120	78	2700	< 51	< 200	< 51
	SB-SS-3_5.5-6	11/5/2019	5.5	6	< 83	< 24	< 160	< 66	< 130	110	2800	< 54	< 200	< 54
	SB-SS-3_7.5-8	11/5/2019	7.5	8	< 79	< 23	230	170	< 120	73	3200	< 51	< 200	< 51
	SB-SS-3_9.5-10	11/5/2019	9.5	10	< 83	< 24	< 160	140	< 130	< 54	3300	< 54	< 210	< 54
	SB-SS-3_11.5-12	11/5/2019	11.5	12	< 8.4	< 24	130	150	< 13	< 55	22	< 55	< 21	< 55
	SB-SS-3_13.75-14.25	11/5/2019	13.75	14.25	8.4	< 21	130	120	< 12	< 49	38	< 49	< 18	< 49

Location ID	Arcadis Sample ID	Collection Date	Start Depth (ft)	End Depth (ft)	SECONDARY CONSTITUENTS OF INTEREST									
					Br-PFHxS		Total PFHxS		PFNA		PFPeA		PFPeS	
					DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method	DoD ELAP Method	Accelerated Method
	SB-SS-3_15.75-16.25	11/5/2019	15.75	16.25	< 8.9	< 25	60	< 70	15	< 58	41	< 58	< 22	< 58
SB-SS-4	SB-SS-4_2.5-3	11/5/2019	2.5	3	130	79	990	870	520	340	650	560	< 190	< 51
	SB-SS-4_4.5-5	11/5/2019	4.5	5	< 81	40	650	630	600	520	590	< 53	< 200	< 53
	SB-SS-4_6.5-7	11/5/2019	6.5	7	< 83	69	850	800	260	200	230	< 54	< 210	< 54
	SB-SS-4_8.5-9	11/5/2019	8.5	9	150	110	1100	1100	330	260	670	63	< 200	< 51
	SB-SS-4_10.5-11	11/5/2019	10.5	11	< 81	40	480	390	< 130	< 53	< 210	< 53	< 200	< 53
	SB-SS-4_12.5-13	11/5/2019	12.5	13	55	65	420	450	33	< 64	37	< 64	< 24	< 64
	SB-SS-4_14.75-15.25	11/5/2019	14.75	15.25	83	70	700	730	210	220	54	< 68	< 26	< 68
	SB-SS-4_16.75-17.25	11/5/2019	16.75	17.25	< 7.6	40	330	370	56	65	31	< 49	< 19	< 49
SB-SS-5	SB-SS-5_1.5-2	11/6/2019	1.5	2	120	120	720	880	2400	2300	570	760	< 220	< 57
	SB-SS-5_3.5-4	11/6/2019	3.5	4	470	93	9400	1400	8500	800	780	120	240	< 51
	SB-SS-5_5.5-6	11/6/2019	5.5	6	160	92	1400	1100	1500	1200	260	98	< 210	< 54
	SB-SS-5_7.5-8	11/6/2019	7.5	8	< 75	170	1200	2000	1300	1500	< 200	95	< 190	< 49
	SB-SS-5_9.5-10	11/6/2019	9.5	10	130	150	1300	1500	1800	1600	560	79	< 190	< 50
	SB-SS-5_11.5-12	11/6/2019	11.5	12	230	250	2100	2100	450	450	72	< 61	100	92
	SB-SS-5_14.25-14.75	11/6/2019	14.25	14.75	200	220	1700	1900	260	280	140	150	97	< 68
	SB-SS-5_16.25-16.75	11/6/2019	16.25	16.75	130	130	1100	1300	450	450	83	64	42	< 57
SB-SS-6	SB-SS-6_1.5-2	11/7/2019	1.5	2	< 82	58	480	510	260	120	270	490	< 200	< 53
	SB-SS-6_3.5-4	11/7/2019	3.5	4	< 79	< 23	< 150	130	170	60	220	< 52	< 200	< 52
	SB-SS-6_5.5-6	11/7/2019	5.5	6	120	< 23	1400	160	2500	210	210	270	< 200	< 52
	SB-SS-6_7.5-8	11/7/2019	7.5	8	< 76	< 22	410	300	170	94	430	< 49	< 190	< 49
	SB-SS-6_9.5-10	11/7/2019	9.5	10	< 79	38	490	570	140	79	< 200	< 51	< 190	< 51
	SB-SS-6_11.5-12	11/7/2019	11.5	12	< 9.7 [56]	< 28 [53]	220 [480]	240 [470]	43 [110]	< 63 [100]	47 [73]	< 63 [370]	< 24 [35]	< 63 [< 74]
	SB-SS-6_14.25-14.75	11/7/2019	14.25	14.75	68	79	640	700	110	100	51	51	28	< 42
	SB-SS-6_16.25-16.75	11/7/2019	16.25	16.75	21	< 20	220	210	16	< 46	41	< 46	< 17	< 46

Abbreviations:

DoD ELAP = Department of Defense Environmental Laboratory Accreditation Program ft = feet

Notes:

1. Soil analytical results are in units nanograms per kilogram (ng/kg).
2. Method Detection Limits (MDLs) are shown for DoD ELAP Method non-detects and Limits of Quantitation (LOQ) are shown for Accelerated Method non-detects.
3. Accelerated Method data are unavailable for Arcadis Sample ID SB-F2-1_17-18 due to sample handling errors at laboratory.
4. Field duplicate analytical results are presented in brackets.

Building 1160: The highest PFOS concentrations in soil were observed in vadose zone and capillary fringe soils in soil borings SS-4, SS-5, and SS-6, located on the west side of Building 1160 in the area associated with former fire truck parking. The highest concentrations of PFOS were observed in vadose zone soils; up to 560,000 nanograms per kilogram (ng/kg) at depths of 5.5 to 6 feet bgs at boring SS-6. Elevated PFOS was also observed at the capillary fringe and just below the water table at total concentrations (saturated soil) up to 95,000 ng/kg at boring SS-5. The PFOA concentrations were typically two to three orders of magnitude lower than PFOS concentrations at Building 1160, with a maximum concentration in soil of 9,100 ng/kg detected at a depth of 3.5 to 4 feet bgs at boring SS-5. Concentrations of both PFOS and PFOA are significantly lower in soils to the east of Building 1160.

As expected, concentrations in groundwater beneath the former fire truck parking area east of Building 1160 were highest at the water table, with PFOS concentrations of 2,432, 833, and 2,130 ng/L at borings SS-4, SS-5, and SS-6, respectively. Groundwater concentrations increase downgradient, with PFOS at concentrations up to 31,000 ng/L observed at Transect 2 located 250 feet southeast of the fire truck parking area. This sample result represents the core of the plume originating near Building 1160 and is detected again at Transect 1, 500 feet further to the southeast, at a concentration of 30,000 ng/L.

Building 1194/95: The primary borings at Building 1194/95 were completed downgradient of the reported fire truck parking area to the east/southeast of Building 1195. PFOS was detected in saturated soil at a maximum concentration of 66,000 ng/kg just below the water table (16.5 to 17 feet bgs) at soil boring PS-1. PFOA was not detected in soils at Building 1194/95. Shallow groundwater sample concentrations east of Building 1194/95 indicate PFOS concentrations of 7,200, 9,600, and 4,500 ng/L at borings PS-1, PS-2, and PS-3, respectively. Concentrations of PFOA in groundwater were an order of magnitude lower, with corresponding concentrations of 130, 110, and 170 ng/L, respectively. As discussed further below, a second groundwater plume was observed along Transects 1, 2, and 3, with concentrations of PFOS up to 10,000 ng/L, likely attributed to the Building 1194/95 source area.

5.3.1 Lysimeter Pore-Water and SPLP Sampling

After completing the source characterization, ceramic cup suction lysimeters (Soil Moisture Equipment Corporation 24-inch pressure/vacuum soil water samplers equipped with two bar ceramic cups) were installed in the vadose zone at Building 1160 to enable collection of pore-water samples for PFAS analysis. Suction lysimeters collect pore water from unsaturated soil. After installation below ground level, vacuum is applied to the lysimeter through tubing leading from the lysimeter to the ground surface. The negative air pressure created inside the lysimeter draws pore water into the lysimeter through the porous section of the lysimeter. The pore water is transported to the surface by applying positive pressure to the lysimeter through a second tube.

The relative mass loading at the source compared to the downgradient mass flux provides a means of evaluating source strength and plume maturity. Higher relative mass loading at the source implies a significant, ongoing source, whereas reduced mass loading implies a depleted source. The comparison can be used to prioritize remediation and focus efforts on source areas with the highest ongoing mass discharge.

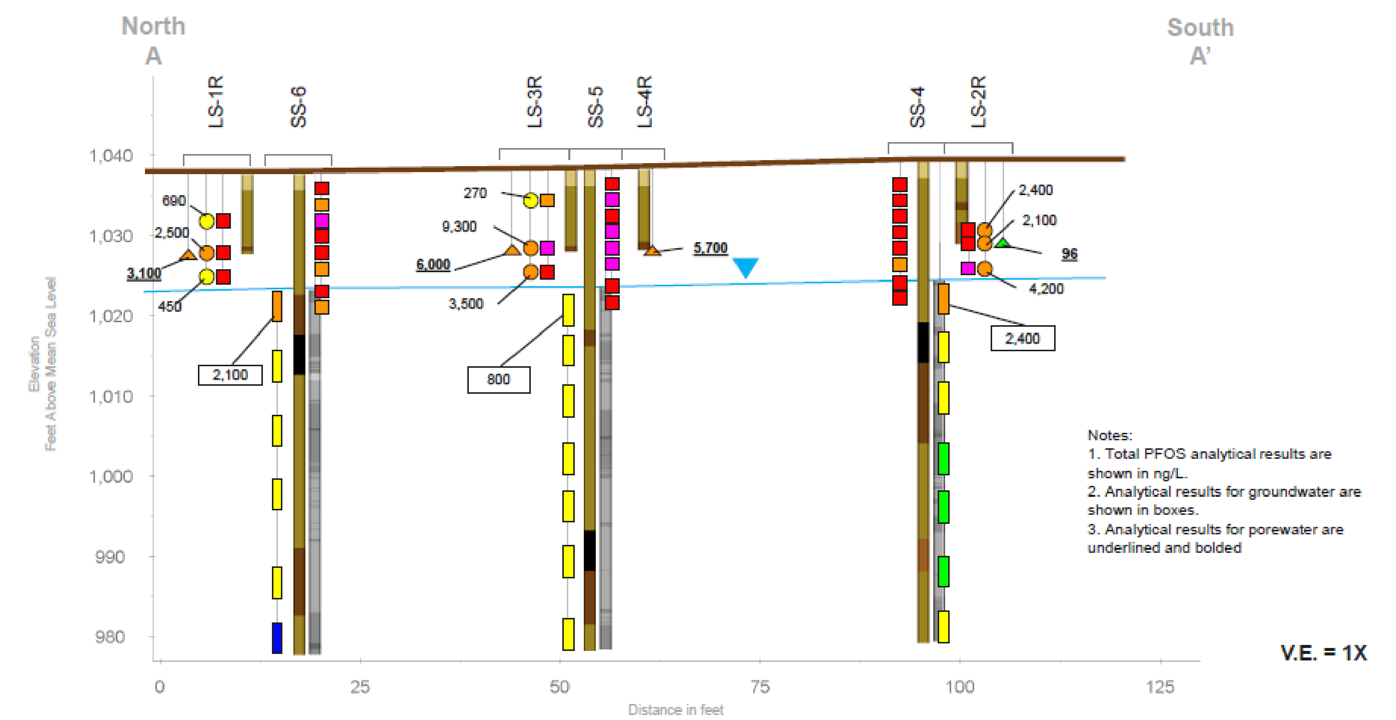
Four ceramic cup suction lysimeters were installed via hand auger on November 26, 2019 adjacent to borings SS-4, SS-5, and SS-6, west of Building 1160 (**Figure 5-1**). Lysimeters were placed below the highest soil analytical results and below the frost line. Lysimeter intakes were installed at depth of approximately 10 feet bgs; above the water table but below the highest concentrations of PFAS observed in vadose zone soil. The lysimeters were installed following the manufacturer's recommendations, which included pressure-testing each assembly before installation using a silica flour slurry to fill the annular space around the ceramic cup and vacuum testing each lysimeter following installation. Vacuum and sample tubing were capped, and flush-mount manhole covers were installed for protection.

Due to the dry, permeable nature of the vadose zone at the site, precipitation at the site infiltrates quickly, leading to a low retention time in the vadose zone, drying of the silica slurry and ceramic cups, and the inability of the lysimeters to hold a vacuum for sample collection. The initial sampling attempt was made on December 20, 2019, during which three of the four lysimeters (LS-2, LS-3, and LS-4) were dry. The remaining lysimeter (LS-1) only yielded a partial sample volume. Arcadis performed the manufacturer's specified reconditioning procedure and attempted to sample the lysimeters again on June 1, 2020 with identical results. After repeated attempts to collect a sample, the lysimeters were pulled, re-installed, allowed to equilibrate, and then a sprinkler was used to simulate a rainfall event. Due to the distribution of the lysimeters and logistics associated with the hoses and sprinklers, the simulated rainfall event was not evenly distributed. The event included 0.5 inch of "rain" over 1.5 hours at LS-1R, 1 inch over 3.5 hours at LS-2R and LS-3R, and 2 inches over a 30-minute period at LS-2R. All four lysimeters were successfully sampled on August 28, 2020. The timeline for lysimeter installation and sampling is provided below:

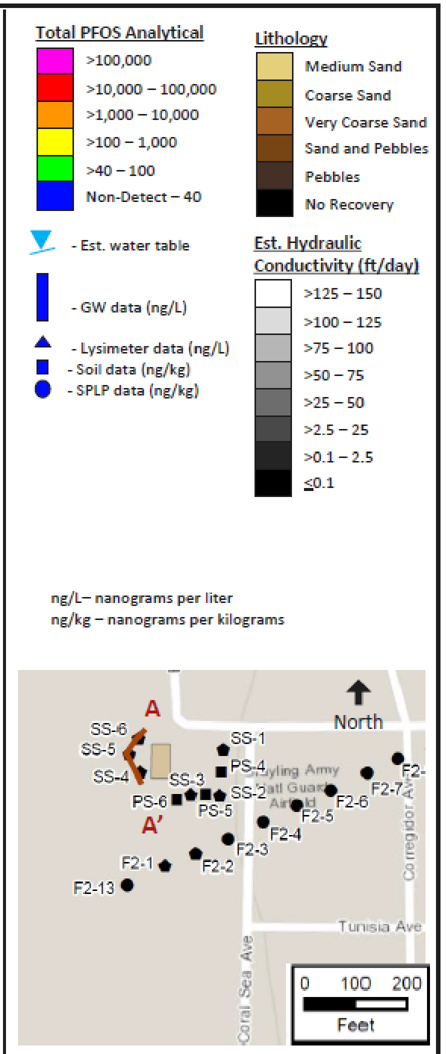
- December 20, 2019: Lysimeter sampling was attempted following a precipitation event; however, sample volume was insufficient for PFAS analysis. It was observed that the surface soils were frozen at that time, which may have prevented infiltration through the vadose zone.
- June 1, 2020: Arcadis returned to the site and successfully obtained a partial sample volume (approximately 100 milliliters [mL]) from lysimeter LS-1; however, the other lysimeters would no longer hold a vacuum, suggesting that the ceramic cup lysimeter had dried out in the interim. Arcadis attempted the manufacture's specified reconditioning procedure to rewet the ceramic cups; however, the lysimeters were still unable to hold a vacuum.
- July 9 and 10, 2020: The reconditioning procedure was attempted a second time, and sampling was attempted unsuccessfully (lysimeters would not hold vacuum).
- August 26 and 27, 2020: Arcadis abandoned all four lysimeters and installed replacements LS-1R, -2R, -3R, and 4R.
- August 28, 2020: Following a simulated rain event, Arcadis was able to collect samples from all four lysimeters.

Following sample collection, the lysimeter samples were analyzed using USEPA Method 537 at Pace Analytical Laboratory in Richmond, Virginia.

During August 2020 reinstallation, additional soil samples were collected at each lysimeter location for SPLP analysis using USEPA Prep Method 1312 and analyzed for PFAS using USEPA Method 537/DoD QSM 5.3 at Pace Analytical Laboratory. The SPLP is designed to simulate leaching conditions associated with infiltration of precipitation through the vadose zone. A summary of the soil, SPLP, groundwater, and lysimeter results is provided as **Figure 5-6** for total PFOS and **Figure 5-7** for PFOA and discussed in **Section 8.2**. The analytical testing reports for the SPLP and lysimeter pore water are presented in **Appendix J**.



Notes:
1. Total PFOS analytical results are shown in ng/L.
2. Analytical results for groundwater are shown in boxes.
3. Analytical results for porewater are underlined and bolded



LS-1R (SS-6)					LS-3R [LS-4R] (SS-5)					LS-2R (SS-4)				
Sample Depth (ft bgs)	Soil (ng/kg)	SPLP (ng/L)	Porewater (ng/L)	Groundwater (ng/L)	Sample Depth (ft bgs)	Soil (ng/kg)	SPLP (ng/L)	Porewater (ng/L)	Groundwater (ng/L)	Sample Depth (ft bgs)	Soil (ng/kg)	SPLP (ng/L)	Porewater (ng/L)	Groundwater (ng/L)
1.5-2	(11,000)				1.5-2	(16,000)				2.5-3	(28,000)			
3.5-4	(3,100)				3.5-4	6,500 (190,000)	270			4.5-5	(83,000)			
5.5-6	11,000 (560,000)	690			5.5-6	(84,000)				6.5-7	(23,000)			
7.5-8	(20,000)				7.5-8	(150,000)				8.5-9	63,000 (87,000)	2,400		
9.5-10	42,000 (24,000)	2,500			9.5-10	230,000 (380,000)	9,300			9.5-10	51,000	2,100		
9.8-10			3,100		9.8-10			6,000 [5,700]		9.8-10			96	
11.5-12	(7,400)				11.5-12	(210,000)				10.5-11	(11,000)			
12.5-13	10,000	450			12.5-13	66,000	3,500			12.5-13	(7,900)			
14.25-14.75	(19,000)				14.25-14.75	(62,000)				13-13.5	110,000	4,200		
14.5-18.5				(2,100)	15.5-19.5				(800)	14.75-15.25	(67,000)			
16.25-16.75	(6,600)				16.25-16.75	(95,000)				15-19				(2,400)
										16.75-17.25	(11,000)			

Notes: 1. Analytical results in parenthesis were collected from the sample locations in parenthesis. 2. Analytical results in brackets were collected from the bracketed sample location.

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CROSS SECTION WITH SUMMARY OF TOTAL PFOS VADOSE SAMPLING RESULTS BUILDING 1160

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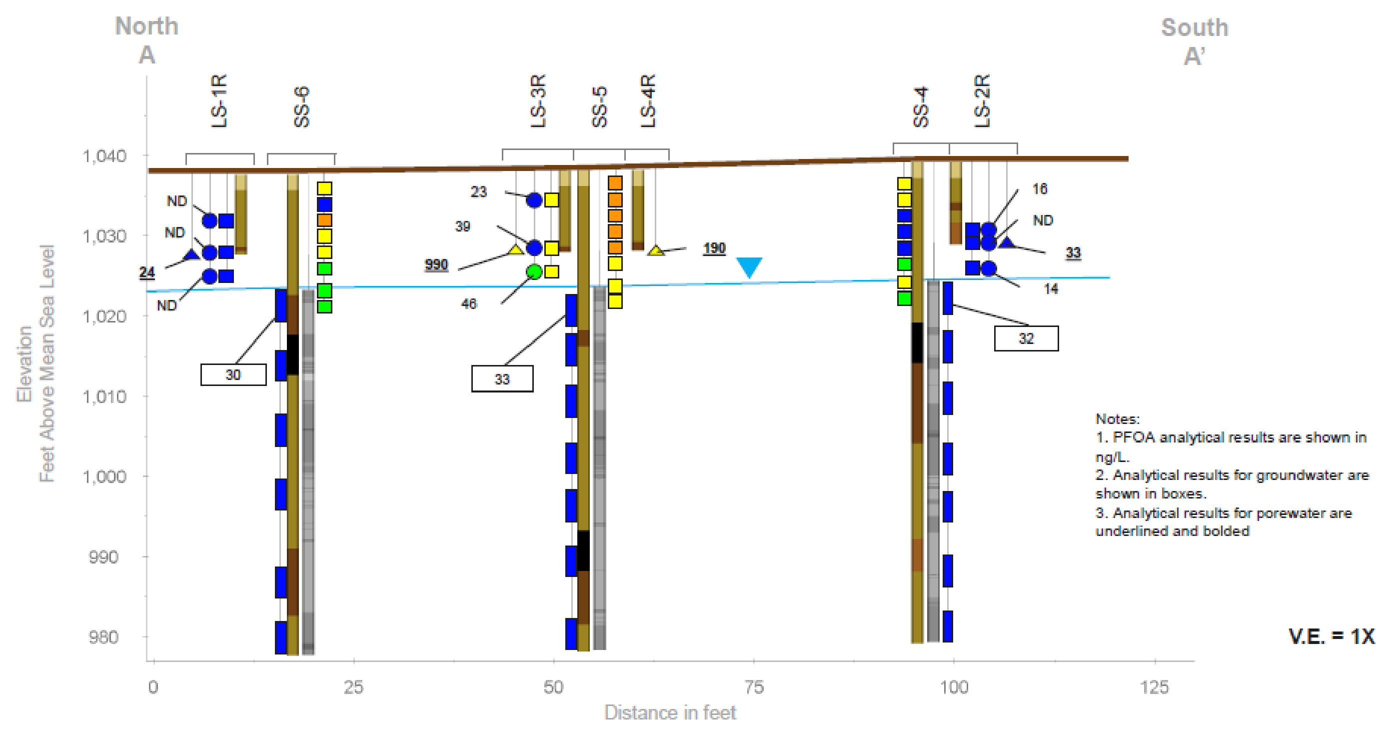
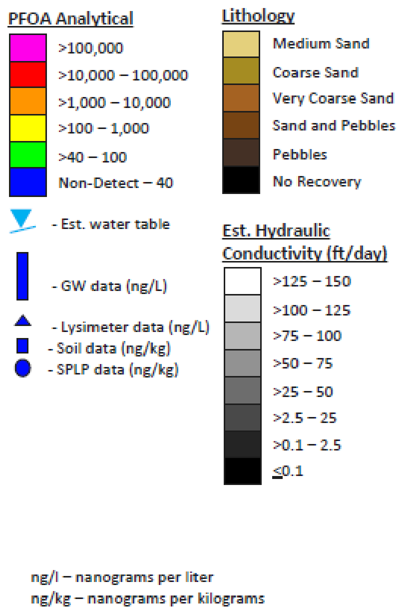
FIGURE
5-6

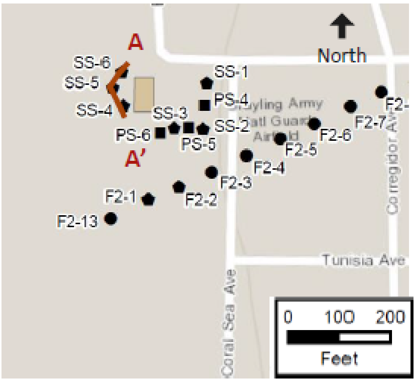
Figure 5-6. Cross Section with Summary of Total PFOS Vadose, Sampling Results Building 1160



Notes:
1. PFOA analytical results are shown in ng/L.
2. Analytical results for groundwater are shown in boxes.
3. Analytical results for porewater are underlined and bolded



ng/l – nanograms per liter
ng/kg – nanograms per kilograms



LS-1R (SB-SS-6)					LS-3R [LS-4R] (SB-SS-5)					LS-2R (SB-SS-4)				
Sample Depth Interval (ft bgs)	Soil (ng/kg)	SPLP (ng/L)	Porewater (ng/L)	Groundwater (ng/L)	Sample Depth Interval (ft bgs)	Soil (ng/kg)	SPLP (ng/L)	Porewater (ng/L)	Groundwater (ng/L)	Sample Depth Interval (ft bgs)	Soil (ng/kg)	SPLP (ng/L)	Porewater (ng/L)	Groundwater (ng/L)
1.5-2	(440)				1.5-2	(1,000)				2.5-3	(560)			
3.5-4	(<420)				3.5-4	710 (9,100)	23			4.5-5	(530)			
5.5-6	<440 (1,100)	<20			5.5-6	(2,700)				6.5-7	(<440)			
7.5-8	(410)				7.5-8	(1,800)				8.5-9	<500 (420)	16		
9.5-10	<500 (420)	<20			9.5-10	920 (1,500)	39			9.5-10	<500	<20		
9.8-10			24		9.8-10			990 [190]		9.8-10			33	
11.5-12	(61)				11.5-12	(740)				10.5-11	(<430)			
12.5-13	<450	<20			12.5-13	(880)	46			12.5-13	(94)			
14.25-14.75	(49)				14.25-14.75	(670)				13-13.5	<480	14		
14.5-18.5				(30)	15.5-19.5				(33)	14.75-15.25	(210)			
16.25-16.75	(42)				16.25-16.75	(370)				15-19				(32)
										16.75-17.25	(67)			

Notes: 1. Analytical results in parenthesis were collected from the sample locations in parenthesis. 2. Analytical results in brackets were collected from the bracketed sample location.

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CROSS SECTION WITH SUMMARY OF PFOA VADOSE SAMPLING RESULTS BUILDING 1160

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FIGURE
5-7

Figure 5-7. Cross Section with Summary of PFOA Vadose, Sampling Results Building 1160

5.4 FLUX TRANSECT VERTICAL AQUIFER PROFILE SAMPLING

The downgradient transects were completed to evaluate PFAS mass flux/mass discharge within the aquifer downgradient of the Building 1160 and Building 1194/95 source areas, progressing to the southeast property boundary and the VAP-27 area. The HPT was advanced at 31 locations along the transects to refusal or to a maximum depth of 60 feet bgs. Additional discussion of the HPT data is provided above in **Section 2.2**. Based on the results of the HPT, VAP sampling intervals were selected biased to more permeable zones identified on the permeability profile. The majority of the soils observed at the site were permeable enough to produce a groundwater sample, except for occasional zones of silty sand and the deeper clayey soils encountered at Transect 3.

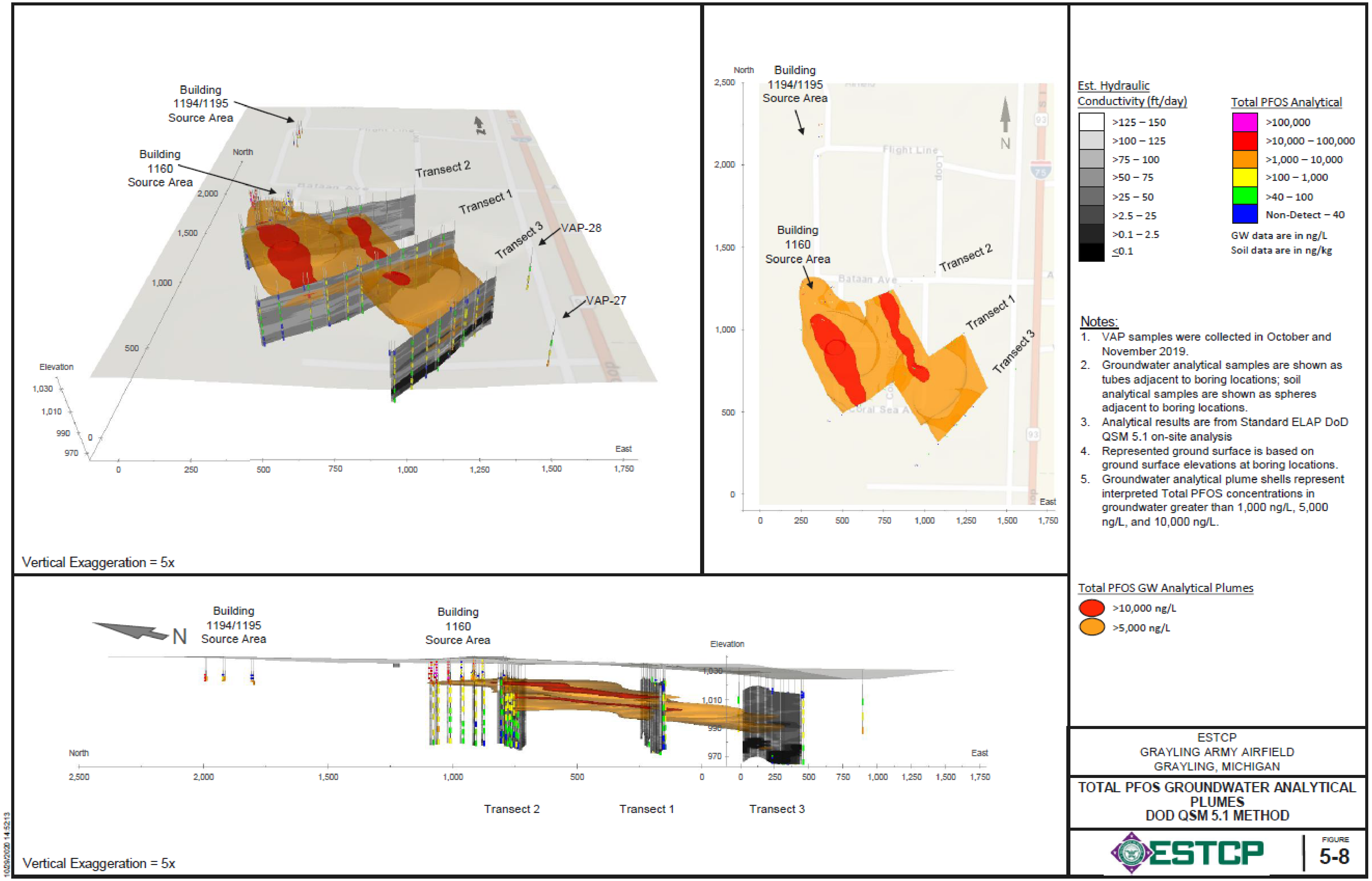
In general, VAP groundwater samples were collected at nominal 8-foot intervals beginning at the water table using direct-push screen point tooling with a 40-inch retractable screen (i.e., screen-point sampler). Top-down sampling methods were used to ensure that samples were representative and to prevent cross-contamination between intervals. Between sampling intervals, the sample tooling was pulled out of the formation, decontaminated at the surface, and then driven to the next sample interval. A peristaltic pump was used to purge the sample interval until it was relatively free of fine-grained sediment, or for a maximum of 60 minutes, and then a sample was collected into a bottle prepared by the mobile laboratory.

The groundwater sampling was adapted during the investigation to focus on the Building 1160 portion of the plume. The analytical results at Transect 1 suggested two plume cores associated with the two source areas (Buildings 1160 and 1194/95). Therefore, to refine the effort, the VAP sampling on Transect 2 (closest to Building 1160) was focused primarily downgradient of Building 1160. In addition, when the mobile laboratory results made clear that the plume originating near Building 1160 extended further south than expected, additional VAP borings were added southwest of Transects 1, 2, and 3 to better capture the lateral extents of Building 1160 impacts. Near the end of the investigation, several VAP borings were added where HPT borings had not been completed to further improve analytical resolution (the HPT had already mobilized off site). A summary of testing completed at each boring location is included as **Figure 5-1**. A 3D rendering of the interpreted PFOS and PFOA groundwater plume is provided as **Figure 5-8** for total PFOS and **Figure 5-9** for PFOA.

The overall orientation of the groundwater plumes in the southwest GAAF was more southerly than expected based on the previously collected data and groundwater flow. Work continued within the time allotted and, although Transect 3 was extended to the southwest, the majority of the impacts identified on Transect 3 are likely associated with Building 1194/95 and/or commingled with the northern portion of the plume emanating near Building 1160. The core of the Building 1160 impacts is likely located further southwest of the limits of Transect 3. The analytical results for each transect are included on the mass flux cross-section figures provided as **Figures 5-10** through **5-12** for total PFOS and **Figures 5-13** through **5-15** for PFOA. Mass flux, mass discharge, and a comparison of the standard and accelerated mobile laboratory methods are discussed further in **Section 8.0**.

Along Transect 2, nearest the source areas, elevated total PFOS concentrations of up to 31,000 ng/L were detected near the water table downgradient of the Building 1160 source area (**Figure 5-10**), and detections of up to 10,000 ng/L at a slightly deeper depth were observed to the northeast downgradient of Building 1194/95. These elevated concentrations are separated by several borings containing PFOS at lower concentrations, suggesting commingling plumes from separate sources. Further downgradient, PFOS concentrations on Transect 1 (**Figure 5-11**) are similar to those observed on Transect 2, with total PFOS concentrations of 30,000 ng/L observed along the core of the plume originating near Building 1160 and concentrations up to 9,800 ng/L observed downgradient of Building 1194/95. As noted above, Transect 3 (**Figure 5-12**) appears to miss the downgradient core of the plume emanating from Building 1160, but concentrations of total PFOS up to 6,600 ng/L are observed associated with the Building 1194/95 plume.

The distribution of the mass along each successive transect suggests that PFAS dives slightly with distance from source areas, either associated with a slight downward gradient or aided by flushing from recharge along the plume length. For example, on Transect 3, PFOS concentrations of up to 4,000 ng/L are observed at depths of 47 to 51 feet bgs, above the less permeable clay.



Notes:

1. VAP samples were collected in October and November 2019.
2. Groundwater analytical samples are shown as tubes adjacent to boring locations; soil analytical samples are shown as spheres adjacent to boring locations.
3. Analytical results are from Standard ELAP DoD QSM 5.1 on-site analysis
4. Represented ground surface is based on ground surface elevations at boring locations.
5. Groundwater analytical plume shells represent interpreted Total PFOS concentrations in groundwater greater than 1,000 ng/L, 5,000 ng/L, and 10,000 ng/L.

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**TOTAL PFOS GROUNDWATER ANALYTICAL PLUMES
DOD QSM 5.1 METHOD**

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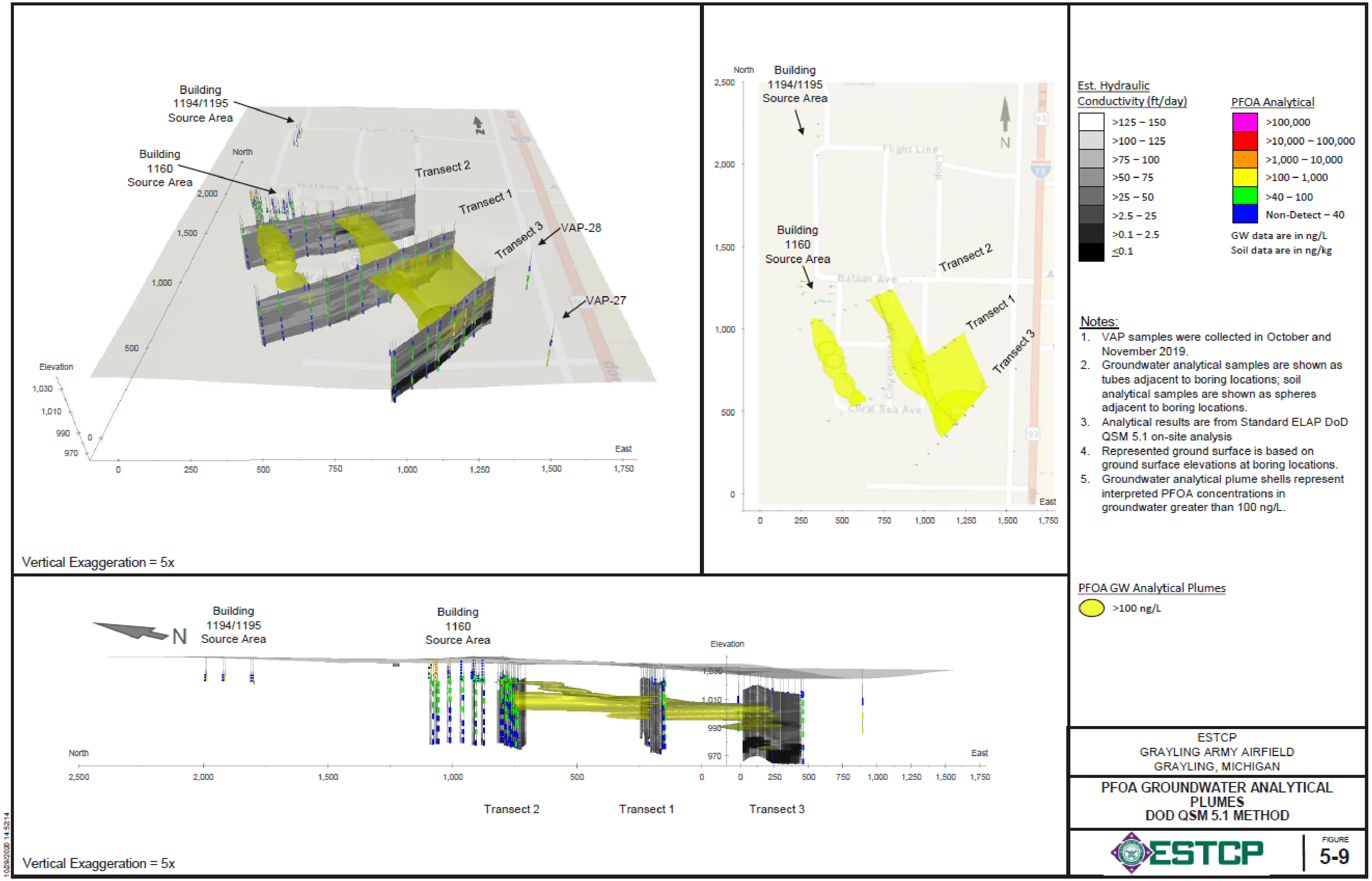
FIGURE
5-8

Figure 5-8. Total, PFOS Groundwater Analytical Plumes DoD QSM 5.1 Method



Est. Hydraulic Conductivity (ft/day)	
⬜	>125 – 150
⬜	>100 – 125
⬜	>75 – 100
⬛	>50 – 75
⬛	>25 – 50
⬛	>2.5 – 25
⬛	>0.1 – 2.5
⬛	≤0.1

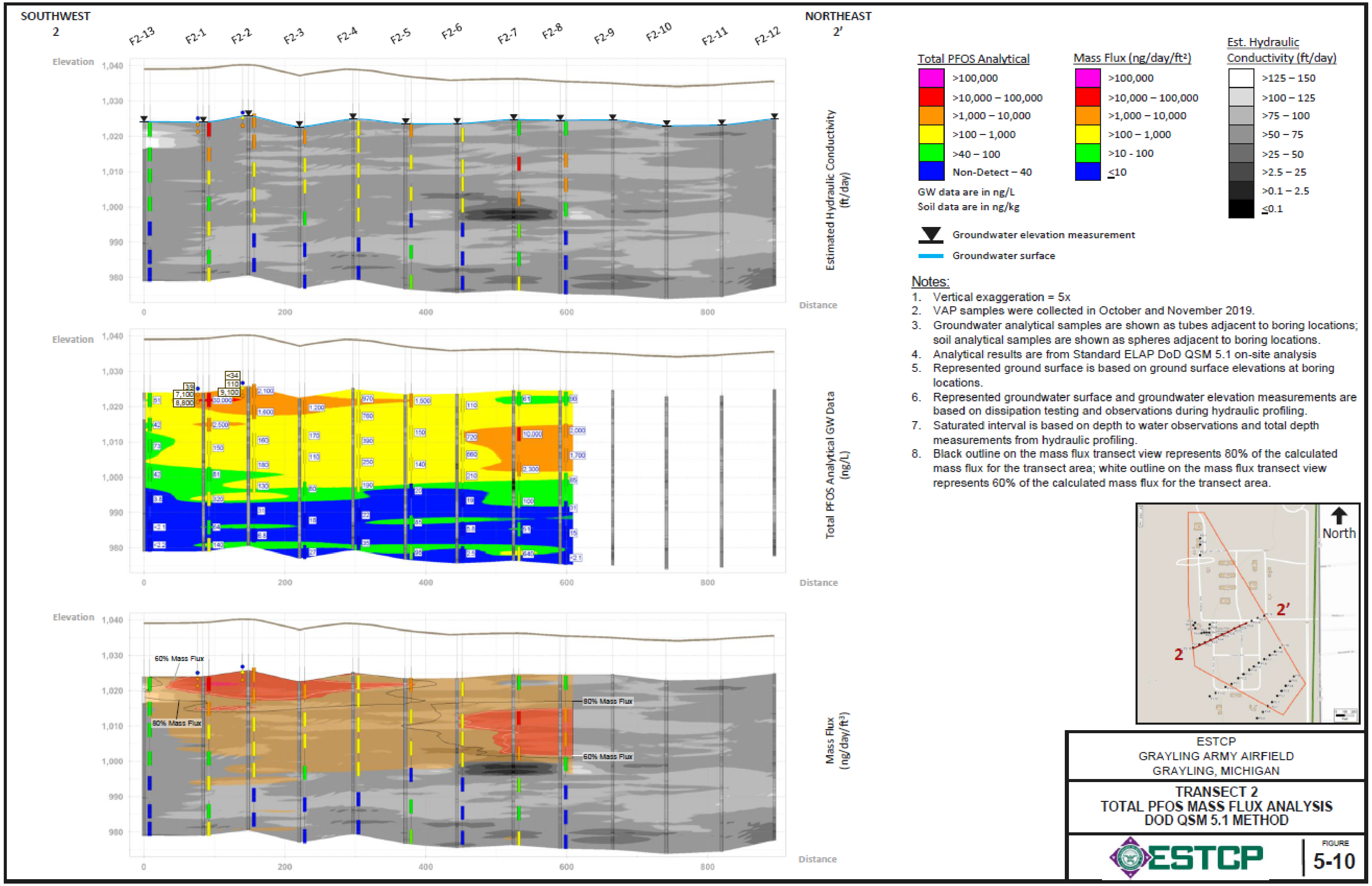
PFOA Analytical	
🟪	>100,000
🟥	>10,000 – 100,000
🟧	>1,000 – 10,000
🟨	>100 – 1,000
🟩	>40 – 100
🟦	Non-Detect – 40

GW data are in ng/L
Soil data are in ng/kg

Notes:

1. VAP samples were collected in October and November 2019.
2. Groundwater analytical samples are shown as tubes adjacent to boring locations; soil analytical samples are shown as spheres adjacent to boring locations.
3. Analytical results are from Standard ELAP DoD QSM 5.1 on-site analysis
4. Represented ground surface is based on ground surface elevations at boring locations.
5. Groundwater analytical plume shells represent interpreted PFOA concentrations in groundwater greater than 100 ng/L.

Figure 5-9. PFOA Groundwater Analytical Plumes DoD QSM 5.1 Method



Total PFOS Analytical

🟪 >100,000
🟥 >10,000 – 100,000
🟧 >1,000 – 10,000
🟨 >100 – 1,000
🟩 >40 – 100
🟦 Non-Detect – 40

GW data are in ng/L
Soil data are in ng/kg

Mass Flux (ng/day/ft²)

🟪 >100,000
🟥 >10,000 – 100,000
🟧 >1,000 – 10,000
🟨 >100 – 1,000
🟩 >10 - 100
🟦 ≤10

Est. Hydraulic Conductivity (ft/day)

⬜ >125 – 150
▨ >100 – 125
▨ >75 – 100
▨ >50 – 75
▨ >25 – 50
▨ >2.5 – 25
▨ >0.1 – 2.5
⬛ ≤0.1

▼ Groundwater elevation measurement
— Groundwater surface

Notes:

1. Vertical exaggeration = 5x
2. VAP samples were collected in October and November 2019.
3. Groundwater analytical samples are shown as tubes adjacent to boring locations; soil analytical samples are shown as spheres adjacent to boring locations.
4. Analytical results are from Standard ELAP DoD QSM 5.1 on-site analysis
5. Represented ground surface is based on ground surface elevations at boring locations.
6. Represented groundwater surface and groundwater elevation measurements are based on dissipation testing and observations during hydraulic profiling.
7. Saturated interval is based on depth to water observations and total depth measurements from hydraulic profiling.
8. Black outline on the mass flux transect view represents 80% of the calculated mass flux for the transect area; white outline on the mass flux transect view represents 60% of the calculated mass flux for the transect area.

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TRANSECT 2
TOTAL PFOS MASS FLUX ANALYSIS
DOD QSM 5.1 METHOD

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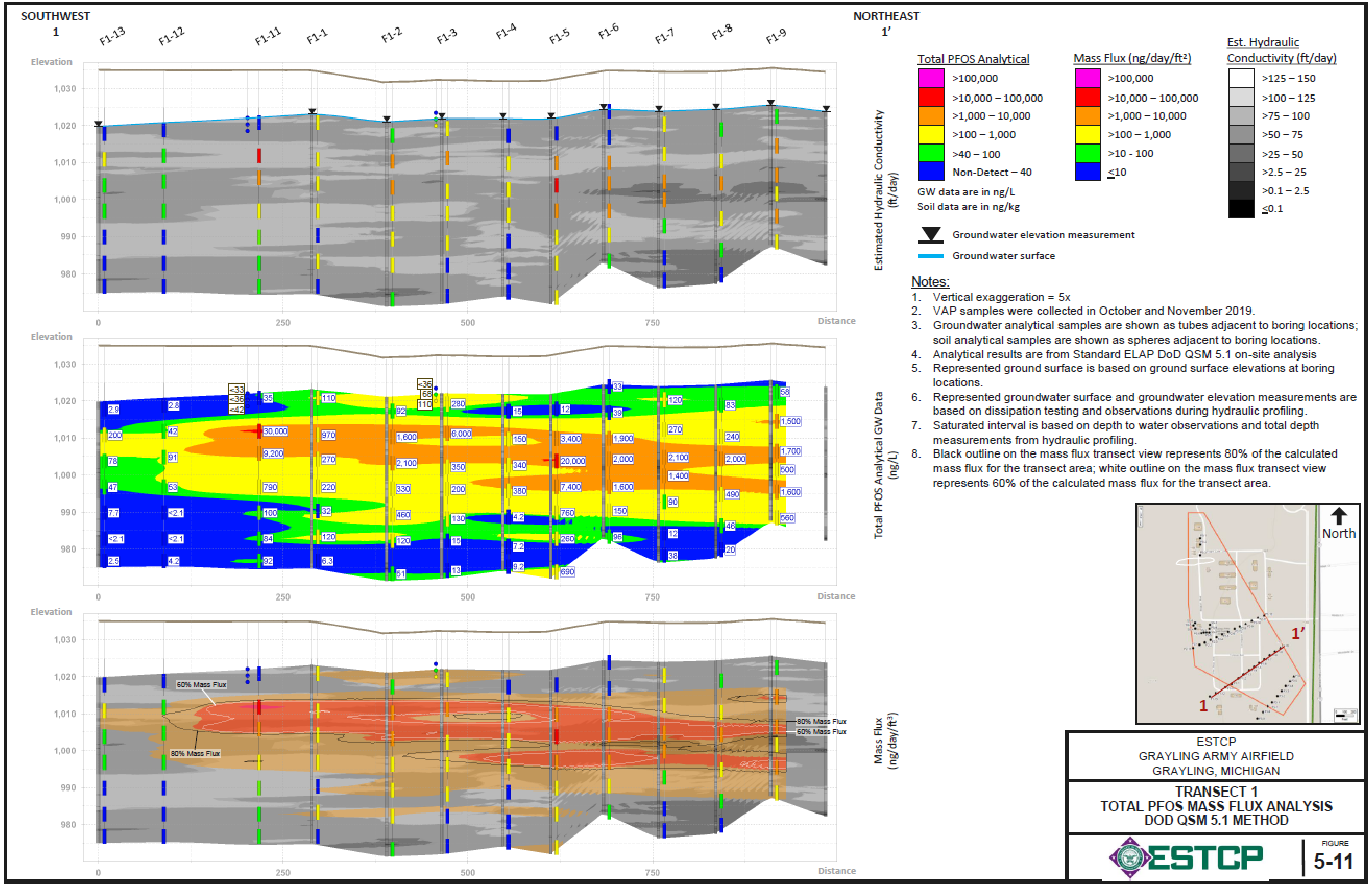
FIGURE
5-10

Figure 5-10. Transect 2 Total PFOS Mass Flux Analysis DoD QSM 5.1 Method



Notes:

1. Vertical exaggeration = 5x
2. VAP samples were collected in October and November 2019.
3. Groundwater analytical samples are shown as tubes adjacent to boring locations; soil analytical samples are shown as spheres adjacent to boring locations.
4. Analytical results are from Standard ELAP DoD QSM 5.1 on-site analysis
5. Represented ground surface is based on ground surface elevations at boring locations.
6. Represented groundwater surface and groundwater elevation measurements are based on dissipation testing and observations during hydraulic profiling.
7. Saturated interval is based on depth to water observations and total depth measurements from hydraulic profiling.
8. Black outline on the mass flux transect view represents 80% of the calculated mass flux for the transect area; white outline on the mass flux transect view represents 60% of the calculated mass flux for the transect area.

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TRANSECT 1
TOTAL PFOS MASS FLUX ANALYSIS
DOD QSM 5.1 METHOD

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FIGURE
5-11

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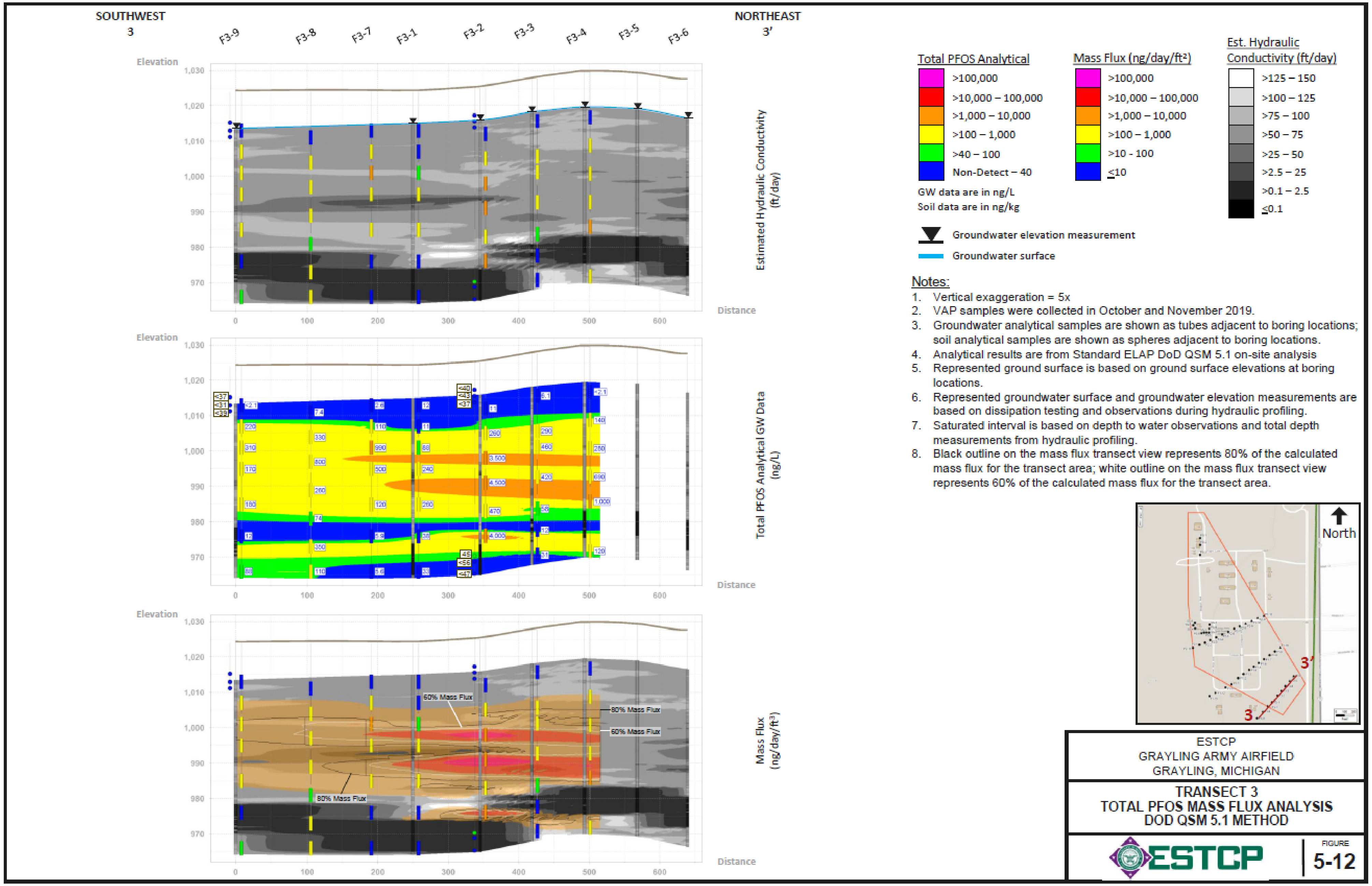
Figure 5-11. Transect 1 Total PFOS Mass Flux Analysis DoD QSM 5.1 Method



Total PFOS Analytical

🟪	>100,000
🟥	>10,000 – 100,000
🟧	>1,000 – 10,000
🟨	>100 – 1,000
🟩	>40 – 100
🟦	Non-Detect – 40

GW data are in ng/L
Soil data are in ng/kg

Mass Flux (ng/day/ft²)

🟪	>100,000
🟥	>10,000 – 100,000
🟧	>1,000 – 10,000
🟨	>100 – 1,000
🟩	>10 - 100
🟦	≤10

Est. Hydraulic Conductivity (ft/day)

⬜	>125 – 150
▨	>100 – 125
▨	>75 – 100
▨	>50 – 75
▨	>25 – 50
▨	>2.5 – 25
⬛	>0.1 – 2.5
⬛	≤0.1

▼ Groundwater elevation measurement
▬ Groundwater surface

Notes:

1. Vertical exaggeration = 5x
2. VAP samples were collected in October and November 2019.
3. Groundwater analytical samples are shown as tubes adjacent to boring locations; soil analytical samples are shown as spheres adjacent to boring locations.
4. Analytical results are from Standard ELAP DoD QSM 5.1 on-site analysis
5. Represented ground surface is based on ground surface elevations at boring locations.
6. Represented groundwater surface and groundwater elevation measurements are based on dissipation testing and observations during hydraulic profiling.
7. Saturated interval is based on depth to water observations and total depth measurements from hydraulic profiling.
8. Black outline on the mass flux transect view represents 80% of the calculated mass flux for the transect area; white outline on the mass flux transect view represents 60% of the calculated mass flux for the transect area.

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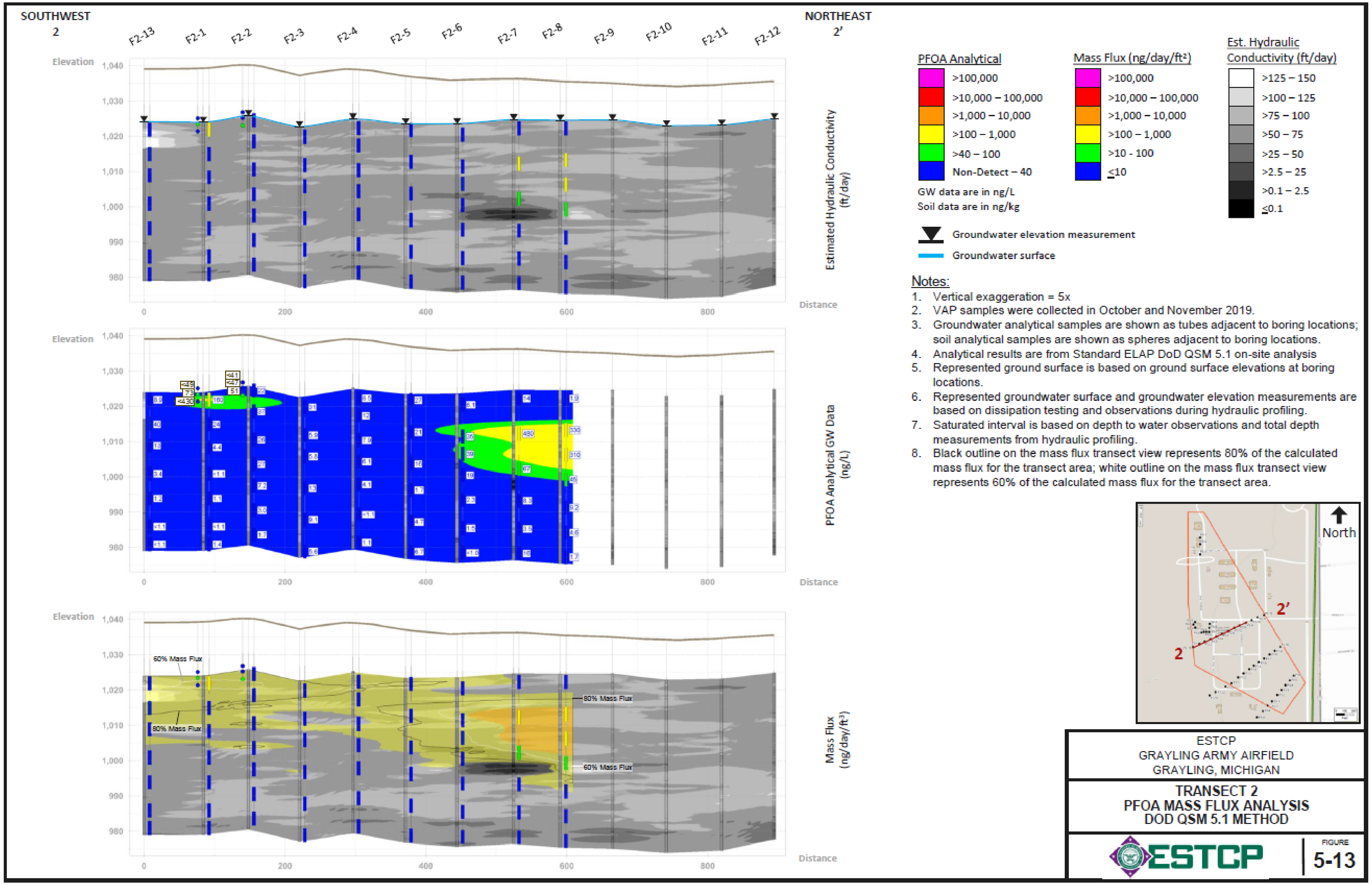
TRANSECT 3
TOTAL PFOS MASS FLUX ANALYSIS
DOD QSM 5.1 METHOD

ESTCP

FIGURE
5-12

11/10/2020 3:51:24

Figure 5-12. Transect 3 Total PFOS Mass Flux Analysis DoD QSM 5.1 Method



Notes:

1. Vertical exaggeration = 5x
2. VAP samples were collected in October and November 2019.
3. Groundwater analytical samples are shown as tubes adjacent to boring locations; soil analytical samples are shown as spheres adjacent to boring locations.
4. Analytical results are from Standard ELAP DoD QSM 5.1 on-site analysis
5. Represented ground surface is based on ground surface elevations at boring locations.
6. Represented groundwater surface and groundwater elevation measurements are based on dissipation testing and observations during hydraulic profiling.
7. Saturated interval is based on depth to water observations and total depth measurements from hydraulic profiling.
8. Black outline on the mass flux transect view represents 80% of the calculated mass flux for the transect area; white outline on the mass flux transect view represents 60% of the calculated mass flux for the transect area.

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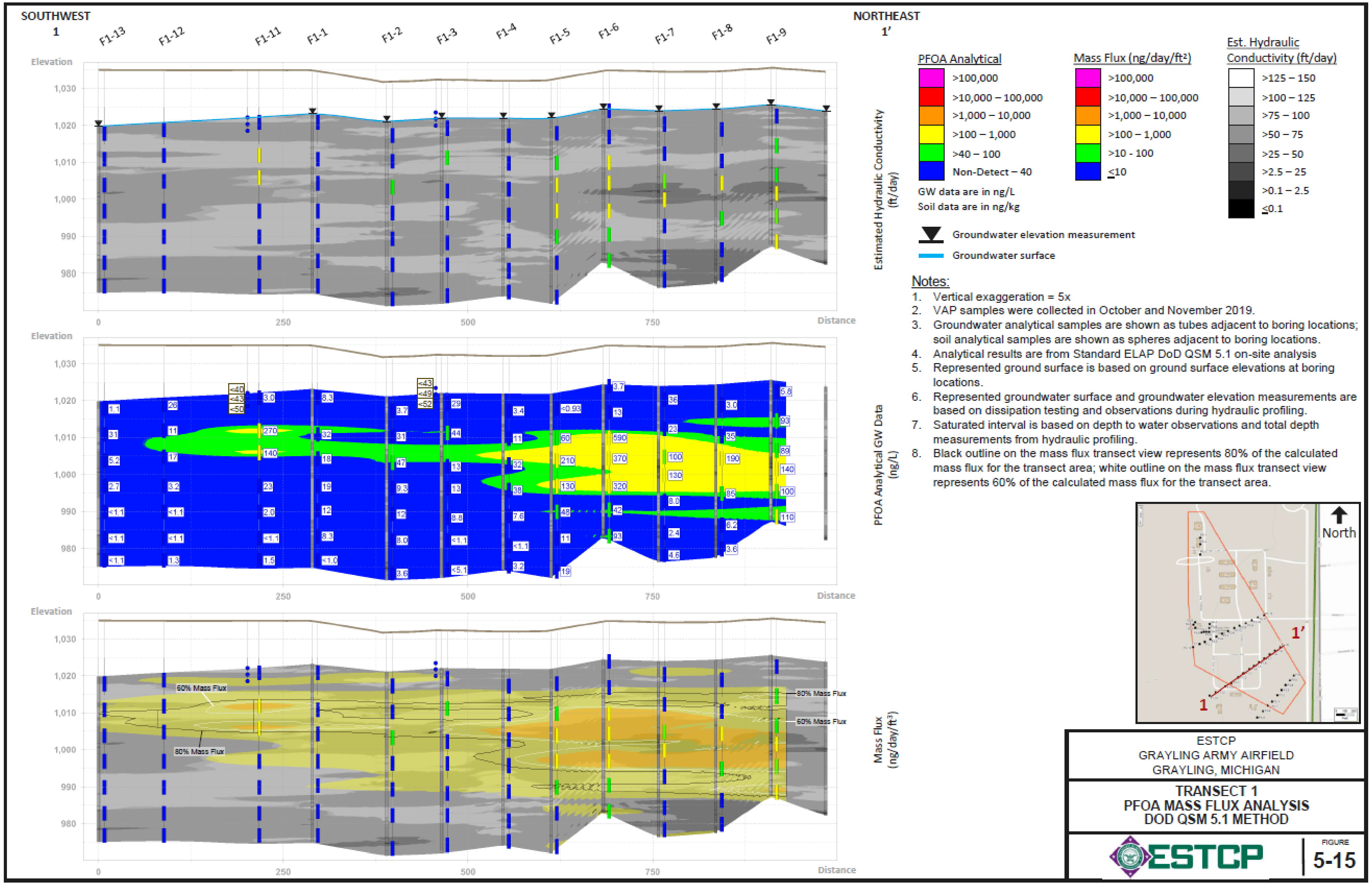
GRAYLING, MICHIGAN

TRANSECT 2
PFOA MASS FLUX ANALYSIS
DOD QSM 5.1 METHOD

ESTCP
FIGURE
5-13

Figure 5-13. Transect 2 PFOA Mass Flux Analysis DoD QSM 5.1 Method



Notes:

1. Vertical exaggeration = 5x
2. VAP samples were collected in October and November 2019.
3. Groundwater analytical samples are shown as tubes adjacent to boring locations; soil analytical samples are shown as spheres adjacent to boring locations.
4. Analytical results are from Standard ELAP DoD QSM 5.1 on-site analysis
5. Represented ground surface is based on ground surface elevations at boring locations.
6. Represented groundwater surface and groundwater elevation measurements are based on dissipation testing and observations during hydraulic profiling.
7. Saturated interval is based on depth to water observations and total depth measurements from hydraulic profiling.
8. Black outline on the mass flux transect view represents 80% of the calculated mass flux for the transect area; white outline on the mass flux transect view represents 60% of the calculated mass flux for the transect area.

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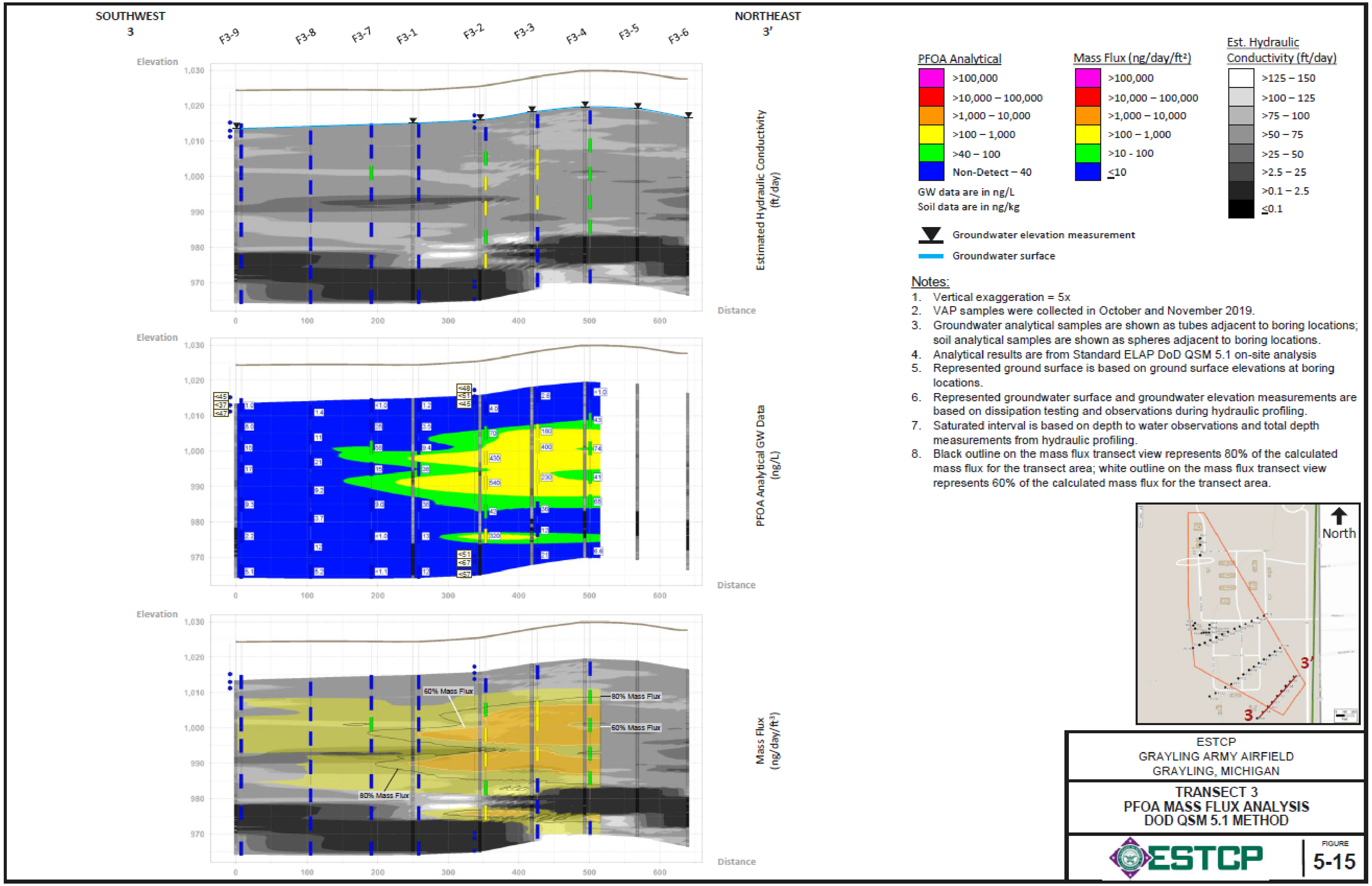
TRANSECT 1
PFOA MASS FLUX ANALYSIS
DOD QSM 5.1 METHOD

ESTCP

FIGURE
5-15

Figure 5-14. Transect 1 PFOA Mass Flux Analysis DoD QSM 5.1 Method



PFOA Analytical
- 🟪 >100,000
- 🟥 >10,000 – 100,000
- 🟧 >1,000 – 10,000
- 🟨 >100 – 1,000
- 🟩 >40 – 100
- 🟦 Non-Detect – 40

GW data are in ng/L
Soil data are in ng/kg

Mass Flux (ng/day/ft²)
- 🟪 >100,000
- 🟥 >10,000 – 100,000
- 🟧 >1,000 – 10,000
- 🟨 >100 – 1,000
- 🟩 >10 - 100
- 🟦 ≤10

Est. Hydraulic Conductivity (ft/day)
- ⬜ >125 – 150
- ▨ >100 – 125
- ▨ >75 – 100
- ▨ >50 – 75
- ▨ >25 – 50
- ▨ >2.5 – 25
- ▨ >0.1 – 2.5
- ⬛ ≤0.1

▼ Groundwater elevation measurement
— Groundwater surface

Notes:
1. Vertical exaggeration = 5x
2. VAP samples were collected in October and November 2019.
3. Groundwater analytical samples are shown as tubes adjacent to boring locations; soil analytical samples are shown as spheres adjacent to boring locations.
4. Analytical results are from Standard ELAP DoD QSM 5.1 on-site analysis
5. Represented ground surface is based on ground surface elevations at boring locations.
6. Represented groundwater surface and groundwater elevation measurements are based on dissipation testing and observations during hydraulic profiling.
7. Saturated interval is based on depth to water observations and total depth measurements from hydraulic profiling.
8. Black outline on the mass flux transect view represents 80% of the calculated mass flux for the transect area; white outline on the mass flux transect view represents 60% of the calculated mass flux for the transect area.

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TRANSECT 3
PFOA MASS FLUX ANALYSIS
DOD QSM 5.1 METHOD

ESTCP

FIGURE
5-15

Figure 5-15. Transect 3 PFOA Mass Flux Analysis DoD QSM 5.1 Method

5.4.1 Downgradient Soil Sampling

Previous studies have suggested that PFAS can accumulate at the capillary fringe due to the hydrophobic tendency of the compounds. To assess this potential at the site, soil samples were collected at the capillary fringe, at the water table, and just below the water table along the core of the plume emanating near Building 1160. Soil sample results are included on the transect **Figures 5-10** through **5-15**. The downgradient soil sample results are also included in **Tables 5-5** and **5-6**.

Detections of PFOS and PFOA in soils along the downgradient transects are limited to saturated samples collected from the water table and just below the water table on Transects 1 and 2. For all downgradient soil sampling locations, the highest PFOS soil concentration (9,100 ng/kg) was detected in the sample collected from soil boring F2-2, approximately 2 feet below the water table, located along the core of the groundwater plume emanating from Building 1160. PFOS and PFOA were not detected in the capillary fringe samples. This may be a result of the shallow, unconfined nature of the water table and sandy soil that promotes vadose flushing during groundwater recharge.

Samples were also collected from the low-permeability clay observed at depth on Transect 3 to assess mass storage in the low-permeability soils. This storage mechanism can play a critical role at mature sites, providing a source of back diffusion to groundwater after a source is removed. Three samples were collected at boring F3-2: at the clay interface and at 1 and 5 feet into the clay. Of the three samples, PFOS was only detected at the clay interface at a concentration of 45 ng/kg. This sample is situated approximately 4 feet below the groundwater sample with PFOS detected at 4,000 ng/L. The contrast in saturated soil and groundwater concentrations at this location indicates that the diffusion into the clay is limited; however, the lack of a groundwater sample immediately atop the clay surface makes it difficult to know if the groundwater concentrations decrease with depth as depicted in the interpolation of the distribution.

The organic carbon content (f_{oc}) in soil can affect transport and migration of PFAS compounds in an aquifer (Andersen et. al. 2019). The f_{oc} sampling at GAAF was completed at boring F1-3 in an area away from the vadose zone impacts and in a relatively clean portion of the aquifer. Samples were collected from the vadose zone at depths of 2 to 3, 5 to 6, 9 to 10 feet bgs, as well as below the water table at 29 to 30 and 54 to 55 feet bgs, at depths below most groundwater impacts. The results of the f_{oc} sampling are summarized in **Table 5-7** below.

Table 5-7. Summary of Fraction of Organic Carbon Soil Sample Results

Sample Location/Depth	F_{oc} (mg/kg)	Soil Description
F1-3_2-3 ft	370	SAND, fine to very coarse, subangular to subround; little granules to very large pebbles, angular to round; little silt; poorly sorted; dry to moist; yellowish-brown (10YR 5/4).
F1-3_5-6 ft	99	SAND, very fine to medium, little coarse sand to granules, subangular to subround; trace very small pebbles, subangular to subround; trace silt; well sorted; dry to moist; light yellowish-brown (10YR 6/4)
F1-3_9-10 ft	670	SAND, fine to very coarse, subangular to subround; little granules to medium pebbles, subangular to round; trace silt; poorly sorted; moist; brown (10YR5/3).
F1-3_29-30 ft	95	SAND, very fine to very coarse, subangular to subround; some granules to small pebbles, subangular to round; little silt; trace medium to large pebbles, subangular to round; poorly sorted; wet; brown (10YR5/3)
F1-3_54-55 ft	210	SAND, very fine to coarse, subangular to subround; little silt; trace granules to medium pebbles, subangular to subround; poorly sorted; wet; light yellowish-brown (10YR 6/4)

The low f_{oc} values are consistent with glacial/fluvial sediments with limited fines (little to trace silt content) and no indication of organic compounds in the soil description. Although the f_{oc} values range by a factor of six, there is no discernable correlation among primary grainsize, silt content, and f_{oc} variability. Even the highest levels of f_{oc} are quite low, resulting in limited organic carbon partitioning of the PFAS compounds and limited impact on retardation of the solutes compared to groundwater migration rates.

6.0 PFAS MOBILE LAB PERFORMANCE EVALUATION

This section provides the following information as it relates to each of the three analytical techniques deployed as part of this work:

- Analytical Method Description
- Performance Evaluation Results
- Summary and Conclusions
- Recommendations for Method Improvements

6.1 DOD ELAP METHOD

6.1.1 Analytical Method Description

Pace deployed its DoD ELAP-accredited mobile PFAS laboratory to the GAAF and conducted LC/MS/MS analyses for quantifying 24 PFAS compounds in soil and groundwater samples. The DQOs for this work were set to comply with DoD's QSM 5.3, Table B-15.

The following are summaries of the water and soil analytical methods. Full details of the method are provided in the analytical laboratory SOPs ENV-SOP-MAD1-0082 for waters and ENV-SOP-MAD1-0084 for soils, which are included in **Appendix K**.

Summary of Water Analytical Method: Approximately 125 mL of acidified water sample was fortified with extraction internal standards (EISs) and passed through a Waters Oasis® weak anion exchange (WAX) SPE cartridge. The compounds were then eluted from the solid phase with an aqueous ammonia solution followed by an ammonia/acetonitrile solution. Extract cleanup was performed using a Supelclean™ ENVI-Carb™ dispersive SPE technique to remove matrix interferences. Sample analysis was performed with a liquid chromatography (LC) system interfaced to a tandem mass spectrometer (MS/MS). The concentration of each analyte was determined by internal standard quantification using the isotopically labeled analog of an analyte (isotope dilution quantitation) when labeled analogs are commercially available.

Note on sediment handling and final bottle rinsing: Throughout these analyses, the laboratory experienced several challenges related to water samples containing excessive amounts of sediment, which prevented the proper function of the SPE cartridge. **Figure 6-1** shows a picture of groundwater samples demonstrating the levels of sediment encountered. The two challenges associated with this sediment were: 1) clogging of the SPE cartridges by the sediment before an adequate amount of sample is used and 2) delays associated with the time required to allow sediment to settle after spiking and shaking the sample. The laboratory's SOP for water did not address the issue of extremely high sediment levels in water samples that hinder the SPE process. The DoD's QSM 5.3, Table B-15 indicates that samples with more than 1 percent solids may require centrifugation before SPE extraction. The laboratory did not have a centrifuge that could accommodate the 125 mL containers. The laboratory addressed this situation in the following manner.

Figure 6-1. Typical Sediment in Groundwater Samples

During the first days of operation, the samples were allowed to settle. The water was removed from the sample container and transferred to the SPE device then weighed per the SOP; however, the sediment remained in the bottle and no final bottle rinse was conducted to avoid transfer of the sediment to the SPE cartridge. This is a deviation from the SOP and Table B-15, and this deviation has been noted in the laboratory narratives. After consulting with the laboratory staff and management team, a modified procedure was established whereby all samples would undergo an overnight settling period followed by the removal of the sediment before solvent rinsing the sample container. In all cases, the volume of water used for the analyses was calculated by weighing the sample before and after the water removal step.

Soil Analytical Method: Approximately 50 grams of soil sample were collected in a 125 mL high-density polyethylene (HDPE) sample container and homogenized by hand using a PFAS-free spatula. Approximately 2 grams of the soil were extracted (via shaking) using a 70/30 ratio of methanol/water solution at pH 10 for 1 hour. All field samples, QC samples, and blanks were fortified with isotopically labeled EISs before extraction. The extract was centrifuged followed by sample cleanup with Supelclean™ ENVI-Carb™ as a dispersive SPE technique to remove matrix interferences. The supernatant was centrifuged and adjusted to pH 3 with formic acid. Analysis was performed via LC/MS/MS and Gerstel inline SPE autosampler using a C18 cartridge. The concentration of each analyte is determined by internal standard quantification using the isotopically labeled analog of an analyte (isotope dilution quantitation) when labeled analogs are commercially available.

At the time of this work, Pace's mobile PFAS lab was ELAP-accredited for groundwater but did not have ELAP accreditation for soils. The lab has since attained this accreditation (April 2020). Because the laboratory did not have the ELAP accreditation, 20 percent of the soil samples were sent to a fixed DoD laboratory (Shealy Environmental Services, now Pace, South Carolina) for confirmatory analyses. An assessment of the comparison between these two datasets is included in **Section 6.1.2.4** below.

Note on Innovations: For the water and soil analytical methods, several innovations were brought into the program. One was to expand on the DoD QSM requirement of baseline separation for branched and linear isomers for the purpose of separately calibrating and quantitating branched and linear isomers for two analytes (PFHxS and PFOS), thus providing the total PFHxS and PFOS concentrations as well as the branched and linear concentrations for client evaluations. Some emerging research has shown value in observing these isomer ratio differences. Another unique approach included in the mobile lab technology was the use of an automated, robotic in-line SPE system before LC/MS/MS analyses for extremely sensitive soils analysis with less solvent waste, faster preparation, and less human error.

6.1.2 Performance Evaluation Results

6.1.2.1 Laboratory Throughput and Turnaround Time

Summary of DoD ELAP Analytical Work: The mobile laboratory arrived on site on October 18, 2019 and demobilized on November 21, 2019. Over 5 weeks (23 days of laboratory operation), the laboratory analyzed and reported 201 groundwater samples and 47 soil samples. The total number of samples collected by the field team was 258 waters (includes field duplicates, equipment blanks, and water blanks) and 90 soils (includes four field duplicates). The progress of the mobile lab over that period is shown in **Table 6-1**. In addition to these samples, 16 matrix spike (MS)/matrix spike duplicate (MSD) pairs (12 water, four soils) were analyzed. The number of samples analyzed and reported in the field equates to approximately 71 percent of the samples generated by the sampling team over this duration. The remaining 29 percent of samples, along with rework analyses, were analyzed in Vermont at the Pace facility between December 3, 2019 and January 8, 2020. Complete Level 2 laboratory reports, with narratives and sample and QC results, for these analyses are provided in **Appendix B**. **Appendix B** also includes a Level 4 data package for a subset of water and soil sample analyses offered as two reports separated by matrix.

The productivity of the DoD ELAP Method is summarized in **Table 6-1**. The table shows the number of initial water and soil analyses conducted over 5 weeks (23 days) of field work. These sample results were provided to the project team as preliminary (and qualified) data used to guide the sampling team and periodically were used to update the 3D visualizations that were constructed. The goal of this program was to provide approximately 20 sample results per day, which the analytical program was not able to achieve for the following primary reasons:

- Sediment in samples – Excessive sediment required overnight settling time before transfer of the sample to the SPE cartridge and removal of the sediment before sample bottle rinse. Even with this overnight spiking procedure, the sediment continued to slow down the SPE process, and this became identified as the laboratory’s rate-limiting step. The majority of water samples required this extra sample handling, and it is also believed that the sediment caused a matrix affect that led to QC outages, as indicated with EIS outages and several MS/MSD analyses exhibiting poor recoveries.
- Switching between water and soil analyses before both methods are calibrated – During these switches (occurring in weeks 1 and 4), the time required to recalibrate the instrument with associated QC was found to delay analysis by 1 full day.
- SPE capacity was limited for a portion of the program.

- Extra work was associated with sample administration and preparation that was needed for the two screening analytical methods deployed with this program.
- An unanticipated amount of time was required to qualify analytical data before reporting.

Table 6-1. DoD ELAP Method - On-site Productivity for Preliminary Results

Date	Day	Prliminary Water Results	Prliminary Soil Results
22-Oct	Saturday	Mobilization and Calibration	
23-Oct	Sunday		
21-Oct	Monday	1	0
22-Oct	Tuesday	0	0
23-Oct	Wednesday	11	0
24-Oct	Thursday	0	19
25-Oct	Friday	0	0
Week 1 Productivity, 5 days	Totals	12	19
		31 samples/6.2 samples per day	
28-Oct	Monday	12	0
29-Oct	Tuesday	20	0
30-Oct	Wednesday	10	0
31-Oct	Thursday	0	0
1-Nov	Friday	0	0
2-Nov	Saturday	17	0
Week 2 Productivity, 6 days	Totals	59	0
		59 samples/9.8 samples per day	
4-Nov	Monday	9	0
5-Nov	Tuesday	16	0
6-Nov	Wednesday	9	0
7-Nov	Thursday	12	0
8-Nov	Friday	0	0
Week 3 Productivity, 5 days	Totals	46	0
		46 samples/9.2 samples per day	
11-Nov	Monday	18	0
12-Nov	Tuesday	19	0
13-Nov	Wednesday	15	0
14-Nov	Thursday	18	0
15-Nov	Friday	14	0
	Totals	84	0
Week 4 Productivity, 5 days		84 samples/16.8 samples per day	
18-Nov	Monday	No work	
19-Nov	Tuesday	0	0
20-Nov	Wednesday	0	10
21-Nov	Thursday	0	18
22-Nov	Friday	Demobilization	
	Totals	0	28
Week 5 Productivity, 3 days		28 samples/ 9.3 samples per day	
On-site Totals **On-site lab days** **Average Daily Productivity Preliminary Runs Only**		**201 GW and 47 soils** **23 days** **10.8**	

To alleviate some of the challenges mentioned above, the analytical team optimized several processes as follows:

- To the extent possible, samples containing excessive sediment were spiked the night before SPE and analyses. This allowed for the sediment to settle overnight and minimize delays during the day.
- Capacity was added to the SPE system by reconfiguring the equipment within the manifold. This led to an increase from six to ten samples per SPE batch. The laboratory also added a second SPE manifold during the fourth week of analyses to increase the throughput for this part of the procedure, leading to an increase of approximately 100 percent (from ten to 20) in the number of samples that could be extracted in a given analytical batch.
- The project team requested that certain samples (either within certain depth horizons and/or within certain drilling locations) be prioritized over non-essential samples – this greatly helped the laboratory to focus on only essential samples.
- After the first week, during which both water and soil samples were analyzed, the laboratory analyzed only water samples during weeks 2, 3, and 4 and did not switch back to soil analyses until the last week, when the soil sample results became priority for the project team.

As shown in **Table 6-1**, the average daily productivity over the 5 weeks of work was fewer than 20 samples per day. On average, Pace reported 11 samples per day for preliminary results. The range of analytical throughput ranged from six samples per day during the first week of work and was significantly higher (17 samples per day) during the fourth week of work. This productivity matches well with the timing of the improvements made during the program. For example, the lowest productivity was noted during week 1, when the laboratory analyzed both soil and water and did not have any of the SPE or prioritization improvements in place. Productivity was highest during the fourth week, when all of the improvements were in place and only water samples were analyzed.

Based on lessons learned and process improvements, average productivity is likely to be closer to 15 samples per day for a normal project, in which all improvements identified above are deployed, and the sample collection allows for a single matrix (water or soil) to be run over a given period in the laboratory.

The expected TAT for these samples was to be within 24 hours from time of sample receipt in the mobile laboratory. In most cases, this objective was not met, primarily due to the sediment issues and the related decreased productivity of the lab previously described. Using the enhanced analytical strategies, the lab was able to turn around high-priority sample results to the team in 24 hours and most of the prioritized sample results to the project team within 48 hours. However, there were instances earlier in the project when the project team had to wait significantly longer to receive preliminary results, as was most commonly found when the matrix switched from water to soil or vice-versa. These elongated TATs did at times adversely impact the flow of the sampling program; however, the project team was able to re-sequence some of the work elements in order to mitigate these extended reporting times. This last point is demonstrated by the fact that the sampling team was able to delineate the southeastern portion of both the Building 1195 source area and the plume boundary along Transect 2 before leaving the site.

The laboratory has identified several additional areas for optimization that will improve QC performance, analytical throughput, and turnaround times. **Section 6.5.1** below describes these areas for improvement and provides recommendations for future work to optimize the analytical program.

6.1.2.2 Cost of Analyses

The cost for the field work portion of these definitive analyses was $175,500. This includes the mobilization/demobilization fees and all expenses and labor associated with 23 days of on-site analyses. Because the laboratory analyzed 248 samples during that time, this equates to approximately $700 per sample analysis. Note that the rework associated with these analyses was performed after the field program completed and is not considered in this costing. Further, costs for rework associated with QC outages are typically not charged to the project.

As stated above in **Section 6.1.2.1** describing laboratory throughput and turnaround, the laboratory was able to overcome several significant challenges that impacted its throughput and, ultimately, the resulting cost per sample.

Based on these and other optimization measures that will be employed going forward, the more likely throughput expectation for the laboratory is up to 15 samples per day for a single matrix when performing DoD ELAP analysis. The current cost for the laboratory to conduct DoD ELAP definitive analyses is approximately $5,500/day. This unit price can fluctuate, however, based on multiple project-specific requirements. Including an illustrative mobilization/demobilization cost of $3,500 for a mid-distance project, an example 10-day project would cost a total of $58,500. Using a range of 10 to 15 samples per day for estimated throughput, this would equate to 100 to 150 samples over 10 days, or between $390 and $585 per sample.

Production rates assume preliminary results within 24 hours and final results within 48 hours. Current pricing for a comparative fixed-lab analysis with 15-day TAT for PFAS is approximately $200 per sample. Using a typical rush surcharge of between 100 and 150 percent for a 48-hour TAT, this equates to between $400 and $500 per sample. Note that, at this time, it is very difficult to find a laboratory that will offer a 24 hr. TAT for PFAS analytical work. That said, the mobile lab pricing is within the range of the fixed-lab rush pricing with the added benefit of having usable results much sooner.

Note that the mobile lab costs do not consider the other project costs that can be minimized via reduced downtime and standby costs associated with other site activities (e.g., drilling, sampling, remediation equipment) that may be waiting for time-sensitive data. These costs savings can be significant and have been demonstrated to be in the range of 30 to 50 percent (USEPA 2001).

6.1.2.3 QA/QC Performance Against Stated DQOs

This section discusses the performance of the DoD ELAP Method against several QC metrics monitored throughout the analytical sequences. The goal of this on-site testing was to provide rapid and definitive PFAS data to the project team as part of a dynamic sampling program. The benchmark for QA/QC and certain method protocols was set to equal that of DoD’s QSM version 5.3 (latest QSM version). To satisfy the time-critical needs of the project, the laboratory focused on providing analytical results to the sampling teams and deferred follow-up work (i.e., dilutions, re-analyses, and re-extractions) that was needed where the QA/QC was not met until after the field sampling was completed. In several instances, the final results for this analytical work do not meet the QA/QC protocol set forth in the DoD’s QSM. Examples of these deficiencies include holding time exceedances, internal standard area response failures, and calibration curve outages. Where these QA/QC outages were observed, the data and related deficiencies are discussed in detail within the individual laboratory case narratives, and the data are flagged accordingly. A summary of the QC testing, compared to the performance objectives, is provided in **Table 6-2**.

Table 6-2. QA/QC Summaries for DoD ELAP Method Water and Soil

PFAS DoD/Definitive - Water

QC Check	Frequency Goal	Frequency Achieved	Tolerance Goal	Tolerance Actual
Initial cal	NA	NA	% relative standard deviation (RSD) of Response factors (RFs) <20%. Linear or non-linear calibrations r2 ≥ 0.99. All analytes in each ICAL standard must recover within +/- 30% of their true value	All curves passed criteria with several exceptions. Exceptions include several analytes that had %RSD values marginally above 20%. These deficiencies are noted in the laboratory report and the data are qualified accordingly. Additionally, several curve levels (both high and low) were dropped for individual analytes; in most cases, the lower levels dropped did not impact the reporting level since the routine calibration curve contains levels that are below the reporting level. In cases where an upper level was dropped, the upper reporting level was always adjusted accordingly. Analytes containing these deficiencies included PFBA, PFPeA, PFNA, PFTrDA, PFOSA and the branched compound T-PFOS.
CCV	1 per 10	Yes	%D ≤ 30%	Deficiencies observed and noted in case narratives. Average % pass rate for all of the CCVs for individual analytes was 95.7%.
LCS	1 per 20	Yes	Table C	Deficiencies observed and noted in case narratives. Average % pass rate for the LCSs for individual analytes was 96.4%.
MS/MSD - Accuracy	1 per 20	Yes	Recoveries established by QSM Table C	Deficiencies observed and noted in case narratives. Average % pass rate for the MS and MSD analyses for individual analytes was 94.1%.
MS/MSD Precision	1 per 20	Yes	RPD ≤ 30%	Deficiencies observed and noted in case narratives. Average % pass rate for the RPD of the MS and MSD paired analyses for individual analytes was 99.6%.
Field Duplicate Analyses	1 per 20	No, marginally less than 1 per 20	RPD ≤ 30%	All sample average RPDs less than 30.

Table 6-2. QA/QC Summaries for DoD ELAP Method Water and Soil (Continued)

PFAS DoD/Definitive - Soil

QC Check	Frequency Goal	Frequency Achieved	Tolerance Goal	Tolerance Actual
Initial cal	NA	NA	% relative standard deviation (RSD) of Response factors (RFs) <20%. Linear or non-linear calibrations r2 ≥ 0.99. All analytes in each ICAL standard must recover within +/-30% of their true value	All curves passed criteria with several exceptions. Exceptions include 1) a PFBA curve for soilsin which a one-point curve was used and 2) several analytes had %RSD values marginally above 20%. These deficiencies are noted in the laboratory report and the data are qualified accordingly. Additionally, several curve levels (both high and low) were dropped for individual analytes; in most cases, the lower levels dropped did not impact the reporting level since the routine calibration curve contains levels that are below the reporting level. In cases where an upper level was dropped, the upper reporting level was always adjusted accordingly.
CCV	1 per 10	Yes	%D ≤ 30%	Deficiencies observed and noted in case narratives. Average pass rate for all of the CCVs for individual analytes was 98.5%.
LCS	1 per 20	Yes	Table C	Deficiencies observed and noted in case narratives. Average % pass pass rate for the LCSs for individual analytes was 97.0%.
MS/MSD - Accuracy	1 per 20	Yes	Recoveries established by QSM Table C	Deficiencies observed and noted in case narratives. Average pass rate for the MS and MSD analyses was 90.4%.
MS/MSD Precision	1 per 20	Yes	RPD ≤ 30%	Deficiencies observed and noted in case narratives. Average pass rate for the RPD of the MS and MSD paired analyses for individual analytes was 95.5%.
Field Duplicate Analyses	1 per 20	No, marginally less than 1 per20	RPD ≤ 50%	Three out of four field duplicates did not meet RPD goal of </=50.

The following sections break out the various QC elements identified in the Demonstration Plan and are listed in **Table 6-2**.

Initial Calibrations: As shown in **Table 6-2**, all calibrations passed criteria with a few exceptions. Several calibration levels associated with the bottoms and tops of the curves were dropped periodically throughout these analyses to allow for the curves to pass criteria. In most cases, the levels dropped on the low end of the curve were below the reporting limits; therefore, the reporting levels were not raised. Where this was not the case, the reporting levels were raised accordingly. PFBA was the most problematic compound from both sensitivity and curve fitting perspectives. Other compounds exhibiting curve fit failures are as follow: PFPeA, PFNA, PFTrDA, PFOSA, and the branched compound T-PFOS. Each had two calibrations with poor fit.

Water detection limits were set to the method detection limit (MDL) for these analyses. MDLs ranged from approximately 0.5 ng/L to 5 ng/L, depending on the compound.

Soil detection limits were also set to MDLs and ranged between approximately 5 and 75 ng/kg; however, PFBA and PFDA concentrations were periodically higher at approximately 250 ng/kg due to calibration issues at the low end of the curve.

QC Testing: A summary of the results of this testing is included in **Table 6-2**. These tests include continuing calibration verification (CCV) recoveries, laboratory control sample (LCS)/laboratory control sample duplicate (LCSD) recoveries, and MS/MSDs (both recoveries and RPD). Deficiencies were observed throughout the analyses; however, overall, the QC testing was in control throughout these analyses. **Table 6-3** presents percent pass rates for the individual compounds for each QC test. It is important to note that these percent pass data were derived using the final dataset, meaning that data associated with initial runs that were re-analyzed due to QC outages are not included in these percent pass data. These data represent all of the QC tests performed as part of this work. To contextualize these data summaries, it is helpful to note that analytes are listed in elution order, with the short-chain PFBA eluting first and the long-chain PFTeDA eluting last.

Overall, the average percent pass rate for all compounds and all QC tests for water and soil was approximately 96 percent. This high passing rate indicates that the program was conducted within the QC tolerances set forth for these analyses. A few notable areas of the QC program where higher rates of deficiencies were observed are as follows:

- Several long-chain compounds (i.e., PFNS, PFTrDA and PFTeDA) exhibited lower average percent pass rates, ranging between 86.9 (PFTrDA) and 92 percent (PFTeDA). Each of these are late-eluting compounds, and two of the compounds (PFNS and PFTrDA) are without an isotopically labelled extracted internal standard.
- PFPeS and PFHpS also exhibited deficiencies with average percent pass rates of 84.1 and 86.9 percent, respectively.
- A matrix effect was evident for total PFOS. The percent pass rate (42 percent) of the MS/MSD recovery tests for this compound was the lowest observed in all of the QC testing. T-PFOS and PFOS, and thus total PFOS, were found to be most sensitive to matrix effects, as some spiked samples passed all analytes except these, and recovery was especially low. These tests were reanalyzed to confirm that the cause for this was a matrix effect.

Table 6-3. QC % Pass Rates DoD ELAP and Accelerated Methods

Method	Matrix	QC Type	n Observations	PFBA	PFPeA	4-2FTS	PFBS	PFHxA	PFPeS	PFHpA	Br-PFHxS	6-2FTS	PFOA	PFHxS	Total PFHxS	PFNA
Standard DoD	**Water**	**CCV Recovery**	**91**	100.0%	98.9%	96.7%	100.0%	100.0%	89.0%	100.0%	97.8%	100.0%	98.9%	100.0%	97.7%	98.9%
		LCS/LCSD Recovery	**59**	98.3%	98.3%	100.0%	96.6%	96.6%	93.2%	96.6%	98.3%	100.0%	96.6%	98.3%	98.3%	96.6%
		MS/MSD Recovery	**20***	100.0%	95.0%	100.0%	100.0%	100.0%	70.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		MSD RPD	**10***	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	Soil	**CCV Recovery**	**14**	92.9%	100.0%	100.0%	100.0%	100.0%	78.6%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		LCS/LCSD Recovery	**6**	83.3%	100.0%	100.0%	100.0%	100.0%	66.7%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		MS/MSD Recovery	**8***	87.5%	100.0%	100.0%	100.0%	100.0%	75.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		MSD RPD	**4**	75.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		Average by Compound		92.1%	99.0%	99.6%	99.6%	99.6%	84.1%	99.6%	99.5%	100.0%	99.4%	99.8%	99.5%	99.4%
Accelerated	**Water**	**CCV Recovery**	**34**	100.0%	97.1%		100.0%	100.0%	73.5%	100.0%	97.1%	100.0%	100.0%	100.0%	100.0%	100.0%
		LCS/LCSD Recovery	**18**	88.9%	100.0%		100.0%	100.0%	77.8%	83.3%	100.0%	94.4%	100.0%	100.0%	100.0%	88.9%
		MS/MSD Recovery	**20**	95.0%	95.0%		95.0%	95.0%	75.0%	85.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
		MSD RPD	**10**	80.0%	80.0%		80.0%	80.0%	90.0%	80.0%	80.0%	80.0%	80.0%	80.0%	80.0%	80.0%
	Soil	**LCS/LCSD Recovery**	**9**	100.0%	100.0%		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		MS/MSD Recovery	**6***	100.0%	100.0%		100.0%	100.0%	83.3%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		MSD RPD	**3**	100.0%	100.0%		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		Average by Compound		94.8%	96.0%	NA	96.4%	96.4%	85.7%	92.6%	96.0%	95.6%	96.4%	96.4%	96.4%	94.8%

*** - Note that for MS and MSD Evaluations, Recovery and RPD were not evaluated for a given analyte when parent sample hits were significantly greater than the spike concentration.**

Table 6-3. QC % Pass Rates DoD ELAP and Accelerated Methods (Continued)

PFHpS	PFOSA	8-2FTS	T-PFOS	PFDA	NMeF OSAA	PFOS	Total PFOS	NEtFO SAA	PFUdA	PFNS	PFDoA	PFDS	PFTrDA	PFTeDA	Average by QC Type	Minimum by QC Type
86.8%	97.8%	97.8%	97.8%	98.9%	95.6%	96.7%	100.0%	98.9%	97.8%	83.5%	98.9%	82.4%	82.4%	85.7%	95.7%	82.4%
94.9%	98.3%	100.0%	98.3%	98.3%	100.0%	100.0%	100.0%	100.0%	96.6%	71.2%	98.3%	96.6%	81.4%	96.6%	96.4%	71.2%
65.0%	100.0%	100.0%	100.0%	100.0%	100.0%	94.4%	100.0%	100.0%	100.0%	65.0%	100.0%	85.0%	90.0%	70.0%	94.1%	65.0%
100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	88.9%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.6%	88.9%
85.7%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	98.5%	78.6%
100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	66.7%	100.0%	97.0%	66.7%
87.5%	100.0%	100.0%	50.0%	87.5%	100.0%	50.0%	42.9%	87.5%	100.0%	100.0%	100.0%	100.0%	75.0%	87.5%	90.4%	42.9%
75.0%	100.0%	100.0%	75.0%	100.0%	100.0%	75.0%	75.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	95.5%	75.0%
86.9%	99.5%	99.7%	90.1%	98.1%	99.5%	88.1%	89.7%	98.3%	99.3%	90.0%	99.7%	95.5%	86.9%	92.5%	Overall Average =	95.9%
94.1%	91.2%	97.1%	91.2%			100.0%	100.0%								96.7%	73.5%
100.0%	88.9%	100.0%	88.9%			100.0%	100.0%								95.1%	77.8%
85.0%	80.0%	95.0%	80.0%			90.0%	95.0%								90.8%	75.0%
80.0%	80.0%	90.0%	80.0%			80.0%	80.0%								81.1%	80.0%
100.0%	100.0%	100.0%	100.0%			100.0%	100.0%								100.0%	100.0%
100.0%	40.0%	100.0%	40.0%			40.0%	40.0%								85.7%	40.0%
100.0%	100.0%	100.0%	100.0%			100.0%	100.0%								100.0%	100.0%
94.2%	82.9%	97.4%	82.9%	NA	NA	87.1%	87.9%	NA	NA	NA	NA	NA	NA	NA	Overall Average =	92.8%

Extracted Internal Standards: Although not specifically called out as a performance goal, due to a significant number of EIS recoveries falling outside of the 50 to 150 percent recovery range, it was deemed important to discuss this metric as part of the performance evaluation. **Table 6-4** shows the percent passing rates for each of the 19 EISs for water and soil analyses, respectively. The data are broken out between samples and QC samples. The overall percent pass rate for all EISs and for both water and QC tests was 89.1 percent. Several of the EISs had significantly lower percent pass rates; the most common EISs with these issues include:

- MPDDoA and M2PFTeDA, the two latest eluting compounds, exhibited average pass rates of 82.5 and 51.5 percent, respectively, for both samples and QC tests. This percent pass rate was as low as 35.1 percent for M2PFTeDA in water samples.
- MPFBA, the earliest eluting compound, exhibited an average percent pass rate of 76.4 percent for both samples and QC, with the majority of this low average being caused by the soils QC and sample percent pass rates being 63.6 and 65.2 percent, respectively.

Rework Rates for Water Analyses: Although not stated as a performance goal, an evaluation of the rework rates was deemed an important variable for evaluating the method's performance. Samples returning QC failures were either re-extracted and/or re-analyzed. The rationale for which samples were re-analyzed versus re-extracted (and re-analyzed) was as follows:

- Re-analyses were conducted on samples from sequences that had passing extraction batch QC but exhibited other QC failures (such as EIS and CCVs) or had blank spikes biased in the same direction as CCV failures.
- Re-extractions/re-analyses were performed on all water samples within sequences with failing batch QC after possible re-analysis. All of these samples were re-analyzed after re-extraction. Soil samples were not re-extracted, even though there were batch QC failures within the analytical sequences.

Table 6-4. EIS % Pass Rates DoD and Accelerated Methods

Method	Matrix	EIS Type	n Observations	MPFBA	M5PFPeA	M2-42FTS	M3PFBS	M5PFHxA	M4PFHpA	M2-62FTS	M8PFOA	M3PFHxS	M9PFNA	M2-82FTS	M6PFDA
Standard DoD	**Water**	**BatchQC**	**88**	88.6%	88.6%	88.6%	88.6%	88.6%	88.6%	85.2%	88.6%	88.6%	88.6%	79.5%	84.1%
		Sample	**259**	88.0%	93.8%	92.7%	94.6%	95.4%	95.4%	89.2%	95.0%	95.4%	95.4%	79.9%	92.3%
	Soil	**BatchQC**	**11**	63.6%	90.9%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		Sample	**89**	65.2%	89.9%	97.8%	93.3%	96.6%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	Average			76.4%	90.8%	94.8%	94.1%	95.2%	96.0%	93.6%	95.9%	96.0%	96.0%	89.9%	94.1%
Accelerated	**Water**	**BatchQC**	**32**	100.0%	100.0%		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	
		Sample	**247**	99.6%	99.6%		99.2%	99.6%	99.6%	99.6%	99.6%	99.6%	99.6%	99.6%	
	Soil	**BatchQC**	**14**	100.0%	100.0%		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	
		Sample	**89**	97.8%	100.0%		100.0%	100.0%	98.9%	98.9%	100.0%	100.0%	100.0%	98.9%	
	Average			99.3%	99.9%	NA	99.8%	99.9%	99.6%	99.6%	99.9%	99.9%	99.9%	99.6%	NA

Table 6-4. EIS % Pass Rates DoD and Accelerated Methods (Continued)

Method	Matrix	EIS Type	n Observations	d3-N-MeFOSAA	M8PFOS	M8FOSA	d5-N-EtFOSAA	M7PFUdA	MPFDoA	M2PFTeDA	
Standard DoD	**Water**	**BatchQC**	**88**	72.7%	84.1%	86.4%	80.7%	81.8%	69.3%	47.7%	
		Sample	**259**	66.8%	94.2%	81.1%	59.8%	78.4%	60.6%	35.1%	
	Soil	**BatchQC**	**11**	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	54.5%	
		Sample	**89**	98.9%	100.0%	100.0%	100.0%	100.0%	100%	68.5%	
	Average			84.6%	94.6%	91.9%	85.1%	90.0%	82.5%	51.5%	**Overall Average = 89.1%**
Accelerated	**Water**	**BatchQC**	**32**		100.0%	100.0%					
		Sample	**247**		99.6%	99.6%					
	Soil	**BatchQC**	**14**		100.0%	100.0%					
		Sample	**89**		97.8%	100.0%					
	Average			NA	99.3%	99.9%	NA	NA	NA	NA	**Overall Average = 99.7%**

This rework for the water analyses is summarized in **Table 6-5**. As shown in this table, there was a significant amount of rework associated with the waters analytical work. For waters, almost 10 percent of the samples needed to be re-extracted, and 86 percent required re-analysis. The most common cause for the rework was due to specific long-chain EIS (noted above) recoveries that were out of tolerance. All of this rework was performed after the field program had ended. This matter of rework is not expected to be as significant an issue for future projects, as the analytical procedures have been refined and improved since the time of this work.

Table 6-5. Analytical Rework

Method	ReExtractions		ReAnalyses (not dilutions)		Cause	
	#	%	#	%	ReExtractions	ReAnalyses
DoD ELAP Water	22	8.9%	214	86.3%	Batch QC	Batch QC and/or EIS
DoD ELAP Soil	0	0.0%	10	11.1%	N/A	Batch QC and/or EIS
Accelerated Water	0	0.0%	17	7.2%	N/A	Batch QC and/or EIS
Accelerated Soil	0	0.0%	9	10.0%	N/A	Batch QC and/or EIS

Batch QC = batch quality control
EIS = extracted internal standards

The soils work returned significantly fewer QC failures than the water analyses; therefore, there was much less rework associated with the soil analyses. The soils analyses only required 11 percent of the samples to be re-analyzed.

The precision goals established for the Accelerated Method were RPD </= 30 for water analyses for both field duplicates and the MS/MSD pairs and RPD </=50 for the soil analyses for both field duplicates and the MS/MSD pairs. Based on **Tables 6-2** and **6-3**, the RPD values for these analyses were less than 30 (or passing) for 99.6 percent of the water analyses, and all of the RPD values were less than 50 (or passing) for 95.5 percent of the soil analyses.

6.1.2.4 Comparison to Off-Site Laboratory Analyses of Soils

Pace's mobile lab was not DoD ELAP-accredited for soils during the field work portion of this project. To comply with DoD's guidance, 20 percent (in this case, 20 of the 86, or 23 percent) of the soil samples were sent off for analyses at a DoD ELAP-accredited laboratory. These soils were homogenized in the laboratory before creating the split samples for the off-site laboratory. The former Shealy Environmental Services laboratory in South Carolina was engaged for the DOD ELAP-accredited analyses. To evaluate the accuracy of the on-site lab, the following statistical equivalence measures were evaluated: R^2, slope, and RPD for each analyte.

The results of this evaluation are shown on **Figure 6-2** and in **Table 6-6**. A complete listing of the data comparisons and the Level 2 laboratory report from the off-site DoD ELAP lab are included in **Appendix B**. As shown, the correlation (as R^2) between the two datasets is 0.976, and the slope is 1.24. This plot shows all compounds detects for both methods – data in which either of the two methods showed non-detects are not included. There appears to be a slightly high bias to the on-site testing based on the slope of 1.24. The average RPD for the entire compound dataset is 36, which is well below the typical goal of 50 for a soil matrix.

There are several individual compounds that have RPD values higher than 50 (PFOA at 66 and PFPeA at 99); however, the data used for these compounds were all very low in concentration and were in the "estimated" value range for either both or one of the laboratory's datasets. The compound with the lowest RPD and the highest number of data points (14) is PFOS at an RPD of 22.

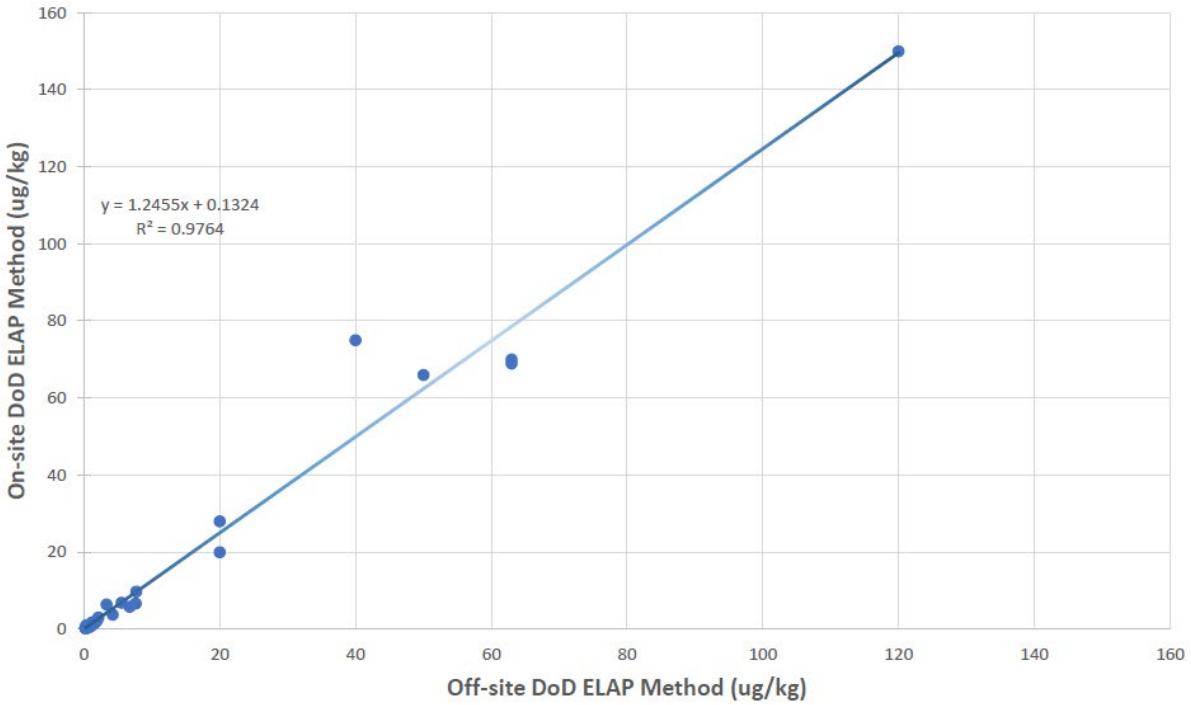


Figure 6-2. On-site vs. Off-site Soils Data, ug/kg

Table 6-6. RPDs by Compound - On-site DoD ELAP vs. Off-site Dod ELAP Soils

Compound	n	Average RPD
6:2FTS	2	13
8:2 FTS	5	22
PFDA	1	29
PFHpS	3	25
PFHxA	2	38
PFHxS	8	16
PFNA	3	41
PFOA	3	66
PFOS	14	22
PFOSA	1	26
PFPeA	1	99
	43	**Overall Average = 36**

RPD = relative percent difference

Although there were no performance goals established for this off-site comparison testing for soil, the metrics used for comparing the two datasets strongly suggest adequate comparability between the two methods.

6.1.3 Summary and Conclusions

This section offers a summary of the findings of this analytical work and presents the conclusions drawn from these findings.

The DoD ELAP Method was deployed successfully for the purposes of generating accurate analytical PFAS data in the field for use by the project team to make reliable decisions regarding sampling. From a performance standpoint, the analytical team encountered several challenges throughout the program that led to lower-than-expected productivities, delayed reporting to the sampling team, and (due to instances in which the initial analytical QA/QC did not meet the specific DQOs) there was a significant amount of rework to be completed after the sampling had ended. The mobile laboratory provided preliminary results in the field and, upon completing the rework and a secondary data review of all data, provided the final product for this work. A detailed review of the QA/QC data for the final dataset indicates that the analytical work was conducted largely in control: an average of 96.4 percent pass rate for all water QC and an average of 95.3 percent pass rate for soil QC tests, both using the tolerances set forth for this work.

The primary challenges included: 1) excessive sediment in water samples causing SPE delays and likely matrix effects; 2) a significant number of EIS failures, which led to extended review and reporting times; and 3) calibration associated with switching between soil and water matrices.

To help overcome these challenges and minimize reporting delays, the analytical team increased the capacity of the SPE system and worked with the sampling team to better stage the workflow. Examples of this improved workflow included the prioritization of sample analyses to include specific depth ranges within certain sampling locations and limiting the matrix for priority samples to a single matrix. These changes led to an increase in productivity for preliminary results from six samples per day during week 1 to a maximum of 17 samples per day during week 4 of the program. On average, the productivity for the 5 weeks was 11 sample results per day, which was well below the anticipated productivity of 20 sample results per day. Once the program was up and running with the identified improvements, the TATs for the results were typically within 48 hours, with prioritized sample results being reported within 24 hours.

The analytical costs for these definitive, DoD ELAP analyses can range between \$390 and \$585 per sample for a program running between 10 and 15 samples per day. This costing assumes that a single matrix (water or soil) is being analyzed. This cost per sample is within the expected range for 48 hr. TAT results from a fixed lab.

Throughout this work, the analytical team identified several areas for improvement (see **Section 6.5.1**). Implementation of recommendations for method improvements should enhance the performance of the analytical program from both quality and productivity standpoints.

Using the information provided in this report, the following conclusions are put forth regarding the validation and efficacy of using a PFAS mobile lab to conduct definitive analytical work (compliant with DoD's QSM 5.3 Table B-15) to support dynamic work strategies:

- A PFAS mobile laboratory, delivering DoD QSM-compliant data, can support a dynamic sampling program by providing reliable analytical data to the sampling team with much faster TATs than those of a fixed lab.
- Definitive quality of data can be provided by the mobile lab at a throughput of between 10 and 15 samples per day. These data are initially provided as preliminary results in the field. This assumes no significant matrix issues and/or interferences, which can lead to reduced productivity and/or rework. Final results can also be delivered while in the field if deemed critical relative to DQOs.
- The costs per sample are within the range typical fixed lab rush 48-hour turnround analyses. However, a 48-hour fixed lab TAT is essentially 3 days from the time of sampling given shipping and considering that the 48-hour window starts when the samples are received at the laboratory.

6.2 ACCELERATED METHOD

6.2.1 Analytical Method Description

The Accelerated Method combines a set of in-line SPE and LC/MS/MS analytical procedures for both water and soil analyses. This work consisted of three phases:

1. The method development/optimization phase conducted in October of 2019 (before the field portion of this project)
2. The field portion consisting of redundant sampling of water samples and spiking all samples with EISs and LCS/MS/MSD samples before leaving the site
3. Implementation of the Accelerated Method for analyzing water and soil samples generated in the fall of 2019 as part of the field work at GAAF. This analytical work occurred off site between the January 14 and March 4, 2020.

6.2.1.1 Method Development/Optimization

The following sections cover the method development phases, which included: 1) in-line SPE and LC optimization using an abbreviated list as the target analyte list, 2) a precision and accuracy study consisting of seven replicates at the reporting limit, and 3) a demonstration of capability (DOC) for the analyst(s).

6.2.1.1.1. In-line SPE and LC Optimization

The Accelerated Method uses an in-line SPE step followed by an LC/MS/MS procedure. To optimize the analytical procedure, the following components were modified:

1. In-line SPE: Using an iterative process, the system parameters for controlling the conditioning, washing, and elution of the in-line SPE protocol were modified to allow for the shortest elution time without loss of compound and minimal cartridge conditioning. Optimizing these steps reduced preparation time by approximately 30 percent to match the reduced compound list elution time on the LC program. Although not completed as part of this work, analysis time can be reduced further by using a multi-prep in-line SPE system that prepares the subsequent SPE cartridge while the current SPE cartridge is eluting to the LC/MS/MS system.

2. LC program was modified using a short column with smaller particle size, ultra-performance liquid chromatography (UPLC) type column to reduce elution time while preserving baseline resolution for branched and linear isomers. In addition, larger injection volumes onto the SPE cartridge allowed lower reporting limits. The analytical run was reduced from a typical 12 minutes to less than 7 minutes.

The reference material used during these method optimization steps contained the full DoD 24-compound list to ensure that the Accelerated Method would be able to accommodate any of the 24 compounds if desired.

Additional aspects/advantages of the Accelerated Method are as follow:

1. Multi-matrix calibration curve: The method is set up to run both soil and water samples on the same calibration curve. The DoD ELAP Method requires separate calibration curves for each matrix. This multi-matrix calibration curve is achieved by having the soil extracts, water extracts, and calibrations standards be identical in composition to each other. Because the extracts are identical in composition and match the calibration standards, the interaction with the solvents associated with the in-line SPE and LC portions of the technique do not discriminate between water and soil matrices. Not needing to switch over to a new calibration curve when changing matrices is a significant advantage, especially when performing on-site analytical work.

2. Small volume water samples: Because the in-line SPE system requires a very small volume of sample, the required volume for groundwater analysis is also very small. Here, the volume requirement for groundwater is approximately 4 mL. Some groundwater sampling techniques produce groundwater at prohibitively slow rates, requiring long sampling periods. Reducing this sample volume requirement enables the sampling crews to be more efficient. Most PFAS analytical methods (including the DoD ELAP Method used for this work) require much larger volumes. Part of this requirement is to ensure that a representative sample of the aquifer is being obtained for analysis and, based on the level of agreement between the DoD ELAP and Accelerated Method waters data, the 4 mL sample appears to have satisfied the sample representativeness factor. This assumes that sufficient purging of the aquifer is attained before sample collection.

6.2.1.1.2. Precision and Accuracy Study and Demonstration of Capability

To demonstrate the precision and accuracy of the Accelerated Method, seven replicate samples were analyzed at the expected reporting level for this work. The results of this work are provided in **Appendix L**. This appendix also provides the results of the initial DOCs. The abbreviated list of compounds used for this method development work was derived from a preliminary review of the Grayling site data generated by earlier investigators (AECOM 2018; AMEC Foster Wheeler 2017). To further support this selection of compounds, the Air Force has generated a list (Anderson et al. 2016) that represents the eight most prevalent compounds typically found at AFFF-impacted sites. This “Pre-Grayling” list was modified to 13 compounds after reviewing the DoD ELAP Method work at the GAAF. A more thorough discussion on the rationale for selecting the 13 compounds is offered below.

6.2.1.2 Method Implementation

The Accelerated Method analyses were conducted over 13 days of analytical work between January 14 and March 4, 2020. The work was not conducted continuously due to several interruptions associated with instrument maintenance and moving the laboratory from Vermont to Wisconsin to allow for a DoD audit that was conducted during this timeframe. The Accelerated Method was deployed as a screening-level method with the goal of meeting the QA/QC objectives identified in the Demonstration Plan and listed in **Table 6-7**. The following are summaries for the water and soil analytical methods. Full details of the method are provided in the Accelerated Method SOP (**Appendix K**). As part of the method implementation, the project team evaluated the dataset from the DoD ELAP Method work to derive a Grayling site-specific analyte list. The rationale for the final list for this work is discussed below.

Water Analytical Method: For groundwater samples, small volumes (3 to 5 mL) were collected in 15 mL centrifuge tubes. All analytical and QC samples were spiked with EISs, and all samples were stabilized by addition of methanol to achieve 70 percent methanol and 30 percent sample ratio to stabilize the PFAS (i.e., PFAS were no longer prone to stratification or adhering to the sample container walls). Samples were then prepared further for in-line SPE followed by analyses via LC/MS/MS. These samples were generated by the sampling team at the point of sampling and prepared accordingly by the lab. These samples were archived for later analyses after the field program ended. Because it was expected that holding times would be elongated for these samples, 5 percent of MS/MSDs and LCS samples were prepared at the field laboratory to monitor the sample integrity during their extended holding times. Given that the recoveries of the LCS and MS/MSD samples were quite good and were consistent with what the original DoD ELAP analyses found, it appears that the elongated holding times did not have an appreciable impact on the integrity of these samples.

Soil Analytical Method: The soil extracts from the DoD ELAP Method analyses were analyzed after the field program ended. Soil extracts were prepared using the DoD ELAP Method before in-line SPE. The analyses were conducted using the modified in-line SPE and LC programs to allow for shorter run times. It is worth noting that the accelerated in-line SPE and LC program for soils is very similar to the DoD ELAP Method from procedure and equipment perspectives; meaning that the same sample preparation, sample cleanup, and introduction and analyses were used for these analyses. The difference between the DoD ELAP and Accelerated Methods is in the timing of the various analytical steps and the number of compounds for which the method is looking.

Table 6-7. Accelerated Method QA/QC Summaries

QC Check	Frequency Goal	Frequency Achieved	Tolerance Goal	Tolerance Actual
PFAS Accelerated/Screening - Water				
Initial cal	NA	NA	% relative standard deviation (RSD) of Response factors (RFs) <20%. Linear or non-linear calibrations r2 ≥ 0.99.	All curves passed criteria. Several curve levels (both high and low) were dropped for individual analytes; in most cases, the lower levels dropped did not impact the reporting level since the routine calibration curve contains levels that are below the reporting level. In cases where an upper level was dropped, the upper reporting level was always adjusted accordingly.
CCV	1 per 20	Yes	%D ≤ 30%	Deficiencies observed and noted in case narratives. Average % pass rate for all of the CCVs for individual analytes was 96.7%.
LCS	1 per 40	Yes	In-house LCS limits. 70-130% and 60-140% for poor performers if in-house limits not established.	Deficiencies observed and noted in case narratives. Average % pass rate for the LCSs for individual analytes was 95.1%.
MS/MSD - Accuracy	1 per 20	Yes	Recoveries established by QSM Table C	Deficiencies observed and noted in case narratives. Average % pass rate for the MS and MSD analyses was 90.8%.
MS/MSD Precision	1 per 20	Yes	RPD ≤ 30%	Deficiencies observed and noted in case narratives. Average % pass rate for the RPD of the MS and MSD paired analyses for individual analytes was 81.1%.
Field Duplicate Analyses	1 per 20	No, marginally less than 1 per 20	RPD ≤ 30%	All sample average RPDs less than 30.
PFAS Accelerated/Screening - Soil				
Initial cal	NA	NA	% relative standard deviation (RSD) of Response factors (RFs) <20%. Linear or non-linear calibrations r2 ≥ 0.99.	All curves passed criteria. Several curve levels (both high and low) were dropped for individual analytes; in most cases, the lower levels dropped did not impact the reporting level since the routine calibration curve contains levels that are below the reporting level. In cases where an upper level was dropped, the upper reporting level was always adjusted accordingly.
CCV	1 per 20	Yes	%D ≤ 30%	No soil-specific CCVs were analyzed since the analytical sequences contained both water and soil
LCS	1 per 40	Yes	In-house LCS limits. 70-130% and 60-140% for poor performers if in-house limits not established.	Average % pass rate for all of the LCSs for individual analytes was 100%.
MS/MSD - Accuracy	1 per 20	Yes	Recoveryies established by QSM Table C	Deficiencies observed and noted in case narratives. Average % pass rate for all of MS and MSD paired analyses for individual analytes was 85.7%.
MS/MSD Precision	1 per 20	Yes	RPD ≤ 30%	Average % pass rate for the RPDs for the MS/MSD pairs for individual analytes was 100%.
Field Duplicate Analyses	1 per 20	No, marginally less than 1 per 20	RPD ≤ 50%	Three out of four field duplicates did not meet RPD goal of </=50. Fourth FD did not have any detects so comparison was indeterminate.

RPD = relative percent difference

CCV = contininining calibration check, LCS = Laboratory Control Sample, MS/MSD = matrix spike/matrix spike duplicate

6.2.1.2.1. Selection of Grayling Site-Specific Analyte List

The analyte list for the Accelerated Method was intended to be focused on a limited number of site-specific PFAS compounds such as PFOS/PFOA. An assessment of the dataset for Camp Grayling indicated that the following compounds adequately represent the makeup of the PFAS: PFHxS, PFHxA, PFPeA, PFHpA, PFOA, PFBA, PFOS, 6:2 FTS, PFNA, 8:2 FTS, PFHpS, PFPeS, and PFBS.

The rationale for this selection was based on the prevalence of these compounds in the water and soil sample analyses. **Table 6-8** and **Figure 6-3** show the percent detections for the water and soil samples. **Table 6-9** shows the following three lists of compounds: 1) Air Force list; 2) pre-Grayling site work (October 2019) list; and 3) the post-Grayling site work, which was used for the Accelerated Method. This table also shows the rationale for selecting the post-Grayling list. It is worth noting that the percentages of detections in the soil samples were significantly lower than that of the water analyses due to the relatively higher detection limit of the soil analytical method. Consequently, the rationale for selecting a given compound was weighted more heavily based on the water analytical data. The first seven analytes on the table were selected because these compounds were detected in more than 50 percent of samples in both the Air Force dataset and the Grayling DoD ELAP Method dataset. 6:2-FTS and PFNA were selected because they were detected more than 50 percent of samples in the Air Force (Anderson et al. 2016) dataset and 43 and 26 percent of samples in the DoD ELAP waters dataset, respectively. Four additional compounds were selected based on the following:

- 8:2-FTS: This compound was detected in less than 50 percent of samples in both Air Force and DoD ELAP Method datasets but was prevalent in soils at almost twice the levels of 6:2 FTS.
- PFHpS: This compound was detected in almost 50 percent of Grayling water samples.
- PFPeS: This compound was detected in more than 50 percent of Grayling water samples.
- PFBS: This compound was detected in more than 50 percent of Grayling water samples.

Pace used the Accelerated Method for the GAAF samples collected between January 14 and March 3, 2020. Complete Level 2 laboratory reports, with narratives and sample and QC results, for these analyses are provided in **Appendix G**.

Table 6-8. % Detections in Water and Soil Samples, DoD ELAP Method

PFAS Analyte, Full DoD List	Number of Detects in Water Samples as Per Fall 2019 DoD Method	% of Water Sampleswith Detects	Number of Detects in Soil Samples as Per Fall2019 DoD Method	% of Soil Sampleswith Detects
4-2FTS	1	0	0	0
6-2FTS	111	43	12	13
8-2FTS	63	24	21	23
NEtFOSAA	1	0	0	0
NMeFOSAA	1	0	0	0
PFBA	185	72	24	27
PFBS	154	60	10	11
PFDA	1	0	4	4
PFDoA	5	2	0	0
PFDS	2	1	5	6
PFHpA	162	63	40	44
PFHpS	123	48	18	20
PFHxA	222	86	55	61
PFNA	67	26	35	39
PFNS	6	2	5	6
PFOA	224	87	24	27
PFOSA	1	0	7	8
PFPeA	211	82	71	79
PFPeS	170	66	7	8
PFTeDA	3	1	1	1
PFTrDA	5	2	2	2
PFUdA	5	2	2	2
Total PFHxS	238	92	49	54
Total PFOS	238	92	66	73

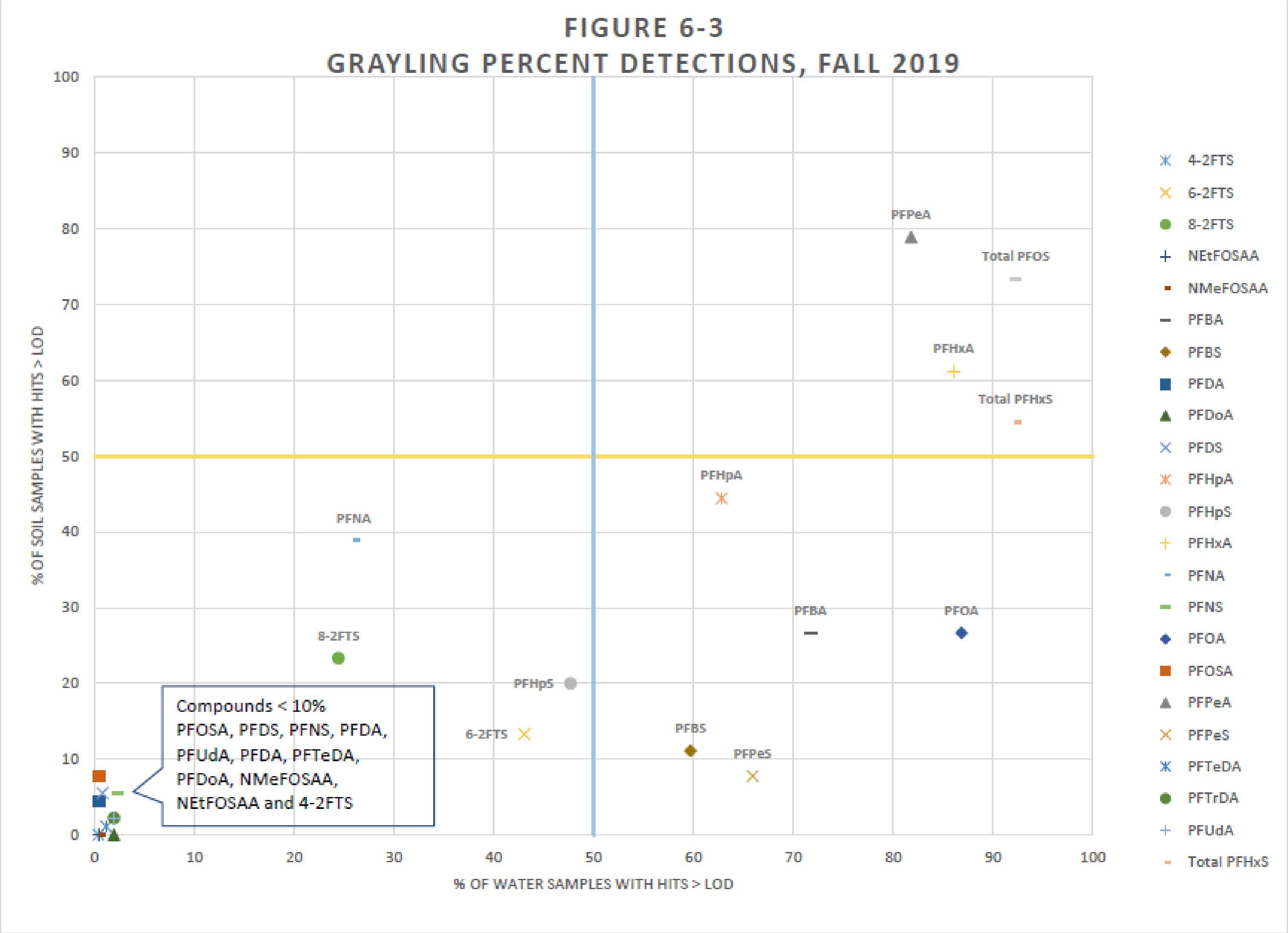
Total number of water samples = 258, includes field duplicates, equipment blanks and water blanks

Total number of soil samples = 90, includes 4 field duplicates

Shaded rows indicate inclusion for Post-Grayling site specific analyte list, used for Accelerated Method

Table 6-9. Rationale for Grayling Accelerated Method Analyte List

Air Force (Anderson) List	Pre-Grayling Work List	Post-Grayling List	Rationale for adding to Post-Grayling 2019 List, Used for Accelerated Method
Total PFHxS	Total PFHxS	Total PFHxS	>50% for Grayling waters and Air Force Data Set
PFHxA	PFHxA	PFHxA	>50% for Grayling waters and Air Force Data Set
PFPeA	PFPeA	PFPeA	>50% for Grayling waters and Air Force Data Set
PFHpA		PFHpA	>50% for Grayling waters and Air Force Data Set
PFOA	PFOA	PFOA	>50% for Grayling waters and Air Force Data Set
PFBA	PFBA	PFBA	>50% for Grayling waters and Air Force Data Set
Total PFOS	Total PFOS	Total PFOS	>50% for Grayling waters and Air Force Data Set
6:2 FTS	6:2 FTS	6:2 FTS	43% for Grayling waters and > 50% in Air Force Data Set
PFNA		PFNA	26% for Grayling waters and > 50% in Air Force Data Set
	8:2 FTS	8:2 FTS	<50% on both lists. BUT, prevalent in soils at 2 X levels of 6:2 FTS
		PFHpS	Almost >50% for Grayling waters
		PFPeS	>50% for Grayling waters
		PFBS	>50% for Grayling waters



Compounds < 10%
PFOSA, PFDS, PFNS, PFDA,
PFUdA, PFDA, PFTeDA,
PFDoA, NMeFOSAA,
NEtFOSAA and 4-2FTS

Figure 6-3. **Grayling Percent Detections, Fall 2019**

6.2.2 Performance Evaluation Results

6.2.2.1 Laboratory Throughput and Turnaround Time

The laboratory analyzed 234 water samples and 89 soil samples (for a total of 323 samples) over 13 days of laboratory work. This equates to 24.8 samples per day. Compared to the DoD ELAP Method, these totals numbers do not include two water samples and one soil sample not analyzed by the Accelerated Method due to sample handling errors at the laboratory. Based on this productivity, it is reasonable to expect the laboratory to turn around results for a group (four to eight samples) of priority samples within the same day and all samples for a given day (up to approximately 25) being reported by mid-morning of the next day. The same-day results are predicated upon the laboratory receiving the samples by mid-morning. Use of a shorter analyte list would increase the throughput of the laboratory.

6.2.2.2 Cost of Analyses

The cost for these screening analyses was $78,544. These costs include all of the labor and expense costs to complete these analyses at the fixed facility. Because the laboratory analyzed 323 (234 waters and 89 soils) samples over 13 analytical days, this equates to $243 per sample analysis.

The current cost for the mobile laboratory to conduct these screening analyses is approximately $5,300/day. This unit price fluctuates, however, based on multiple project-specific requirements. Including an illustrative mobilization/demobilization cost of $3500 for a mid-distance project, an illustrative 10-day project would cost a total of $56,500. Using a range of 20 to 25 samples per day for estimated throughput, this would equate to 200 to 250 samples over 10 days or between $283 and $226 per sample. It is assumed that preliminary results would be provided within 24 hours, and final results would be provided within 48 hours. Current pricing for a fixed-lab analysis for PFAS is approximately $200 per sample. Using a typical rush surcharge of between 100 and 150 percent for 48-hour TAT, this equates to between $400 and $500 per sample. Note that, at this time, it is very difficult to find a laboratory that will offer a 24 hr. TAT for PFAS analytical work. That said, the mobile lab pricing for the Accelerated Method is likely to be below fixed-lab pricing for 48-hour service. Given that these are screening data, definitive analyses would normally be required to support these screening data. Even with the extra fees for the supporting definitive analytical work, the overall analytical costs are typically lower than those for a program that uses all quick-turn definitive analyses. This matter is further explored and demonstrated in **Section 9.4** below.

6.2.2.3 QA/QC Performance Against Stated DQOs

This section discusses the performance of the Accelerated Method against several QC metrics monitored throughout the analytical sequences. The following sections break out the various QC elements and state whether the given QC metric passed the stated performance goals established as part of the Demonstration Plan and listed in **Table 6-7**.

Initial Calibrations: As shown in **Table 6-7**, all calibrations passed criteria. Several calibration levels associated with the bottoms and tops of the curves were dropped periodically throughout these analyses to allow for the curves to pass criteria. In most cases, the levels dropped on the low side of the curve were below the reporting limits; therefore, the reporting levels were not raised. Where this was not the case, the reporting levels were raised accordingly.

Water detection limits were set to the limit of quantitation (LOQ). No MDLs were used for these analyses. LOQs ranged between approximately 20 and 40 ng/L for most of the analytes; however, LOQs ranging from 40 to 190 ng/L were periodically used for PFHpS, PFPeA, PFHxA, and PFBA due to calibration issues at the low ends of the curves.

Soil detection limits were also set to the LOQ. No MDLs were used for these analyses. LOQs ranged between approximately 40 to 100 ng/L; however, PFBA LOQs were set higher at approximately 250 ng/kg due to calibration issues at the low end of the curve.

A summary of the QC results of this testing is included in **Table 6-7**. These tests include CCV recoveries, LCS/LCSD recoveries, and MS/MSDs (both recoveries and RPD). Deficiencies were observed throughout the analyses; however, overall, the QC testing was in control throughout these analyses. **Table 6-3** presents percent pass rates for the individual compounds for each QC test. It is important to note that these percent pass data are derived using the final dataset, meaning that data associated with initial runs re-analyzed due to QC outages are not included in these percent pass data. These data represent all of the QC testing conducted as part of this work. To contextualize these data summaries, it is helpful to note that analytes are listed in elution order, with the short-chain PFBA eluting first and the long-chain PFTeDA eluting last.

Overall, the average percent pass rate for all compounds and all QC tests was 92.8 percent. This high percentage of passing rates indicates that the program was conducted largely within the QC tolerances set forth for these analyses.

A few notable areas of the QC program where higher rates of deficiencies were observed are as follow:

- The compound exhibiting the lowest average percent pass rates for all QC samples for water and soil was T-PFOS at 82.9 percent.
- Consistent with what was found with the DoD ELAP Method, a matrix effect was evident for total PFOS in soil samples. The percent pass rate (40 percent) of the MS/MSD recovery tests for this compound (made up of T-PFOS and PFOS) was the lowest observed in all of the QC testing.

The time between sampling and analyses for the Accelerated Method samples ranged from 75 to 118 days for water samples and 102 to 122 days for soil samples, which are well beyond the established holding time for PFAS analyses. The time between sampling and preparation, in which the samples were placed into solvent, ranged from 7 to 28 days for water samples and 1 to 18 days for soil samples. These prolonged holding times were expected, as these analyses were planned to be conducted after the field program. With the extensive amount of rework associated with the DoD ELAP Method, these holding times were extended even further than originally anticipated. As a measure to determine if the actual holding times would adversely impact the quality of these data, all the Accelerated Method water samples (includes batch QC and EISs) were pre-spiked before the end of the field program. As a reminder, the soil extracts from the DoD ELAP Method were used for these Accelerated Method analyses. Therefore, the pre-spiking program effectively followed the same timeline as the water samples. Based on the satisfactory recoveries of the LCS, MS, and EISs, it appears that the extended holding times did not adversely impact the integrity of these samples.

Extracted Internal Standards: As shown in **Table 6-4**, the overall average percent pass rate for the EIS recoveries was 99.7 percent. The data are broken out between samples and QC samples. The lowest average percent pass rate was 97.8 percent for the MPFBA and M8PFOS in the soil samples.

Rework Rates: Although not stated as a performance goal, an evaluation of the rework rates was deemed an important variable for evaluating the method's performance. Samples containing QC failures were re-analyzed. The rationale for selecting samples for re-analysis was as follows:

- Re-analyses were conducted only on samples from sequences that exhibited passing batch QC but exhibited other QC failures (e.g., EISs, CCVs).

This work is summarized in **Table 6-5**. As shown in **Table 6-5**, the percent of samples requiring re-analyses for water and soil samples was 7.2 and 10 percent for water and soil, respectively. The most common cause for the rework was due to EIS recoveries that were out of tolerance.

The precision goals established for the Accelerated Method were RPD </= 30 for water analyses, for both field duplicates and the MS/MSD pairs, and RPD </=50 for the soil analyses, both field duplicates and the MS/MSD pairs. Based on **Tables 6-3** and **6-7**, the RPD values for these analyses were less than 30 (or passing) for 80 percent of the water analyses, and all of the RPD values were less than 50 (or passing) for the soil analyses.

6.2.3 Summary and Conclusions

The Accelerated Method was developed as a hybrid LC/MS/MS method using the DoD ELAP Method soil sample preparation protocol for both soil and water matrices - the primary benefit being a single calibration curve for both soil and water samples. The method used EIS spiking before SPE for all sample analyses as well as EnviCarb cleanup; therefore, there are many commonalities between this method and the DoD ELAP Method. Because the method offers faster analytical run times and simpler sample preparation, this is a viable method to support high-resolution dynamic sampling strategies. The daily throughput of this method (at 25 per day) was demonstrated to be approximately twice that of the DoD ELAP Method.

As a screening-level technology, the method was conducted using less stringent DQOs than those used for the DoD ELAP Method and only analyzed for an abbreviated list of 13 compounds. However, based on the QA/QC performance for both the water and soil analyses, the method demonstrated a high degree of precision and accuracy and could likely be deployed as a definitive technology in the future. The average percent pass rates for all QC testing were 90.9 percent and 95.2 percent for waters and soils, respectively. For the EIS recoveries, these were almost perfect with a percent pass rate of 99.7 percent. As with the DoD ELAP Method, the lowest performing QC metric was the MS/MSD recoveries for PFOS in soil at approximately 40 percent for both methods.

The primary limitation for this method in its use as a screening technology is the elevated detection limit for water analyses. The reporting limit (RL) used for this work was set to approximately 20 ng/L. Although the instrument is adequately sensitive to meet lower detection limits that would reach single-digit parts per trillion (ppt) levels for water, the elevated RL was due to background contamination associated with the in-line SPE materials and some of the related solvents.

Since the time of this work, Pace has purchased solvents from other vendors and has devised a plan to reduce the effect of background contamination. The analytical team has also identified other areas for improvement and provides recommendations that should enhance the performance of this method.

Using the information provided in this report, the following conclusions are put forth regarding the validation and efficacy of using the Accelerated Method for conducting screening-level analytical work to support dynamic work strategies:

- The Accelerated Method, which uses LC/MS/MS technology with in-line SPE, provides analytical data of sufficient quality for screening purposes.
- As a screening method, caution should be taken when using data that approach the method's RL. As with other screening-level technologies, the RL should be sufficiently lower than the action levels established for the site work. For this work, where the RLs for PFOS and PFOA were typically around 20 ng/L, this RL was low enough to be used for the DoD OSD standard of 40 ng/L.
- The higher throughput of the Accelerated Method provides better value to site investigation and remediation projects. The costs per sample are significantly lower than fixed laboratory 48-hour turnaround work. This statement of better value is true even when conducting additional definitive analyses to support these screening-level analyses. This concept is further explored in cost and performance compared to fixed laboratory, **Section 9**.

6.3 METHYLENE BLUE ANIONIC SUBSTANCE SCREENING ANALYSES

6.3.1 Analytical Method Description and Implementation

MBAS test kits were obtained from Chemetrics Corporation for measuring anionic surfactants within the range of 100 to 2,000 micrograms per liter (µg/L; as PFOS) in water samples and 150 to 3,000 µg/kg as PFOS in soil. Calibration standards were prepared using a certified PFOS reference material (Wellington, part number L-PFOS, at 50,000 µg/L) diluted accordingly to make up the three-point calibration curves for the water and soil testing. Calibration levels of 100, 500, and 2,000 µg/L and 150, 750, and 3,000 µg/kg were used for the water and soil curves, respectively. The concentration of the salt was assumed to be accurate enough for these measurements; the actual concentration of the acid version of PFOS is within 10 percent of the values used for the calibration curves. The manufacturer's test procedure (R-9423) for the measurement of anionic surfactants was used and, based on this procedure, Pace developed an SOP (SSS-DRAFT MBAS-2019.10.17) that was submitted as part of the white paper for this project (See **Appendix K**). The procedure was set up for water samples and modified to allow for soil analyses. The modification for the soil samples involved the use of a water extraction fluid pH-adjusted to 10 using ammonium hydroxide to facilitate the extraction of the PFAS from the soil material. The water/soil extract was centrifuged, and the water portion of the mixture was used for subsequent analyses following the manufacturer's procedure for water samples.

Due to the relatively high detection limits of this method, this technique was intended to be used on samples collected at and/or near a high strength source area with some evaluation in the downgradient zones that exhibited significant PFAS concentrations. However, based on the DoD

ELAP Method data, the anionic PFAS levels in water never approached the MBAS detection limit for water (100 µg/L), and only two soil samples exhibited DoD ELAP Method detections greater than 150 µg/kg. Total anionic PFAS was calculated by summing all of the detectable levels of perfluorinated carboxylic acids and sulfonates in a given sample.

The analytical team observed that the MBAS detections were always at least an order of magnitude higher than what was being observed via the DoD ELAP Method. This was surprising because it was expected that the utility of the MBAS Method was likely only to be found where the PFAS concentrations were significant: higher than 100 µg/L for waters and 150 µg/kg for soils. This trend of biased high results persisted throughout these analyses.

The analytical team was aware that other anions present in the subsurface could cause a positive interference; one being chloride released from salts used in potential snow melting operations during this early winter period. To determine if chloride was causing the high results, a chloride removal step was deployed. This step involved treating the water with a sulfuric acid/sodium phosphate monobasic monohydrate solution before analysis. The removal step was conducted on samples that had already undergone the standard MBAS procedure. Initially, the post-chloride removal MBAS results appeared to yield lower results; therefore, the team decided to deploy chloride removal for all water samples. However, results from the 15 water samples analyzed with and without the chloride removal step demonstrate an insignificant difference between the two results. More importantly, even with the chloride removal step, the MBAS Method results continued to be significantly higher than the DoD ELAP Method results. The team also successfully ran this chloride removal step through several water MS/MSD sample analyses to confirm that there were no recovery issues. The chloride removal step was also attempted on the soil samples; however, the recoveries for the MS/MSD analyses were very poor. Therefore, the chloride removal step was not used for the soil analyses.

To further explore what could be causing the high MBAS results, samples were sent to two off-site labs (Pace Analytical and former Shealy Laboratories, now Pace) for anions analyses including nitrate, chloride, and sulfate. These data are shown in **Table 6-10A** (water) and **6-10B** (soil), and the laboratory reports for these analyses are included as part of **Appendix H**. According to the manufacturer of the MBAS test, nitrate interferes positively at concentrations of 10 mg/L, and chloride interferes positively at concentrations above 100 mg/L. No data for the level at which sulfate interferes with the test were available. None of the anion data obtained from the off-site labs approached these levels for nitrate and chloride; therefore, it does not appear that these specific anions were the cause for these high MBAS results.

Table 6-10A. Summary of MBAS Waters Data with Comparison to DoD ELAP

Sample ID	Lab ID	Location	MBAS, ng/L Pre Cl Removal	Q	MBAS, ng/LPost Cl Removal	Q	[1]LC/MS/MS Total Anionic PFAS Results(ng/L)	Q	RPD	False Positive	Nitrate Results, mg/L	Chloride Results, mg/L	Sulfate Results,mg/L
VAP-PS-2_14-17	P194301-02	Source Bldg 1194/1195	1.00E+05	U			1.17E+04		NA	NA			
VAP-PS-1_14-17	P194303-04	Source Bldg 1194/1195	2.60E+06		3.90E+06		8.61E+03		199	Yes	0.23	<2	<5
VAP-PS-3_16.5-19.5	P194303-05	Source Bldg 1194/1195	1.00E+05	U			5.58E+03		NA	NA			
VAP-F1-6_9-13	P194304-01	Transect 1	1.00E+05	U	1.00E+05	U	4.54E+01		200	NA			
VAP-F1-6_16-20	P194304-02	Transect 1	1.00E+05	U			1.06E+02		NA	NA			
VAP-F1-6_23-27	P194304-03	Transect 1	1.04E+05				5.39E+03		180	Yes			
VAP-PS-6_14-17	P194304-05	Source Bldg 1160	1.00E+05	U			4.83E+03		NA	NA			
VAP-PS-5_14-17	P194304-10	Source Bldg 1160	1.00E+05	U			1.56E+03		NA	NA			
VAP-PS-4_13-16	P194304-14	Source Bldg 1160	1.00E+05	U			4.02E+03		NA	NA			
VAP-F1-6_28.5-32.5	P194304-18	Transect 1	1.00E+05	U			5.12E+03		NA	NA			
VAP-F1-6_36-40	P194304-19	Transect 1	1.00E+05	U			4.40E+03		NA	NA			
VAP-F1-6_42.5-46.5	P194304-20	Transect 1	1.00E+05	U			6.20E+02		NA	NA			
VAP-F1-6_49.5-53.5	P194304-21	Transect 1	1.00E+05	U			3.35E+02		NA	NA			
VAP-F1-2_12-16	P194304-22	Transect 1	2.79E+05		1.04E+05		2.00E+02		199	Yes			
VAP-F1-2_19-23	P194304-23	Transect 1	4.10E+05		2.24E+05		2.07E+03		196	Yes	0.37	15.20	<5
VAP-F1-2_26-30	P194304-24	Transect 1	5.53E+05		1.92E+05		3.43E+03		193	Yes			
DUP02_102219, Parent =VAP-F1-2_19-23	P194304-25	Transect 1	4.10E+05				2.32E+03		198	Yes			
VAP-F1-4_12.5-16.5	P194304-26	Transect 1	1.04E+05				3.79E+01		200	Yes			
VAP-F1-2_33-37	P194305-01	Transect 1	6.84E+05				5.94E+02		200	Yes			
VAP-F1-2_40-44	P194305-02	Transect 1	7.06E+05				7.46E+02		200	Yes			
VAP-F1-2_47-51	P194305-03	Transect 1	7.94E+05				1.94E+02		200	Yes			
VAP-F1-2_56-60	P194305-04	Transect 1	5.09E+05				8.91E+01		200	Yes			
VAP-F1-4_20-24	P194305-05	Transect 1	1.00E+05	U			2.91E+02		NA	NA			
VAP-F1-4_27-31	P194305-06	Transect 1	1.00E+05	U			7.15E+02		NA	NA			
VAP-F1-4_34-38	P194305-07	Transect 1	1.00E+05	U			7.83E+02		NA	NA			
VAP-F1-4_41-45	P194305-08	Transect 1	1.00E+05	U			1.07E+02		NA	NA			
VAP-F1-4_49-53	P194305-09	Transect 1	3.45E+05				2.27E+01		200	Yes			
VAP-F1-4_54.5-58.5	P194305-10	Transect 1	3.34E+05				2.40E+01		200	Yes			
VAP-F1-8_13.5-17.5	P194306-01	Transect 1	2.13E+05		3.12E+05		1.28E+02		200	Yes			
VAP-F1-8_22-26	P194306-02	Transect 1	2.02E+05		1.48E+05		7.51E+02		198	Yes			
VAP-F1-8_28-32	P194306-03	Transect 1	2.02E+05		2.35E+05		4.74E+03		192	Yes			
VAP-F1-8_37.5-41.5	P194306-04	Transect 1	2.79E+05		2.68E+05		1.60E+03		198	Yes			
VAP-F1-8_46-50	P194306-05	Transect 1	2.02E+05		2.35E+05		1.27E+02		200	Yes			
VAP-F1-8_52.5-56.5	P194306-06	Transect 1	1.00E+05	U	1.15E+05		5.38E+01		NA	NA			
VAP-F2-3_15-19	P194306-07	Transect 2	1.15E+05		1.26E+05		1.72E+03		195	Yes	1.80	39.40	5.60
VAP-F2-3_23-27	P194306-08	Transect 2	1.81E+05		1.70E+05		2.85E+02		199	Yes			
VAP-F2-3_29-33	P194306-09	Transect 2	1.37E+05		1.92E+05		2.48E+02		199	Yes			
VAP-F2-3_38-42	P194306-10	Transect 2			1.04E+05		3.55E+02		199	Yes			
VAP-F2-7_12-16	P194307-01	Transect 2			1.00E+05	U	4.98E+02		NA	NA			
VAP-F2-7_22-26	P194307-02	Transect 2			1.00E+05	U	1.36E+04		NA	NA			
VAP-F2-7_32-36	P194307-03	Transect 2			1.00E+05	U	2.80E+03		NA	NA			
VAP-F2-3_47-51	P194307-04	Transect 2			1.15E+05		7.74E+01		200	Yes			
VAP-F2-3_56-60	P194307-05	Transect 2			1.70E+05		7.77E+01		200	Yes			
VAP-F2-5_13-17	P194307-06	Transect 2			1.00E+05	U	1.88E+03		NA	NA			
VAP-F2-5_22-26	P194307-07	Transect 2			1.15E+05		3.47E+02		199	Yes			

Sample ID	Lab ID	Location	MBAS, ng/L Pre Cl Removal	Q	MBAS, ng/LPost Cl Removal	Q	[1]LC/MS/MS Total Anionic PFAS Results(ng/L)	Q	RPD	False Positive	Nitrate Results, mg/L	Chloride Results, mg/L	Sulfate Results,mg/L
VAP-F2-5_31-35	P194307-08	Transect 2			1.15E+05		3.07E+02		199	Yes			
VAP-F2-5_38.5-42.5	P194307-09	Transect 2			1.04E+05		5.44E+01		200	Yes			
VAP-F2-5_47.5-51.5	P194307-10	Transect 2			1.15E+05		1.40E+02		200	Yes			
VAP-F2-5_56-60	P194307-11	Transect 2			2.79E+05		1.60E+02		200	Yes			
VAP-F2-7_41-45	P194401-01	Transect 2			1.00E+05	U	2.11E+02		NA	NA			
VAP-F2-7_49-53	P194401-02	Transect 2			1.04E+05		7.85E+01		200	Yes			
VAP-F2-7_56-60	P194401-03	Transect 2			1.81E+05		8.48E+02		198	Yes			
VAP-F3-2_11-15	P194401-04	Transect 3			1.37E+05		8.50E+01		200	Yes			
VAP-F3-2_18-22	P194401-05	Transect 3			1.00E+05	U	1.19E+03		NA	NA			
VAP-F3-2_25-29	P194401-06	Transect 3			2.13E+05		7.11E+03		187	Yes			
VAP-F3-2_32-36	P194401-07	Transect 3			1.26E+05		8.75E+03		174	Yes			
VAP-F3-2_40-44	P194401-08	Transect 3			1.70E+05		1.06E+03		198	Yes			
DUP01_102819, Parent = VAP-F3_18-22	P194401-09	Transect 3			1.00E+05	U	1.19E+03		NA	NA			
VAP-F3-2_47-51	P194402-01	Transect 3			3.67E+05		6.81E+03		193	Yes			
VAP-F1-1_12-16	P194402-02	Transect 1			3.34E+05		2.40E+02		200	Yes			
VAP-F1-1_22-26	P194402-03	Transect 1			1.26E+05		1.58E+03		195	Yes			
VAP-F1-1_28.5-32.5	P194402-04	Transect 1			1.81E+05		5.88E+02		199	Yes			
VAP-F1-1_36-40	P194402-05	Transect 1			1.00E+05	U	5.55E+02		NA	NA			
VAP-F1-1_42.5-46.5	P194402-06	Transect 1			1.26E+05		3.59E+02		199	Yes			
VAP-F1-1_49.5-53.5	P194402-07	Transect 1			1.00E+05	U	2.50E+02		NA	NA			
VAP-F1-1_56-60	P194402-08	Transect 1			1.00E+05	U	6.20E+00		NA	NA			
VAP-F2-1_15-19	P194601-06	Transect 2			1.00E+05	U	3.19E+04		NA	NA			
VAP-F1-11_21-25	P194603-10	Transect 1			1.00E+05	U	3.37E+04		NA	NA			
VAP-SS-6_14.5-18.5		Source Bldg 1194/1195	No MBAS conducted on these samples									0.76 J	
VAP-SS-5_15.5-19.5		Source Bldg 1194/1195										0.84 J	From Shealy

1 = Total anionic PFAS includes all carboxylic acids and sulfonates

U = undetected above the stated reporting limit

J = estimated value
Field duplicate pairs

Table 6-10B. Summary of MBAS Soils Data with Comparison to DoD ELAP

Sample ID	Lab ID	Location	MBAS (ng/Kg) no Cl Removal	Q	[1]LC/MS/MS Total Anionis PFAS Results (ng/Kg)	Q	RPD	False Positive	Nitrate Results, mg/kg	Chloride Results, mg/kg	Sulfate Results, mg/kg
SB-PS-2_14.7-15.2	P194302-01	Source Bldg 1160	5.06E+05		1.01E+03		>100	Yes			
SB-PS-2_12.5-13.0	P194302-02	Source Bldg 1160	3.96E+05		2.10E+02		>100	Yes	<1.0	<20.4	<51.1
SB-PS-2_16.5-17.0	P194302-03	Source Bldg 1160	6.53E+05		3.93E+03		>100	Yes			
SB-PS-3_12.5-13	P194303-01	Source Bldg 1160	1.50E+05	U	1.70E+03		NA	NA			
SB-PS-3_16.5-17	P194303-02	Source Bldg 1160	1.50E+05	U	2.71E+03		NA	NA			
SB-PS-3_14.5-15	P194303-03	Source Bldg 1160	1.13E+06		7.10E+02		>100	Yes			
SB-PS-1_12.5-13	P194303-06	Source Bldg 1160	5.06E+05		2.01E+04		>100	Yes			
SB-PS-1_16.5-17	P194303-07	Source Bldg 1160	1.20E+06		7.18E+04		>100	Yes			
SB-PS-1_14.7-15.2	P194303-08	Source Bldg 1160	1.68E+06		3.28E+04		>100	Yes			
DUP01_102219, Parent = SB-PS6_12.12.5	P194304-06	Source Bldg 1194/1195	1.50E+05	U	6.41E+03		NA	NA			
SB-PS-6_12-12.5	P194304-07	Source Bldg 1194/1195	1.50E+05	U	1.57E+03		NA	NA			
SB-PS-6_14.2-14.7	P194304-08	Source Bldg 1194/1195	1.50E+05	U	6.17E+03		NA	NA			
SB-PS-6_15.5-16	P194304-09	Source Bldg 1194/1195	1.50E+05	U	3.24E+03		NA	NA			
SB-PS-5_12-12.5	P194304-11	Source Bldg 1194/1195	6.16E+05		6.70E+02		>100	Yes	<1	<20.5	<51.2
SB-PS-5_14-14.5	P194304-12	Source Bldg 1194/1195	1.50E+05	U	6.50E+03		NA	NA			
SB-PS-5_15.5-16	P194304-13	Source Bldg 1194/1195	1.09E+06		6.42E+03		>100	Yes			
SB-PS-4_11-11.5	P194304-15	Source Bldg 1194/1195	1.50E+05	U	8.99E+02		NA	NA			
SB-PS-4_13.2-13.7	P194304-16	Source Bldg 1194/1195	9.09E+05		9.52E+02		>100	Yes	<1.1	<21.7	<54.2
SB-PS-4_15.5-16	P194304-17	Source Bldg 1194/1195	2.13E+05		3.06E+03		>100	Yes			
SB-SS-5_5.5-6	P194507-03	Source Bldg 1194/1195	3000000	E	9.24E+04		>100	Yes			
SB-SS-5_7.5-8	P194507-04	Source Bldg 1194/1195	[2]Not Reported		1.50E+05		NA	NA			
SB-SS-5_9.5-10	P194507-05	Source Bldg 1194/1195	[2]Not Reported		3.88E+05		NA	NA			
SB-SS-6_4-4.5		Source Bldg 1194/1195	No MBAS Conducted on these Samples							<2.5	
SB-SS-6_8.5-9		Source Bldg 1194/1195								<2.8	
SB-SS-4_4.5-5		Source Bldg 1194/1195								<2.8	
SB-SS-4_9-9.5		Source Bldg 1194/1195								<2.5	
SB-SS-4_14-14.5		Source Bldg 1194/1195								<2.5	
SB-SS-6_13.5-14		Source Bldg 1194/1195								<2.5	
SB-SS-5_13-13.5		Source Bldg 1194/1195								<2.5	
SB-SS-5-8-8.5		Source Bldg 1194/1195								<2.5	
SB-SS-5-3.5-4		Source Bldg 1194/1195								<2.8	

1 = Total anionic PFAS includes all caboxylic acids and sulfonates

2 = Emulsion formed, prohibited test from being conducted

U = Undetected above the specified reporting limit

E = exceeds calibration range

MBAS analysis was conducted on two water samples (VAP-F2-1_15-19 and VAP-F1-11_21-25) and three soil samples (SB-SS-5-5.5-6, SB-SS-5-7.5-8, and SB-SS-5-9.5-10) containing the highest levels of PFAS that had been observed up to that point. The results of the water testing were consistent with what had been found with the earlier water testing; significantly biased high MBAS results relative to the known PFAS concentrations. The three soil samples were from the source area and, based on the DoD ELAP Method, the levels of anionic PFAS were 92, 150, and 390 µg/kg, which were near or above the detection limit for the MBAS soils method. Upon conducting the initial portion of the test for the two sample results that exceeded the MBAS MDL, where chloroform is mixed with the MBAS reagent and the sample, a persistent emulsion was formed for both samples. In other samples, the emulsion initially formed, but within approximately 1 minute, this emulsion dissipated and allowed for the test to be finished via the colorimetric reading. The persistent emulsion in these two samples ultimately prevented the test from being completed for both soil samples. It is not understood at this time what caused the persistent emulsion to form; however, it is plausible that the source area material could have contained significant quantities of PFAS material that the LC/MS/MS technique was not able to detect. PFAS material that may have resulted in the elevated MBAS results relative to the LC/MS/MS results could be the zwitterionic components of AFFF, which have both anionic and cationic functionality. These zwitterionic compounds, along with the cationic PFAS components, can comprise a large portion of some AFFF's makeup (Houtz et al. 2013) and of the PFAS content in impacted environmental matrices (up to 97 percent in soil samples, Nickerson et al. 2020).

Another possible reason for the discrepancy between the MBAS and LC/MS/MS data is the anionic precursor content known to exist or form as byproducts of AFFF materials. Either anionic or zwitterionic precursors could cause binding of the methylene blue and hence the blue (positive) coloration of the test samples. This notion of the positive bias being caused by the organic PFAS anions zwitterions becomes less plausible when one considers the fact that this bias existed in both source area samples and downgradient samples. Because samples collected far from the source area are not likely to contain high levels of AFFF-related organic anions, this interference should not be present to the same extent in the downgradient samples. Future evaluations of this MBAS method may be better served by comparing the results to a total organic fluorine (TOF) or total oxidizable precursor (TOP) assay set of data and using simulated matrices that are low in inorganic anions and other unknown constituents that may cause the method interference.

Although the MBAS test demonstrated an apparent significant positive bias as a surrogate indicator for anionic PFAS, the team evaluated several factors that might explain results and perhaps create enough data to determine if there was any reliable trend between the two datasets. In other words, although there was significant bias, if the trend was consistent, the goal was to determine whether the test could still be used to reliably screen the relative amounts of PFAS anions present in the samples. Unfortunately, after a review of the comparison data, it was determined that data exhibited very poor intercorrelation and, consequently, the program was terminated early (after 8 days).

6.3.2 Performance Evaluation Results

6.3.2.1 Laboratory Throughput and Turnaround Times

Summary of MBAS Analytical Work: A mobile-mini construction container was used as the laboratory for these MBAS analyses. The laboratory was set up on October 21, 2019, and MBAS analyses started on October 22, 2019. Over 9 days (October 22 through November 1), 2019, the laboratory analyzed and reported results for 68 groundwater samples (including two field duplicates) and 22 soil samples (including one field duplicate). In addition, five MS/MSD pairs (four water, one soil) were analyzed.

Given that 90 samples (68 water and 22 soil) were analyzed over 9 days, this equates to a throughput rate of 10 samples per day. This rate does not reflect the actual rate that can be achieved using these tests. The test for a single sample requires approximately 10 minutes per sample or six tests per hour. The optimal throughput, with 20 percent of the runs allocated to QC measurements for a given 8 hr. day would be approximately 48 samples per day. The lower actual throughput of this testing was largely due to the time spent researching the chloride removal step, re-running a number of samples, and performing in-field comparisons to the LC/MS/MS results.

6.3.2.2 Cost of Analyses

The actual costs for these MBAS analyses was $26,482. This cost includes all of the labor and expenses to research and set up the method, mobilize and demobilize to/from the site, and conduct 10 days of analyses. Given that 90 samples were reported as part of this work, this equates to $294 per sample. As stated above, the throughput for the MBAS work was not optimal; if the team were able to analyze 48 samples per day (or 480 samples total), the cost per sample would have been significantly lower at approximately $55/sample.

6.3.2.3 QA/QC Performance Against Stated DQOs

Overall, the QC testing satisfied the QA/QC performance goals for this project. Summaries of these QC measures, including the continuing calibration checks, laboratory control standards, and MS results, indicate adequate performance with a few marginal exceptions. These QC summaries are shown in **Table 6-11**. The full lab report for the MBAS program is included in **Appendix H**.

The precision goal for the MBAS was an RPD of <50 for both water and soil for the field duplicates and the MS/MSD pairs. In all cases, this was achieved.

Table 6-11. QA/QC Summaries MBAS Method

PFAS MBAS/Screening - Water				
QC Check	**Frequency Goal**	**Frequency Actual**	**Tolerance Goal**	**Tolerance Actual**
Inititial cal	One at the beginning of analyses	Criteria achieved	Linear calibrations r2 ≥ 0.99.	All calibrations passed criteria. Note that only one calibration curve was required for all work.
CCV	1 per 20, and at end of sequence	Criteria achieved, except on 2/23/20 where no closing CCV was performed.	%D ≤ 30%	All criteria achieved with minor exceptions
LCS	NA in Demo Plan, every 40 in SOP	Criteria achieved	60-140% recovery	All criteria achieved
MS/MSD - Accuracy	1 per 40	Criteria achieved	60-140% recovery	All criteria achieved
MS/MSD Precision	1 per 40	Criteria achieved	RPD ≤ 50%	All criteria achieved
Field Duplicate Analyses	1 per 20	Criteria not achieved	RPD ≤ 50%	All criteria achieved
PFAS MBAS/Screening - Soil				
Inititial cal	NA	Criteria achieved	Linear calibrations r2 ≥ 0.99.	All calibrations passed criteria. Note that only one calibration curve was required for all work.
CCV	1 per 20	Criteria achieved	%D ≤ 30%	All criteria achieved with minor exceptions
LCS	NA in Demo Plan, every 40 in SOP	Criteria achieved	60-140% recovery	All criteria achieved
MS/MSD - Accuracy	1 per 20	Criteria achieved	60-140% recovery	All criteria achieved
MS/MSD Precision	1 per 20	Criteria achieved	RPD ≤ 50%	All criteria achieved
Field Duplicate Analyses	1 per 20	Criteria not achieved	RPD ≤ 50%	All criteria achieved

RPD = relative percent difference

CCV = contininining calibration check, LCS = Laboratory Control Sample, MS/MSD = matrix spike/matrix spike duplicate

6.3.2.4 Comparison to DoD ELAP Analyses

As shown in **Tables 6-10A** (water) and **6-10B** (soil), and based on the discussion above (**Section 6.3.1**), the method comparisons did not meet the goals of this program. All of the MBAS results were at least one order of magnitude (and in some cases four orders) higher than anionic PFAS measured by the DoD ELAP Method. As for the correlation and/or trends to the DoD ELAP Method data, the RPDs for all of the pairs, including water and soil data, were greater than 150, and there was no discernible trend between the two datasets. Further conclusions regarding the efficacy of using the MBAS Method are provided in the conclusions section below. A laboratory report is provided in **Appendix H**.

6.3.3 Summary and Conclusions

In general, the MBAS method was determined to be unreliable at this site for screening water and soils for anionic PFAS. The data derived from this method were poorly correlated with the anionic PFAS levels found using the DoD ELAP Method. Where the MBAS Method samples exhibited detections, the concentrations were significantly higher than the DoD ELAP Method concentrations, and there did not appear to be any trend between the two datasets.

The reasons for this unreliability due to positive interferences with the MBAS analysis are not understood at this time. The concept of inorganic ions causing the positive interference was explored, but the concentrations of three key inorganic ions were not high enough to result in MBAS detections. It is possible that other PFAS material (i.e., zwitterionic compounds and anionic precursors) were present that caused the positive interference in the analysis, and the levels of these interfering anions were not at all consistent with the levels of PFAS determined by LC/MS/MS. This notion is more defensible for the source area soil samples and less so for the downgradient water samples where it is unlikely that significant amounts of AFFF-related material is present. Additional testing would be required to better understand what other anionic (organic and inorganic) substances were present in the subsurface and how these impacted the accuracy of the MBAS test for anionic PFAS screening. Future evaluations of this MBAS method may be better served by comparing the results to a TOF or TOP assay set of data. Further, if the goal of this test is to be used as a surrogate for quantifying a select PFAS (i.e., PFOS/PFOA), this test does not exhibit the selectivity required to meet this objective.

The other matter that should be evaluated is the MBAS Method's ease of use. The use of chloroform presents additional health and safety challenges when conducting the work. Chloroform is a known carcinogen and requires a fume hood and special hazardous waste handling practices to be in place. These health and safety items are not often available in a field setting, making this test especially burdensome to deploy.

In conclusion, the MBAS Method does not appear at this time to be a viable screening tool for anionic PFAS, whether it be for determining source zone locations and/or for helping a LC/MS/MS laboratory determine how to dilute potentially "hot" samples. This is especially true at sites where the total anionic PFAS levels are lower than 100 µg/L, and the groundwater and soil anion chemistry is not well understood. Further, the requirement for a fume hood and special handling practices to be in place also detracts from its efficacy as a field-friendly analytical tool.

6.4 FIELD DUPLICATE SAMPLE RESULTS

The following sections discuss the evaluation of precision between the parent and field duplicates collected for the DoD ELAP, Accelerated, and MBAS Methods. The results of the DoD ELAP and Accelerated Method field duplicates are shown in Table 6-12. The results for the MBAS Method field duplicates are shown on Table 6-10A (waters) and 6-10B (soils). In all cases, RPD calculations were only conducted for pairs in which both analyses registered a detect. If one or both of the methods recorded a non-detect value, the RPD result in the table is listed as NA.

The goal of this duplicate sampling was to evaluate the precision of the field sampling as well as that of the analytical programs. The performance goals, given as RPD for these analyses, were established as part of the Demonstration Plan for this project. These goals were set to </=30 and </=50 for the water and soil, respectively.

6.4.1 DoD ELAP Field Duplicate Analyses

Waters: Twelve field duplicate water samples were collected as part of this work. Given that 236 water samples were collected, the frequency of these field duplicates was 5.1 percent, which met the frequency goal of 5 percent. **Table 6-12** shows the results of these comparisons. The averages, broken out between the primary and Secondary PFAS compounds, are shown in the table. Of the 12 samples, 11 sample pairs compared very well to each other. One of the field duplicate sample (DUP02_111519) did not match its parent sample; in this case, this parent sample was deemed an outlier by virtue of the outlier evaluation in **Section 7.3**. Excluding this duplicate result, the RPDs for all of the average RPDs never exceeded 16; indicating excellent sampling and analytical precision.

Soils: Four field duplicate soil samples were collected as part of this work. Given that 86 soil samples were collected, the frequency of these field duplicates was 4.7 percent, which falls marginally short of the frequency goal of 5 percent. These duplicate samples were collected in the field and were placed directly into two separate sample jars; no homogenization of the soil was conducted before the samples were placed into the jars. This is noteworthy because it is well known that the spatial variability of contaminants can vary significantly over short distances and can result in field duplicates not matching well with their parent samples.

Overall, there appears to be significantly less correlation between the parent and field duplicate compared to the water analyses. Only one of the field duplicate samples (DUP02-111419) met the RPD criteria of </=50; in this pair, the average RPD was determined to be 29. The remaining three field duplicates did not meet the RPD goal of </=50. To provide possible reasons for these poor correlations, the Accelerated Method data (also shown in **Table 6-12**) are brought into the discussion. As a reminder, the Accelerated Method work used the same extracts as those used for the DoD ELAP Method. The following are a few observations regarding the results of these analyses:

- The field duplicate DUP01_110719 did have acceptable RPDs for the Primary PFAS compounds but exceeded the 50 RPD for several of the Secondary PFAS compounds.
- DUP01_110719/SBSS-6_11.5-12 and DUP03_111419/SB-F2_1718: As shown in **Table 6-12**, it appears that the parent samples do not match the duplicate samples for both the DoD ELAP and the Accelerated Method data. However, both parent samples match very well between the two methods. As mentioned above, these samples were collected separately into sample containers without a homogenization step. It is very likely that the cause for this lack of precision is due to the spatial variability of contaminant distribution in the region where these soil samples were collected.

Table 6-12. Parent and Field Duplicate Analytical Results and Relative Percent Differences

Matrix	GROUNDWATER															
Arcadis Sample IDs	VAP-F1-2_19-23 (DUP02_102219)				VAP-F1-12_36-40 (DUP01_111419)				VAP-F2-2_28-32 (DUP01_110119)				VAP-F2-6_48-52 (DUP02_103119)			
Analysis Method	DoD ELAP Method		Accelerated Method		DoD ELAP Method		Accelerated Method		DoD ELAP Method		Accelerated Method		DoD ELAP Method		Accelerated Method	
Analyte	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)
PRIMARY CONSTITUENTS OF INTEREST																
PFOA	28 [31]	10	41 [55]	29	3.2 [3.1]	3	< 17 [< 17]	NA	26 [26]	0	31 [33]	6	1.5 [< 1.0]	NA	< 17 [< 17]	NA
PFOS	1000 [1100]	10	910 [920]	1	31 [36]	15	38 [40]	5	100 [98]	2	110 [110]	0	< 1.3 [2.8]	NA	21 [< 17]	NA
T-PFOS	390 [470]	19	330 [360]	9	18 [18]	0	< 11 [19]	NA	59 [48]	21	59 [61]	3	< 0.79 [3]	NA	19 [< 11]	NA
Total PFOS	1400 [1600]	13	1200 [1300]	8	49 [53]	8	38 [59]	43	160 [150]	6	160 [170]	6	< 2.1 [5.8]	NA	40 [< 27]	NA
PFBS	4.6 [4.5]	2	< 33 [< 36]	NA	< 1.4 [< 1.4]	NA	< 17 [< 17]	NA	17 [17]	0	20 [< 17]	NA	< 1.4 [< 1.4]	NA	< 17 [< 17]	NA
Averages		11		12		6		24		6		4		NA		NA
SECONDARY CONSTITUENTS OF INTEREST																
6-2FTS	< 1.0 [< 1.1]	NA	< 33 [< 36]	NA	< 0.79 [< 0.79]	NA	< 17 [< 17]	NA	< 0.76 [1.8]	NA	< 17 [< 17]	NA	< 0.77 [< 0.77]	NA	< 17 [< 17]	NA
8-2FTS	< 1.9 [< 2.1]	NA	< 33 [< 36]	NA	< 1.5 [< 1.5]	NA	< 17 [< 17]	NA	< 1.5 [< 1.5]	NA	< 17 [< 17]	NA	< 1.5 [< 1.5]	NA	< 17 [< 17]	NA
PFHpA	16 [19]	17	< 33 [< 36]	NA	< 3.7 [< 3.7]	NA	< 17 [< 17]	NA	14 [14]	0	29 [29]	0	< 3.6 [< 3.6]	NA	< 17 [< 17]	NA
PFHpS	22 [26]	17	< 33 [< 36]	NA	< 3 [< 3]	NA	< 17 [< 17]	NA	9.1 [8.2]	10	< 17 [< 17]	NA	< 3 [< 2.9]	NA	< 17 [< 17]	NA
PFHxA	36 [38]	5	34 [37]	8	3.3 [2.8]	16	< 17 [< 17]	NA	26 [25]	4	29 [32]	10	< 1.4 [< 1.4]	NA	< 17 [< 17]	NA
PFHxS	460 [500]	8	400 [400]	0	28 [33]	16	35 [31]	12	220 [220]	0	220 [230]	4	4.6 [3.9]	16	< 17 [< 17]	NA
Br-PFHxS	66 [74]	11	43 [45]	5	5.1 [5.3]	4	< 7.3 [< 7.3]	NA	48 [54]	12	54 [58]	7	1.3 [1.2]	8	< 7.3 [< 7.3]	NA
Total PFHxS	530 [570]	7	440 [450]	2	33 [38]	14	35 [38]	8	260 [270]	4	270 [290]	7	5.9 [5]	17	< 24 [< 24]	NA
PFNA	5.9 [6.5]	10	< 33 [< 36]	NA	< 3.5 [< 3.6]	NA	< 17 [< 17]	NA	< 3.4 [< 3.5]	NA	< 17 [< 17]	NA	< 3.5 [< 3.5]	NA	< 17 [< 17]	NA
PFPeA	21 [23]	9	< 33 [< 36]	NA	3.5 [4.2]	18	< 17 [< 17]	NA	13 [12]	8	< 17 [< 17]	NA	< 1.7 [< 1.7]	NA	< 17 [< 17]	NA
PFPeS	9.9 [12]	19	< 33 [< 36]	NA	< 1.5 [< 1.5]	NA	< 17 [< 17]	NA	28 [29]	4	18 [26]	36	< 1.5 [< 1.5]	NA	< 17 [< 17]	NA
Averages		12		4		14		10		5		11		14		NA

Matrix	GROUNDWATER															
Arcadis Sample IDs	VAP-F2-8_56-60 (DUP01-103119)				VAP-F2-13_22-26 (DUP01_111219)				VAP-F3-2_18-22 (DUP01_102819)				VAP-F3-3_10-14 (DUP02_110119)			
Analysis Method	DoD ELAP Method		Accelerated Method		DoD ELAP Method		Accelerated Method		DoD ELAP Method		Accelerated Method		DoD ELAP Method		Accelerated Method	
Analyte	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)
PRIMARY CONSTITUENTS OF INTEREST																
PFOA	1.7 [1.9]	11	< 17 [< 17]	NA	40 [39]	3	45 [45]	0	69 [70]	1	81 [120]	39	2.6 [1.6]	48	< 17 [< 17]	NA
PFOS	< 1.2 [< 1.2]	NA	< 17 [< 17]	NA	24 [22]	9	24 [23]	4	71 [75]	5	90 [90]	0	1.8 [1.7]	6	< 17 [< 17]	NA
T-PFOS	< 0.78 [< 0.76]	NA	< 10 [< 10]	NA	18 [15]	18	19 [21]	10	170 [180]	6	190 [190]	0	4.1 [4.4]	7	< 11 [< 11]	NA
Total PFOS	< 2.1 [< 2]	NA	< 27 [< 27]	NA	42 [38]	10	44 [45]	2	250 [260]	4	280 [280]	0	5.9 [6.1]	3	< 27 [< 27]	NA
PFBS	< 1.3 [< 1.3]	NA	< 17 [< 17]	NA	1.9 [2]	5	< 17 [< 17]	NA	20 [22]	10	33 [27]	20	< 1.3 [< 1.4]	NA	< 17 [< 17]	NA
Averages		11		NA		9		4		5		12		16		NA
SECONDARY CONSTITUENTS OF INTEREST																
6-2FTS	< 0.76 [< 0.74]	NA	< 17 [< 17]	NA	< 0.76 [< 0.77]	NA	< 17 [< 17]	NA	260 [250]	4	280 [290]	4	< 0.76 [3.2]	NA	< 17 [< 17]	NA
8-2FTS	< 1.4 [< 1.4]	NA	< 17 [< 17]	NA	< 1.5 [< 1.5]	NA	< 17 [< 17]	NA	1.5 [2.6]	54	< 17 [< 17]	NA	< 1.5 [< 1.5]	NA	< 17 [< 17]	NA
PFHpA	< 3.5 [< 3.5]	NA	< 17 [< 17]	NA	17 [16]	6	26 [25]	4	65 [67]	3	80 [54]	39	< 3.5 [< 3.6]	NA	< 17 [< 17]	NA
PFHpS	< 2.9 [< 2.8]	NA	< 17 [< 17]	NA	< 2.9 [< 3]	NA	< 17 [< 17]	NA	23 [19]	19	25 [34]	31	< 2.9 [< 3]	NA	< 17 [< 17]	NA
PFHxA	< 1.3 [< 1.3]	NA	< 17 [< 17]	NA	13 [17]	27	18 [< 17]	6	190 [190]	0	230 [230]	0	< 1.3 [< 1.4]	NA	< 17 [< 17]	NA
PFHxS	< 1.4 [1.5]	NA	< 17 [< 17]	NA	110 [120]	9	130 [120]	8	190 [180]	5	230 [210]	9	4.5 [4.2]	7	< 17 [< 17]	NA
Br-PFHxS	< 0.48 [< 0.47]	NA	< 7.3 [< 7.3]	NA	14 [15]	7	14 [12]	15	41 [37]	10	50 [45]	11	< 0.48 [< 0.49]	NA	< 7.3 [< 7.3]	NA
Total PFHxS	< 2.0 [< 1.9]	NA	< 24 [< 24]	NA	130 [140]	7	140 [130]	7	230 [220]	4	280 [260]	7	4.5 [4.2]	7	< 24 [< 24]	NA
PFNA	< 3.4 [< 3.4]	NA	< 17 [< 17]	NA	< 3.5 [3.8]	NA	< 17 [< 17]	NA	< 3.5 [< 3.4]	NA	< 17 [< 17]	NA	< 3.4 [< 3.5]	NA	< 17 [< 17]	NA
PFPeA	< 1.7 [< 1.6]	NA	19 [< 17]	NA	13 [18]	32	25 [27]	8	250 [250]	0	380 [360]	5	< 1.7 [< 1.7]	NA	< 17 [< 17]	NA
PFPeS	< 1.4 [< 1.4]	NA	< 17 [< 17]	NA	3.8 [4]	5	< 17 [< 17]	NA	19 [20]	5	24 [21]	13	< 1.5 [< 1.5]	NA	< 17 [< 31]	NA
Averages		NA		NA		13		8		10		13		7		NA

Matrix	GROUNDWATER															
Arcadis Sample IDs	VAP-F3-3_24.5-28.5 (DUP01_110419)				VAP-F3-8_18-22 (DUP01_111519)				VAP-F3-8_25-29 (DUP02_111519)				VAP-SS-2_36-40 (DUP01_110519)			
Analysis Method	DoD ELAP Method		Accelerated Method		DoD ELAP Method		Accelerated Method		DoD ELAP Method		Accelerated Method		DoD ELAP Method		Accelerated Method	
Analyte	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)
PRIMARY CONSTITUENTS OF INTEREST																
PFOA	400 [370]	8	410 [410]	0	11 [9.1]	19	< 17 [< 17]	NA	14 [21]	40	22 [23]	4	2.6 [2.3]	12	< 17 [< 17]	NA
PFOS	57 [69]	19	94 [93]	1	220 [220]	0	220 [230]	4	11 [480]	191	540 [530]	2	55 [53]	4	61 [66]	8
T-PFOS	510 [390]	27	610 [560]	9	120 [110]	9	110 [110]	0	35 [320]	161	370 [370]	0	23 [20]	14	34 [35]	3
Total PFOS	460 [460]	0	700 [650]	7	330 [330]	0	330 [340]	3	46 [800]	178	910 [900]	1	78 [73]	7	95 [100]	5
PFBS	40 [45]	12	53 [< 17]	NA	4.1 [4.2]	2	< 17 [< 17]	NA	1.9 [8]	123	< 17 [< 17]	NA	1.8 [< 1.3]	NA	< 17 [< 17]	NA
Averages		13		4		6		2		139		2		9		5
SECONDARY CONSTITUENTS OF INTEREST																
6-2FTS	220 [230]	4	260 [270]	4	< 0.79 [< 0.8]	NA	< 17 [< 17]	NA	< 0.83 [< 0.8]	NA	< 17 [< 17]	NA	0.98 [< 0.75]	NA	< 17 [< 17]	NA
8-2FTS	< 1.5 [< 1.4]	NA	< 17 [< 17]	NA	< 1.5 [< 1.5]	NA	< 17 [< 17]	NA	< 1.6 [< 1.5]	NA	< 17 [< 17]	NA	< 1.4 [< 1.4]	NA	< 17 [< 17]	NA
PFHpA	210 [220]	5	230 [250]	8	8.1 [7.5]	8	< 17 [< 17]	NA	16 [14]	13	22 [< 17]	NA	< 3.5 [< 3.5]	NA	19 [21]	10
PFHpS	110 [100]	10	120 [120]	0	5.8 [5.6]	4	< 17 [< 17]	NA	< 3.2 [25]	NA	29 [29]	0	< 2.9 [< 2.9]	NA	< 17 [< 17]	NA
PFHxA	310 [340]	9	390 [360]	8	19 [18]	5	24 [24]	0	20 [45]	77	55 [45]	20	6.2 [6.4]	3	< 17 [< 17]	NA
PFHxS	1100 [1200]	9	1300 [1200]	8	200 [200]	0	200 [190]	5	53 [470]	159	470 [430]	9	43 [41]	5	40 [46]	14
Br-PFHxS	230 [220]	4	220 [240]	9	36 [37]	3	31 [29]	7	8.9 [97]	166	80 [66]	19	8 [8.6]	7	11 [12]	9
Total PFHxS	1400 [1400]	0	1500 [1500]	0	240 [240]	0	230 [220]	4	62 [560]	160	550 [500]	10	51 [49]	4	51 [58]	13
PFNA	18 [19]	5	22 [21]	5	< 3.6 [< 3.6]	NA	< 17 [< 17]	NA	< 3.7 [< 3.6]	NA	< 17 [< 17]	NA	< 3.4 [< 3.4]	NA	< 17 [< 17]	NA
PFPeA	350 [350]	0	380 [370]	3	15 [14]	7	< 17 [< 17]	NA	22 [36]	48	44 [42]	5	3.9 [3.4]	14	< 67 [< 67]	NA
PFPeS	58 [58]	0	68 [57]	18	6.6 [6.6]	0	< 17 [< 17]	NA	3 [21]	150	21 [23]	9	3.8 [3.6]	5	< 17 [< 17]	NA
Averages		5		6		3		4		111		10		6		11

Matrix	SOIL															
Arcadis Sample IDs	SB-F2-1_13.5-14 (DUP02_111419)				SB-F2-2_17-18 (DUP03_111419)				SB-PS-6_12-12.5 (DUP01_102219)				SB-SS-6_11.5-12 (DUP01_110719)			
Analysis Method	DoD ELAP Method		Accelerated Method		DoD ELAP Method		Accelerated Method		DoD ELAP Method		Accelerated Method		DoD ELAP Method		Accelerated Method	
Analyte	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)	Results	RPD (%)
PRIMARY CONSTITUENTS OF INTEREST																
PFOA	< 33 [< 49]	NA	< 40 [< 60]	NA	51 [< 36]	NA	56 [< 44]	NA	< 410 [< 450]	NA	< 50 [72]	NA	61 [96]	45	84 [92]	9
PFOS	< 22 [< 32]	NA	< 40 [< 60]	NA	7100 [< 24]	NA	7100 [< 44]	NA	670 [4400]	147	390 [7100]	179	6700 [7100]	6	6700 [7400]	10
T-PFOS	18 [< 8.9]	NA	< 28 [< 42]	NA	2100 [< 6.5]	NA	2700 [< 31]	NA	200 [1200]	143	160 [3000]	180	680 [450]	41	1000 [770]	26
Total PFOS	39 [< 41]	NA	< 68 [< 100]	NA	9100 [< 30]	NA	9800 [< 74]	NA	870 [5600]	146	560 [10000]	179	7400 [7500]	1	7700 [8200]	6
PFBS	< 11 [< 17]	NA	< 40 [< 60]	NA	< 13 [< 12]	NA	< 48 [< 44]	NA	< 140 [< 150]	NA	< 50 [< 55]	NA	< 18 [< 21]	NA	< 63 [< 74]	NA
Averages		NA		NA		NA		NA		145		179		23		13
SECONDARY CONSTITUENTS OF INTEREST																
6-2FTS	< 23 [< 35]	NA	< 40 [< 60]	NA	< 28 [< 25]	NA	< 48 [< 44]	NA	< 290 [< 320]	NA	< 50 [< 55]	NA	< 37 [< 43]	NA	< 63 [< 74]	NA
8-2FTS	< 15 [< 23]	NA	< 40 [< 60]	NA	< 18 [< 17]	NA	< 48 [< 44]	NA	< 190 [< 210]	NA	< 50 [< 55]	NA	< 24 [< 28]	NA	< 63 [< 74]	NA
PFHpA	< 23 [< 35]	NA	< 40 [< 60]	NA	36 [< 25]	NA	< 48 [< 44]	NA	< 290 [< 320]	NA	< 50 [< 55]	NA	< 37 [56]	NA	< 63 [< 74]	NA
PFHpS	< 15 [< 23]	NA	< 40 [< 60]	NA	54 [< 17]	NA	76 [< 44]	NA	< 190 [< 210]	NA	< 50 [88]	NA	37 [< 28]	NA	< 63 [< 74]	NA
PFHxA	15 [25]	50	< 40 [< 60]	NA	30 [15]	67	< 48 [< 44]	NA	< 170 [< 190]	NA	< 50 [< 55]	NA	31 [53]	52	< 63 [< 74]	NA
PFHxS	24 [20]	18	< 31 [< 47]	NA	370 [15]	184	400 [< 34]	NA	< 76 [290]	NA	< 39 [440]	NA	220 [420]	63	230 [420]	58
Br-PFHxS	< 6.2 [< 9.2]	NA	< 18 [< 26]	NA	46 [< 6.7]	NA	51 [< 19]	NA	< 78 [< 85]	NA	< 22 [57]	NA	< 9.7 [56]	NA	< 28 [53]	NA
Total PFHxS	24 [20]	18	< 49 [< 73]	NA	410 [15]	186	450 [< 53]	NA	< 150 [290]	NA	< 62 [490]	NA	220 [480]	74	240 [470]	65
PFNA	< 9.6 [< 14]	NA	< 40 [< 60]	NA	26 [< 11]	NA	< 48 [< 44]	NA	150 [130]	14	< 50 [< 55]	NA	43 [110]	88	< 63 [100]	NA
PFPeA	< 16 [41]	NA	< 40 [< 60]	NA	39 [32]	20	< 48 [< 44]	NA	550 [390]	34	< 50 [< 55]	NA	47 [73]	43	< 63 [370]	NA
PFPeS	< 15 [< 23]	NA	< 40 [< 60]	NA	< 18 [< 17]	NA	< 48 [< 44]	NA	< 190 [< 210]	NA	< 50 [< 55]	NA	< 24 [35]	NA	< 63 [< 74]	NA
Averages		29		NA		114		NA		24		NA		64		62

Abbreviations:

DoD ELAP = Department of Defense Environmental Laboratory Accreditation Program; NA = not applicable; RPD = relative percent difference

Notes:

1. Groundwater analytical results are in units nanograms per liter (ng/L) and soil analytical results are in units nanograms per kilogram (ng/kg).
2. Field duplicate analytical results are presented in brackets.
3. Relative Percent Difference is calculated as the absolute value of the DoD ELAP Method minus the Accelerated Method, divided by the average of the DoD ELAP Method and the Accelerated Method, times 100.

For waters, split sampling leads to representative samples and allows evaluation of the precision of the lab. For soils, duplicates are often quite different without homogenization and therefore might not enable the assessment of laboratory precision. For VOCs and 1,4-dioxane, we recommend splitting the soil extraction as another alternative, but this is not practical, as the labs add surrogates to the extract. The results from the of the fixed lab "confirmatory" analyses on-site lab, as discussed in **Section 6.1.2.4**, illustrates this point. The confirmatory samples were homogenized before creating the split samples. As shown in **Section 6.1.2.5**, the average RPD values are below the </=50 threshold and indicate that the DoD ELAP Method offers adequate precision for soil analyses. These results also emphasize the matter of variable contaminant distributions known to exist in soil over very short physical distances and how this should be considered an important variable when trying to measure precision in soil samples.

6.4.2 Accelerated Method Field Duplicate Analyses

Waters: Twelve field duplicate water samples were collected as part of this work. Given that 236 water samples were collected, the frequency of these field duplicates was 5.1 percent, which met the frequency goal of 5 percent. **Table 6-12** shows the results of these comparisons. The averages, broken out between the primary and Secondary PFAS compounds, are shown in the table. All 12 field duplicates compared very well with their respective parent samples. The RPDs for all of the average RPDs never exceeded 13, indicating excellent sampling and analytical precision.

Soils: Four field duplicate soil samples were collected as part of this work. Given that 86 soil samples were collected, the frequency of these field duplicates was 4.7 percent, which falls marginally short of the frequency goal of 5 percent. These duplicate analyses were conducted using the same extracts as those used for the DoD ELAP Method work. This was done to eliminate the sampling variability when comparing the two analytical methods; however, in this case where parent samples are compared to their field duplicates, the sampling variability appears to exist.

Overall, and similar to the DoD field duplicate assessment, there appears to be significantly less correlation between the parent and field duplicate compared to the water analyses. None of the pairs achieved an average RPD of </=50. One sample (DUP02_111419) did not have any detectable levels for the Accelerated Method; therefore, no RPDs were available. To provide possible reasons for these poor correlations, the DoD ELAP Method data (also shown in **Table 6-12**) are brought into the discussion. The following are a few observations regarding the results of these analyses:

- DUP01_110719 did have acceptable RPDs for the Primary PFAS compounds but exceeded the 50 RPD for two of the Secondary PFAS compounds.

- DUP01_110719/SBSS-6_11.5-12 and DUP03_111419/SB-F2_1718: Looking at **Table 6-12**, it appears that the parent samples do not match the duplicate samples for both the DoD ELAP and the Accelerated Method data. However, both parent samples match very well between the two methods. As mentioned above, these samples were collected separately into sample containers without a homogenization step. It is very likely that the cause for this lack of precision is due to the spatial variability of contaminant distribution in the region where these soil samples were collected.

- DUP01_102219: The Accelerated Method duplicate results appear to be very well matched with the DoD ELAP and Accelerated Method's parent sample for SB-F2-2_17-18. Here it is believed that this duplicate sample for the Accelerated Method was lost in the laboratory and was possibly never analyzed. The parent sample for SB-F2-2_17_18 was analyzed instead. Efforts to resolve this matter by going back to the physical samples/extracts and evaluating the analytical batch and sequence bench sheets were unsuccessful.

6.4.3 MBAS Method Field Duplicate Analyses

Waters: Two field duplicate water samples were collected as part of this work. Given that 68 water samples were collected, the frequency of these field duplicates was 2.9 percent, which did not meet the frequency goal of 5 percent. **Table 6-10A** shows the results of these comparisons. DUP02_102219 matched exactly to its parent VAP-F1-2_19-23, and both DUP01_102819 and its parent values were non-detect.

Soils: One field duplicate soil sample was collected as part of this work. Given that 22 soil samples were collected, the frequency of these field duplicates was 4.5 percent, which falls marginally short of the frequency goal of 5 percent. **Table 6-10B** shows the results of this comparison. DUP01_102219 and its parent SB-PS-6_12-12.5 both were non-detect; therefore, precision was not evaluated.

6.5 RECOMMENDATIONS FOR FUTURE METHOD IMPROVEMENTS

The following improvements and optimizations to the DoD ELAP and Accelerated Methods are recommended. No improvements for the MBAS Method are offered.

6.5.1 DoD ELAP Method

6.5.1.1 DoD ELAP Method, Water

- The sediment challenge will continue with future groundwater sampling; therefore, using a centrifuge will allow quicker processing and reporting of sample results.

- The removal of the sediment after the water sample is centrifuged and transferred to the SPE cartridge will ensure that the sample bottle is rinsed with appropriate solvent.

- EIS failures occur more frequently with the longer-chained EISs. To mitigate this, the final extract could be modified to have a higher organic solvent concentration, which will likely achieve better stability and recovery.

- Future automated SPE systems will be investigated; however, with sediment present, these systems may not be feasible due to inherent clogging issues.

- Compounds with no labelled analogue should be re-assigned to EISs that behave more similar to the native compound. It was observed that the area counts of these native compounds are at times well within the 30 percent range of calibration; however, the assigned EIS exhibits different variation and incorrectly compensates for the native compound, causing the concentration calculation to be outside the 30 percent limit.

- The LC/MS/MS system should undergo more frequent multiple reaction monitoring (MRM) optimization and perhaps optimization of the sample extract to reduce the baseline interferences shown to compete with PFBA and other early eluting compounds.

- The LC/MS/MS system should be reconfigured to use a diverter valve to divert unwanted matrix before and after the elution of compounds of interest.

No improvements for the soil method are deemed warranted.

6.5.2 Accelerated Method

6.5.2.1 Accelerated Method, Water

- The 4 mL sample volume for water samples at times challenged the sample team, as it was difficult to avoid overfilling the sample tube. Future work might include a larger sample tube to avoid this risk.
- To achieve lower detection limits, new solvents and new SPE chemistries are currently being evaluated. The challenge is to lower the background levels of PFAS compounds in solvents and consumables. If background levels can be lowered, then larger injection volumes can be concentrated on the SPE cartridge, therefore lowering the detection limits. The goal would be to have RLs in the single-digit ng/L range for the water analyses.
- The 70/30 ratio of methanol and water sample should be modified to 60/40 or 50/50, which will lower detection limits provided there is no loss of PFAS during the EnviCarb cleanup step. Previous observations show a loss of PFAS in the EnviCarb step if that extract is primarily aqueous in nature. This needs to be further evaluated.

6.5.2.2 Accelerated Method, Soil

One minor improvement would be to evaluate acetonitrile as a substitute for methanol in the extraction process and calibration standards. Observations suggest a possible methylation that occurs and interferes with PFBA and PFPeA. These methods use three compounds of PFBA (native and two analogues for EIS and surrogate). The MRMs are all very close for these three compounds, and earlier method development has demonstrated that using acetonitrile instead of methanol is superior in discerning the MRM responses among these three compounds.

7.0 COMPARISON OF ACCELERATED METHOD TO DOD ELAP METHOD

7.1 OBJECTIVES AND APPROACH

The objective of this section is to quantitatively evaluate the comparability of the Accelerated Method to the "gold standard" DoD ELAP Method. To do this, several statistical techniques were used. The statistical comparison section is divided into two separate subsections, described as follows:

Base Level Statistical Evaluation: This section covers the statistical methods and performance goals identified in the Demonstration Plan. These methods include:

1. Ordinary least squares (OLS) regression with calculation of R2 and slope
2. Average RPD.

Advanced Level Statistical Evaluation: This evaluation provides a more in-depth look at the reliability and accuracy of using the Accelerated Method compared to the DoD ELAP Method. The Advanced Level Statistical Evaluation also provides the statistical equivalence results of the Accelerated Method compared to the DoD ELAP Method using multiple statistical equivalence tests described in more detail in **Section 7.5.3**. The elements included in the Advanced Level Statistical Evaluation were as follows:

1. Reliability
2. Accuracy
3. Statistical Equivalence.

Before performing both the Base Level Statistics and the Advanced Level Statistics, an outlier evaluation was conducted, and the statistics were calculated both including and excluding outliers for comparison purposes. A detailed discussion of the outlier evaluation is presented in **Section 7.3**.

7.2 PFAS COMPOUNDS EVALUATED QUANTITATIVELY

A total of 28 PFAS compounds were analyzed by the DoD ELAP Method, and a total of 17 PFAS compounds were analyzed by the Accelerated Method. Both the DoD ELAP and Accelerated Methods included branched and linear versions of PFOS and PFHxS and totals of PFOS and PFHxS. PFBA results by the Accelerated Method did not match the DoD ELAP Method results and therefore were not included in the statistical evaluations. This left 16 compounds evaluated in these comparisons. Groundwater analytical data are summarized in **Tables 5-3** (Primary PFAS compounds) and **5-4** (Secondary PFAS compounds), and soil analytical data are summarized in **Table 5-5** and **Table 5-6**. Note that PFBA is not included in these tables. As discussed earlier in the report, the DoD ELAP Method data are reported down to the MDL whereas, the Accelerated Method data are reported down to the LOQ. No MDLs were available for the Accelerated Method. Due to this, there are instances where the non-detect values are different between the two methods. This was most evident with the groundwater data where the DoD ELAP Method's MDLs were as much as 10 times lower than the LOQ for the Accelerated Method.

The 16 PFAS compounds were categorized as either Primary PFAS compounds or Secondary PFAS compounds depending on if there was a screening level available for the compound. The Primary PFAS compounds have screening levels prescribed by the OSD (October 2019), while the Secondary PFAS compounds do not currently have DoD-established screening levels.

The following is the list of Primary and Secondary PFAS compounds.

Primary PFAS Compounds

- PFOA = Perfluorooctanoic acid
- PFOS = Perfluorooctane sulfonate
- T-PFOS = Technical product (branched) perfluorooctane sulfonate
- Total PFOS = Total perfluorooctane sulfonate
- PFBS = Perfluorobutane sulfonate.

Secondary PFAS Compounds

- 6-2FTS = 6,2-Fluorotelomer sulfonate
- 8-2FTS = 8,2-Fluorotelomer sulfonate
- PFHpA = Perfluoroheptanoic acid
- PFHpS = Perfluoroheptanesulfonic acid
- PFHxA = Perfluorohexanoic acid
- PFHxS = Perfluorohexanesulfonic acid
- Br-PFHxS = Branched-Perfluorohexanesulfonic acid
- Total PFHxS = Total Perfluorohexanesulfonic acid
- PFNA = Perfluorononanoic acid
- PFPeA = Perfluoropentanoic acid
- PFPeS = Perfluoropentanesulfonic acid

7.3 OUTLIER EVALUATION METHODS

Outliers are observations that are extremely small or extremely large compared to the rest of the observations in the dataset. In this analysis, the reliability and accuracy proportion analyses were performed excluding outliers, and the statistical equivalence tests were performed both including and excluding outliers for comparison purposes.

Potential outliers were determined using the three lines of evidence described below and professional judgement:

- Visual evaluation of X-Y scatterplots of the DoD ELAP Method results (X-axis) versus the Accelerated Method results (Y-axis). Data points that differ considerably from the majority of all data points were considered potential outliers and evaluated further. The X-Y scatterplots are presented for the Primary and Secondary PFAS compounds on **Figures 7-1** and **7-2**, respectively.
- Tukey test of the Percent Difference (% Difference) of the paired DoD ELAP Method result and the Accelerated Method result.
- Tukey test of the distance of the paired DoD ELAP Method result and the Accelerated Method result to the 1:1 line on X-Y scatterplots.

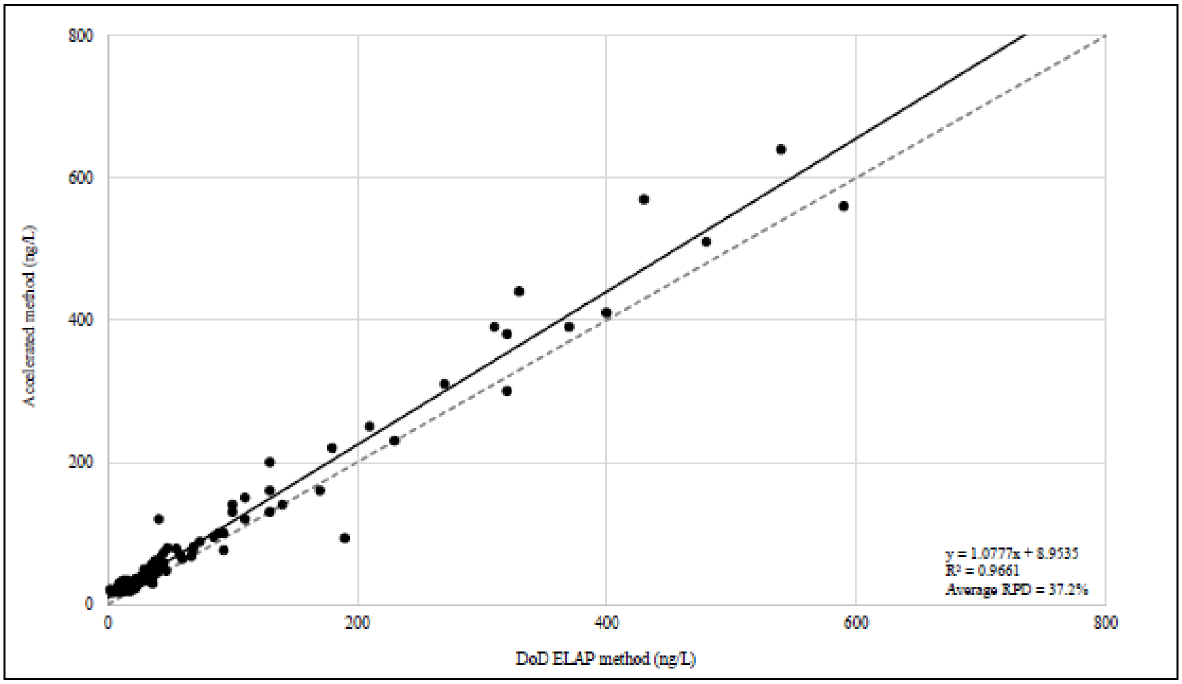
The Tukey outlier screening method, also referred to as the Interquartile Range (IQR) screening method, is a non-parametric method for identifying potential outliers. In this evaluation, the Tukey method was used to identify potential outliers for four iterations as described below:

- % Difference values either greater than the 75th percentile plus 3.0 times the IQR or % difference values less than the 25th percentile minus 3.0 times the IQR for **all data pairs**.
- Distance values greater than the 75th percentile plus 3.0 times the IQR for **all data pairs**.
- % Difference values either greater than the 75th percentile plus 3.0 times the IQR or % difference values less than the 25th percentile minus 3.0 times the IQR for **detect pairs only**.
- Distance values greater than the 75th percentile plus 3.0 times the IQR for **detect pairs only**.

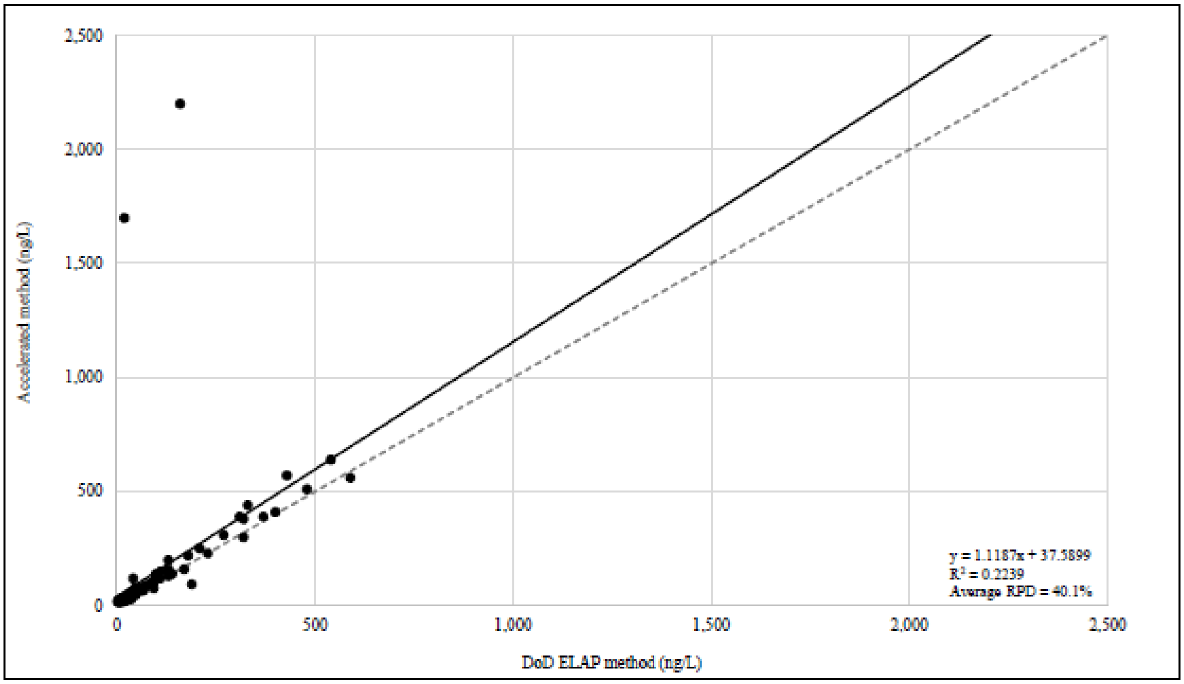
Samples with a high number of compounds outside the Tukey 3.0 IQR cutoff values in the four iterations were visually evaluated on the X-Y scatterplots. Samples that appear to be consistent with the majority of data points for most compounds were retained in the dataset because the data for the compounds for which they differed by more than 3.0 IQR may potentially represent natural variability. Samples that are notably different than the majority of data points for most of the compounds were considered potential outliers, likely representative of measurement error.

Figure 7-1. Primary PFAS Compounds – Detect Pair X-Y Scatterplots

PFOA - Groundwater - Outliers Removed



PFOA - Groundwater - All Detect Pairs

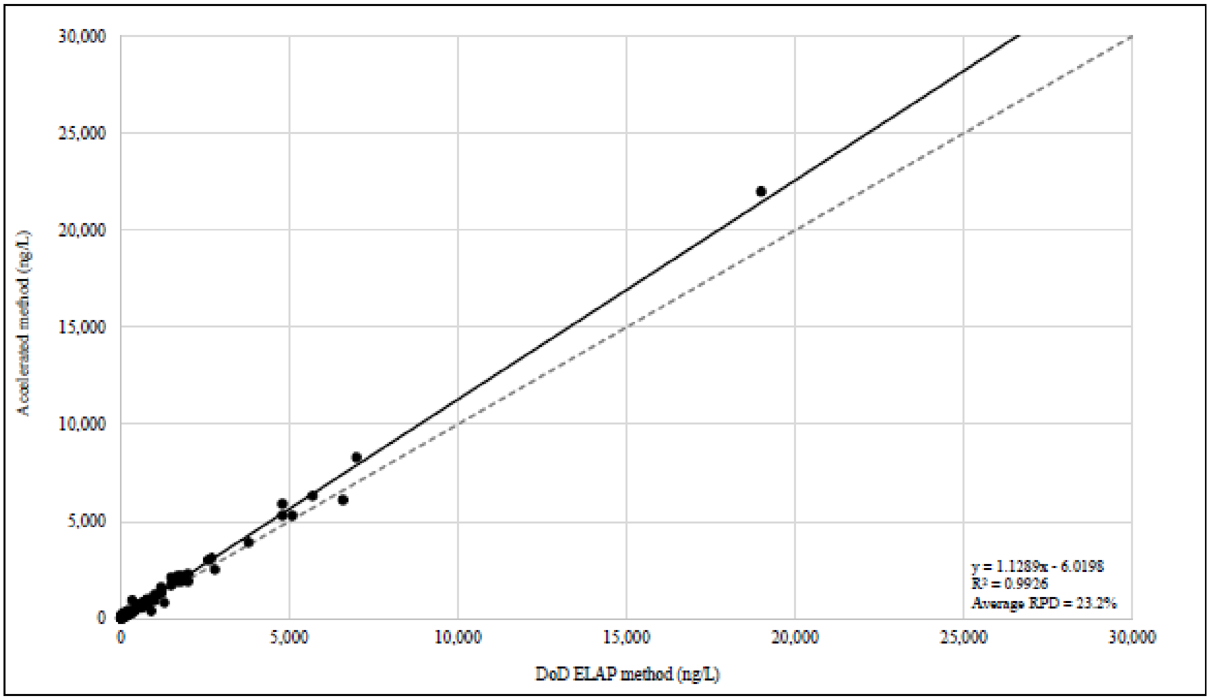


Legend
● Detect Pair ---- 1:1 Line —— OLS Regression Line (i.e., linear regression line)

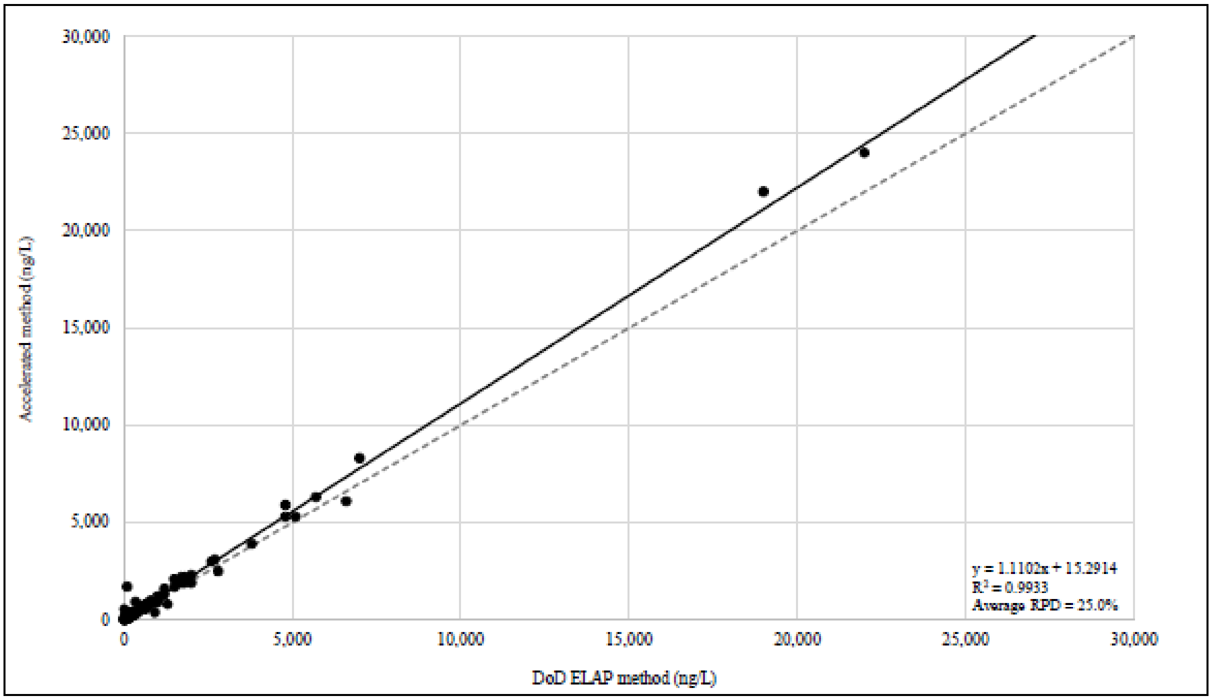
Abbreviations
ng/L = nanograms per liter RPD = relative percent difference

Figure 7.1A. Primary PFAS Compound - PFOA - Groundwater - Detect Pair X-Y Scatterplots

PFOS - Groundwater - Outliers Removed



PFOS - Groundwater - All Detect Pairs



Legend

●	Detect Pair
——	1:1 Line
——	OLS Regression Line (i.e., linear regression line)

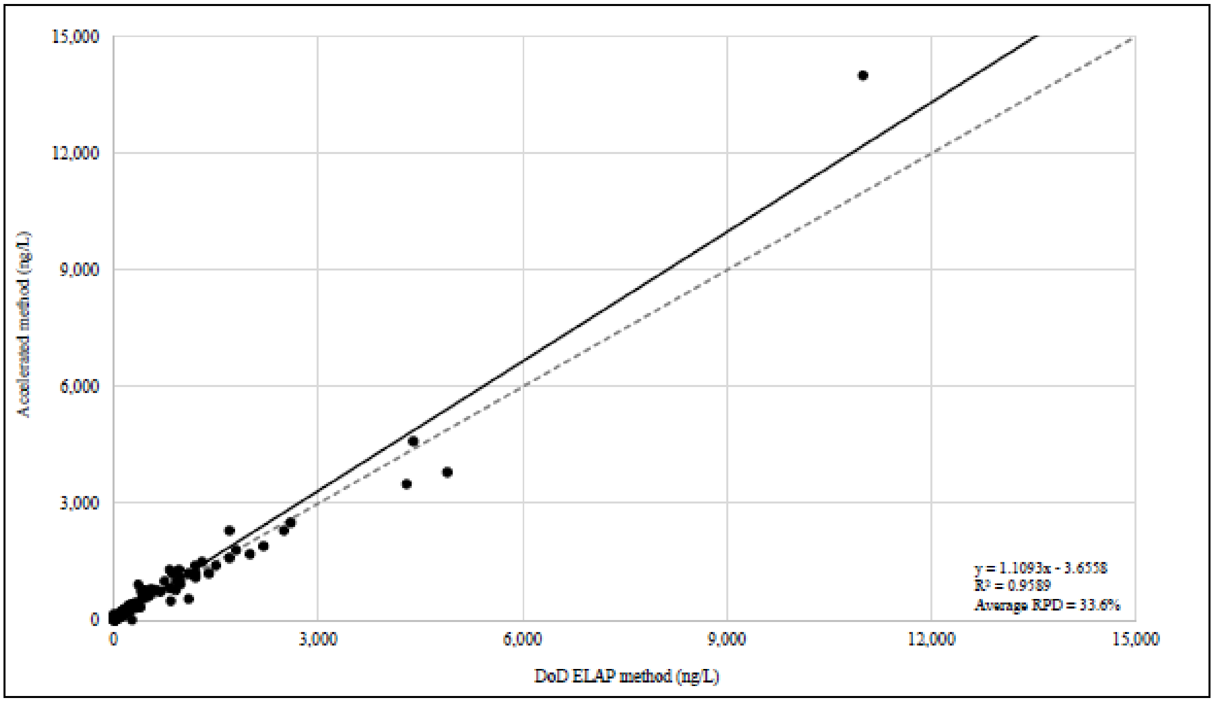
Abbreviations

ng/L = nanograms per liter

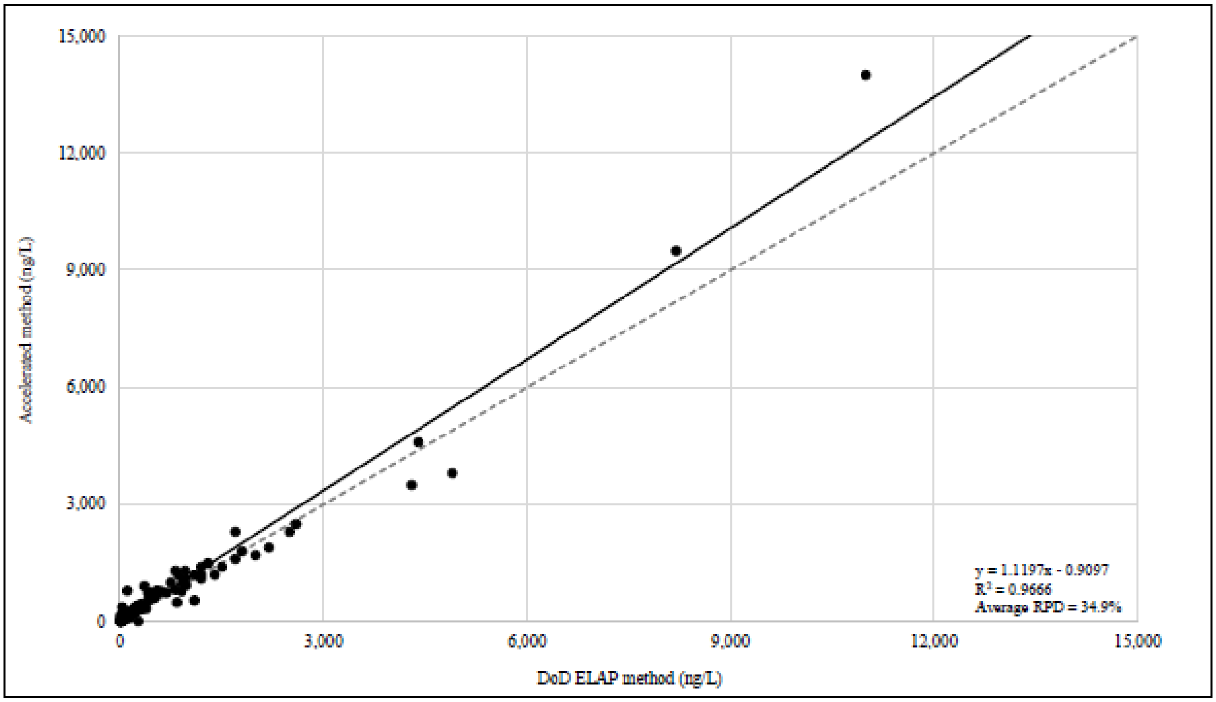
RPD = relative percent difference

Figure 7-1B. Primary PFAS Compound - PFOS - Groundwater - Detect Pair X-Y Scatterplots

T-PFOS - Groundwater - Outliers Removed



T-PFOS - Groundwater - All Detect Pairs



Legend

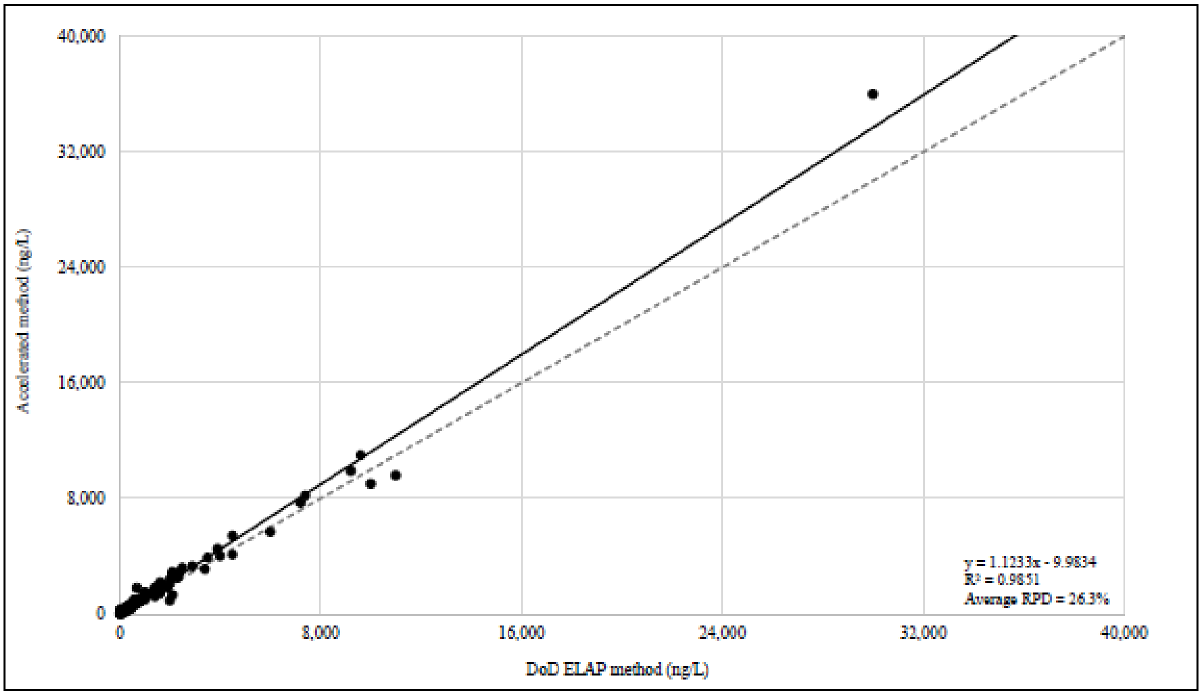
● Detect Pair ---- 1:1 Line —— OLS Regression Line (i.e., linear regression line)

Abbreviations

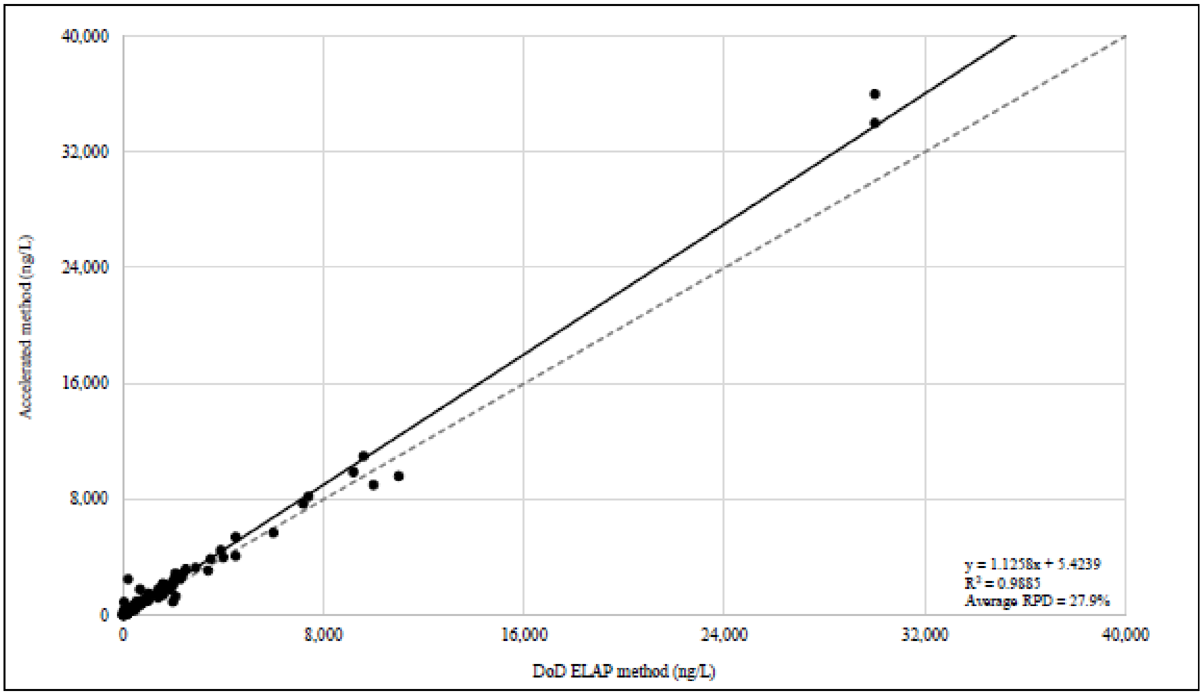
ng/L = nanograms per liter RPD = relative percent difference

Figure 7-1C. Primary PFAS Compound - T-PFOS - Groundwater - Detect Pair X-Y Scatterplots

Total PFOS - Groundwater - Outliers Removed



Total PFOS - Groundwater - All Detect Pairs



Legend

● Detect Pair — 1:1 Line — OLS Regression Line (i.e., linear regression line)

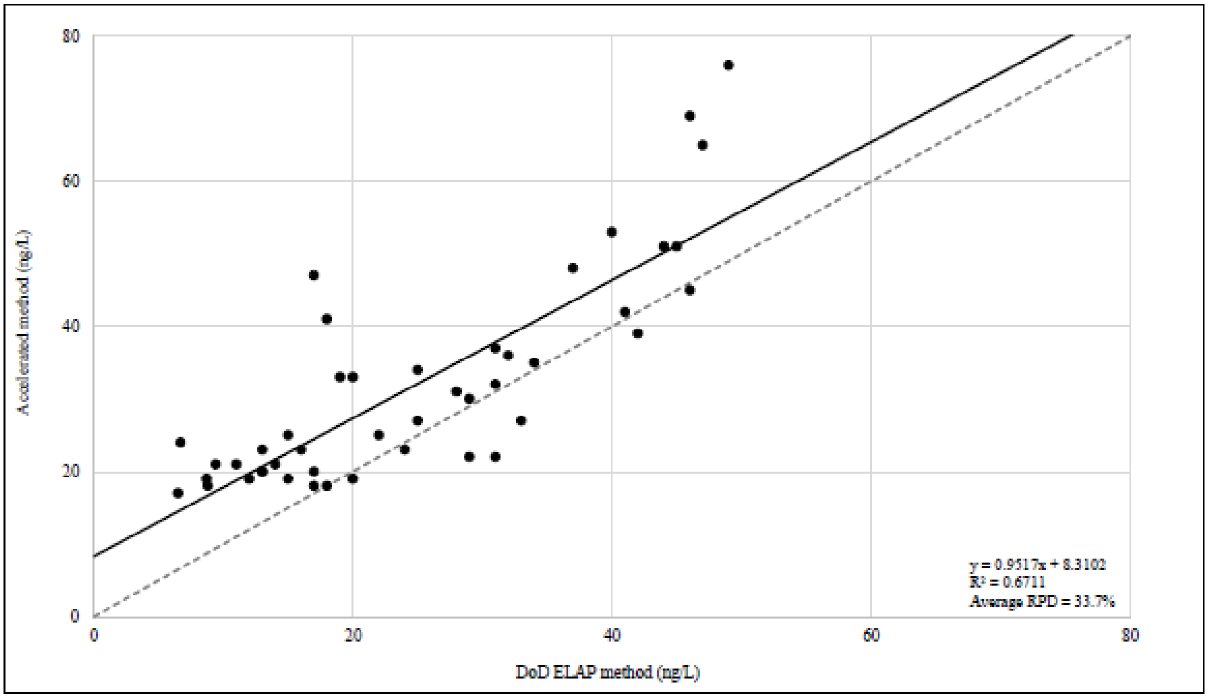
Abbreviations

ng/L = nanograms per liter

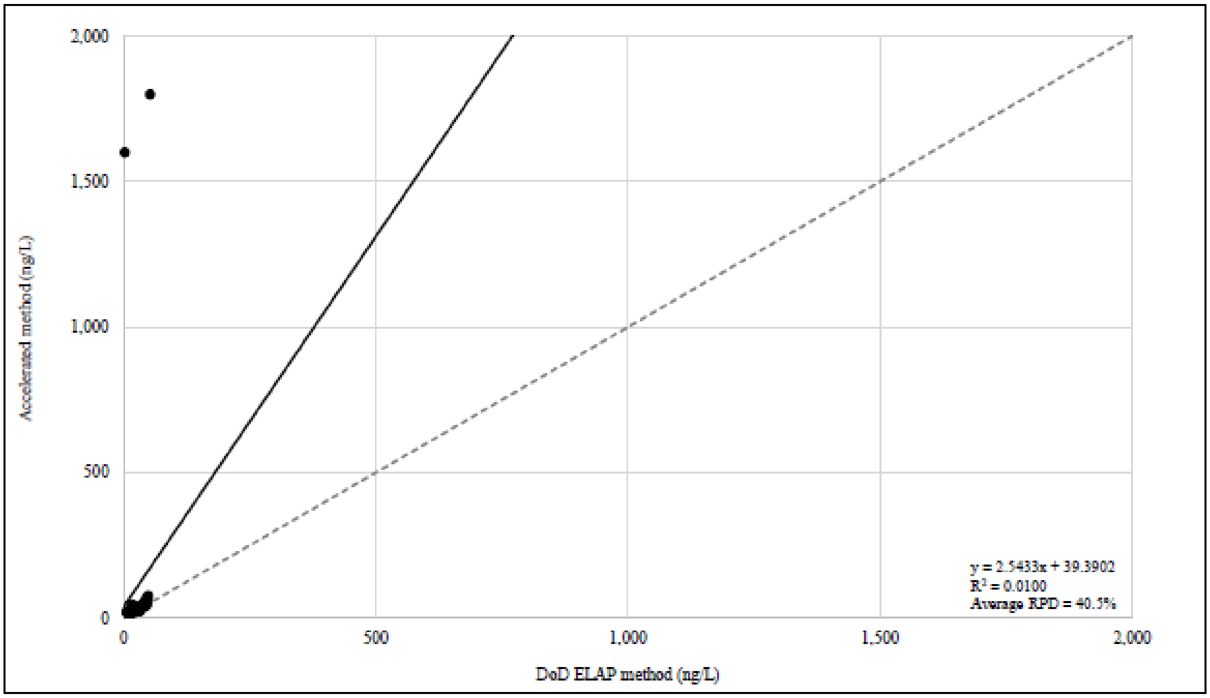
RPD = relative percent difference

Figure 7-1D. Primary PFAS Compound - Total PFOS - Groundwater - Detect Pair X-Y Scatterplots

PFBS - Groundwater - Outliers Removed



PFBS - Groundwater - All Detect Pairs



Legend

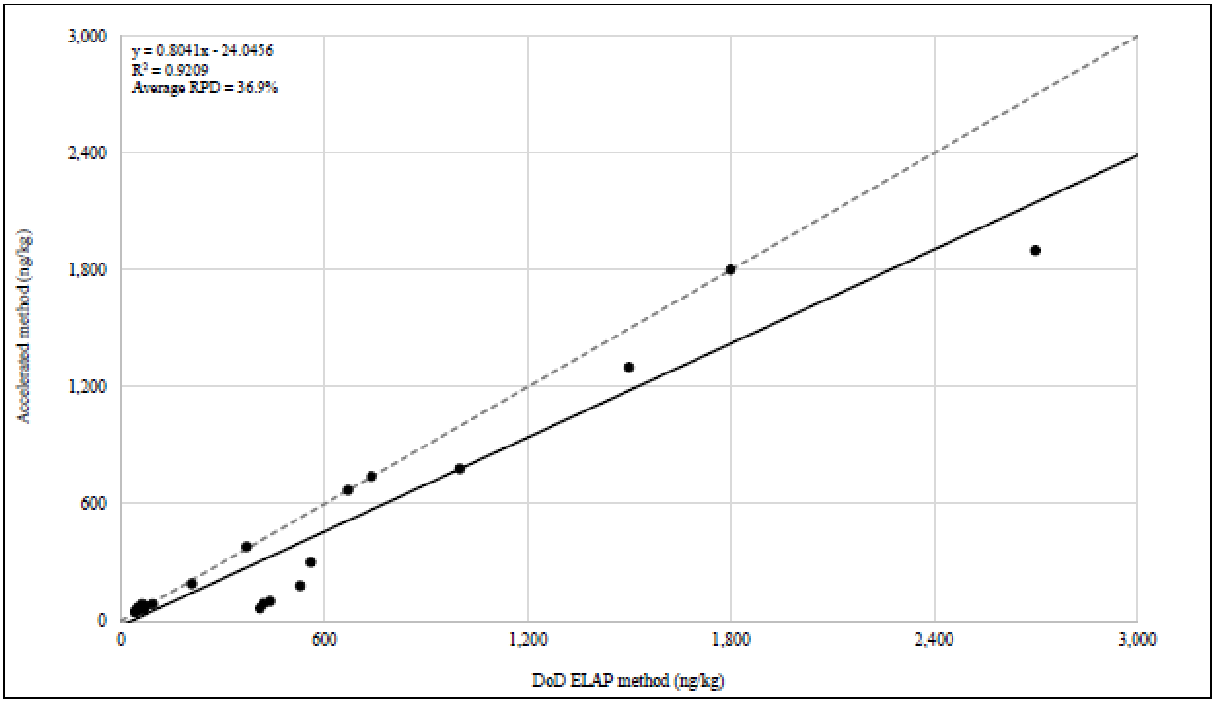
● Detect Pair ---- 1:1 Line —— OLS Regression Line (i.e., linear regression line)

Abbreviations

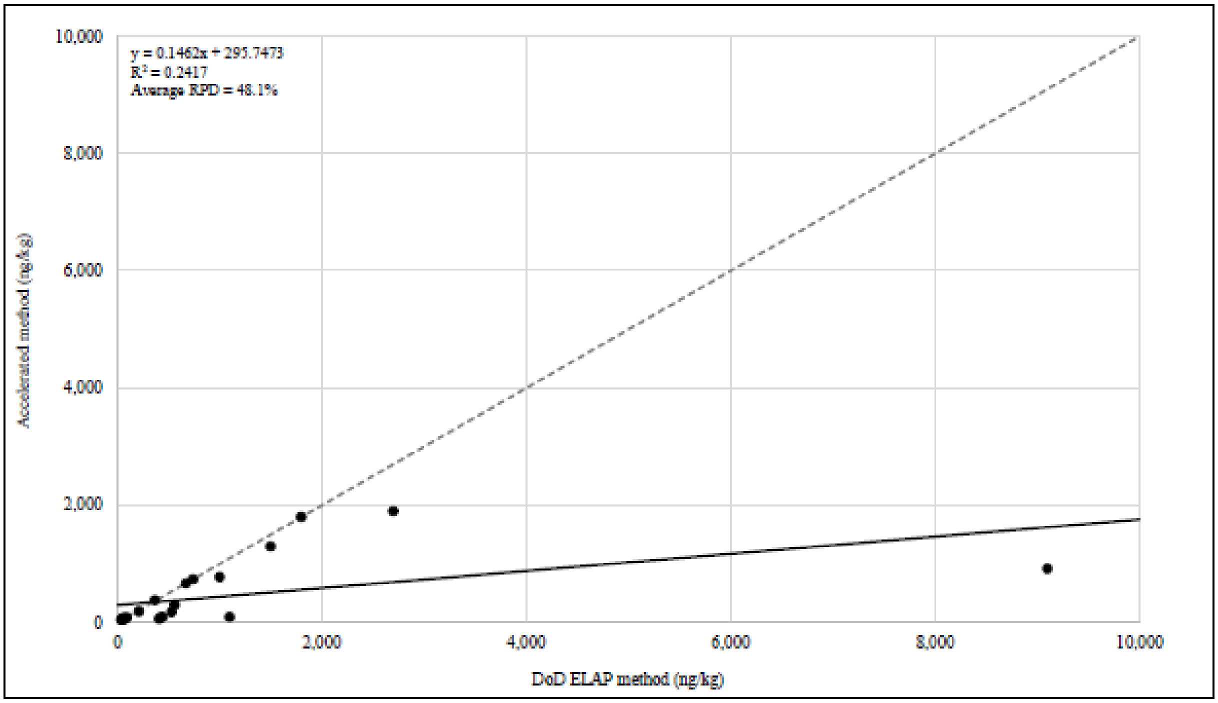
ng/L = nanograms per liter RPD = relative percent difference

Figure 7-1E. Primary PFAS Compound - PFBS - Groundwater - Detect Pair X-Y Scatterplots

PFOA - Soil - Outliers Removed



PFOA - Soil - All Detect Pairs



Legend

●	Detect Pair	- - -	1:1 Line	———	OLS Regression Line (i.e., linear regression line)

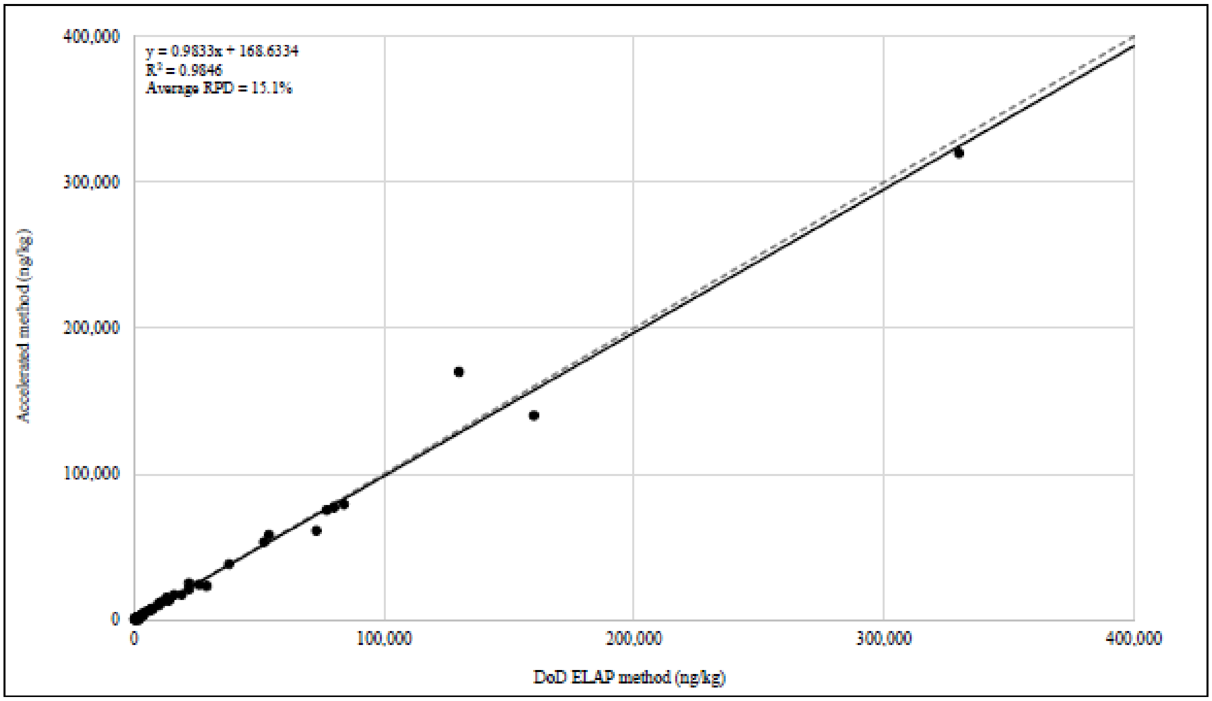
Abbreviations

ng/kg = nanograms per kilogram

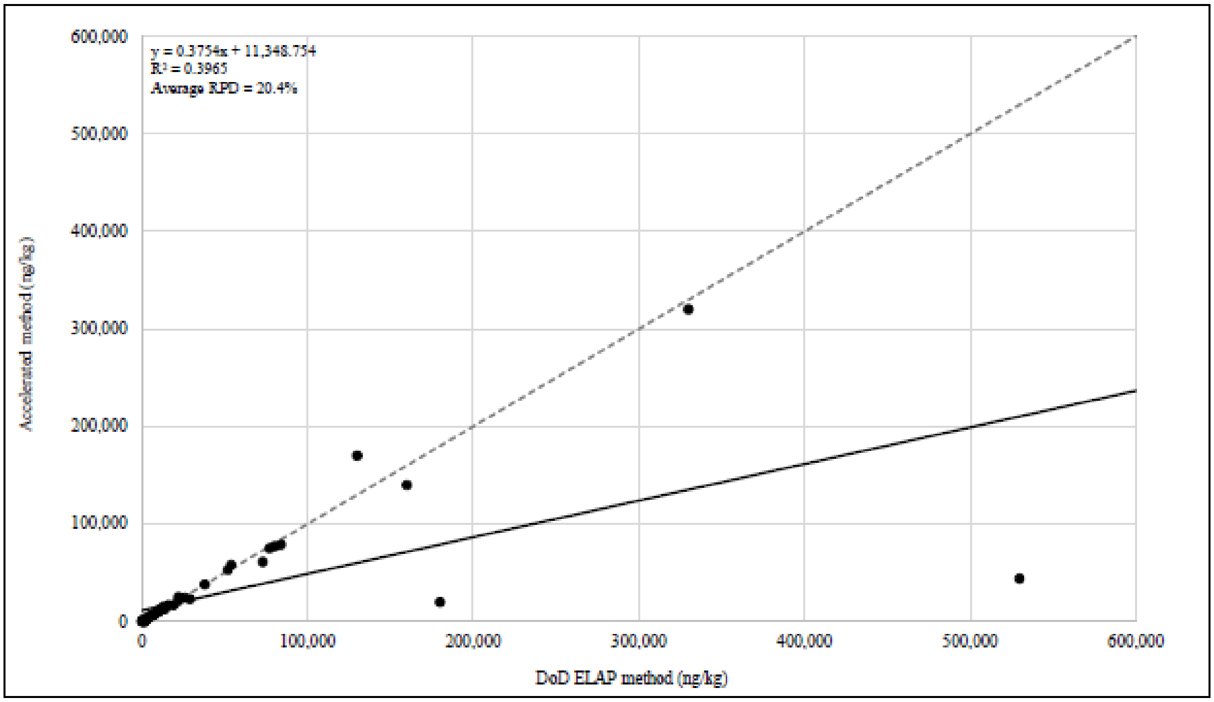
RPD = relative percent difference

Figure 7-1F. Primary PFAS Compound - PFOA - Soil - Detect Pair X-Y Scatterplots

PFOS - Soil - Outliers Removed



PFOS - Soil - All Detect Pairs



Legend

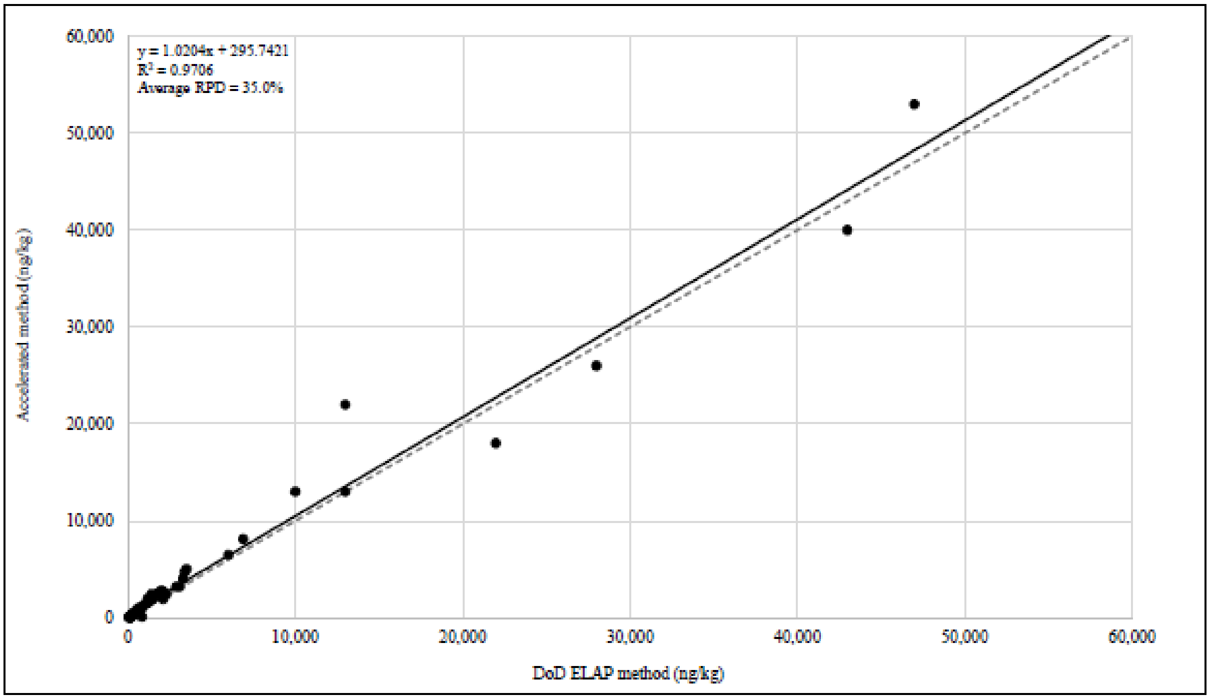
● Detect Pair   - - - 1:1 Line   —— OLS Regression Line (i.e., linear regression line)

Abbreviations

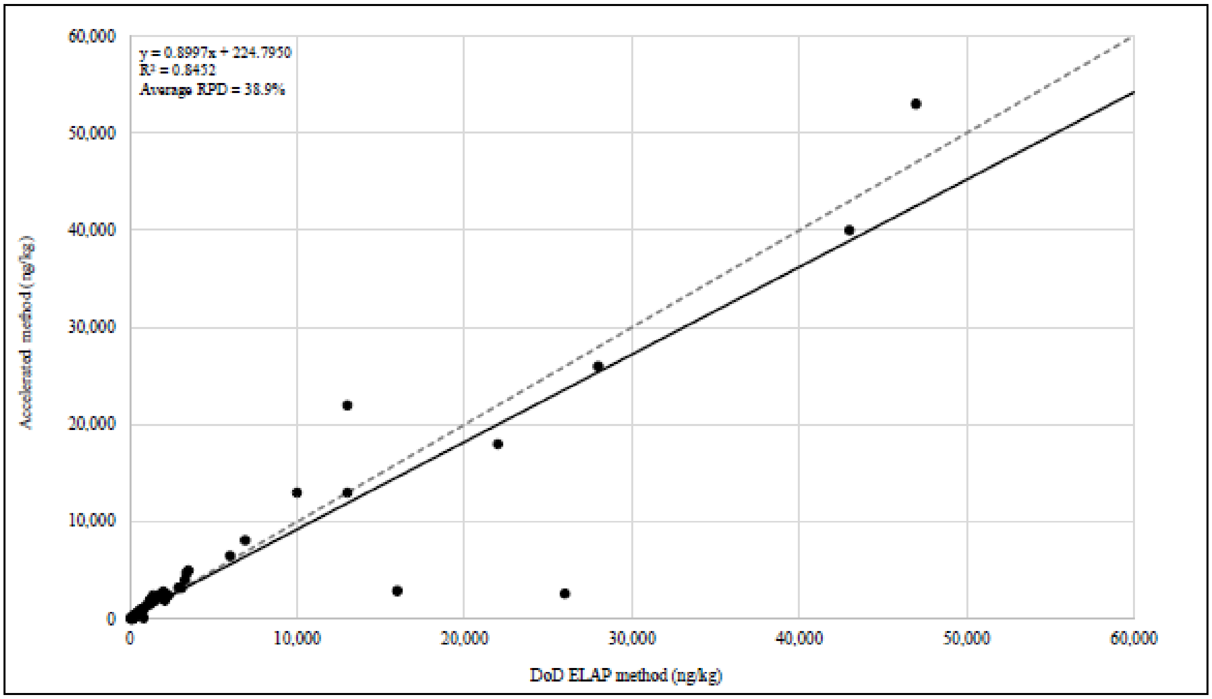
ng/kg = nanograms per kilogram   RPD = relative percent difference

Figure 7-1G. Primary PFAS Compound - PFOS - Soil - Detect Pair X-Y Scatterplots

T-PFOS - Soil - Outliers Removed



T-PFOS - Soil - All Detect Pairs



Legend

● Detect Pair

1:1 Line

OLS Regression Line (i.e., linear regression line)

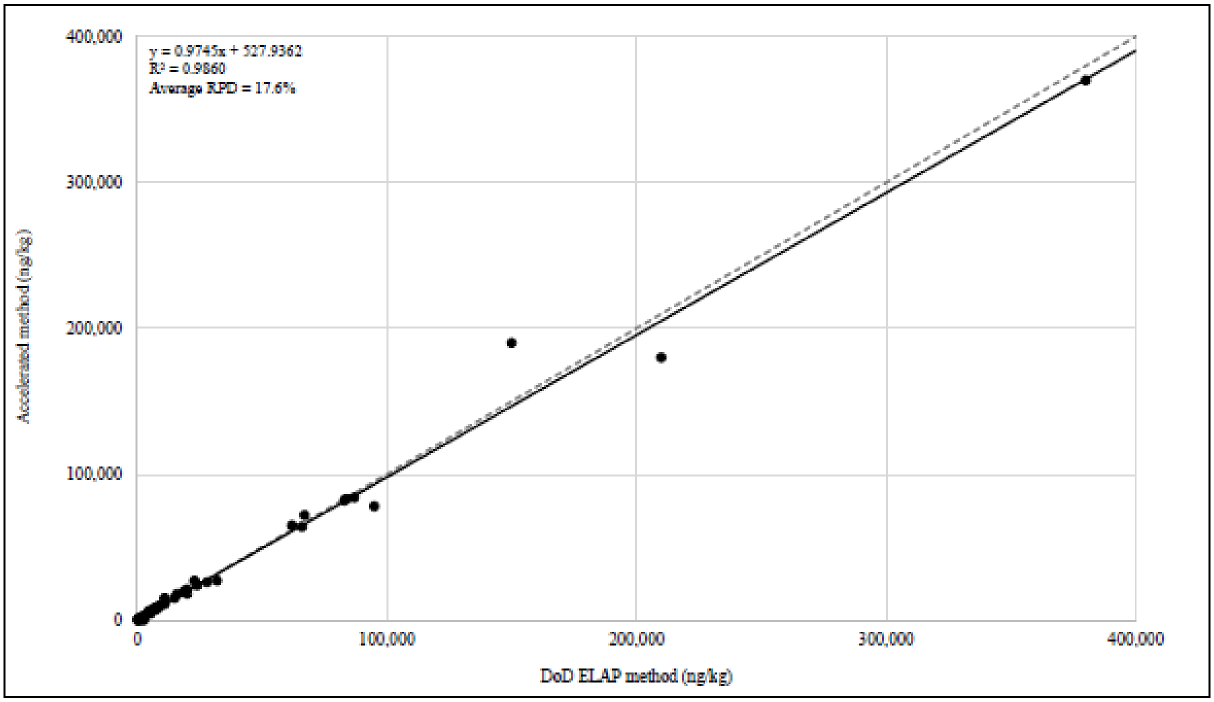
Abbreviations

ng/kg = nanograms per kilogram

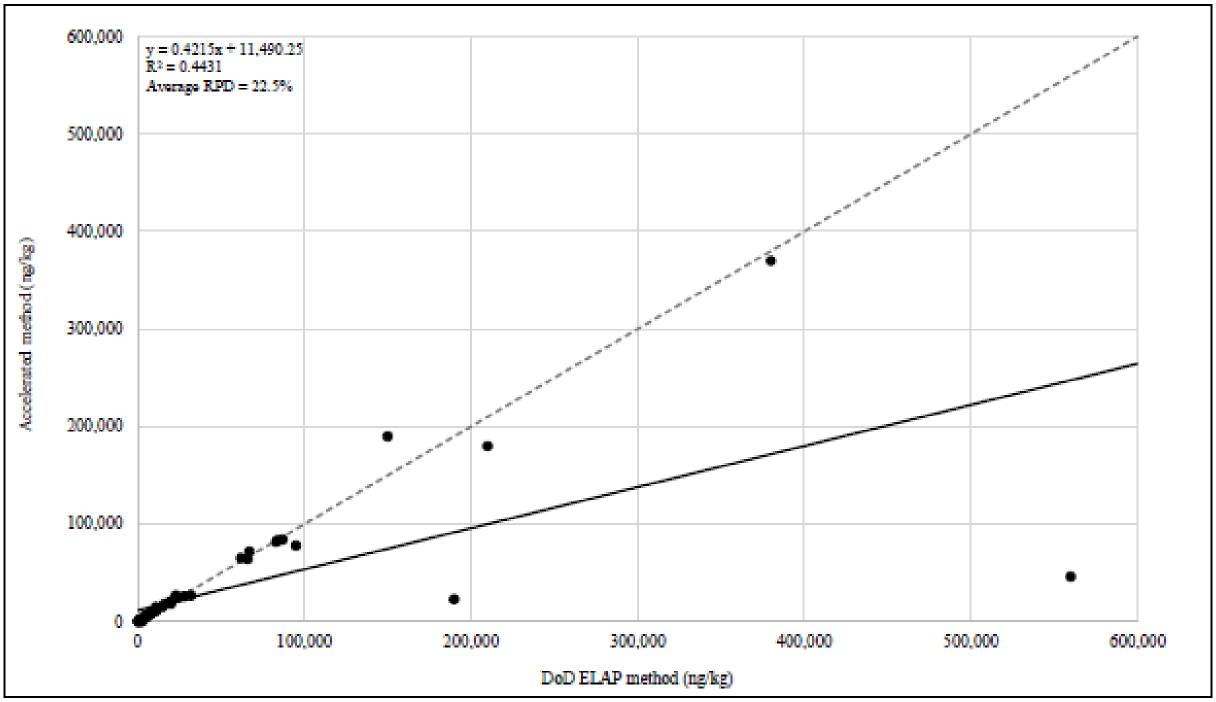
RPD = relative percent difference

Figure 7-1H. Primary PFAS Compound - T-PFOS - Soil - Detect Pair X-Y Scatterplots

Total PFOS - Soil - Outliers Removed



Total PFOS - Soil - All Detect Pairs



Legend

● Detect Pair —— 1:1 Line —— OLS Regression Line (i.e., linear regression line)

Abbreviations

ng/kg = nanograms per kilogram

RPD = relative percent difference

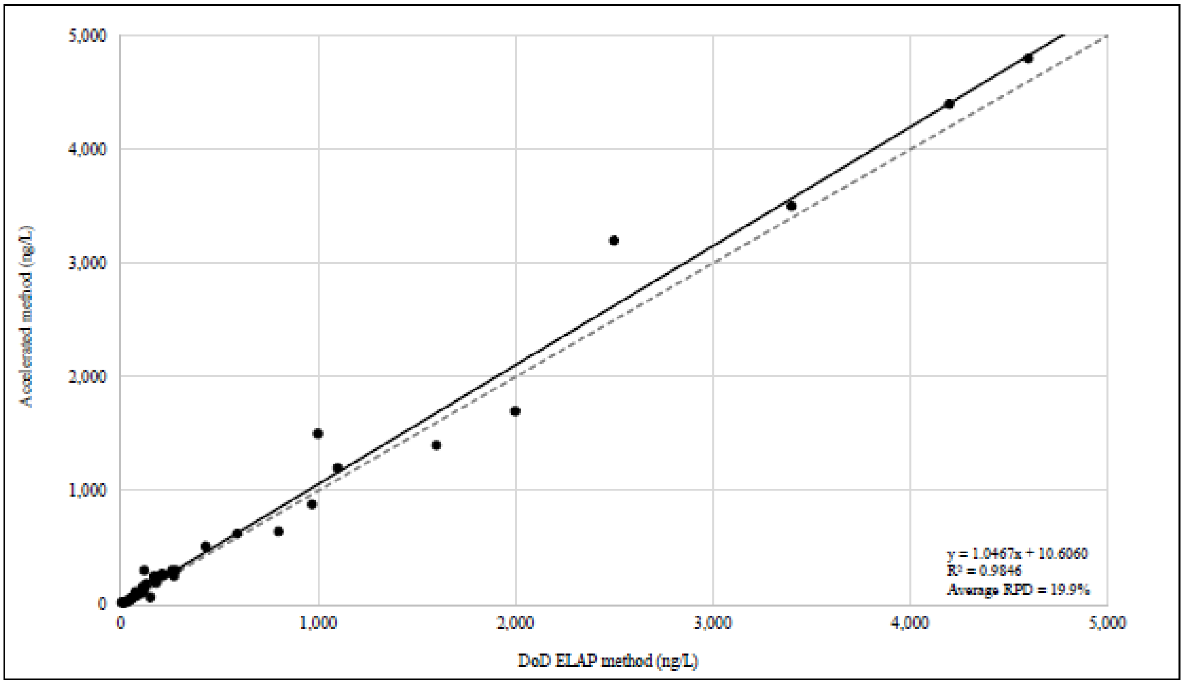
Figure 7-1I. Primary PFAS Compound - Total PFOS - Soil - Detect Pair X-Y Scatterplots

Page intentionally left blank. No detect pairs of PFBS in soil.

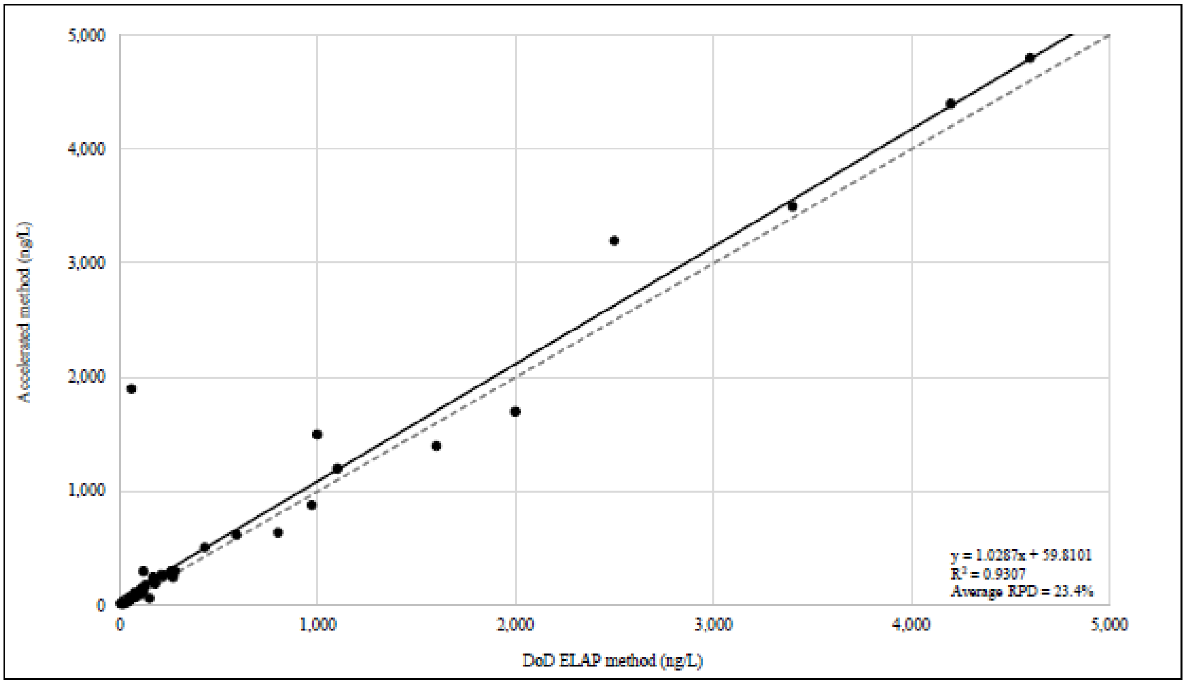
Figure 7-1J. Primary PFAS Compound - PFBS - Soil - Detect Pair X-Y Scatterplots

Figure 7-2. Secondary PFAS Compounds – Detect Pair X-Y Scatterplots

6-2FTS - Groundwater - Outliers Removed



6-2FTS - Groundwater - All Detect Pairs



Legend

● Detect Pair — 1:1 Line — OLS Regression Line (i.e., linear regression line)

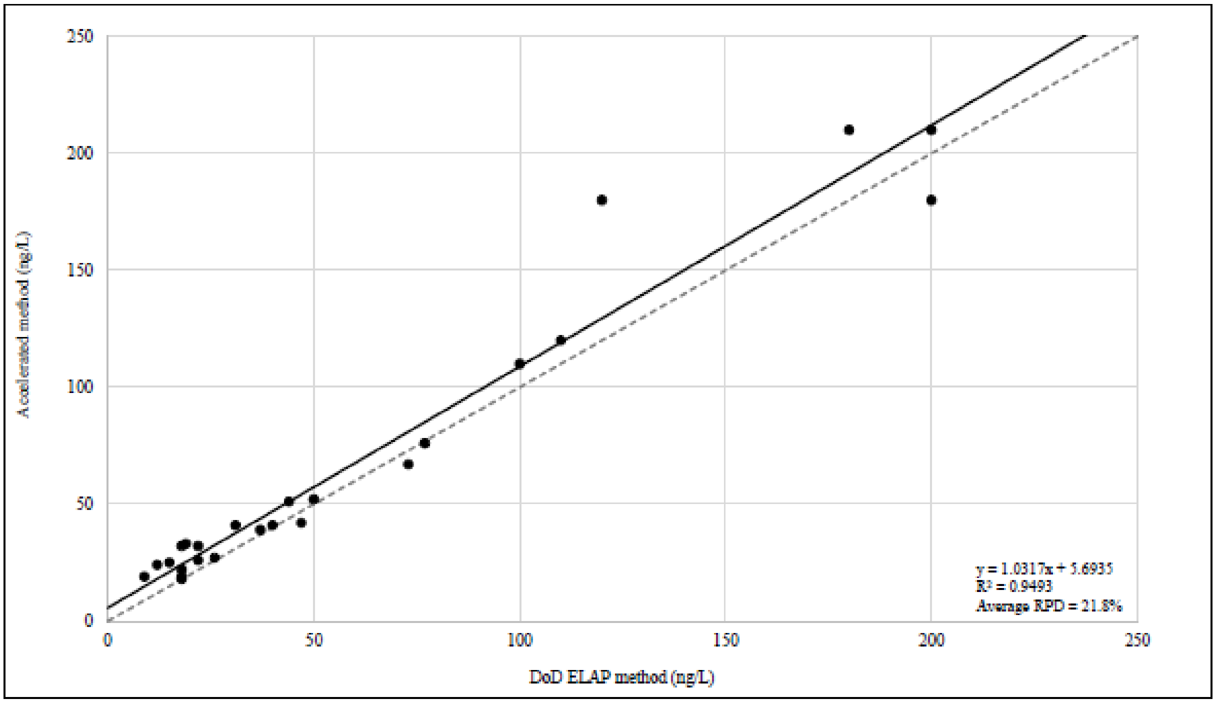
Abbreviations

ng/L = nanograms per liter

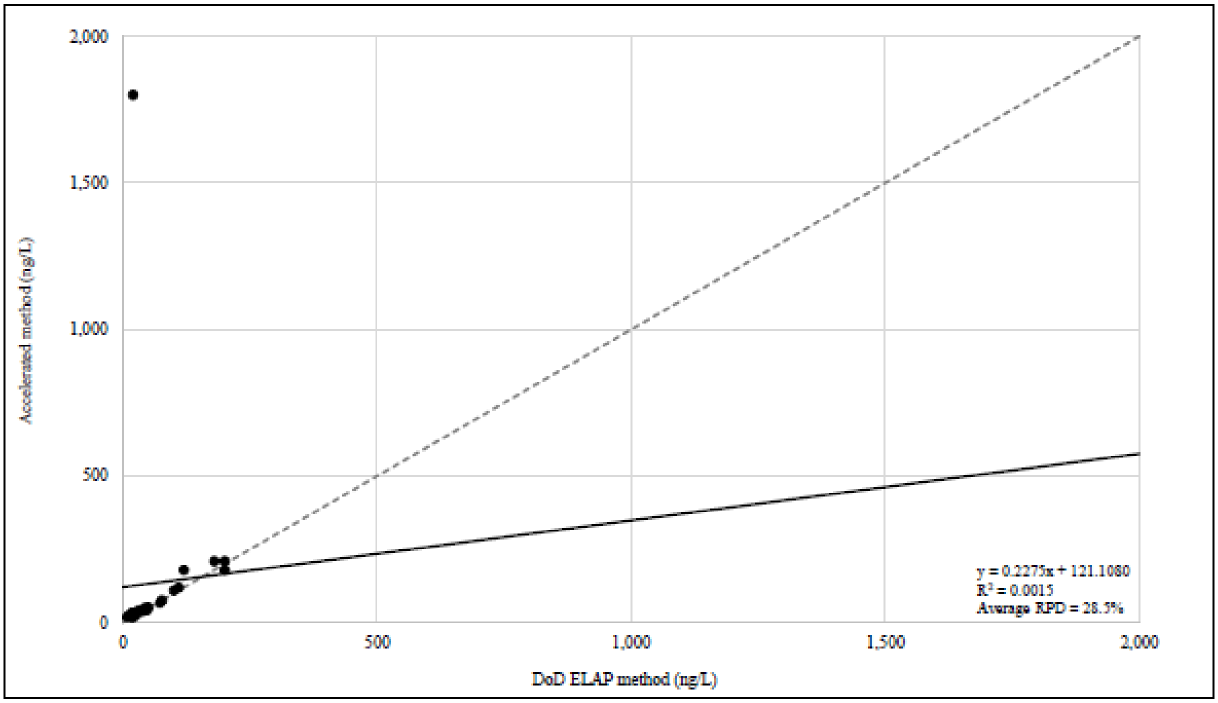
RPD = relative percent difference

Figure 7.2A. Secondary PFAS Compound - 6-2FTS - Groundwater - Detect Pair X-Y Scatterplots

8-2FTS - Groundwater - Outliers Removed



8-2FTS - Groundwater - All Detect Pairs



Legend

● Detect Pair ---- 1:1 Line —— OLS Regression Line (i.e., linear regression line)

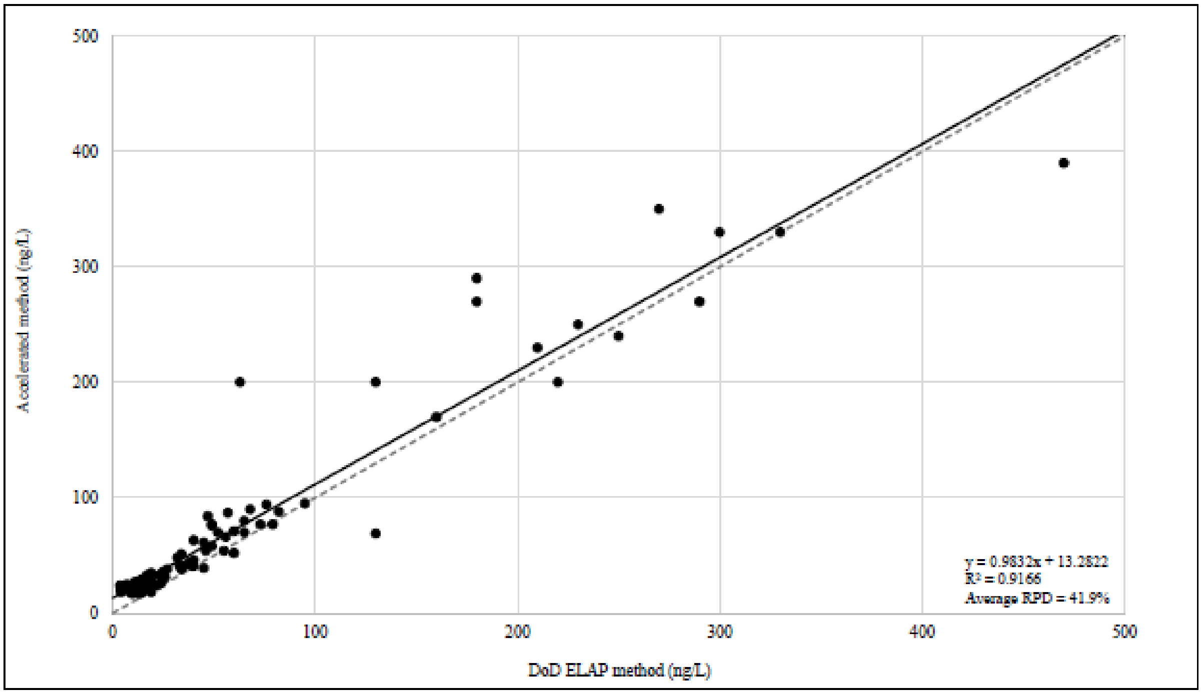
Abbreviations

ng/L = nanograms per liter

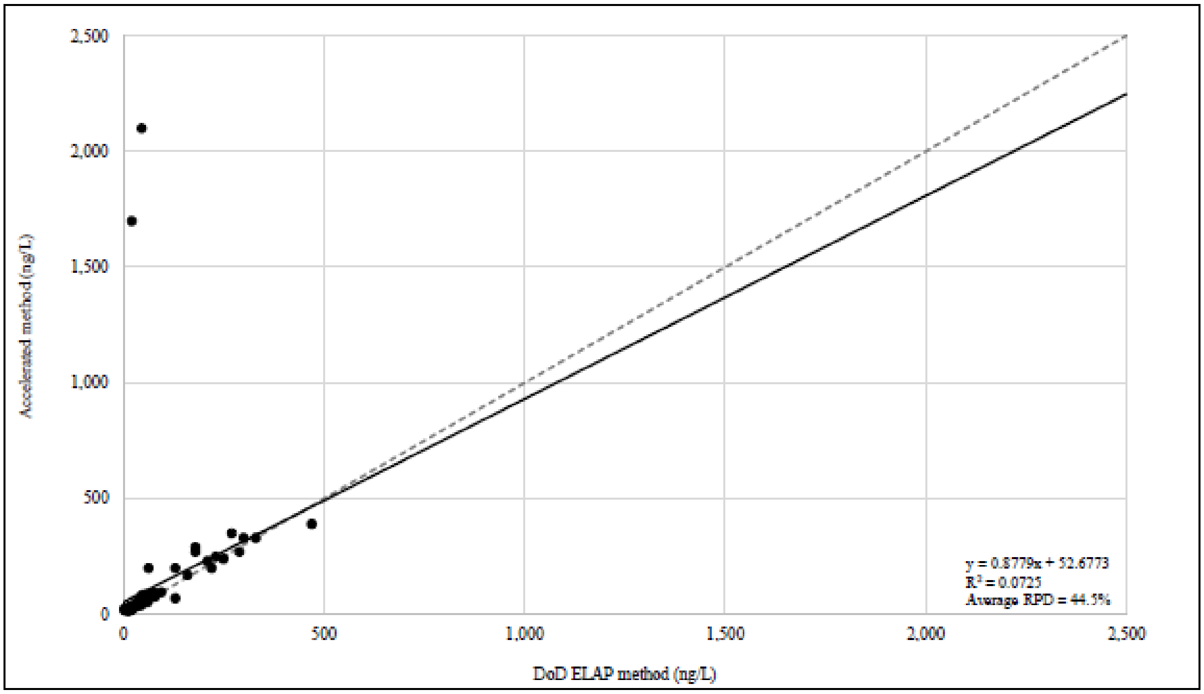
RPD = relative percent difference

Figure 7-2B. Secondary PFAS Compound - 8-2FTS - Groundwater - Detect Pair X-Y Scatterplots

PFHpA - Groundwater - Outliers Removed



PFHpA - Groundwater - All Detect Pairs



Legend

●	Detect Pair
—	1:1 Line
—	OLS Regression Line (i.e., linear regression line)

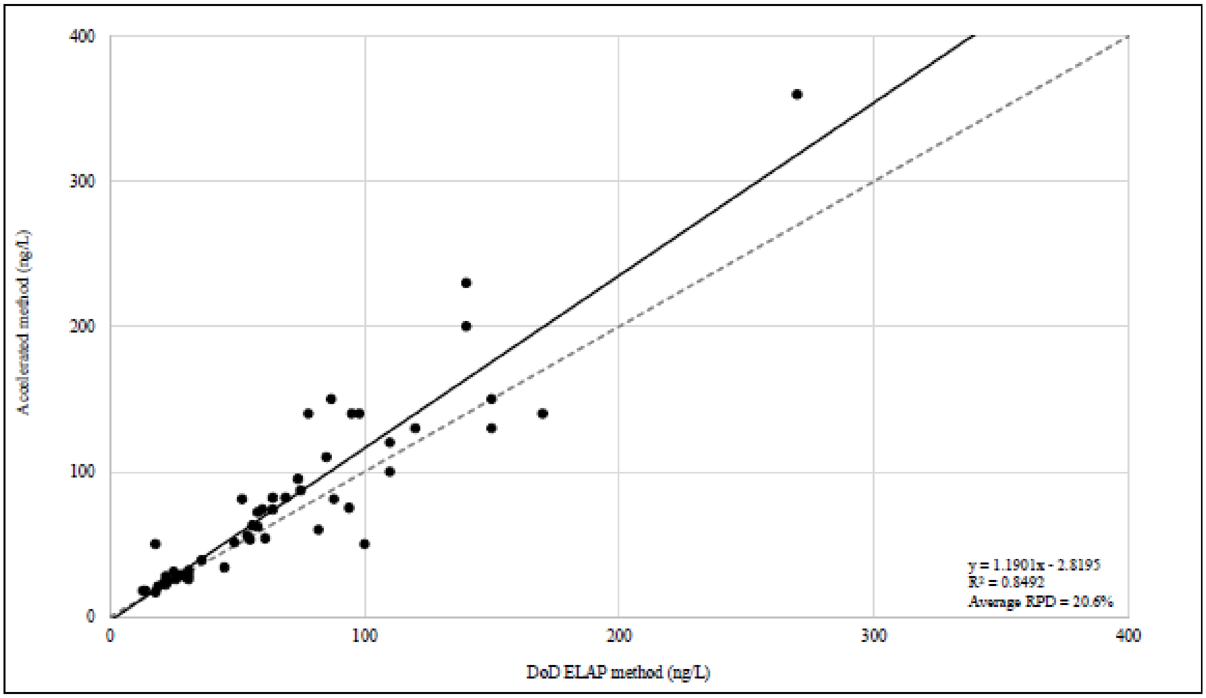
Abbreviations

ng/L = nanograms per liter

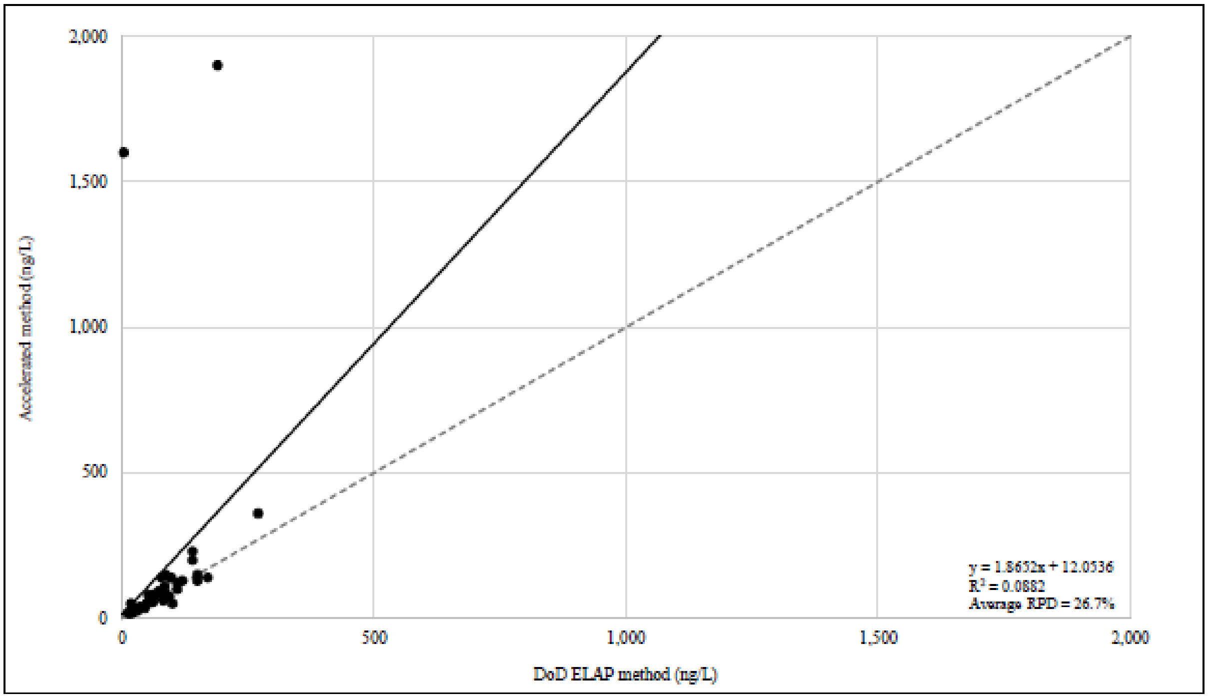
RPD = relative percent difference

Figure 7-2C. Secondary PFAS Compound - PFHpA - Groundwater - Detect Pair X-Y Scatterplots

PFHpS - Groundwater - Outliers Removed



PFHpS - Groundwater - All Detect Pairs



Legend

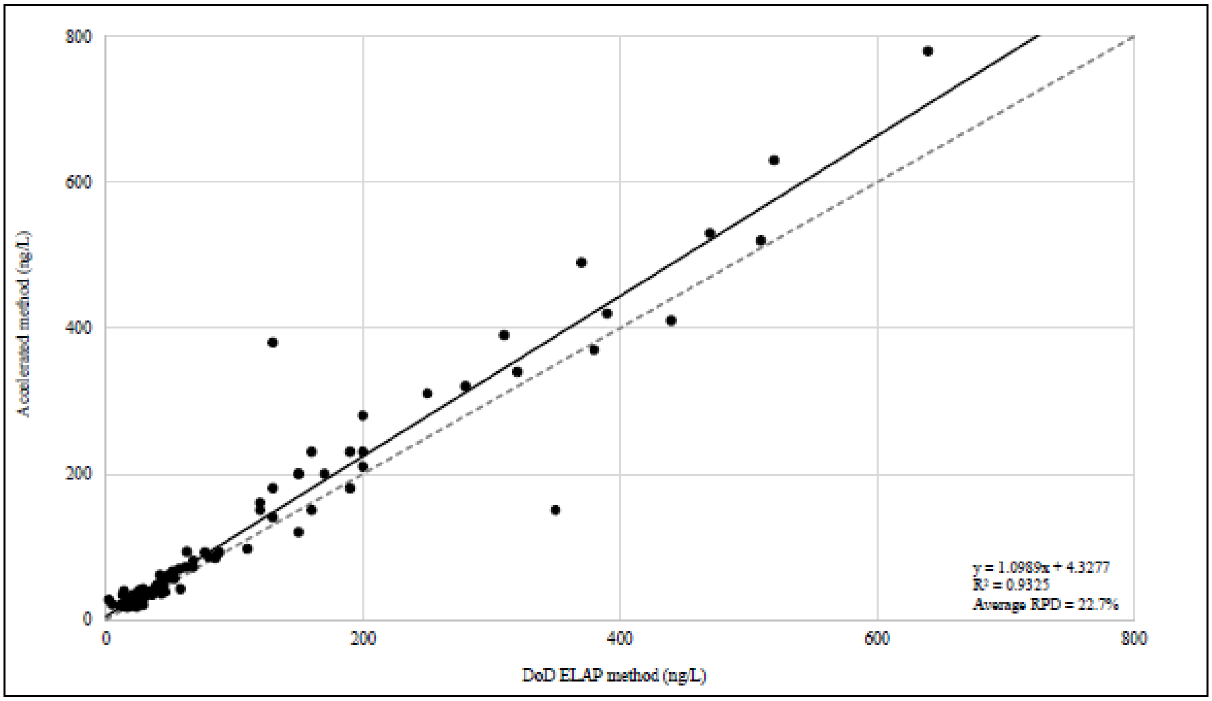
● Detect Pair — 1:1 Line — OLS Regression Line (i.e., linear regression line)

Abbreviations

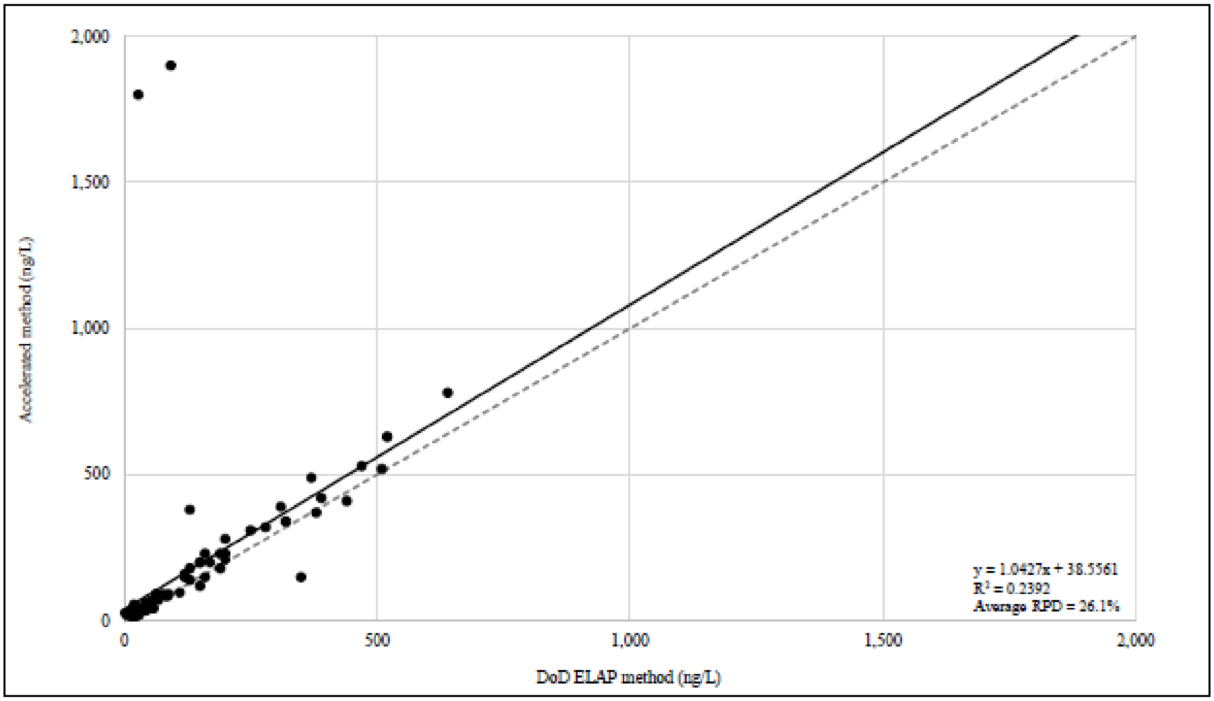
ng/L = nanograms per liter RPD = relative percent difference

Figure 7-2D. Secondary PFAS Compound - PFHpS - Groundwater - Detect Pair X-Y Scatterplots

PFHxA - Groundwater - Outliers Removed



PFHxA - Groundwater - All Detect Pairs



Legend

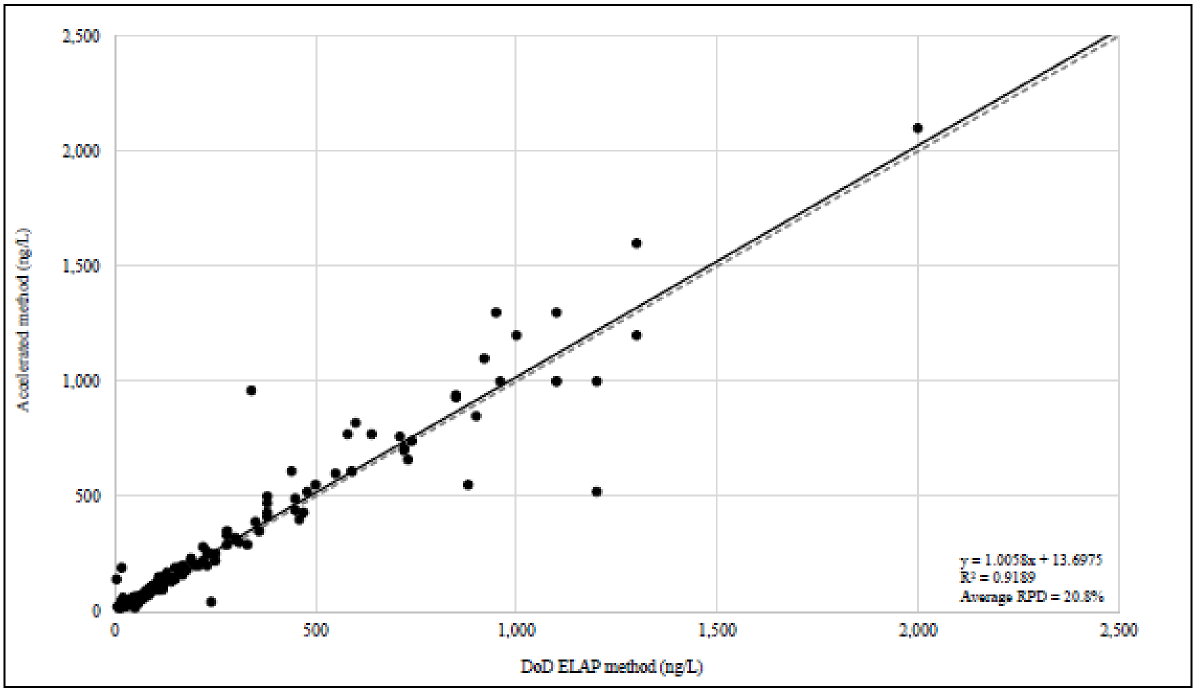
● Detect Pair ---- 1:1 Line —— OLS Regression Line (i.e., linear regression line)

Abbreviations

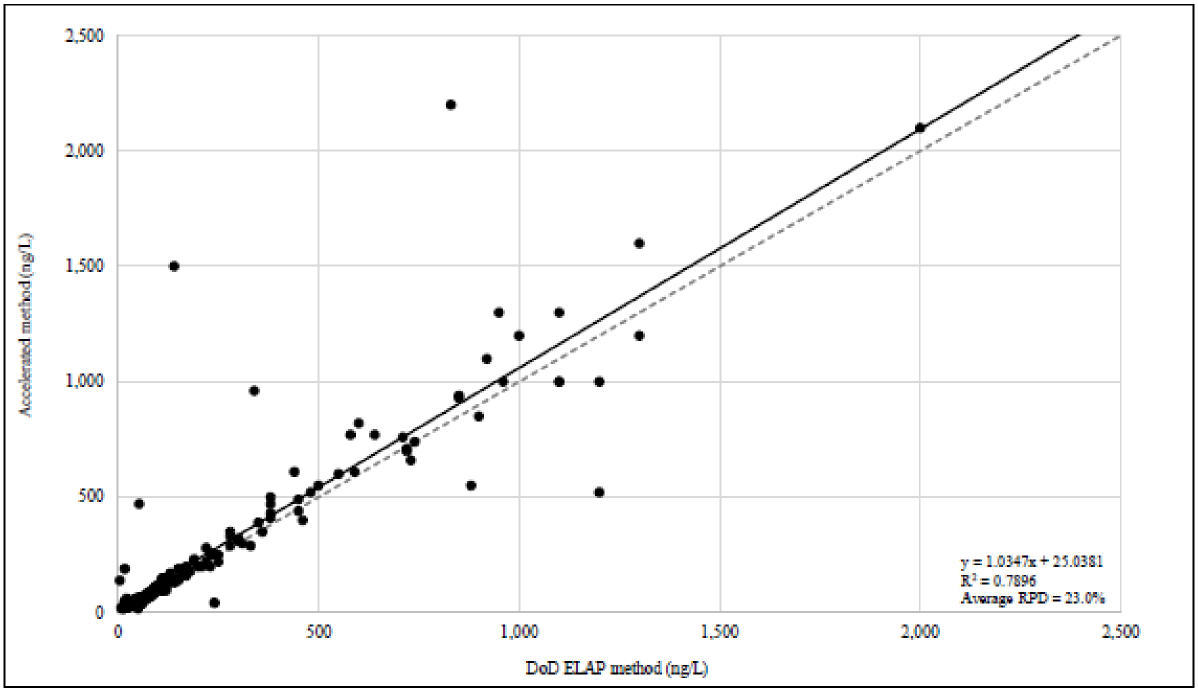
ng/L = nanograms per liter RPD = relative percent difference

Figure 7-2E. Secondary PFAS Compound - PFHxA - Groundwater - Detect Pair X-Y Scatterplots

PFHxS - Groundwater - Outliers Removed



PFHxS - Groundwater - All Detect Pairs



Legend

● Detect Pair

1:1 Line

OLS Regression Line (i.e., linear regression line)

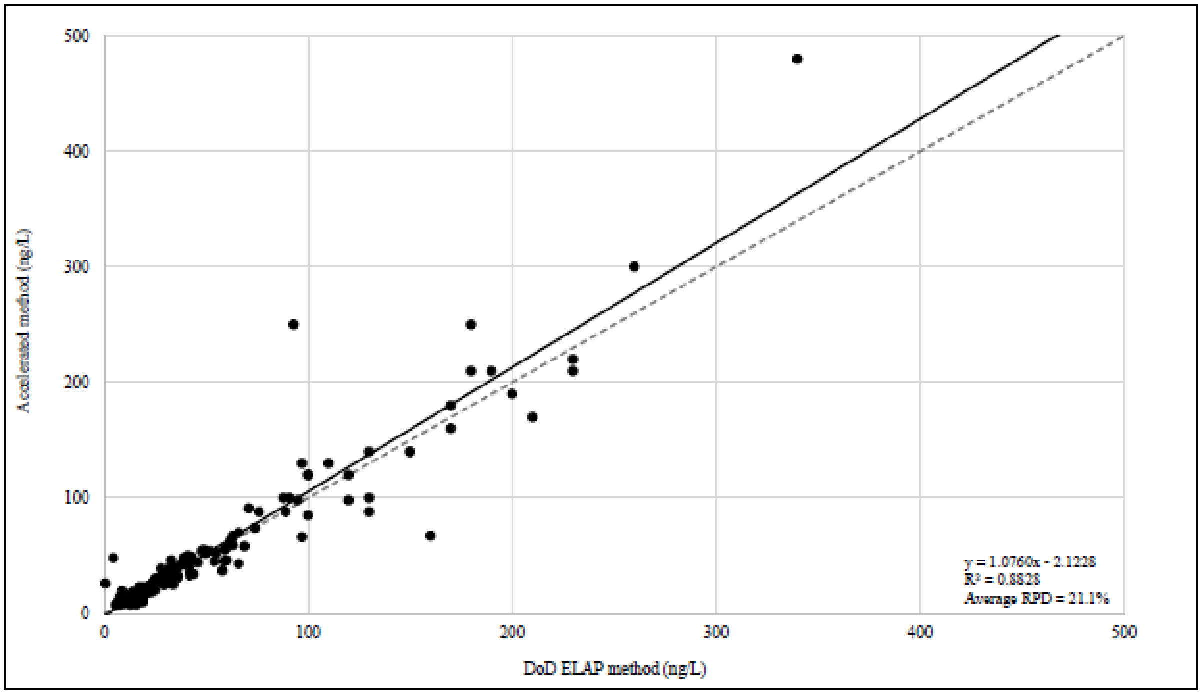
Abbreviations

ng/L = nanograms per liter

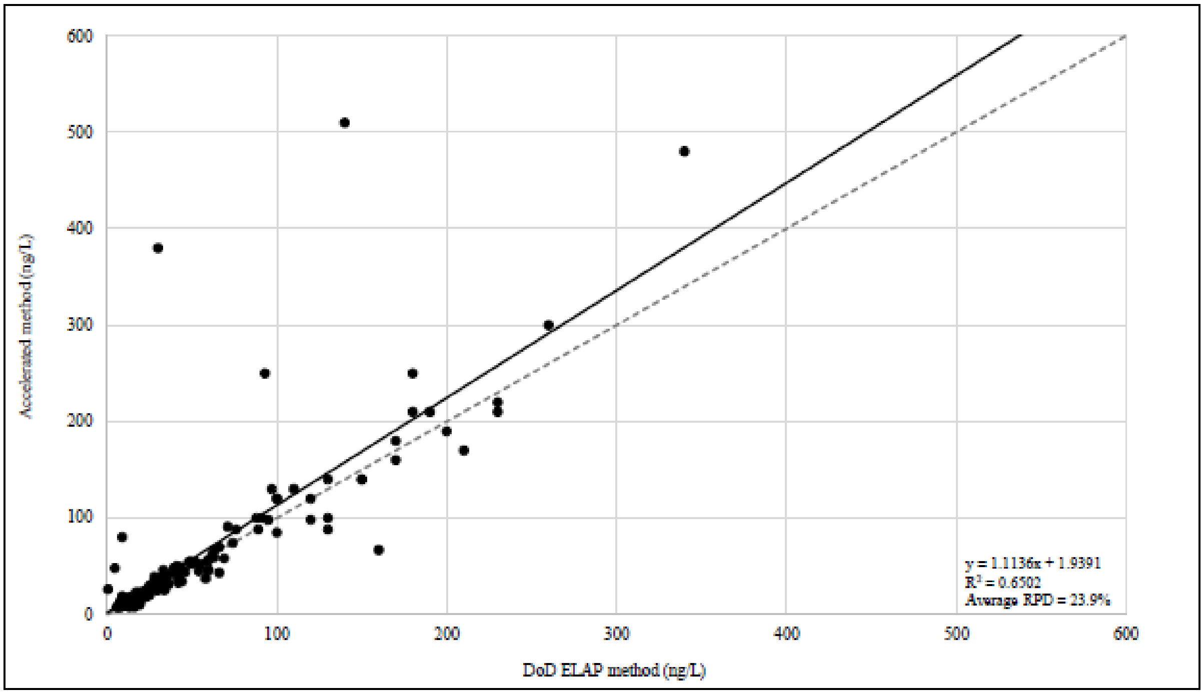
RPD = relative percent difference

Figure 7-2F. Secondary PFAS Compound - PFHxS - Groundwater - Detect Pair X-Y Scatterplots

Br-PFHxS - Groundwater - Outliers Removed



Br-PFHxS - Groundwater - All Detect Pairs



Legend

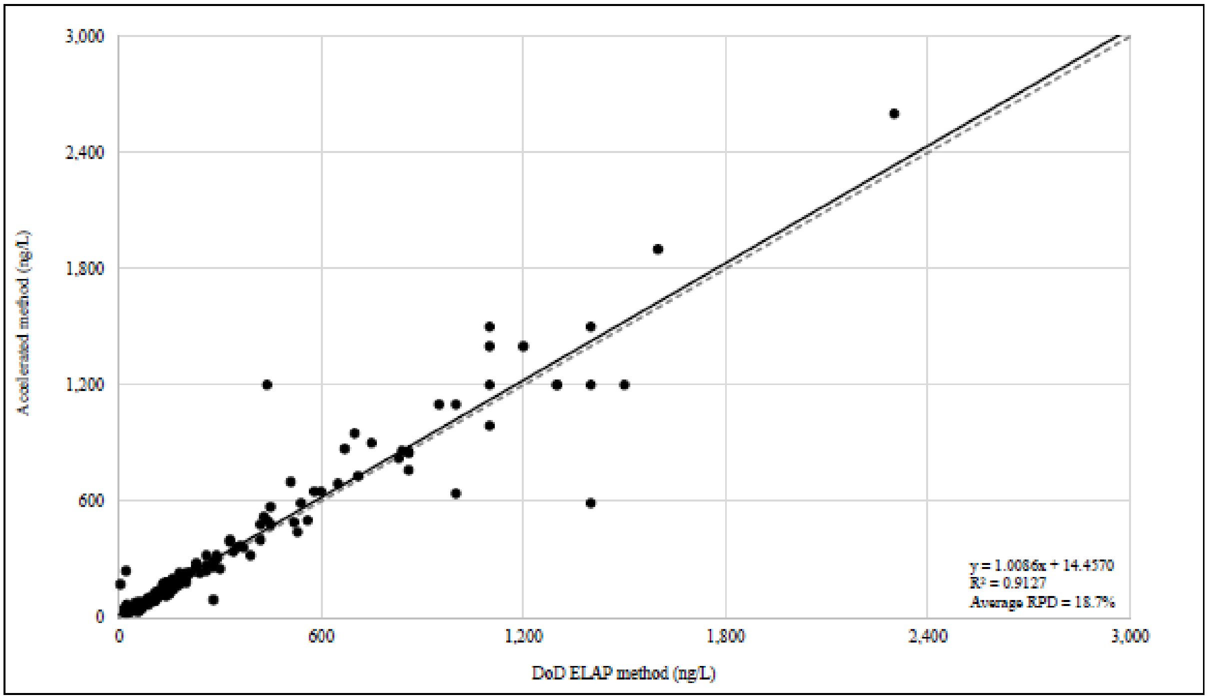
● Detect Pair —— 1:1 Line —— OLS Regression Line (i.e., linear regression line)

Abbreviations

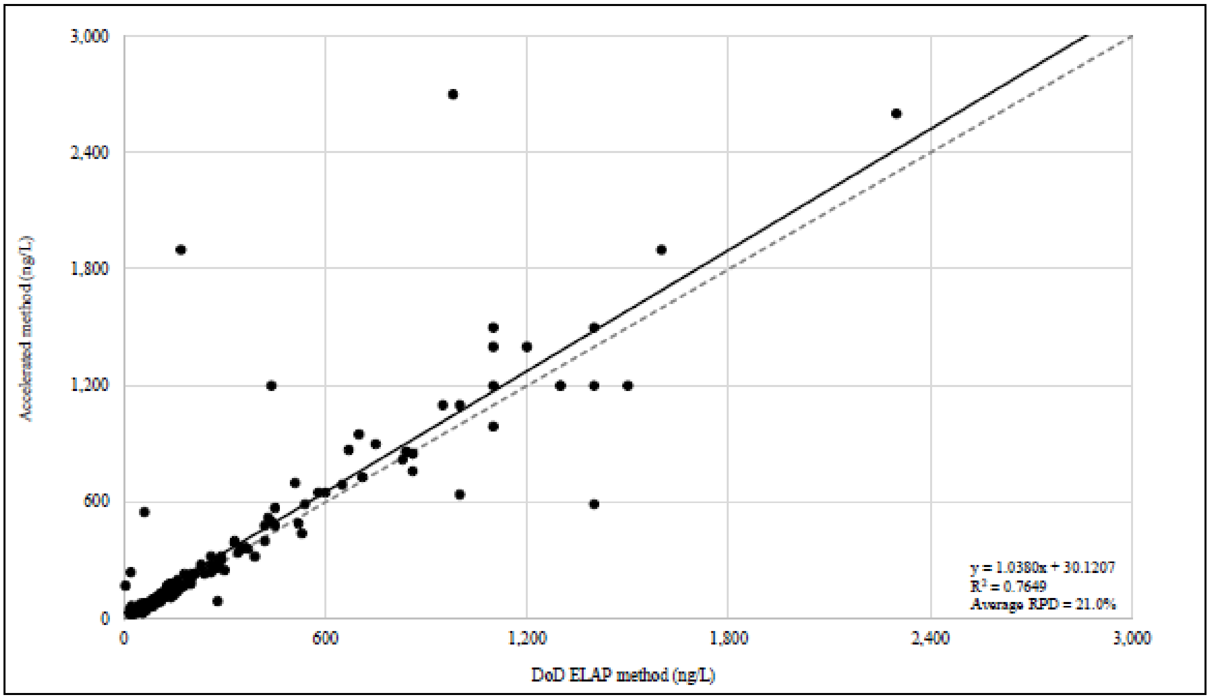
ng/L = nanograms per liter RPD = relative percent difference

Figure 7-2G. Secondary PFAS Compound - Br-PFHxS - Groundwater - Detect Pair X-Y Scatterplots

Total PFHxS - Groundwater - Outliers Removed



Total PFHxS - Groundwater - All Detect Pairs



Legend

● Detect Pair

1:1 Line

OLS Regression Line (i.e., linear regression line)

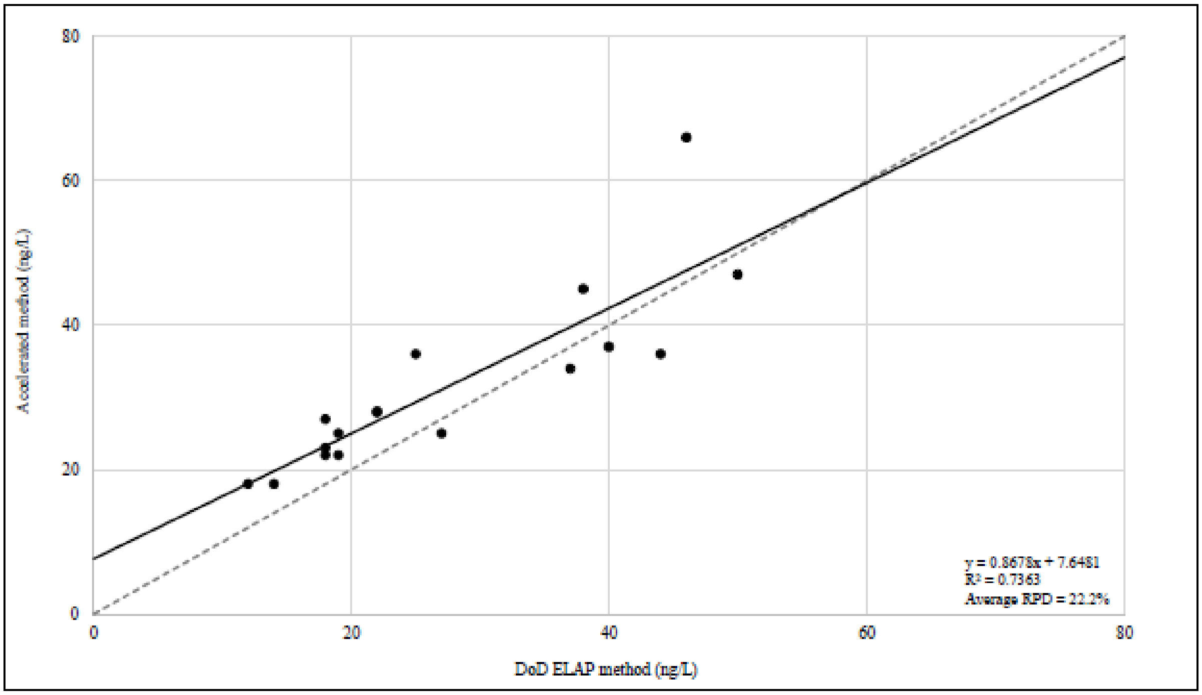
Abbreviations

ng/L = nanograms per liter

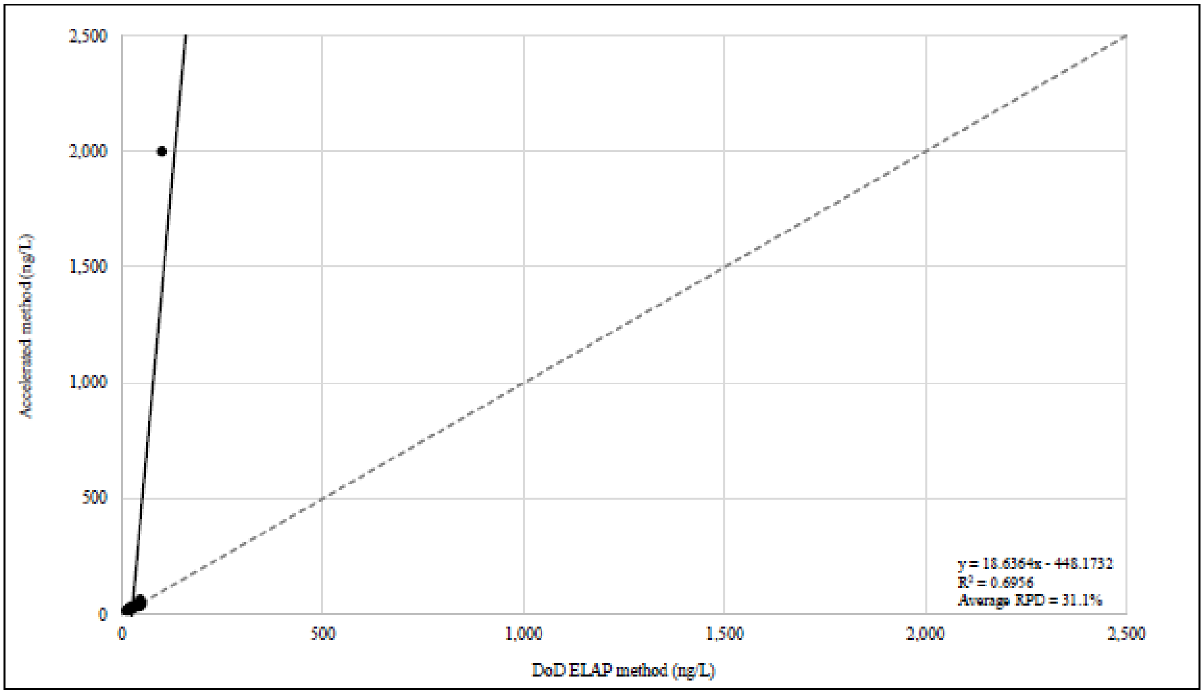
RPD = relative percent difference

Figure 7-2H. Secondary PFAS Compound - Total PFHxS - Groundwater - Detect Pair X-Y Scatterplots

PFNA - Groundwater - Outliers Removed



PFNA - Groundwater - All Detect Pairs



Legend

● Detect Pair

1:1 Line

OLS Regression Line (i.e., linear regression line)

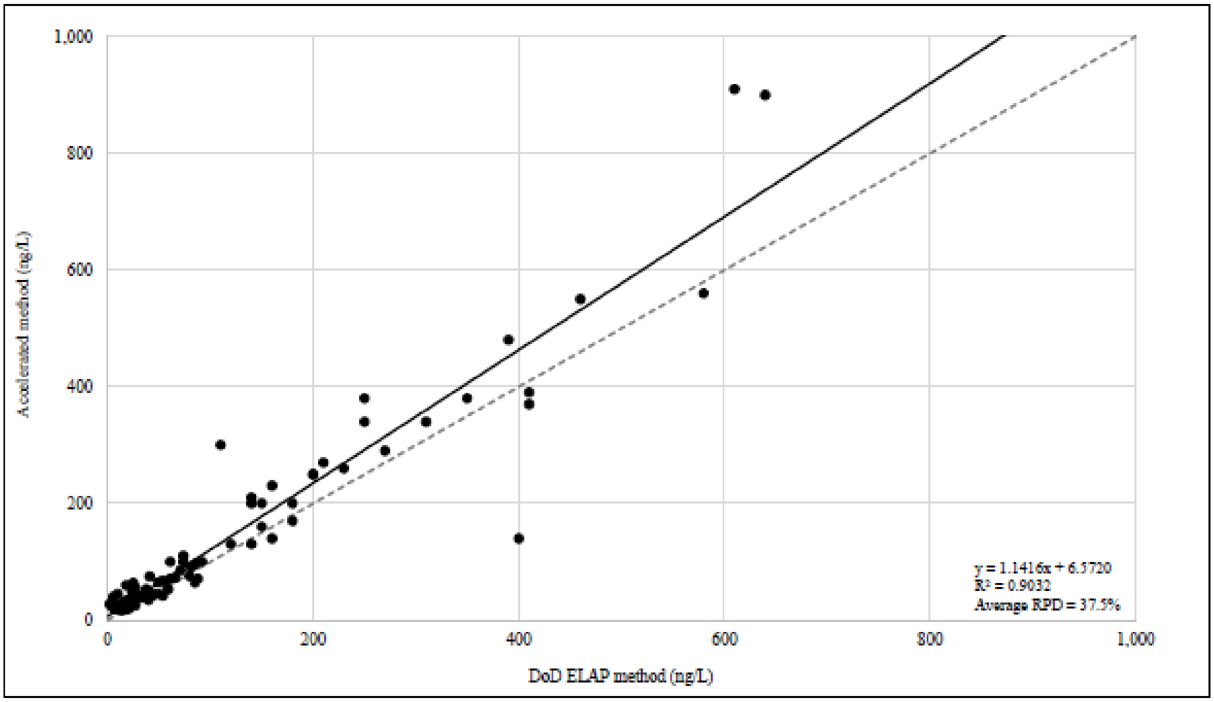
Abbreviations

ng/L = nanograms per liter

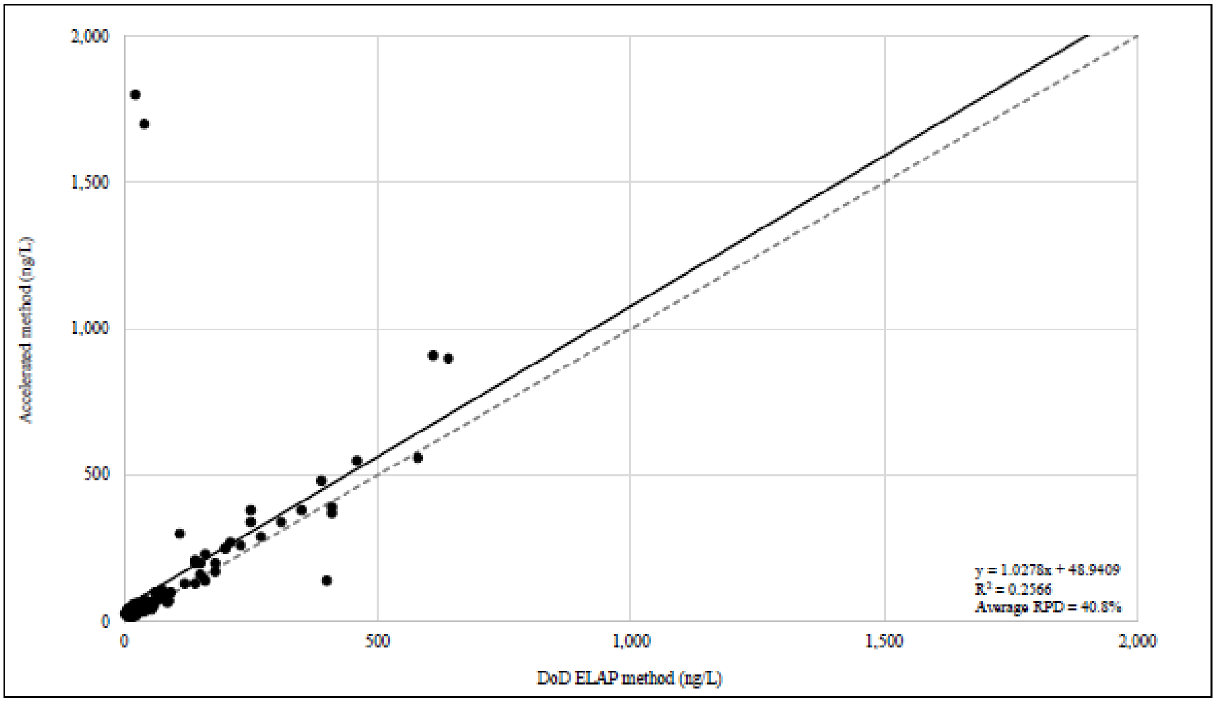
RPD = relative percent difference

Figure 7-2I. Secondary PFAS Compound - PFNA - Groundwater - Detect Pair X-Y Scatterplots

PFPeA - Groundwater - Outliers Removed



PFPeA - Groundwater - All Detect Pairs



Legend

● Detect Pair — 1:1 Line — OLS Regression Line (i.e., linear regression line)

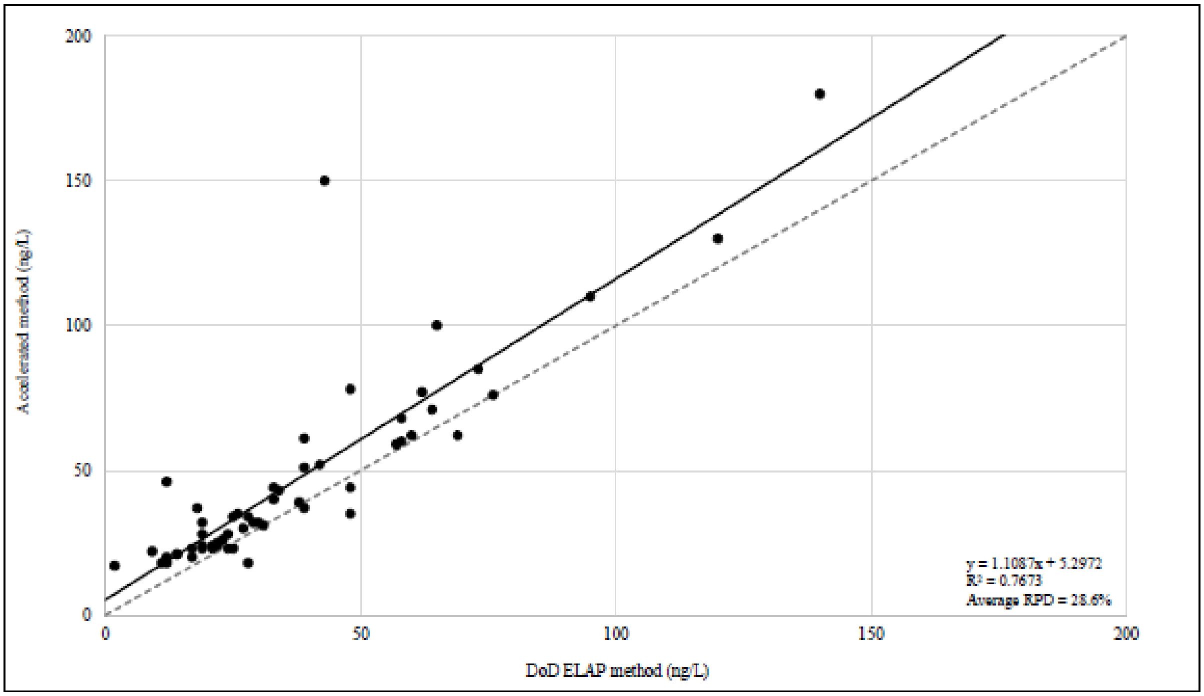
Abbreviations

ng/L = nanograms per liter

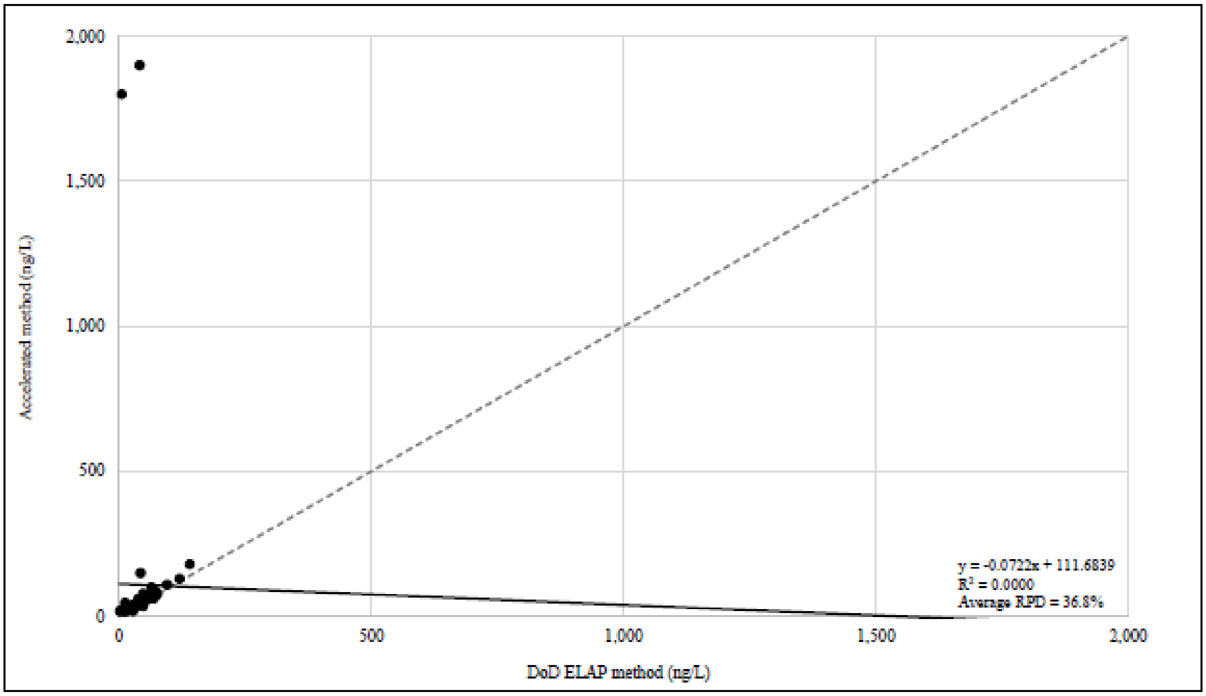
RPD = relative percent difference

Figure 7-2J. Secondary PFAS Compound - PFPeA - Groundwater - Detect Pair X-Y Scatterplots

PFPeS - Groundwater - Outliers Removed



PFPeS - Groundwater - All Detect Pairs



Legend

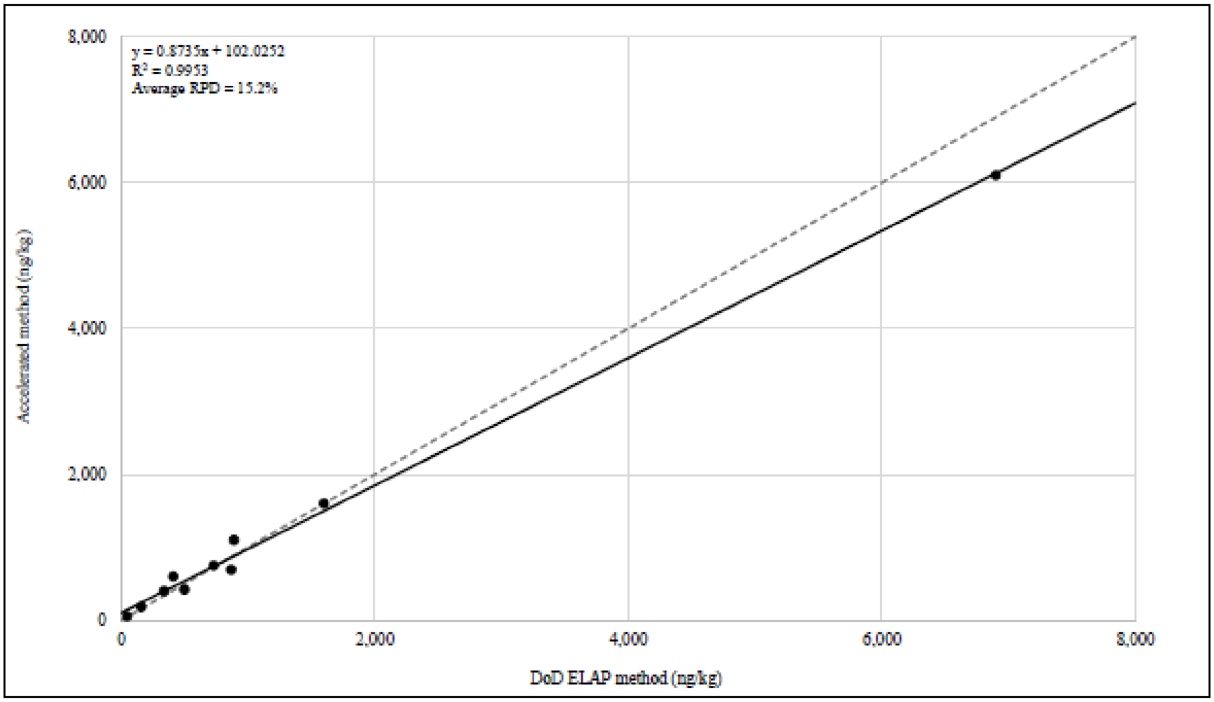
● Detect Pair — 1:1 Line — OLS Regression Line (i.e., linear regression line)

Abbreviations

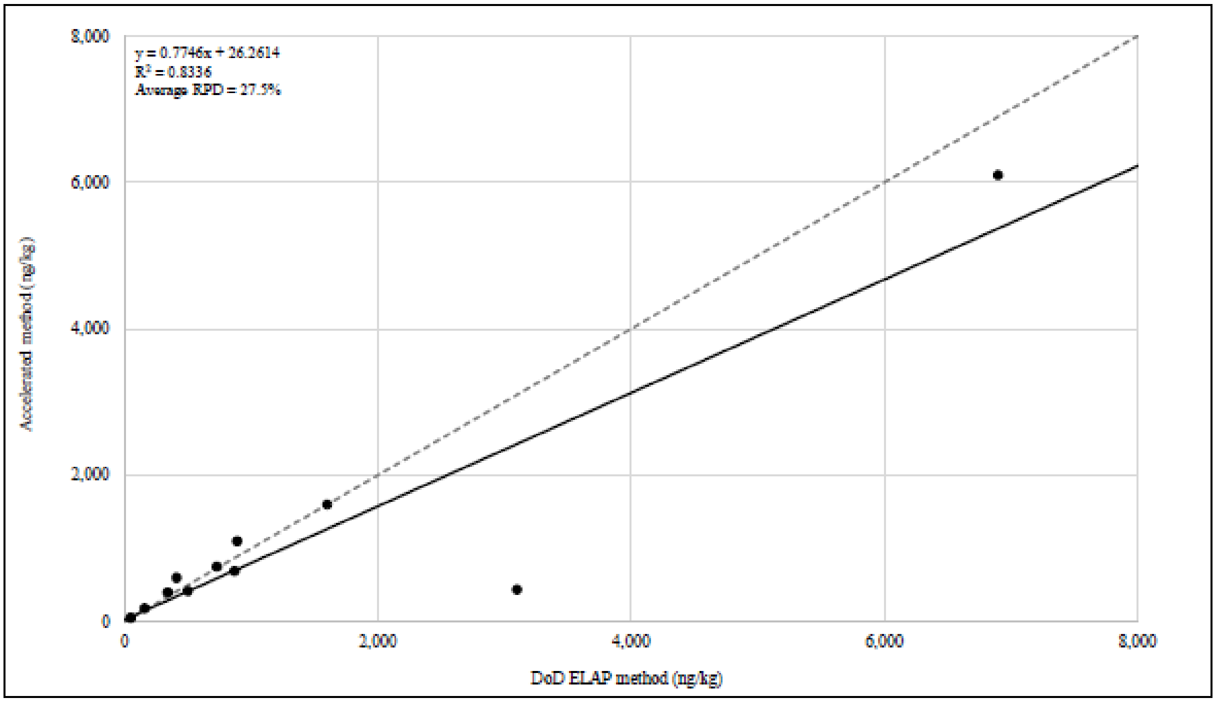
ng/L = nanograms per liter
RPD = relative percent difference

Figure 7-2K. Secondary PFAS Compound - PFPeS - Groundwater - Detect Pair X-Y Scatterplots

6-2FTS - Soil - Outliers Removed



6-2FTS - Soil - All Detect Pairs



Legend

● Detect Pair

1:1 Line

OLS Regression Line (i.e., linear regression line)

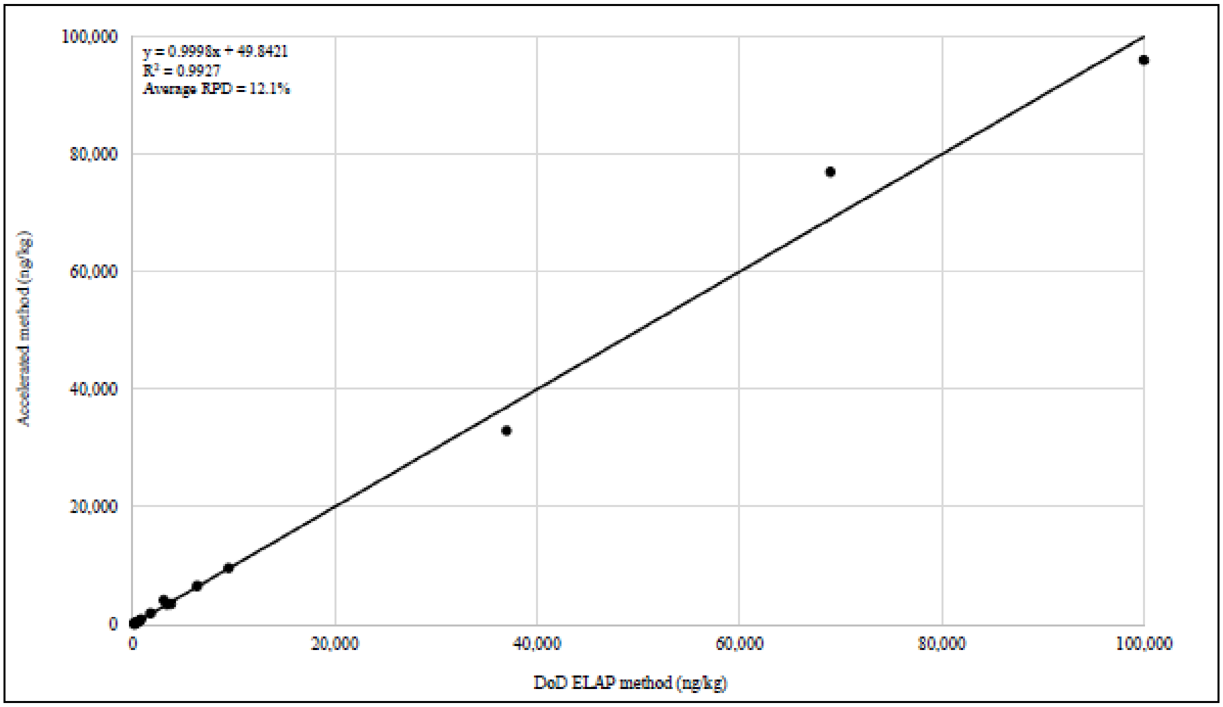
Abbreviations

ng/kg = nanograms per kilogram

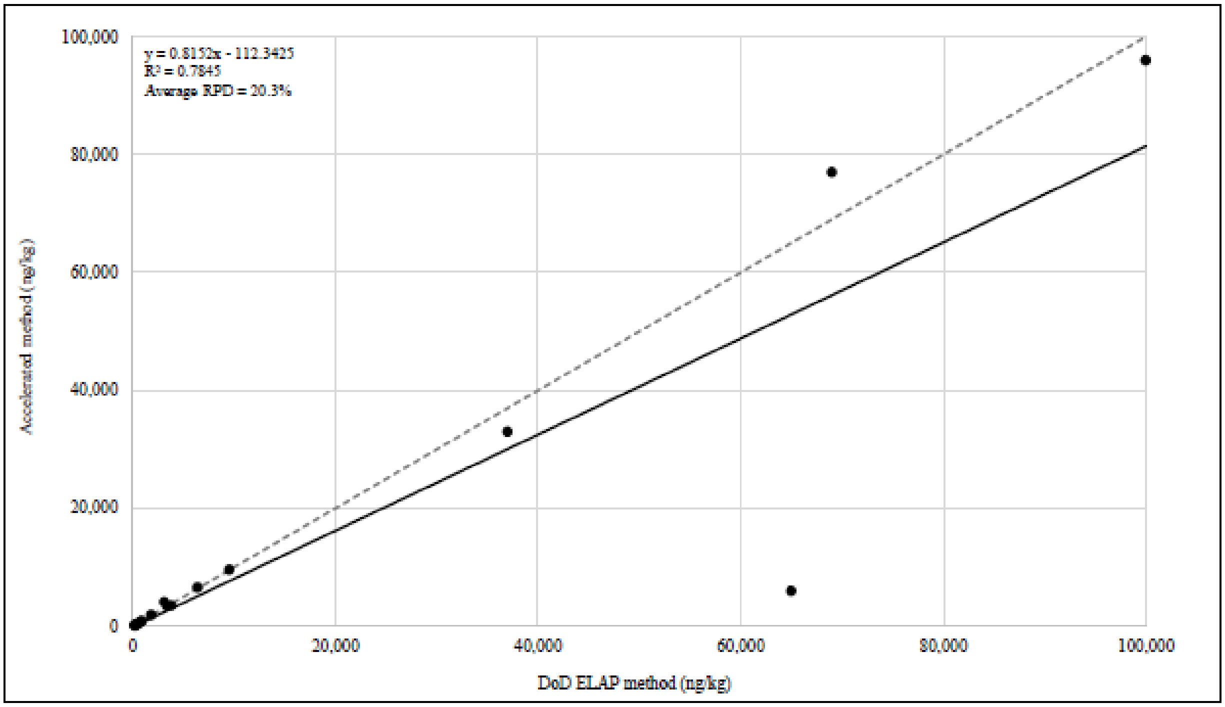
RPD = relative percent difference

Figure 7-2L. Secondary PFAS Compound - 6-2FTS - Soil - Detect Pair X-Y Scatterplots

8-2FTS - Soil - Outliers Removed



8-2FTS - Soil - All Detect Pairs



Legend

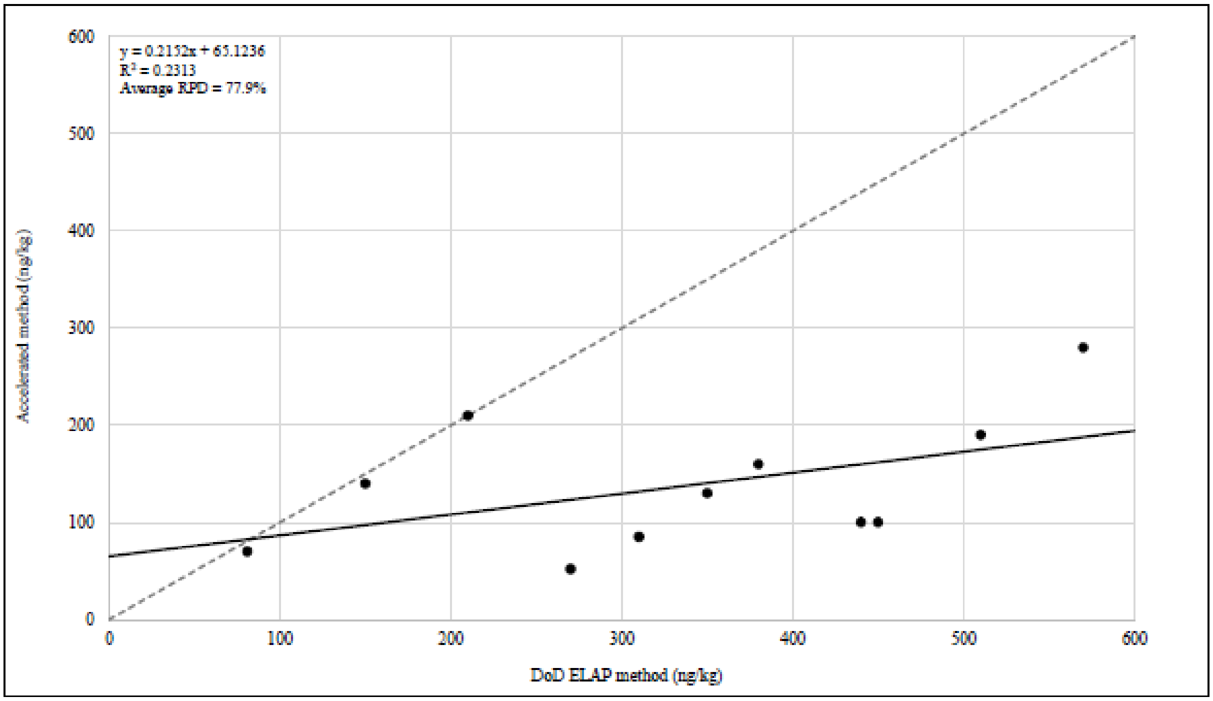
● Detect Pair ---- 1:1 Line —— OLS Regression Line (i.e., linear regression line)

Abbreviations

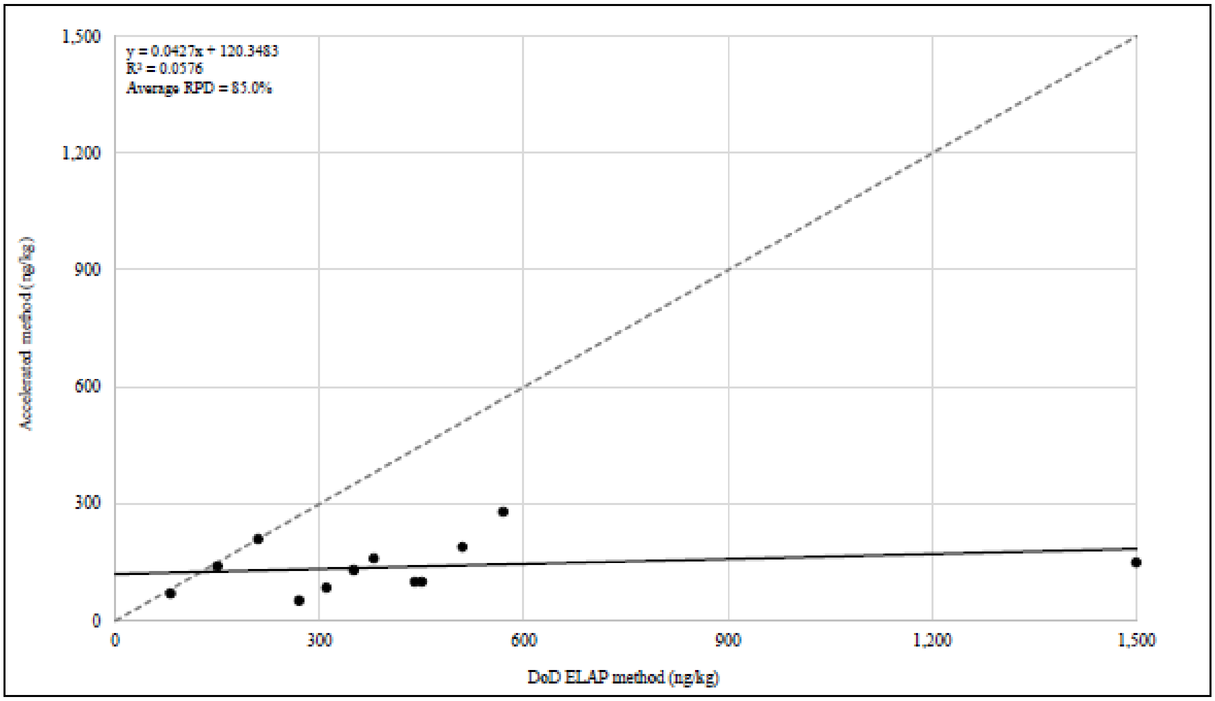
ng/kg = nanograms per kilogram RPD = relative percent difference

Figure 7-2M. Secondary PFAS Compound - 8-2FTS - Soil - Detect Pair X-Y Scatterplots

PFHpA - Soil - Outliers Removed



PFHpA - Soil - All Detect Pairs



Legend

●	Detect Pair
- - -	1:1 Line
———	OLS Regression Line (i.e., linear regression line)

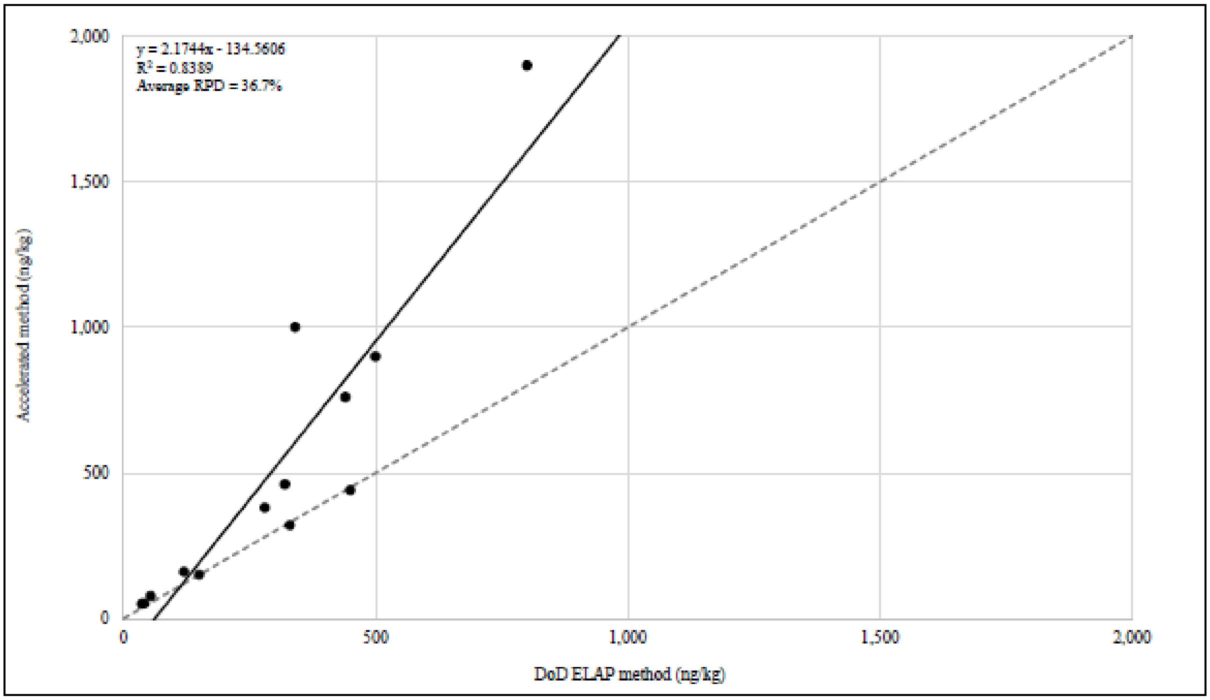
Abbreviations

ng/kg = nanograms per kilogram

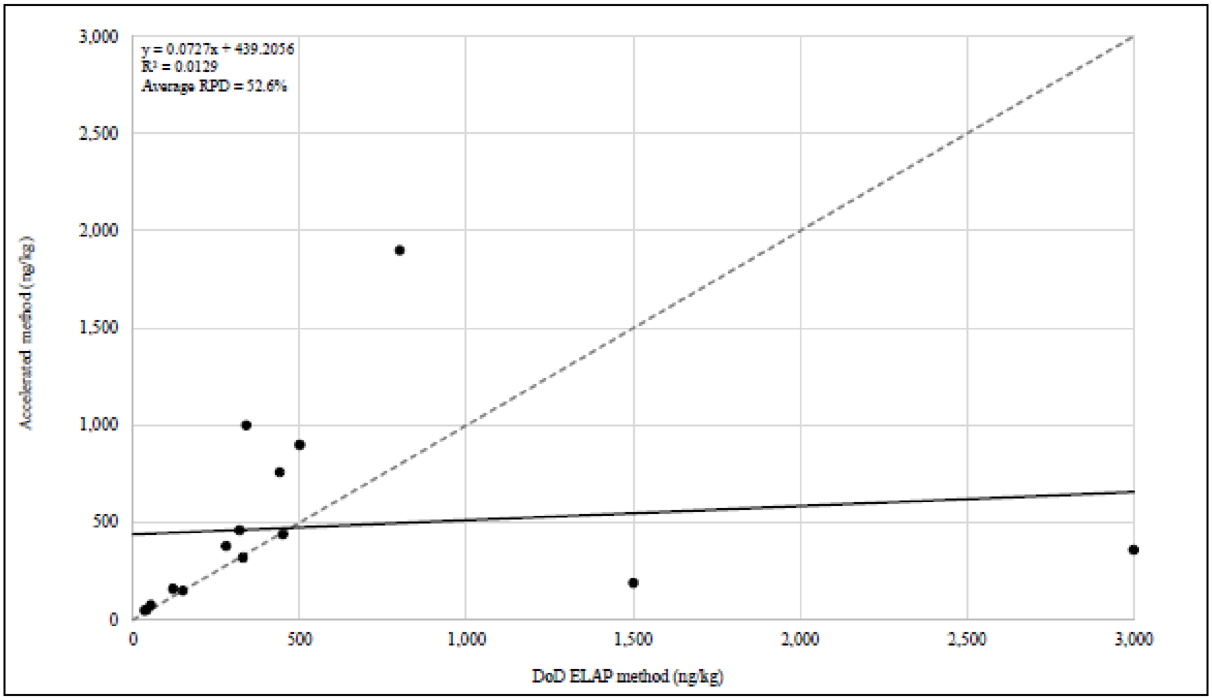
RPD = relative percent difference

Figure 7-2N. Secondary PFAS Compound - PFHpA - Soil - Detect Pair X-Y Scatterplots

PFHpS - Soil - Outliers Removed



PFHpS - Soil - All Detect Pairs



Legend

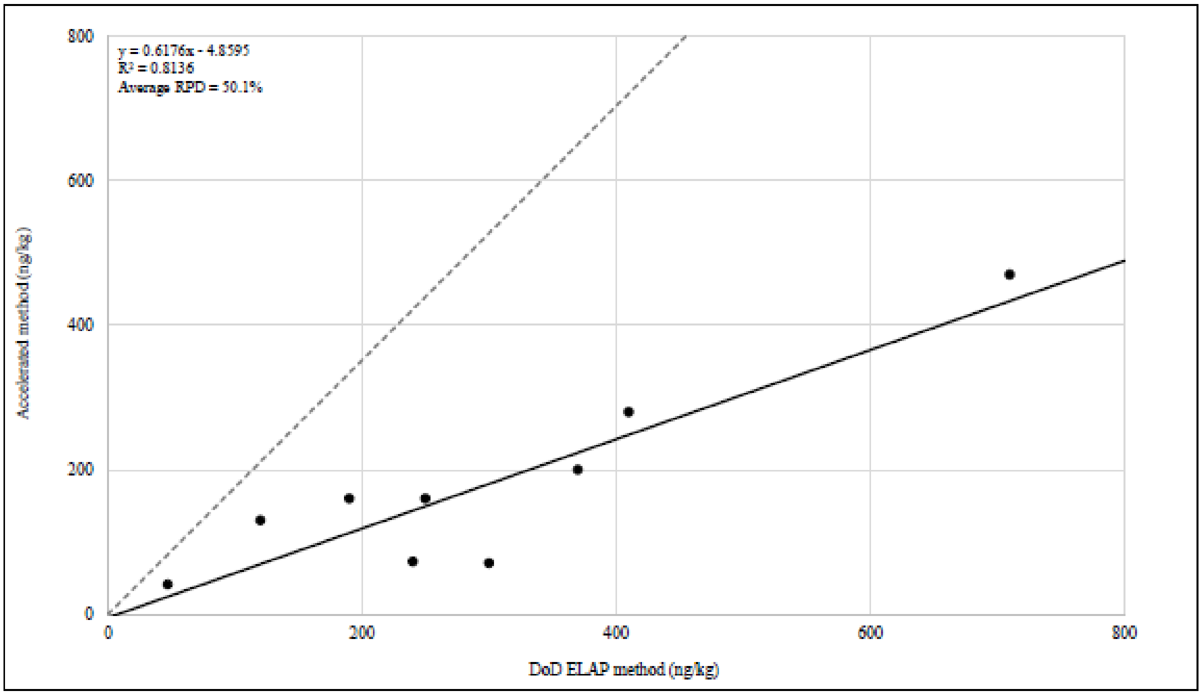
● Detect Pair - - - 1:1 Line —— OLS Regression Line (i.e., linear regression line)

Abbreviations

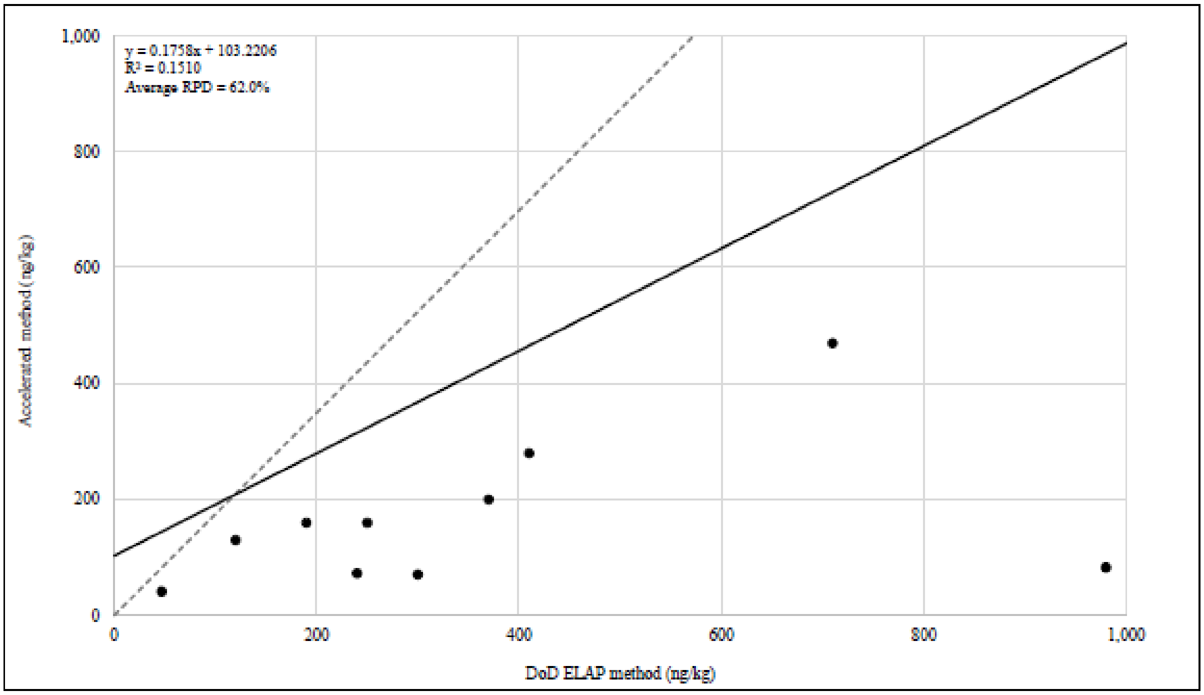
ng/kg = nanograms per kilogram RPD = relative percent difference

Figure 7-2O. Secondary PFAS Compound - PFHpS - Soil - Detect Pair X-Y Scatterplots

PFHxA - Soil - Outliers Removed



PFHxA - Soil - All Detect Pairs



Legend

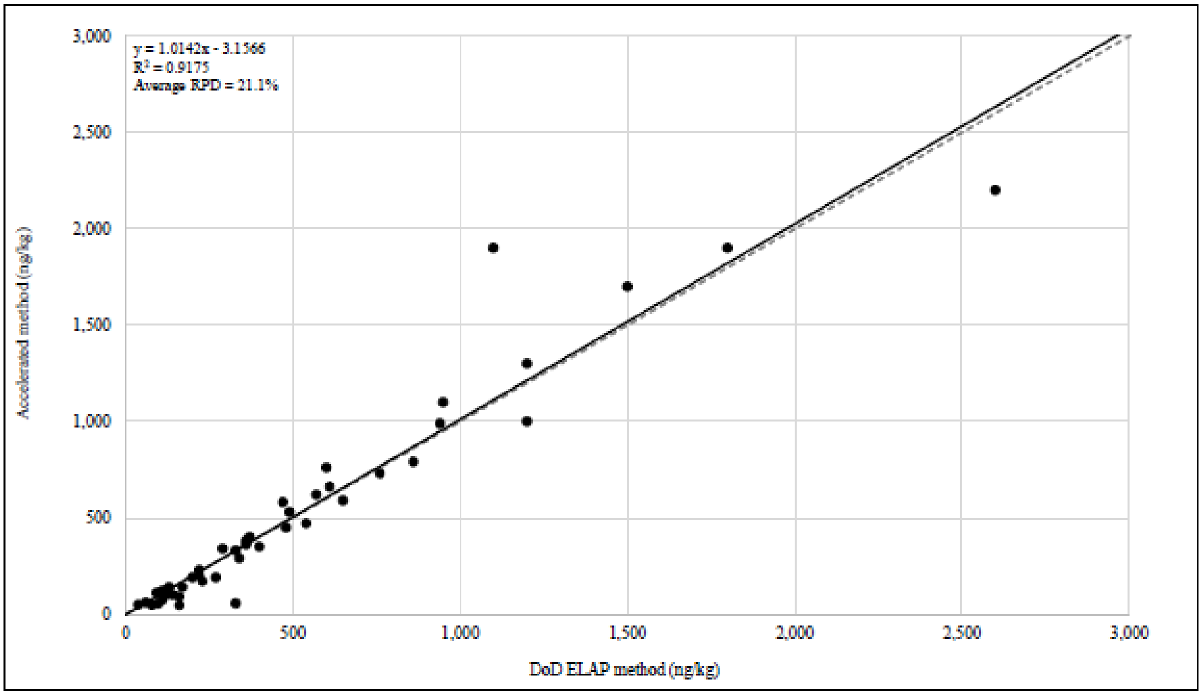
● Detect Pair ---- 1:1 Line —— OLS Regression Line (i.e., linear regression line)

Abbreviations

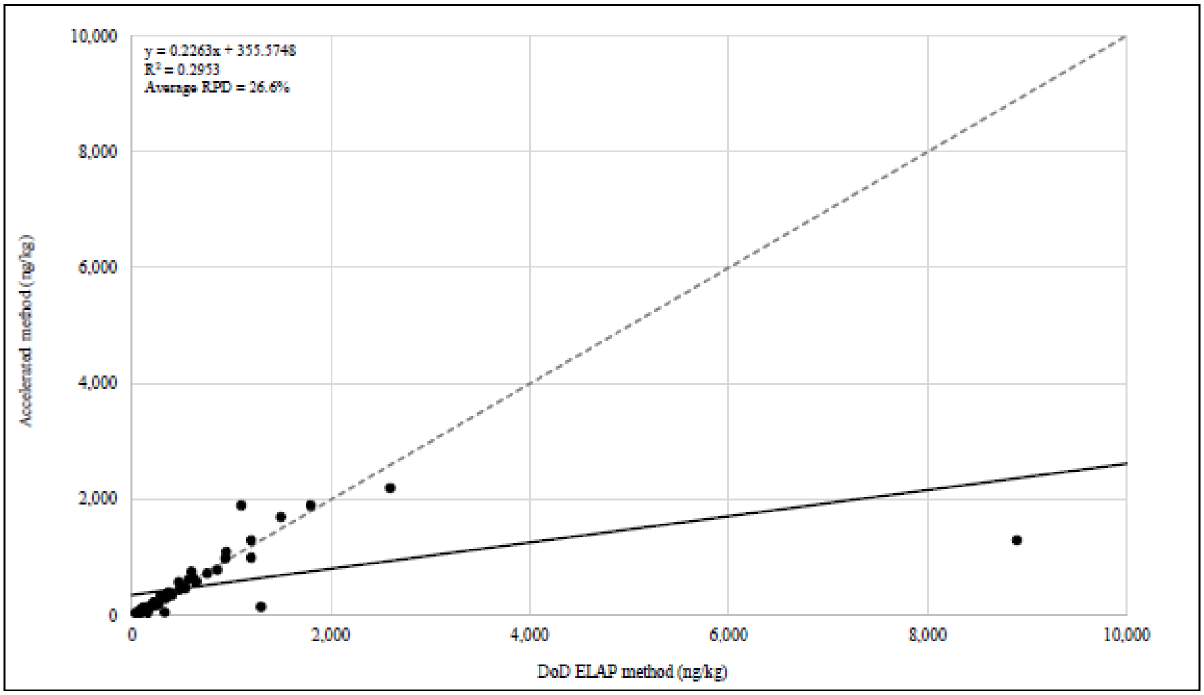
ng/kg = nanograms per kilogram RPD = relative percent difference

Figure 7-2P. Secondary PFAS Compound - PFHxA - Soil - Detect Pair X-Y Scatterplots

PFHxS - Soil - Outliers Removed



PFHxS - Soil - All Detect Pairs



Legend

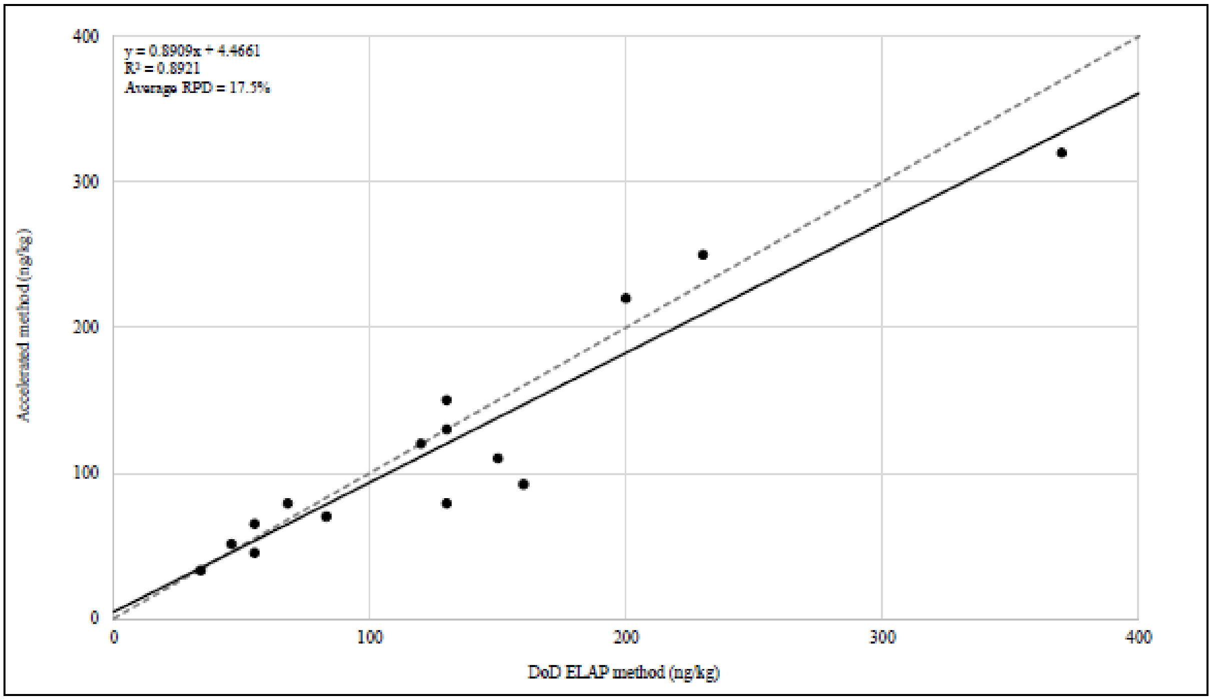
● Detect Pair ┄ 1:1 Line ― OLS Regression Line (i.e., linear regression line)

Abbreviations

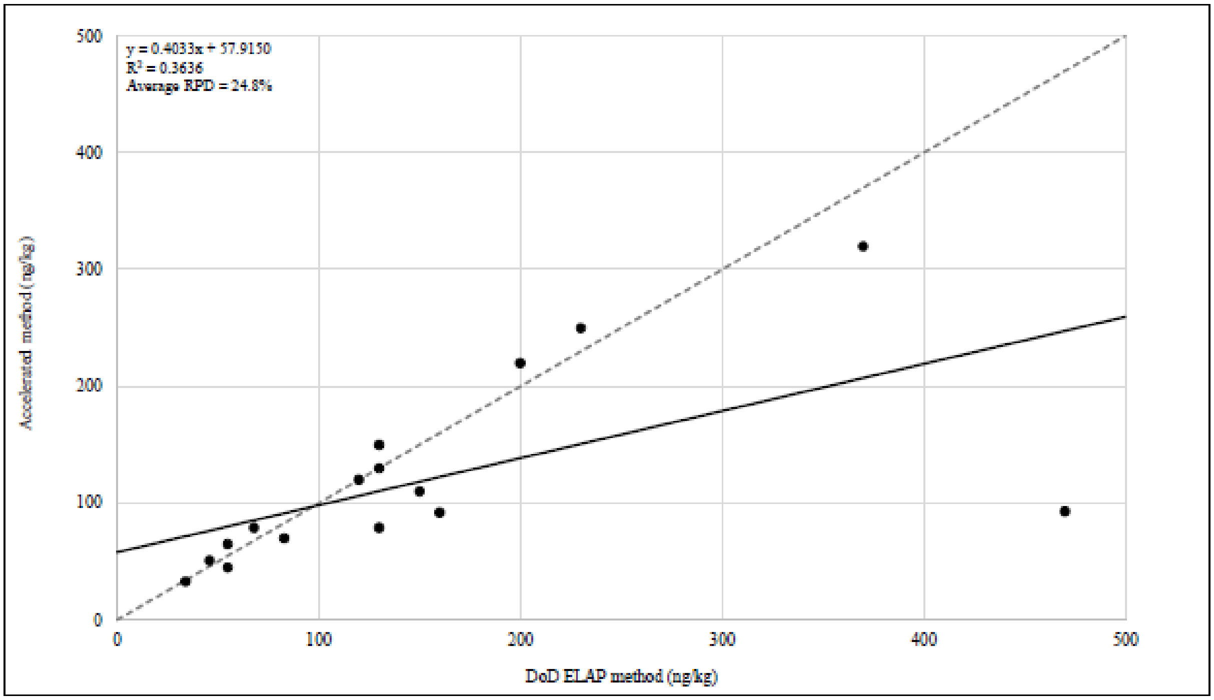
ng/kg = nanograms per kilogram RPD = relative percent difference

Figure 7-2Q. Secondary PFAS Compound - PFHxS - Soil - Detect Pair X-Y Scatterplots

Br-PFHxS - Soil - Outliers Removed



Br-PFHxS - Soil - All Detect Pairs



Legend

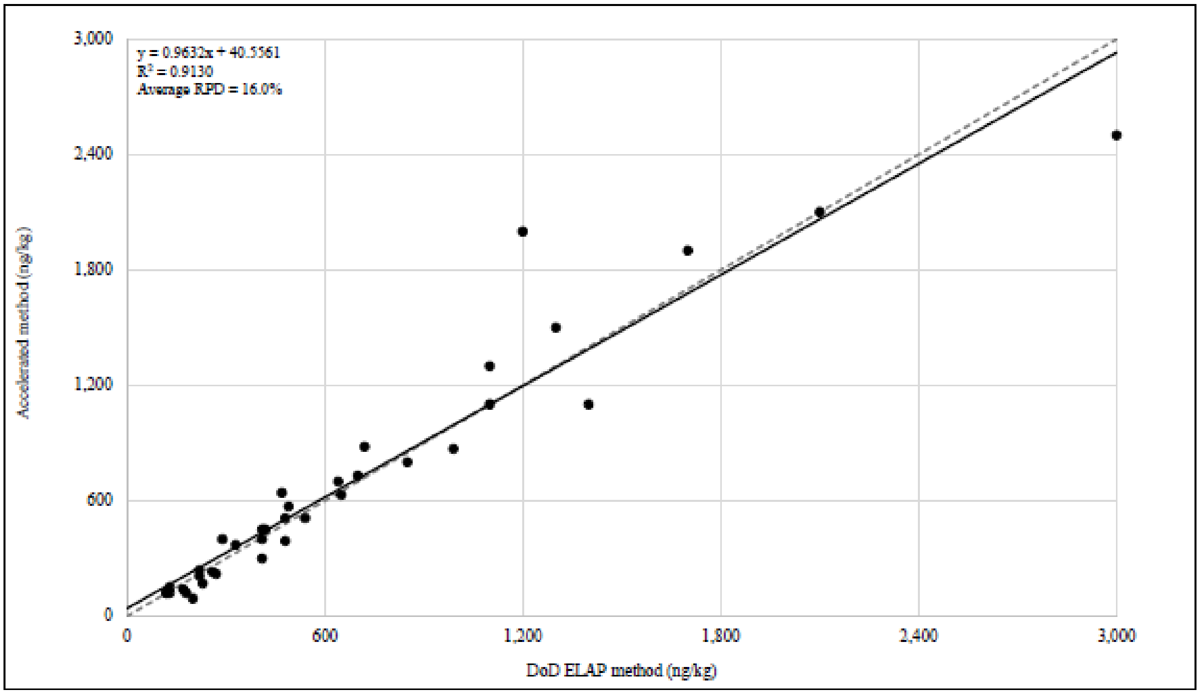
● Detect Pair ---- 1:1 Line —— OLS Regression Line (i.e., linear regression line)

Abbreviations

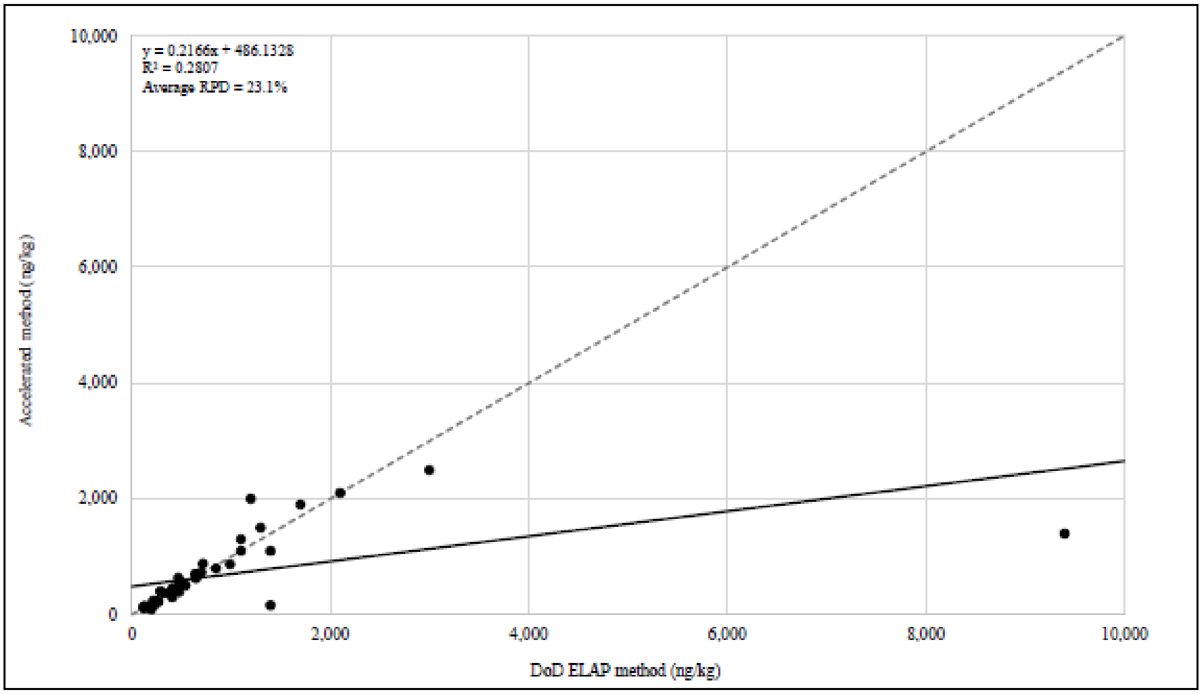
ng/kg = nanograms per kilogram RPD = relative percent difference

Figure 7-2R. Secondary PFAS Compound - Br-PFHxS - Soil - Detect Pair X-Y Scatterplots

Total PFHxS - Soil - Outliers Removed



Total PFHxS - Soil - All Detect Pairs



Legend

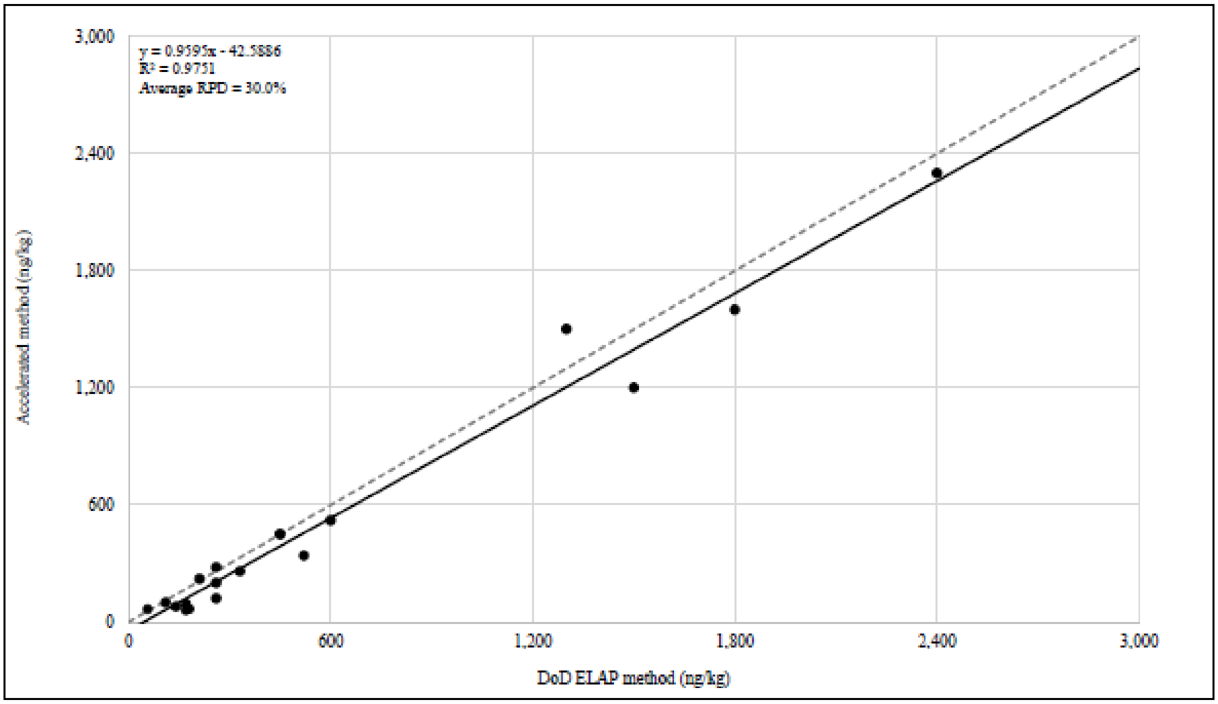
● Detect Pair ── 1:1 Line ── OLS Regression Line (i.e., linear regression line)

Abbreviations

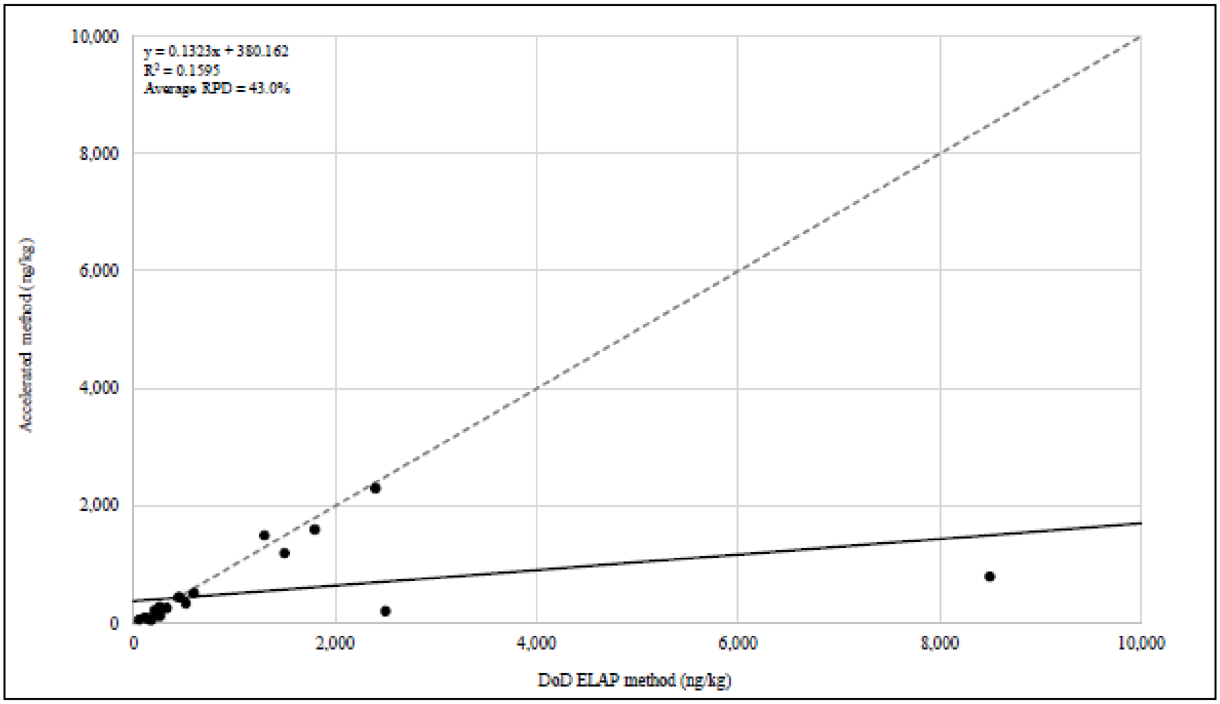
ng/kg = nanograms per kilogram RPD = relative percent difference

Figure 7-2S. Secondary PFAS Compound - Total PFHxS - Soil - Detect Pair X-Y Scatterplots

PFNA - Soil - Outliers Removed



PFNA - Soil - All Detect Pairs



Legend

●	Detect Pair
----	1:1 Line
——	OLS Regression Line (i.e., linear regression line)

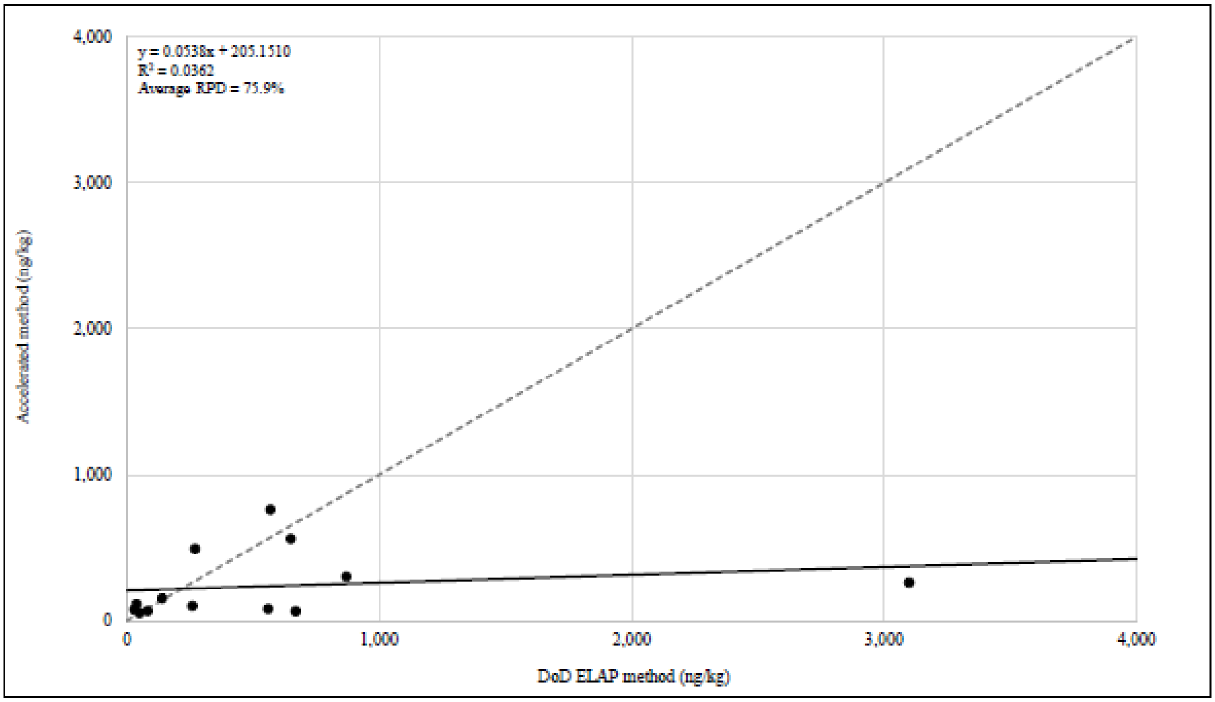
Abbreviations

ng/kg = nanograms per kilogram

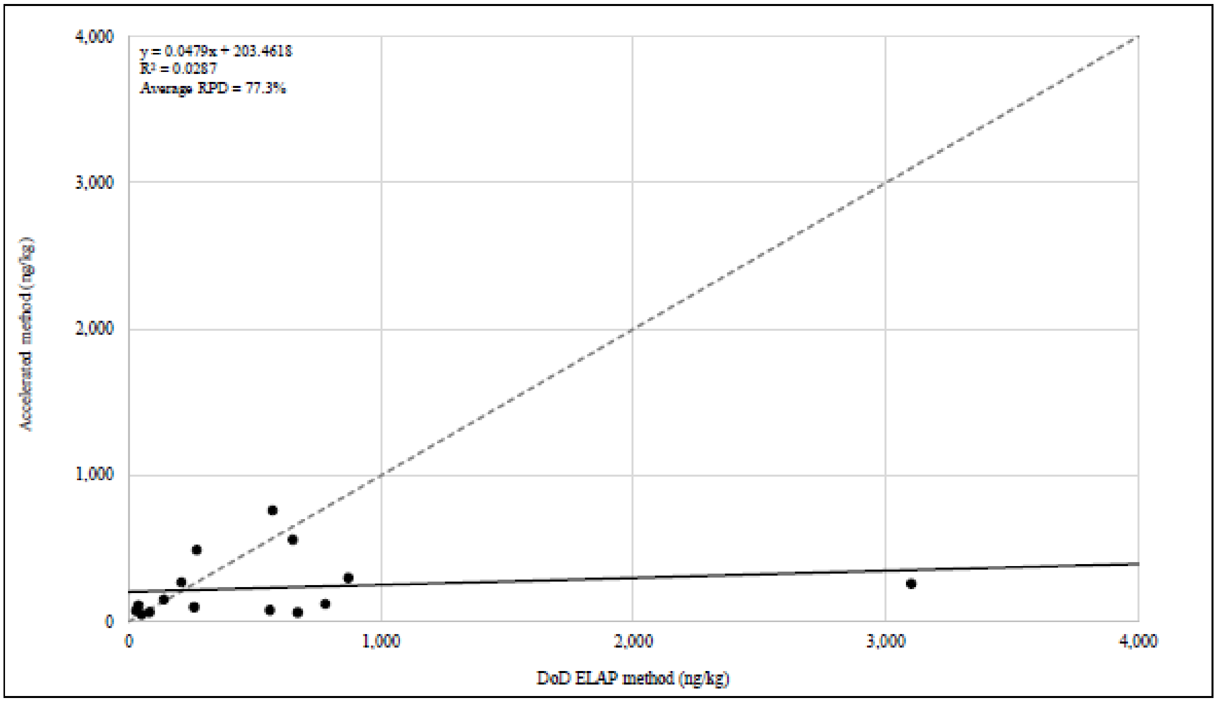
RPD = relative percent difference

Figure 7-2T. Secondary PFAS Compound - PFNA - Soil - Detect Pair X-Y Scatterplots

PFPeA - Soil - Outliers Removed



PFPeA - Soil - All Detect Pairs



Legend

● Detect Pair
1:1 Line
OLS Regression Line (i.e., linear regression line)

Abbreviations

ng/kg = nanograms per kilogram

RPD = relative percent difference

Figure 7-2U. Secondary PFAS Compound - PFPeA - Soil - Detect Pair X-Y Scatterplots

Page intentionally left blank. Only one detect pair of PFPeS in soil.

Figure 7-2V. Secondary PFAS Compound - PFPeS - Soil - Detect Pair X-Y Scatterplots

7.3.1 Outlier Results for Groundwater

The results of the Tukey outlier screening method for groundwater are presented in **Table 7-1**. In total, 145 of the 234 groundwater samples yielded at least one compound that was outside the Tukey 3.0 IQR cutoff value in one of the four iterations. Of these 145 samples, four samples yielded a large number of compounds outside the Tukey 3.0 IQR cutoff value for all four iterations:

- VAP-F1-1_42.5-46.5: The number of compounds outside the Tukey 3.0 IQR cutoff values ranged from three to seven in the four iterations. On the X-Y scatterplots, this sample plots near the majority of data points for the majority of analytes. This sample appears to be potentially representative of natural variability and was retained in the dataset.

- VAP-F2-1_15-19: The number of compounds outside the Tukey 3.0 IQR cutoff values ranged from six to 16 in the four iterations. On the X-Y scatterplots, this sample plots far from the majority of data points for almost all the compounds. For this reason, this sample was considered to be a potential outlier, likely representative of measurement error.

- VAP-F2-6_33-37: The number of compounds outside the Tukey 3.0 IQR cutoff values ranged from 13 to 16 in the four iterations. On the X-Y scatterplots, this sample plots far from the majority of data points for all the compounds. For this reason, this sample was considered to be a potential outlier, likely representative of measurement error.

- VAP-F3-8_25-29: The number of compounds outside the Tukey 3.0 IQR cutoff values ranged from five to eight. On the X-Y scatterplots, this sample plots far from the majority of data points for approximately half of the compounds. A field duplicate sample was collected with this sample. The field duplicate results were highly consistent with the majority of data points and were substituted for the parent sample in the statistical equivalence tests in which outliers were excluded.

In summary, three samples were considered to be groundwater outliers: VAP-F2-1_15-19, VAP-F3-8_33-37, and VAP-F3-8_25-29. The statistical analyses were performed including these samples and excluding VAP-F2-1_15-19 and VAP-F3-8_33-37, and substituting VAP-F3-8_25-29 with its field duplicate.

7.3.2 Outlier Results for Soil

The results of the Tukey outlier screening method for soil are presented in **Table 7-2**. In total, 45 of the 85 soil samples yielded at least one compound that was outside the Tukey 3.0 IQR cutoff value in one of the four iterations. Of these 45 samples, two samples yielded a large number of compounds outside the Tukey 3.0 IQR cutoff value for almost all iterations:

- SB-SS-5_3.5-4: The number of compounds outside the Tukey 3.0 IQR cutoff values ranged from zero to 13 in the four iterations. On the X-Y scatterplots, this sample plots far from the majority of data points for almost all the compounds.

- SB-SS-6_5.5-6: The number of compounds outside the Tukey 3.0 IQR cutoff values ranged from one to eight in the four iterations. On the X-Y scatterplots, this sample plots far from the majority of data points for almost all the compounds.

In summary, two soil samples (SB-SS-5_3.5-4 and SB-SS-6_5.5-6) were considered outliers, and the statistic evaluation was performed both including and excluding these samples.

Table 7-1. Tukey Outlier Screening Method Results for Groundwater

Arcadis Sample ID	ALL PAIRS		DETECT PAIRS	
	No. Analytes % Difference Greater than 75th Percentile + 3.0xIQR or Less than 25th Percentile 3.0xIQR	No. Analytes Distance to 1:1 Line Greater than 75th Percentile + 3.0xIQR	No. Analytes % Difference Greater than 75th Percentile + 3.0xIQR or Less than 25th Percentile 3.0xIQR	No. Analytes Distance to 1:1 Line Greater than 75th Percentile + 3.0xIQR
VAP-F1-1_12-16	0	0	0	0
VAP-F1-1_22-26	0	0	0	0
VAP-F1-1_28.5-32.5	0	0	0	0
VAP-F1-1_36-40	0	0	0	0
VAP-F1-1_42.5-46.5	**5**	**3**	**7**	**3**
VAP-F1-1_49.5-53.5	0	0	0	0
VAP-F1-1_56-60	**5**	0	0	0
VAP-F1-2_12-16	**2**	**5**	0	0
VAP-F1-2_19-23	0	**5**	0	0
VAP-F1-2_26-30	0	**9**	0	**5**
VAP-F1-2_33-37	**2**	**5**	0	0
VAP-F1-2_40-44	0	**4**	0	0
VAP-F1-2_47-51	0	**5**	0	0
VAP-F1-2_56-60	**2**	**5**	0	0
VAP-F1-3_11-15	0	0	**1**	0
VAP-F1-3_19-23	**1**	**1**	0	0
VAP-F1-3_28-32	0	0	0	0
VAP-F1-3_34-38	0	0	0	0
VAP-F1-3_42-46	0	0	0	0
VAP-F1-3_48-52	0	0	0	0
VAP-F1-3_56-60	**1**	0	0	0
VAP-F1-4_12.5-16.5	**1**	**5**	0	0
VAP-F1-4_20-24	**1**	**4**	0	0
VAP-F1-4_27-31	**1**	**4**	0	0
VAP-F1-4_34-38	**1**	**4**	0	0
VAP-F1-4_41-45	**4**	**5**	0	0
VAP-F1-4_49-53	**4**	**5**	0	0
VAP-F1-4_54.5-58.5	**3**	**5**	0	0
VAP-F1-5_12-16	0	0	0	0
VAP-F1-5_20-24	**2**	**2**	0	0
VAP-F1-5_26-30	**1**	**10**	0	**3**
VAP-F1-5_33-37	**1**	**10**	0	**9**
VAP-F1-5_40-44	0	**1**	0	0
VAP-F1-5_47-51	0	0	0	0
VAP-F1-5_56-60	0	**1**	0	0
VAP-F1-6_9-13	**3**	**5**	0	0
VAP-F1-6_16-20	**2**	**5**	0	0
VAP-F1-6_23-27	**1**	**6**	0	**3**
VAP-F1-6_28.5-32.5	0	**5**	0	0
VAP-F1-6_36-40	0	**4**	0	0
VAP-F1-6_42.5-46.5	**2**	**2**	0	0
VAP-F1-6_49.5-53.5	0	**4**	0	0
VAP-F1-7_12-16	0	0	0	0
VAP-F1-7_20-24	0	0	0	0
VAP-F1-7_27.5-31.5	**1**	**3**	0	0
VAP-F1-7_32.5-36.5	**1**	**1**	0	0
VAP-F1-7_39.5-43.5	0	0	0	0
VAP-F1-7_48-52	0	0	**1**	0
VAP-F1-7_54-58	0	0	0	0
VAP-F1-8_13.5-17.5	**2**	**5**	0	0
VAP-F1-8_22-26	**1**	**3**	0	0
VAP-F1-8_28-32	**1**	**13**	0	**10**
VAP-F1-8_37.5-41.5	**1**	**2**	0	0
VAP-F1-8_46-50	**2**	**5**	0	0
VAP-F1-8_52.5-56.5	**3**	**5**	**3**	0
VAP-F1-9_11-15	0	0	**1**	0
VAP-F1-9_19-23	0	**2**	0	0
VAP-F1-9_27-31	0	0	0	0
VAP-F1-9_38-42	0	**5**	0	**2**
VAP-F1-9_45-49	0	**7**	0	**2**
VAP-F1-11_12-16	0	0	0	0
VAP-F1-11_21-25	**1**	**9**	0	**5**
VAP-F1-11_27-31	**1**	**2**	0	**1**
VAP-F1-11_36-40	0	0	0	0
VAP-F1-11_43-47	0	0	0	0
VAP-F1-11_50-54	**3**	0	0	0
VAP-F1-11_56-60	**1**	0	0	0
VAP-F1-12_14-18	**3**	0	0	0
VAP-F1-12_21-25	0	0	0	0
VAP-F1-12_28-32	0	0	0	0
VAP-F1-12_36-40	0	0	0	0
VAP-F1-12_43-47	**6**	0	0	0
VAP-F1-12_50-54	**6**	0	0	0
VAP-F1-12_56-60	**5**	0	0	0
VAP-F1-13_15-19	**2**	0	0	0
VAP-F1-13_22-26	0	**2**	0	0
VAP-F1-13_29-33	0	0	0	0
VAP-F1-13_36-40	0	0	0	0

Arcadis Sample ID	ALL PAIRS		DETECT PAIRS	
	No. Analytes % Difference Greater than 75th Percentile + 3.0xIQR or Less than 25th Percentile 3.0xIQR	No. Analytes Distance to 1:1 Line Greater than 75th Percentile + 3.0xIQR	No. Analytes % Difference Greater than 75th Percentile + 3.0xIQR or Less than 25th Percentile 3.0xIQR	No. Analytes Distance to 1:1 Line Greater than 75th Percentile + 3.0xIQR
VAP-F1-13_43-47	4	0	0	0
VAP-F1-13_50-54	7	0	0	0
VAP-F1-13_56-60	7	0	0	0
VAP-F2-1_15-19	6	16	13	16
VAP-F2-1_22-26	1	2	0	0
VAP-F2-1_28.5-32.5	0	0	0	0
VAP-F2-1_36-40	0	0	0	0
VAP-F2-1_43-47	1	0	0	0
VAP-F2-1_51-55	3	0	0	0
VAP-F2-1_56-60	4	0	0	0
VAP-F2-2_14-18	1	3	0	2
VAP-F2-2_20-24	0	2	0	1
VAP-F2-2_28-32	0	0	0	0
VAP-F2-2_35-39	0	2	0	2
VAP-F2-2_41-45	0	0	1	0
VAP-F2-2_48-52	0	0	0	0
VAP-F2-2_55-59	2	0	0	0
VAP-F2-3_15-19	0	2	0	0
VAP-F2-3_23-27	1	5	0	0
VAP-F2-3_29-33	1	4	0	0
VAP-F2-3_38-42	3	4	0	0
VAP-F2-3_47-51	0	0	1	0
VAP-F2-3_56-60	0	0	1	0
VAP-F2-4_15-19	0	0	0	0
VAP-F2-4_20-24	0	0	0	0
VAP-F2-4_27-31	0	0	2	0
VAP-F2-4_33-37	0	0	0	0
VAP-F2-4_39.5-43.5	0	0	0	0
VAP-F2-4_48-52	0	0	0	0
VAP-F2-4_56-60	0	0	0	0
VAP-F2-5_13-17	1	0	0	0
VAP-F2-5_22-26	1	0	0	0
VAP-F2-5_31-35	0	0	0	0
VAP-F2-5_38.5-42.5	0	0	1	0
VAP-F2-5_47.5-51.5	0	0	0	0
VAP-F2-5_56-60	0	0	0	0
VAP-F2-6_13-17	0	0	0	0
VAP-F2-6_22-26	1	0	0	0
VAP-F2-6_27-31	1	5	0	0
VAP-F2-6_33-37	16	16	13	13
VAP-F2-6_40-44	6	3	9	0
VAP-F2-6_48-52	3	0	0	0
VAP-F2-6_55-59	6	0	0	0
VAP-F2-7_12-16	2	3	0	0
VAP-F2-7_22-26	1	5	0	2
VAP-F2-7_32-36	0	1	0	0
VAP-F2-7_41-45	0	0	0	0
VAP-F2-7_49-53	0	0	2	0
VAP-F2-7_56-60	0	0	0	0
VAP-F2-8_11-15	0	0	2	0
VAP-F2-8_20-24	1	9	0	6
VAP-F2-8_27-31	1	8	0	3
VAP-F2-8_34-38	0	0	0	0
VAP-F2-8_42-46	1	0	8	0
VAP-F2-8_49-53	0	0	1	0
VAP-F2-8_56-60	6	0	0	0
VAP-F2-13_15-19	0	0	0	0
VAP-F2-13_22-26	0	0	0	0
VAP-F2-13_28-32	0	0	0	0
VAP-F2-13_36-40	0	0	3	0
VAP-F2-13_43-47	4	0	0	0
VAP-F2-13_51-55	7	0	0	0
VAP-F2-13_56-60	7	0	0	0
VAP-F3-1_9-13	1	0	0	0
VAP-F3-1_21-25	0	0	0	0
VAP-F3-1_27-31	0	0	0	0
VAP-F3-1_37-41	0	0	0	0
VAP-F3-1_46-50	0	0	0	0
VAP-F3-1_56-60	0	0	0	0
VAP-F3-2_11-15	1	0	1	0
VAP-F3-2_18-22	0	2	0	1
VAP-F3-2_25-29	1	8	0	6
VAP-F3-2_32-36	1	12	0	10
VAP-F3-2_40-44	0	1	0	0
VAP-F3-2_47-51	1	10	0	6
VAP-F3-3_10-14	3	0	0	0
VAP-F3-3_20-24	1	1	0	0
VAP-F3-3_24.5-28.5	1	4	0	2
VAP-F3-3_33-37	0	2	0	0
VAP-F3-3_42-46	0	0	0	0
VAP-F3-3_48-52	1	0	0	0

Arcadis Sample ID	ALL PAIRS		DETECT PAIRS	
	No. Analytes % Difference Greater than 75th Percentile + 3.0xIQR or Less than 25th Percentile 3.0xIQR	No. Analytes Distance to 1:1 Line Greater than 75th Percentile + 3.0xIQR	No. Analytes % Difference Greater than 75th Percentile + 3.0xIQR or Less than 25th Percentile 3.0xIQR	No. Analytes Distance to 1:1 Line Greater than 75th Percentile + 3.0xIQR
VAP-F3-3_55-59	0	0	0	0
VAP-F3-4_11-15	**6**	0	0	0
VAP-F3-4_19-23	0	0	0	0
VAP-F3-4_27-31	0	**1**	0	0
VAP-F3-4_35-39	0	**14**	**10**	**11**
VAP-F3-4_42-46	0	**3**	0	0
VAP-F3-4_56-60	0	0	0	0
VAP-F3-7_9-13	**6**	0	0	0
VAP-F3-7_15-19	0	0	0	0
VAP-F3-7_21-25	0	**1**	0	0
VAP-F3-7_27-31	0	0	0	0
VAP-F3-7_37-41	0	0	0	0
VAP-F3-7_46-50	**4**	0	0	0
VAP-F3-7_56-60	**3**	0	0	0
VAP-F3-8_11-15	**3**	0	0	0
VAP-F3-8_18-22	0	0	0	0
VAP-F3-8_25-29	**5**	**7**	**8**	**5**
VAP-F3-8_33-37	0	**1**	0	0
VAP-F3-8_41-45	**1**	**1**	0	0
VAP-F3-8_49-53	0	**4**	0	0
VAP-F3-8_56-60	**1**	**2**	0	0
VAP-F3-9_9-13	**6**	0	0	0
VAP-F3-9_15-19	0	0	0	0
VAP-F3-9_21-25	0	0	0	0
VAP-F3-9_27-31	0	0	0	0
VAP-F3-9_37-41	0	0	0	0
VAP-F3-9_46-50	**1**	0	0	0
VAP-F3-9_56-60	0	0	0	0
VAP-PS-1_14-17	**1**	**5**	0	**1**
VAP-PS-2_14-17	**1**	**5**	0	**2**
VAP-PS-3_16.5-19.5	**1**	**3**	0	0
VAP-PS-4_13-16	**1**	**5**	0	0
VAP-PS-5_14-17	**1**	**3**	0	0
VAP-PS-6_14-17	0	**5**	0	**1**
VAP-SS-1_13-17	0	0	0	0
VAP-SS-1_20.5-24.5	0	0	0	0
VAP-SS-1_26-30	0	0	0	0
VAP-SS-1_34-38	0	0	0	0
VAP-SS-1_44-48	0	0	0	0
VAP-SS-1_50-54	0	0	0	0
VAP-SS-1_56-60	0	0	0	0
VAP-SS-2_14-18	0	0	0	0
VAP-SS-2_23-27	0	0	0	0
VAP-SS-2_28.5-32.5	0	0	0	0
VAP-SS-2_36-40	0	0	0	0
VAP-SS-2_43-47	0	0	**1**	0
VAP-SS-2_49-53	**1**	0	**1**	0
VAP-SS-2_58-62	**5**	0	0	0
VAP-SS-3_14-18	0	0	0	0
VAP-SS-3_22-26	**1**	0	**2**	0
VAP-SS-3_30-34	0	**1**	**3**	0
VAP-SS-3_38-42	0	0	0	0
VAP-SS-3_44.5-48.5	**6**	0	0	0
VAP-SS-3_50-54	0	0	0	0
VAP-SS-3_58-62	**1**	0	0	0
VAP-SS-4_15-19	**1**	**1**	0	**1**
VAP-SS-4_21-25	0	0	0	0
VAP-SS-4_27.5-31.5	0	0	0	0
VAP-SS-4_35-39	0	0	0	0
VAP-SS-4_41-45	**3**	0	0	0
VAP-SS-4_49-53	0	0	0	0
VAP-SS-4_56-60	**1**	0	0	0
VAP-SS-5_15.5-19.5	0	0	0	0
VAP-SS-5_20.5-24.5	0	0	0	0
VAP-SS-5_27-31	0	0	0	0
VAP-SS-5_34-38	0	0	0	0
VAP-SS-5_40-44	0	0	0	0
VAP-SS-5_47-51	0	**1**	0	0
VAP-SS-5_56-60	0	0	0	0
VAP-SS-6_14.5-18.5	0	**1**	0	**1**
VAP-SS-6_22-26	0	0	0	0
VAP-SS-6_30-34	0	0	0	0
VAP-SS-6_38-42	0	0	0	0
VAP-SS-6_49-53	0	0	**1**	0
VAP-SS-6_56-60	**3**	0	0	0

Abbreviations:
IQR = interquantile range

Notes:
The IQR is calculated as the 75th percentile minus the 25th percentile.

Table 7-2. Tukey Outlier Screening Method Results for Soil

Arcadis Sample ID	ALL PAIRS		DETECT PAIRS	
	No. Analytes % Difference Greater than 75th Percentile + 3.0xIQR or Less than 25th Percentile 3.0xIQR	No. Analytes Distance to 1:1 Line Greater than 75th Percentile + 3.0xIQR	No. Analytes % Difference Greater than 75th Percentile + 3.0xIQR or Less than 25th Percentile 3.0xIQR	No. Analytes Distance to 1:1 Line Greater than 75th Percentile + 3.0xIQR
SB-F1-3_8.5-9	**3**	0	0	0
SB-F1-3_10.25-10.75	**2**	0	0	0
SB-F1-3_12-12.5	**2**	0	0	0
SB-F1-11_12.5-13	**4**	0	0	0
SB-F1-11_14.25-14.75	**3**	0	0	0
SB-F1-11_16-16.5	**3**	0	0	0
SB-F2-1_13.5-14	0	0	0	0
SB-F2-1_15.25-15.75	0	0	0	0
SB-F2-2_13.5-14	**3**	0	0	0
SB-F2-2_15-15.5	0	0	0	0
SB-F2-2_17-18	0	0	0	0
SB-F3-2_7.5-8	**3**	0	0	0
SB-F3-2_9.25-9.75	**3**	0	0	0
SB-F3-2_11-11.5	**4**	0	0	0
SB-F3-2_54.5-55	0	0	0	0
SB-F3-2_56-56.5	**2**	0	0	0
SB-F3-2_59.5-60	**4**	0	0	0
SB-F3-9_8.5-9	**4**	0	0	0
SB-F3-9_10.75-11.25	**2**	0	0	0
SB-F3-9_12.5-13	**3**	0	0	0
SB-PS-1_12.5-13	0	0	0	0
SB-PS-1_14.7-15.2	0	**2**	0	0
SB-PS-1_16.5-17	0	**2**	0	**3**
SB-PS-2_12.5-13	**4**	**1**	0	0
SB-PS-2_14.7-15.2	0	0	0	0
SB-PS-2_16.5-17	**1**	**2**	**2**	0
SB-PS-3_12.5-13	**1**	0	0	0
SB-PS-3_14.5-15	**3**	0	0	0
SB-PS-3_16.5-17	**1**	0	**2**	0
SB-PS-4_11-11.5	0	0	0	0
SB-PS-4_13.2-13.7	0	0	0	0
SB-PS-4_15.5-16	0	0	0	0
SB-PS-5_12-12.5	0	0	0	0
SB-PS-5_14-14.5	0	0	0	0
SB-PS-5_15.5-16	0	0	0	0
SB-PS-6_12-12.5	0	0	0	0
SB-PS-6_14.2-14.7	0	0	0	0
SB-PS-6_15.5-16	0	0	0	0
SB-SS-1_2.5-3	0	0	0	0
SB-SS-1_4.5-5	0	0	0	0
SB-SS-1_6.5-7	0	0	0	0
SB-SS-1_8.5-9	0	0	0	0
SB-SS-1_10.5-11	0	**1**	0	0
SB-SS-1_12.75-13.25	0	**1**	0	0
SB-SS-1_14.75-15.25	0	0	0	0
SB-SS-2_1.5-2	0	**1**	0	**1**
SB-SS-2_3.5-4	0	**1**	0	0
SB-SS-2_5.5-6	0	0	0	0
SB-SS-2_7.5-8	0	**1**	0	0
SB-SS-2_9.5-10	0	0	0	0
SB-SS-2_11.5-12	0	**1**	0	0
SB-SS-2_13.75-14.25	0	0	0	0
SB-SS-2_15.5-16.5	0	0	0	0
SB-SS-3_1.5-2	0	0	0	0
SB-SS-3_3.5-4	0	**1**	0	0
SB-SS-3_5.5-6	0	**1**	0	0
SB-SS-3_7.5-8	0	**1**	0	0
SB-SS-3_9.5-10	0	**1**	0	0
SB-SS-3_11.5-12	0	0	0	0
SB-SS-3_13.75-14.25	0	0	0	0
SB-SS-3_15.75-16.25	0	0	0	0
SB-SS-4_2.5-3	0	0	0	0
SB-SS-4_4.5-5	0	0	0	0
SB-SS-4_6.5-7	0	0	0	0
SB-SS-4_8.5-9	0	**1**	0	0
SB-SS-4_10.5-11	0	0	0	0
SB-SS-4_12.5-13	0	0	0	0
SB-SS-4_14.75-15.25	0	**2**	0	0
SB-SS-4_16.75-17.25	**1**	**1**	0	0
SB-SS-5_1.5-2	0	**2**	0	0
SB-SS-5_3.5-4	0	**13**	**3**	**13**
SB-SS-5_5.5-6	0	**4**	0	**1**
SB-SS-5_7.5-8	0	**8**	0	**6**
SB-SS-5_9.5-10	0	**6**	0	**4**
SB-SS-5_11.5-12	0	**3**	0	**3**
SB-SS-5_14.25-14.75	0	**2**	0	**1**
SB-SS-5_16.25-16.75	0	**3**	0	**3**

Arcadis Sample ID	ALL PAIRS		DETECT PAIRS	
	No. Analytes % Difference Greater than 75th Percentile + 3.0xIQR or Less than 25th Percentile 3.0xIQR	No. Analytes Distance to 1:1 Line Greater than 75th Percentile + 3.0xIQR	No. Analytes % Difference Greater than 75th Percentile + 3.0xIQR or Less than 25th Percentile 3.0xIQR	No. Analytes Distance to 1:1 Line Greater than 75th Percentile + 3.0xIQR
SB-SS-6_1.5-2	0	0	**1**	0
SB-SS-6_3.5-4	0	0	0	0
SB-SS-6_5.5-6	**1**	**8**	**2**	**6**
SB-SS-6_7.5-8	0	0	0	0
SB-SS-6_9.5-10	0	0	0	0
SB-SS-6_11.5-12	0	0	0	0
SB-SS-6_14.25-14.75	0	0	0	0
SB-SS-6_16.25-16.75	0	0	0	0

Abbreviations:

IQR = interquantile range

Notes:

The IQR is calculated as the 75th percentile minus the 25th percentile.

7.4 BASE LEVEL STATISTICAL EVALUATION

7.4.1 Statistical Methods and Datasets

To evaluate the comparability of the Accelerated Method to the DoD ELAP Method, the following statistical techniques were performed: OLS regression with calculation of R2 and slope, and average RPD. The analytical results used for statistical calculations are presented in **Tables 5-3** through **5-6** (Groundwater Primary PFAS Constituents, Groundwater Secondary PFAS Constituents, Soil Primary PFAS Constituents, and Soil Secondary PFAS Constituents, respectively).

To assess these statistics, the data were organized into two different groups:

1. **Agreed detects.** All agreed detects with outliers included.

2. **Agreed detects with outliers removed.** Here, the outliers have been removed from the dataset for both water and soil samples.

The performance objectives established as part of the Demonstration Plan for this project are as follow:

1. Linear regression coefficient (as R^2) >/= 0.9

2. Slope of linear regression between 0.8 and 1.2

3. Average RPD </= 30 for waters and </= 50 for soils.

7.4.2 Results

The results of the Base Level Statistical Evaluation are shown in **Table 7-3** for the Primary PFAS compounds and **Table 7-4** for the Secondary PFAS compounds. Scatterplots with regression and RPD results are shown on **Figure 7-1** for the Primary PFAS compounds and **Figure 7-2** for the Secondary PFAS compounds. As a reminder, PFBA is not included in this evaluation. Two compounds (PFBS and PFPeS) did not have enough data pairs available for several of the metrics in the soils data. These compounds show “NA” for their respective cells within the table. Where the performance goals were not met for an individual metric or the average of that metric, these values are shaded gray in the table. The number of observations (or pairs) is listed in the table.

Table 7-3. Descriptive Statistics, Average RPD, and OLS Slope and R2 for the Primary PFAS Compounds

Matrix	Analyte	Dataset	Analytical Method	Descriptive Statistics							Performance Goal Evaluation for Detect Pairs			
				Sample Size	Detects	NDs	Min ND	Max ND	Min Detect	Max Detect	No. Detect Pairs	Average RPD	OLS Regression	
													Slope	R^2
Primary PFAS Compounds														
Groundwater											**Performance Goal**	**</=30**	**0.8 - 1.2**	**> 0.9**
Groundwater	PFOA	Outliers Removed	DoD ELAP	232	208	24	0.93	5.1	1	590	114	37.2	1.0777	0.9661
			Accelerated	232	114	118	16	34	17	640				
		Full	DoD ELAP	234	210	24	0.93	5.1	1	590	116	40.1	1.1187	0.2239
			Accelerated	234	116	118	16	34	17	2,200				
	PFOS	Outliers Removed	DoD ELAP	232	223	9	1.2	1.3	1.3	19,000	180	23.2	1.1289	0.9926
			Accelerated	232	181	51	16	33	17	22,000				
		Full	DoD ELAP	234	225	9	1.2	1.3	1.3	22,000	182	25.0	1.1102	0.9933
			Accelerated	234	183	51	16	33	17	24,000				
	T-PFOS	Outliers Removed	DoD ELAP	232	219	13	0.78	0.82	1	11,000	186	33.6	1.1093	0.9589
			Accelerated	232	189	43	10	11	9.5	14,000				
		Full	DoD ELAP	234	221	13	0.78	0.82	1	11,000	188	34.9	1.1197	0.9666
			Accelerated	234	191	43	10	11	9.5	14,000				
	Total PFOS	Outliers Removed	DoD ELAP	232	223	9	2.1	2.2	2.5	30,000	185	26.3	1.1233	0.9851
			Accelerated	232	186	46	27	44	27	36,000				
		Full	DoD ELAP	234	225	9	2.1	2.2	2.5	30,000	187	27.9	1.1258	0.9885
			Accelerated	234	188	46	27	44	27	36,000				
	PFBS	Outliers Removed	DoD ELAP	232	144	88	1.2	6.6	1.3	49	45	33.7	0.9517	0.6711
			Accelerated	232	48	184	16	35	17	76				
		Full	DoD ELAP	234	146	88	1.2	6.6	1.3	53	47	40.5	2.5433	0.0100
			Accelerated	234	50	184	16	35	17	1,800				
								Water Compound Averages, outliers removed				30.8	1.0782	0.9148
Soil											**Performance Goal**	**</=50**	**0.8 - 1.2**	**> 0.9**
Soil	PFOA	Outliers Removed	DoD ELAP	83	21	62	33	510	42	2,700	21	36.9	0.8041	0.9209
			Accelerated	83	36	47	40	82	46	1,900				
		Full	DoD ELAP	85	23	62	33	510	42	9,100	23	48.1	0.1462	0.2417
			Accelerated	85	38	47	40	82	46	1,900				
	PFOS	Outliers Removed	DoD ELAP	83	57	26	22	290	46	330,000	54	15.1	0.9833	0.9846
			Accelerated	83	63	20	40	82	71	320,000				
		Full	DoD ELAP	85	59	26	22	290	46	530,000	56	20.4	0.3754	0.3965
			Accelerated	85	65	20	40	82	71	320,000				
	T-PFOS	Outliers Removed	DoD ELAP	83	71	12	7.3	78	8	47,000	58	35.0	1.0204	0.9706
			Accelerated	83	62	21	28	57	37	53,000				
		Full	DoD ELAP	85	73	12	7.3	78	8	47,000	60	38.9	0.8997	0.8452
			Accelerated	85	64	21	28	57	37	53,000				
		Outliers Removed	DoD ELAP	83	61	22	31	360	39	380,000	57	17.6	0.9745	0.9860

Matrix	Analyte	Dataset	Analytical Method	Descriptive Statistics							Performance Goal Evaluation for Detect Pairs			
				Sample Size	Detects	NDs	Min ND	Max ND	Min Detect	Max Detect	No. Detect Pairs	Average RPD	OLS Regression	
													Slope	R^2
Primary PFAS Compounds														
	Total PFOS		Accelerated	83	64	19	68	140	100	370,000				
		Full	DoD ELAP	85	63	22	31	360	39	560,000	59	22.5	0.4215	0.4431
			Accelerated	85	66	19	68	140	100	370,000				
	PFBS	Outliers Removed	DoD ELAP	83	9	74	11	170	53	390	0	NA	NA	NA
			Accelerated	83	4	79	40	82	66	180				
		Full	DoD ELAP	85	10	75	11	170	53	420	0	NA	NA	NA
			Accelerated	85	4	81	40	82	66	180				
								Soil Compound Averages, outliers removed				26.1	0.9456	0.9655

Abbreviations:

DoD ELAP = U.S. Department of Defense Environmental Laboratory Accreditation Program NA = not available

ND = non-detect

OLS = ordinary least squares (i.e., linear regression) PFBS = perfluorobutane sulfonate

PFOA = perfluoroctanoic acid PFOS = perfluorooctane sulfonate RPD = relative percent difference

Notes:

1. Groundwater analytical results are in units nanograms per liter (ng/L) and soil analytical results are in units nanograms per kilogram (ng/kg).
2. Method Detection Limits (MDLs) are shown for DoD ELAP Method non-detects and Limits of Quantitation (LOQ) are shown for Accelerated Method non-detects.
3. Gray shading indicates data sets that were not within the established Performance Goals.

Groundwater Primary PFAS Compounds: Based on the data presented in **Table 7-3**, and the scatterplots on **Figure 7-1**, the Accelerated Method data correlated well with the DoD ELAP Method data for the Primary PFAS compounds. The following observations were documented regarding the results of these data:

- The overall average RPD for all five compounds was 30.8 with the water sample outliers removed. Note that this average is for all five compounds and is not weighted by the number of detectable pairs.
- The overall averages for the slope and R2 for all five compounds were 1.08 and 0.91, respectively, with the water outliers removed. Note that this average is for all five compounds and is not weighted by the number of detectable pairs.
- With outliers included, nine of the 15 (60 percent) individual metrics (three [RPD, slope and R^2] for each of the five compounds) achieved the performance goals with the dataset that included the outliers.
- Removing the outliers improved the comparisons such that 11 of the 15 (73 percent) individual metrics were achieved. Specific details are as follow:
    - R^2 of </= 0.9 was achieved for Primary PFAS compounds, except for PFBS, which achieved R^2 of 0.67.
    - All of the slope measurements were within the 0.8 to 1.2 goal, indicating no significant bias.
    - RPD of </= 30 was not achieved for three of the five compounds including PFOA (37.2), T-PFOS (33.6), and PFBS (33.7). The RPDs for total PFOS and PFOS were both below 30.
- In summary, none of five compounds' performance data deviated dramatically from the stated goals.

Soil Primary PFAS Compounds: Based on the data presented in **Table 7-3** and the scatterplots on **Figure 7-1**, the Accelerated Method data correlated well with the DoD ELAP Method data for the Primary PFAS compounds. The following observations were documented regarding the results of these data:

- The overall average for the RPD for all five compounds was 26.1 with the soil outlier samples removed. Note that this average is for all five compounds and is not weighted by the number of detectable pairs.
- The overall averages for the slope and R2 for all five compounds were 0.95 and 0.97, respectively, with the soil outlier samples removed. Note that this average is for all five compounds and is not weighted by the number of detectable pairs.
- Eight of the 12 (75 percent) individual metrics (three for each of the four compounds, PFBS did not have sufficient data) achieved the performance goals with the dataset that included the outliers.
- Removing the outliers improved the comparisons such that all 12 individual metrics were achieved.
- In summary, all five compounds' performance data met the stated goals.

Groundwater Secondary PFAS Compounds: Based on the data presented in **Table 7-4** and the scatterplots on **Figure 7-2**, the Accelerated Method data correlated less with the DoD ELAP Method data for the Primary PFAS compounds. The following observations were documented regarding the results of these data:

- The overall average for the RPD for all 11 compounds was 25.1 with the water outlier samples removed. Note that this average is for all 11 compounds and is not weighted by the number of detectable pairs.
- The overall averages for the slope and R^2 for all 11 compounds were 1.05 and 0.89, respectively, with the water outlier samples removed. Note that this average is for all 11 compounds and is not weighted by the number of detectable pairs.
- Eighteen of the 33 (55 percent) individual metrics (three for each of the 11 compounds) achieved the performance goals with the dataset that included the outliers.
- Removing the outliers improved the comparisons such that 27 of the 33 (82 percent) individual metrics were achieved. Specific details are as follow:
  - R2 of </= 0.9 was not achieved for PFHpS (0.85), Br-PFHxS (0.88), PFNA (0.74), and PFPeS (0.77).
  - All of the slope measurements were within the 0.8 to 1.2 goal, indicating no significant bias.
  - RPD of </= 30 was not achieved for PFHpA (41.9) and PFPeA (31.1).
- In summary, none of 11 compounds' performance data deviated dramatically from the stated goals.

Soil Secondary PFAS Compounds: Based on the data presented in **Table 7-4** and the scatterplots on **Figure 7-2**, the Accelerated Method data correlated less with the DoD ELAP Method data for the Primary PFAS compounds. The following observations were documented regarding the results of these data:

- The overall average for the RPD for all 11 compounds was 35.2 with the soil outlier samples removed. Note that this average is for all 11 compounds and is not weighted by the number of detectable pairs.
- The overall averages for the slope and R^2 for all 11 compounds were 0.88 and 0.76, respectively, with the soil outlier samples removed. Note that this average is for all 11 compounds and is not weighted by the number of detectable pairs.
- Seven of the 30 (23 percent) available metrics (three for each of the 10 compounds; PFPeS did not have sufficient data) achieved the performance goals with the dataset that included the outliers.
- Removing the outliers improved the correlations such that 18 of the 30 (60 percent) of the metrics met the goals. Specific details are as follow:
  - R2 of </= 0.9 was not achieved for PFHpA (0.23), PFHpS (0.84), PFHxA (0.81), Br-PFHxS (0.89), and PFPeA (0.04).
  - Slopes between 0.8 and 1.2 were not achieved for PFHpA (0.22), PFHpS (2.2), PFHxA (0.62), and PFPeA (0.05).
  - RPD of </= 50 was not achieved for PFHpA (77.9), PFHxA (50.1), and PFPeA (75.9).
- In summary, PFHpA, PFPeA, and PFHpS represent the three compounds that deviated significantly from the stated performance goals.

Table 7-4. Descriptive Statistics, Average RPD, and OLS Slope and R2 for the Secondary PFAS Compounds

Matrix	Analyte	Dataset	Analytical Method	Descriptive Statistics							Performance Goal Evaluation for Detect Pairs			
				Sample Size	Detects	NDs	Min ND	Max ND	Min Detect	Max Detect	No. Detect Pairs	Average RPD	OLS Regression	
													Slope	R^2
Secondary PFAS Compounds														
Groundwater						**Performance Goal**		**</=30**	**0.8 - 1.2**					**> 0.9**
Groundwater	6-2FTS	Outliers Removed	DoD ELAP	232	105	127	0.68	3.7	0.78	4,600	46	19.9	1.0467	0.9846
			Accelerated	232	46	186	16	36	17	4,800				
		Full	DoD ELAP	234	106	128	0.68	3.7	0.78	4,600	47	23.4	1.0287	0.9307
			Accelerated	234	48	186	16	36	17	4,800				
	8-2FTS	Outliers Removed	DoD ELAP	232	61	171	1.3	7.1	1.5	200	25	21.8	1.0317	0.9493
			Accelerated	232	26	206	16	36	17	210				
		Full	DoD ELAP	234	62	172	1.3	7.1	1.5	200	26	28.5	0.2275	0.0015
			Accelerated	234	28	206	16	36	17	1,800				
	PFHpA	Outliers Removed	DoD ELAP	232	152	80	3.2	17	3.5	470	107	41.9	0.9832	0.9166
			Accelerated	232	118	114	16	35	17	390				
		Full	DoD ELAP	234	154	80	3.2	17	3.5	470	110	44.5	0.8779	0.0725
			Accelerated	234	121	113	16	35	17	2,100				
	PFHpS	Outliers Removed	DoD ELAP	232	115	117	2.6	14	2.9	270	51	20.6	1.1901	0.8492
			Accelerated	232	52	180	16	67	17	360				
		Full	DoD ELAP	234	116	118	2.6	14	2.9	270	53	26.7	1.8652	0.0882
			Accelerated	234	54	180	16	67	17	1,900				
	PFHxA	Outliers Removed	DoD ELAP	232	208	24	1.2	6.6	1.4	640	121	22.7	1.0989	0.9325
			Accelerated	232	122	110	16	67	17	780				
		Full	DoD ELAP	234	210	24	1.2	6.6	1.4	640	123	26.1	1.0427	0.2392
			Accelerated	234	124	110	16	67	17	1,900				
	PFHxS	Outliers Removed	DoD ELAP	232	227	5	1.4	1.5	1.4	2,000	166	20.8	1.0058	0.9189
			Accelerated	232	166	66	16	33	17	2,100				
		Full	DoD ELAP	234	229	5	1.4	1.5	1.4	2,000	168	23.0	1.0347	0.7896
			Accelerated	234	168	66	16	33	17	2,200				
	Br-PFHxS	Outliers Removed	DoD ELAP	232	210	22	0.46	0.53	0.53	340	130	21.1	1.0760	0.8828
			Accelerated	232	130	102	6.6	7.3	7.2	480				
		Full	DoD ELAP	234	212	22	0.46	0.53	0.53	340	132	23.9	1.1136	0.6502
			Accelerated	234	132	102	6.6	7.3	7.2	510				
	Total PFHxS	Outliers Removed	DoD ELAP	232	222	10	1.9	2.1	2	2,300	155	18.7	1.0086	0.9127
			Accelerated	232	155	77	24	41	25	2,600				
		Full	DoD ELAP	234	224	10	1.9	2.1	2	2,300	157	21.0	1.0380	0.7649
			Accelerated	234	157	77	24	41	25	2,700				
	PFNA	Outliers Removed	DoD ELAP	232	63	169	3.1	17	3.5	50	17	22.2	0.8678	0.7363
			Accelerated	232	17	215	16	36	18	66				
		Full	DoD ELAP	234	64	170	3.1	17	3.5	100	18	31.1	18.6364	0.6956
			Accelerated	234	19	215	16	36	18	2,000				
	PFPeA	Outliers Removed	DoD ELAP	232	197	35	1.5	8.1	1.7	640	107	37.5	1.1416	0.9032
			Accelerated	232	109	123	17	67	17	910				
		Full	DoD ELAP	234	199	35	1.5	8.1	1.7	640	109	40.8	1.0278	0.2566

Matrix	Analyte	Dataset	Analytical Method	Descriptive Statistics							Performance Goal Evaluation for Detect Pairs			
				Sample Size	Detects	NDs	Min ND	Max ND	Min Detect	Max Detect	No. Detect Pairs	Average RPD	OLS Regression	
													Slope	R^2
Secondary PFAS Compounds														
			Accelerated	234	111	123	17	67	17	1,800				
	PFPeS	Outliers Removed	DoD ELAP	232	158	74	1.3	7.1	1.4	140	56	28.6	1.1087	0.7673
			Accelerated	232	56	176	16	67	17	180				
		Full	DoD ELAP	234	160	74	1.3	7.1	1.4	140	58	36.8	-0.0722	0.0000
			Accelerated	234	58	176	16	67	17	1,900				
							Water Compound Averages, outliers removed					25.1	1.051	0.8867
Soil							**Performance Goal**	**</=50**	**0.8 - 1.2**					**> 0.9**
Soil	6-2FTS	Outliers Removed	DoD ELAP	83	11	72	23	350	48	6,900	10	15.2	0.8735	0.9953
			Accelerated	83	15	68	40	82	53	6,100				
		Full	DoD ELAP	85	12	73	23	350	48	6,900	11	27.5	0.7746	0.8336
			Accelerated	85	16	69	40	82	53	6,100				
	8-2FTS	Outliers Removed	DoD ELAP	83	19	64	15	230	180	100,000	18	12.1	0.9998	0.9927
			Accelerated	83	21	62	40	82	59	96,000				
		Full	DoD ELAP	85	21	64	15	230	180	100,000	19	20.3	0.8152	0.7845
			Accelerated	85	22	63	40	82	59	96,000				
	PFHpA	Outliers Removed	DoD ELAP	83	36	47	23	340	24	570	11	77.9	0.2152	0.2313
			Accelerated	83	12	71	40	82	52	280				
		Full	DoD ELAP	85	38	47	23	340	24	1,500	12	85.0	0.0427	0.0576
			Accelerated	85	13	72	40	82	52	280				
	PFHpS	Outliers Removed	DoD ELAP	83	16	67	15	230	28	800	13	36.7	2.1744	0.8389
			Accelerated	83	24	59	40	82	49	1,900				
		Full	DoD ELAP	85	18	67	15	230	28	3,000	15	52.6	0.0727	0.0129
			Accelerated	85	26	59	40	82	49	1,900				
	PFHxA	Outliers Removed	DoD ELAP	83	50	33	15	200	15	710	9	50.1	0.6176	0.8136
			Accelerated	83	9	74	40	82	41	470				
		Full	DoD ELAP	85	52	33	15	200	15	980	10	62.0	0.1758	0.1510
			Accelerated	85	10	75	40	82	41	470				
	PFHxS	Outliers Removed	DoD ELAP	83	52	31	6.8	88	11	2,600	46	21.1	1.0142	0.9175
			Accelerated	83	57	26	31	64	39	2,200				
		Full	DoD ELAP	85	54	31	6.8	88	11	8,900	48	26.6	0.2263	0.2953
			Accelerated	85	59	26	31	64	39	2,200				
Soil							**Performance Goal**	**</=50**	**0.8 - 1.2**					**> 0.9**
Soil	Br-PFHxS	Outliers Removed	DoD ELAP	83	19	64	6.2	94	8.4	370	15	17.5	0.8909	0.8921
			Accelerated	83	28	55	18	36	28	320				
		Full	DoD ELAP	85	21	64	6.2	94	8.4	470	16	24.8	0.4033	0.3636
			Accelerated	85	29	56	18	36	28	320				
	Total PFHxS	Outliers Removed	DoD ELAP	83	43	40	14	180	24	3,000	37	16.0	0.9632	0.9130
			Accelerated	83	47	36	49	100	73	2,500				
		Full	DoD ELAP	85	45	40	14	180	24	9,400	39	23.1	0.2166	0.2807
			Accelerated	85	49	36	49	100	73	2,500				
	PFNA	Outliers Removed	DoD ELAP	83	31	52	9.6	150	15	2,400	19	30.0	0.9595	0.9751

Matrix	Analyte	Dataset	Analytical Method	Descriptive Statistics							Performance Goal Evaluation for Detect Pairs			
				Sample Size	Detects	NDs	Min ND	Max ND	Min Detect	Max Detect	No. Detect Pairs	Average RPD	OLS Regression	
													Slope	R^2
Secondary PFAS Compounds														
			Accelerated	83	23	60	40	82	51	2,300				
		Full	DoD ELAP	85	33	52	9.6	150	15	8,500	21	43.0	0.1323	0.1595
			Accelerated	85	25	60	40	82	51	2,300				
	PFPeA	Outliers Removed	DoD ELAP	83	65	18	16	220	22	3,300	13	75.9	0.0538	0.0362
			Accelerated	83	17	66	40	70	51	760				
		Full	DoD ELAP	85	67	18	16	220	22	3,300	15	77.3	0.0479	0.0287
			Accelerated	85	19	66	40	70	51	760				
	PFPeS	Outliers Removed	DoD ELAP	83	5	78	15	240	24	100	1	NA	NA	NA
			Accelerated	83	2	81	40	82	92	120				
		Full	DoD ELAP	85	6	79	15	240	24	240	1	NA	NA	NA
			Accelerated	85	2	83	40	82	92	120				
							Soil Compound Averages, outliers removed					35.2	0.8762	0.7606

Abbreviations:

DoD ELAP = U.S. Department fo Defense Environmental Laboratory Accreditation Program NA = not available

ND = non-detect

OLS = ordinary least squares (i.e., linear regression) RPD = relative percent difference

Notes:

1. Groundwater analytical results are in units nanograms per liter (ng/L) and soil analytical results are in units nanograms per kilogram (ng/kg).
2. Method Detection Limits (MDLs) are shown for DoD ELAP Method non-detects and Limits of Quantitation (LOQ) are shown for Accelerated Method non-detects.
3. Gray shading indicates data sets that were not within the established Performance Goals.

7.5 ADVANCED LEVEL STATISTICAL EVALUATION

The Accelerated Method and the DoD ELAP Method for analyzing soil and groundwater data for the concentrations of the 16 PFAS compounds were compared statistically. Several statistical methods were used to make this comparison. Three categories of evaluation were used: reliability, accuracy, and statistical equivalence.

7.5.1 Reliability Evaluation

In this evaluation, reliability was determined by how often the Accelerated Method produced the same field screening decision as the DoD ELAP Method. To determine reliability, the DoD ELAP Method and Accelerated Method result pairs were compared to see if the field screening decision would be the same or different for each pair. The sample pairs were then classified based on results of that comparison. Proportion analyses were then conducted on the classification assignments. The classifications assigned to each pair were as follow:

- Both Action – The DoD ELAP Method result and the Accelerated Method result were both above the screening limit.
- Both No Action – The DoD ELAP Method result and the Accelerated Method result were both below the screening limit (including non-detects below the screening limit).
- False Positive – The DoD ELAP Method result was **below** the screening limit, indicating no further action, and the Accelerated Method result was **above** the screening limit, indicating further action.
- False Negative – The DoD ELAP Method result was **above** the screening limit, and the Accelerated Method result was **below** the screening limit.

For the Primary PFAS compounds, which have screening levels available, the field screening decision value used for the reliability evaluation was each Primary PFAS compound's respective screening level. For the Secondary PFAS compounds, which do not have screening levels available, field screening decision values were applied at 40 ng/L for groundwater and 100 ng/kg for soil, which are equal to approximately two times the typical RLs of the Accelerated Method. The reliability evaluation was performed for all sample pairs with outliers excluded.

For each compound, when both tests agreed, results were categorized as "Reliable." When the two tests did not agree, results were summed, including the false positive cases and the false negative cases, and were categorized as "Not Reliable." Dividing by the total number of data points excluding outliers computed a proportion for the data points that were Reliable and Not Reliable.

As an added measure of verification, the upper confidence limit (UCL) and a lower confidence limit (LCL) were computed at 95 percent confidence for each of the proportions. If neither confidence interval lies at least in part outside of the range of acceptability, then one can be confident that the correct field decision would be made with an acceptable proportion of the samples.

In summary, if for a given PFAS compound the proportion of "Reliable" pairs is greater than or equal to 85 percent, and the proportion of "Not Reliable" pairs is 10 percent or less, then the Accelerated Method can be considered sufficiently reliable for making field decisions for that compound.

One can be 95 percent confident that the proportions of pairs meet these criteria, providing an added measure of confidence that the Accelerated Method is a reliable way to make field decisions for the respective PFAS compound.

7.5.2 Accuracy Evaluation

Accuracy was determined by evaluating if the DoD ELAP Method and Accelerated Method result values in each sample pair were similar. For the accuracy evaluation, the percent difference was used. If the percent difference was between -30 and +30 percent, the sample pair results were considered "Accurate." If the percent difference was greater than +30 percent or less than -30 percent, then the sample pair results were considered "Not Accurate." Accuracy was evaluated for detect pairs only, excluding outliers.

The proportion of accurate pairs was computed, as well as the proportion of inaccurate pairs. As with the reliability proportions discussed in the previous section, the UCL and an LCL were computed at 95 percent confidence for the portions of accurate and inaccurate pairs.

If for a given PFAS compound, the proportion of accurate pairs is greater or equal to 85 percent, and the proportion of inaccurate pairs is 10 percent or less, then the Accelerated Method can be considered to be sufficiently accurate. If the confidence intervals lie within the acceptance criteria, then one can be 95 percent confident that the proportions of pairs meet these criteria, providing an added measure of confidence that the Accelerated Method is an accurate measure of the concentrations of the given PFAS compound.

7.5.3 Statistical Equivalence

Whereas the reliability analysis shows the proportion of correct decisions that would be made in the field, and the accuracy analysis gives the proportion of how often the two tests come within a certain margin of one another, statistical equivalence is a measure of how interchangeable the two methods are with each other. Statistical equivalence can be expressed in more than one way: how well a function could be derived to relate the methods, the margins between the two methods, and how well the test method reproduces the reference method. In this evaluation, all three of these lines were pursued. Consequently, three types of methods were used to assess statistical equivalence: regression methods, margin of equivalence methods, and Lin's Concordance Correlation Coefficient.

7.5.3.1 Regression Methods

Regression analysis assumes that one parameter is functionally related to another, and that the relationship is determined by a few parameters. For example, if the functional relationship between the two parameters is linear, then the regression is a linear regression (Breiman 1973). Three kinds of regressions were considered in this analysis: linear regression, Passing-Bablok regression, and orthogonal (Deming) regression. However, only the Passing-Bablok regression proved to be useful in evaluating the equivalence of the two analytical methods. The linear regression was only useful as a preliminary indicator, but not as a proof of equivalence. The prerequisite conditions for the use of the orthogonal regression were not met by most of the COI datasets.

7.5.3.1.1 Linear Regression

In linear regression, the functional relationship among a pair of parameters, an independent variable, and a dependent variable is linear. A fit between the measured and predicted data can be quantified in terms of a correlation coefficient, the value of which can vary from -1 to +1, with values near 1 indicating a strong correlation, values near -1 indicating anticorrelation, and values near zero indicating a lack of correlation.

It is common for investigators to assume equivalence if the coefficient is sufficiently high. However, that may not necessarily be the case (Bland and Altman 2003). For example, suppose a field instrument measures the concentration of a certain compound and always obtains a value that is exactly half what a laboratory obtained. Clearly, the two methods would not be equivalent, yet the correlation coefficient between the two methods would be 1.0. This hypothetical example illustrates the difference between correlation and equivalence. For this reason, very little weight was placed on the results of linear regressions in this study.

7.5.3.1.2 Passing-Bablok Regression

Passing-Bablok regression is a non-parametric method that is useful when comparing two methods that should yield the same measurements (NCSS 2020). Passing-Bablok regression fits the intercept and the slope of a linear equation, whereby the estimate of the slope is calculated as the median of all the slopes that can be formed from all possible pairs of data points, except those that result in a slope of 0 or -1. The intercept represents the systematic bias (difference) of the two methods, and the slope measures the amount of proportional bias (difference) between the two methods.

One of the benefits of the Passing-Bablok regression is that it allows the user to determine if the Accelerated Method is biased high or low, which in turn allows the user to predict whether unreliable points are more likely to be false positives or false negatives. The distinction between this regression and the linear regression is that the data from the two methods are compared to the 1:1 (45°) line, whereas a linear regression is satisfied if the two methods could be fit to any line.

7.5.3.1.3 Orthogonal (Deming) Regression

Orthogonal regression (also referred to as Deming regression) is a statistical technique for fitting a straight line to two-dimensional data in which both variables (i.e., the independent variable [X] and the dependent variable [Y]) are measured with error (Martin 2000). This differs from simple linear regression where only the dependent variable (Y) is measured with error.

In order to perform orthogonal regression, the data must satisfy two assumptions upon which this regression is based. First, the independent variable (X) and the dependent variable (Y) must have moderate to strong correlation. Second, the optimized residuals must be normally distributed. For both groundwater and soil, the majority of the compounds failed the assumption of the optimized residuals being normally distributed. The remainder either exhibited poor correlation or insufficient sample size. For this reason, the Deming regression results were not tabulated in the summary tables.

7.5.3.2 Margin of Equivalence Methods

The use of correlation methods alone can produce misleading conclusions regarding equivalence. In this section, two methods are presented that consider the margin of equivalence: Bland-Altman Analysis and two one-sided t-test (TOST) hypothesis tests. Each of these methods goes beyond mere correlation and addresses the question of equivalence.

7.5.3.2.1 Bland-Altman Analysis

In the Bland-Altman method of analysis, an upper and lower limit of agreement are determined from the data pairs (Bland and Altman 1986; NCSS 2020). The difference and the average are computed for each data pair. These data points are plotted with the differences on the y-axis and the averages on the x-axis. The resulting plot would be a normal probability plot of differences. In these plots, sample points above the 0 line indicate instances where the Accelerated Method concentration is lower than the DoD ELAP Method concentration. Samples below the 0 line indicate instances where the Accelerated Method concentration is greater than the DoD ELAP Method concentration. A higher proportion of sample points below the 0 line indicates bias where the Accelerated Method concentrations tend to be greater than their paired DoD ELAP Method concentrations. This type of bias may lead to occasionally over-estimating concentrations in the field while using the Accelerated Method.

The outcome of Bland-Altman analysis is a range between the upper and lower limits of agreement, or more generally, a range between the UCL of the upper limit of agreement and the LCL of the lower limit of agreement. If this range is acceptable, then the Bland-Altman analysis indicates satisfactory agreement between the two methods for a given PFAS compound.

7.5.3.2.2 Two One-Sided T-Tests Hypothesis Tests

TOSTs determine if there is equivalence of means between two independent samples within a specified margin (NCSS 2020). If the margin is small and passes the two statistical hypothesis tests, it indicates that the two means are similar and equivalent. If the margin is large and does not pass the two statistical hypothesis tests, it indicates that the two means are different and not equivalent.

The margin of equivalence was determined using an iterative approach where the hypothesis test was performed using different margins until a margin was found for which both of the two simple one-sided hypotheses that comprise the TOST hypothesis test passed. Thus, in this study, the outcome of the TOST hypothesis tests was a margin and not a pass/fail determination.

7.5.3.3 Lin's Concordance Correlation Coefficient

Lin's Concordance Correlation Coefficient is an index of how well a new method, such as the Accelerated Method, reproduces a reference method; in this case, the DoD ELAP Method. Lin's Concordance Correlation Coefficient quantifies agreement between the two measurements of the same variable. Like other types of correlation, the correlation coefficient values range from -1 to 1, with values close to -1 and 1 indicating high agreement and values close to 0 indicating poor agreement (NCSS 2020).

7.5.4 Advanced Level Statistics Results

The methods described in the previous section were applied to the 16 PFAS compounds data for which there were sufficient detections to allow for statistical analysis. The results are discussed in two sections: the Primary PFAS compounds (for which screening levels exist) and the Secondary PFAS compounds (which do not have screening levels). For each compound, the tests were applied to groundwater and soil data, except for PFBS and PFPeS, for which there were insufficient detections in soil to perform statistical equivalence analyses. For groundwater, the statistical tests were applied to the subset of the 232 non-outlier data pairs for which both methods detected the compound. In a like manner for soil, the statistical tests were applied to the subset of the 83 non-outlier data pairs for which both methods detected the compound.

The results of the statistical tests can be interpreted on two levels: the practical and the academic. From the practical standpoint, the single most important issue is whether field personnel will correctly decide whether the soil concentration of a specific compound is within or above an acceptable level. In the former case, a sample would demonstrate that an impacted area does not exist, or if it is believed to exist based on results from another sample location, that sample would delineate the area of contamination in a given direction. In the latter case, the sample would indicate that the compound is not delineated and cause the field team to step out. In this study, the DoD ELAP Method is presumed to be correct. The question is how often the Accelerated Method would lead the field personnel to the correct field decisions (i.e., the same field decisions as those that would have been made using the DoD ELAP Method). Therefore, the single test of most value in this study is reliability. This test estimates the proportion of measurements for which the Accelerated Method would make the correct field decision for a given compound. The reliability was determined conservatively: if the DoD ELAP Method indicated no action and the Accelerated Method gave a non-detection with a detection limit that exceeded the screening level (or other criterion for the Secondary PFAS compounds), that pair was considered a false positive and was grouped with the Not Reliable portion. The reliability proportions are summarized in **Tables 7-5** and **7-6** and graphed on **Figures 7-3** and **7-4** for primary and Secondary PFAS compounds, respectively.

These statistical tests provide insight into comparison accuracy, equivalence, and correlation of both analytical methods. The proportion of accurate data pairs reveals how many of the analyses exhibit acceptable agreement (**Tables 7-7** and **7-8**). The Passing-Bablok regression shows the bias of the Accelerated Method with regard to the 1:1 (45°) line of agreement. Bland-Altman and TOST show the measure of agreement, the margin based on two different criteria, upper and lower limits of agreement, and the satisfaction of two hypotheses regarding the means of two parameters. Lin’s Concordance Correlation Coefficient examines how well the Accelerated Method reproduces the results of the DoD ELAP Method. The results for these four tests of equivalence are summarized in **Tables 7-9** and **7-10** for groundwater and soil, respectively. Precision is not discussed in this section because it is an intra-method test. This section is concerned with inter-method tests, which compare two methods. For a discussion of precision, refer to **Sections 6.1.2** and **6.2.2** for the DoD ELAP Method and the Accelerated Method, respectively.

Table 7-5. Reliability in Making Field Decisions for Primary PFAS Compounds - Proportional Analysis Results and Confidence Intervals

Matrix	Analyte	Sample Size	Classification	Total No. Pairs	Sample Proportion	P-Value	Reject Null Hypothesis at $\alpha = 0.05$?	95% Lower Confidence Limit	95% Upper Confidence Limit
Groundwater	PFOA	232	Reliable	218	94%	0.00002	Yes	90%	97%
			Not Reliable	14	6%	0.02278	Yes	3%	10%
	PFOS	232	Reliable	216	93%	0.00012	Yes	89%	96%
			Not Reliable	16	7%	0.06592	No	4%	11%
	T-PFOS	232	Reliable	208	90%	0.02501	Yes	85%	93%
			Not Reliable	24	10%	0.62217	No	7%	15%
	Total PFOS	232	Reliable	214	92%	0.00064	Yes	88%	95%
			Not Reliable	18	8%	0.15110	No	5%	12%
	PFBS	232	Reliable	232	100%	0.00000	Yes	98%	100%
			Not Reliable	0	0%	0.00000	Yes	0%	2%
Soil	PFOA	83	Reliable	83	100%	0.00000	Yes	96%	100%
			Not Reliable	0	0%	0.00016	Yes	0%	4%
	PFOS	83	Reliable	83	100%	0.00000	Yes	96%	100%
			Not Reliable	0	0%	0.00016	Yes	0%	4%
	T-PFOS	83	Reliable	83	100%	0.00000	Yes	96%	100%
			Not Reliable	0	0%	0.00016	Yes	0%	4%
	Total PFOS	83	Reliable	83	100%	0.00000	Yes	96%	100%
			Not Reliable	0	0%	0.00016	Yes	0%	4%
	PFBS	83	Reliable	83	100%	0.00000	Yes	96%	100%
			Not Reliable	0	0%	0.00016	Yes	0%	4%

Notes:

1. Reliability for groundwater determined using a decision value of 40 nanograms per liter (ng/L) for PFOA, PFOS, T-PFOS, and Total PFOS, and 400,000 ng/L for PFBS.
2. Reliability for soil determined using a decision value of 126,000 nanograms per kilogram (ng/kg) for PFOA, PFOS, T-PFOS, and Total PFOS, and 130,000,000 ng/L for PFBS.

PFOA = perfluorooctanoic acid
PFOS = perfluorooctane sulfonate
PFBS = perfluorobutane sulfonate

Table 7-6. Reliability in Making Field Decisions for Secondary PFAS Compounds - Proportional Analysis Results and Confidence Intervals

Matrix	Analyte	Sample Size	Classification	Total No. Pairs	Sample Proportion	P-Value	Reject Null Hypothesis at α = 0.05?	95% Lower Confidence Limit	95% Upper Confidence Limit
Groundwater	6-2FTS	232	Reliable	229	99%	0.00000	Yes	96%	100%
			Not Reliable	3	1%	0.00000	Yes	0%	4%
	8-2FTS	232	Reliable	230	99%	0.00000	Yes	97%	100%
			Not Reliable	2	1%	0.00000	Yes	0%	3%
	PFHpA	232	Reliable	222	96%	0.00000	Yes	92%	98%
			Not Reliable	10	4%	0.00115	Yes	2%	8%
	PFHpS	232	Reliable	225	97%	0.00000	Yes	94%	99%
			Not Reliable	7	3%	0.00005	Yes	1%	6%
	PFHxA	232	Reliable	206	89%	0.05947	No	84%	93%
			Not Reliable	26	11%	0.76923	No	7%	16%
	PFHxS	232	Reliable	213	92%	0.00134	Yes	88%	95%
			Not Reliable	19	8%	0.21189	No	5%	12%
	Br-PFHxS	232	Reliable	221	95%	0.00000	Yes	92%	98%
			Not Reliable	11	5%	0.00274	Yes	2%	8%
	Total PFHxS	232	Reliable	212	91%	0.00264	Yes	87%	95%
			Not Reliable	20	9%	0.28383	No	5%	13%
	PFNA	232	Reliable	229	99%	0.00000	Yes	96%	100%
			Not Reliable	3	1%	0.00000	Yes	0%	4%
	PFPeA	232	Reliable	201	87%	0.27661	No	82%	91%
			Not Reliable	31	13%	0.96080	No	9%	18%
	PFPeS	232	Reliable	224	97%	0.00000	Yes	93%	98%
			Not Reliable	8	3%	0.00015	Yes	2%	7%
Soil	6-2FTS	41	Reliable	41	100%	0.00128	Yes	91%	100%
			Not Reliable	0	0%	0.01330	Yes	0%	9%
	8-2FTS	48	Reliable	46	96%	0.01826	Yes	86%	99%

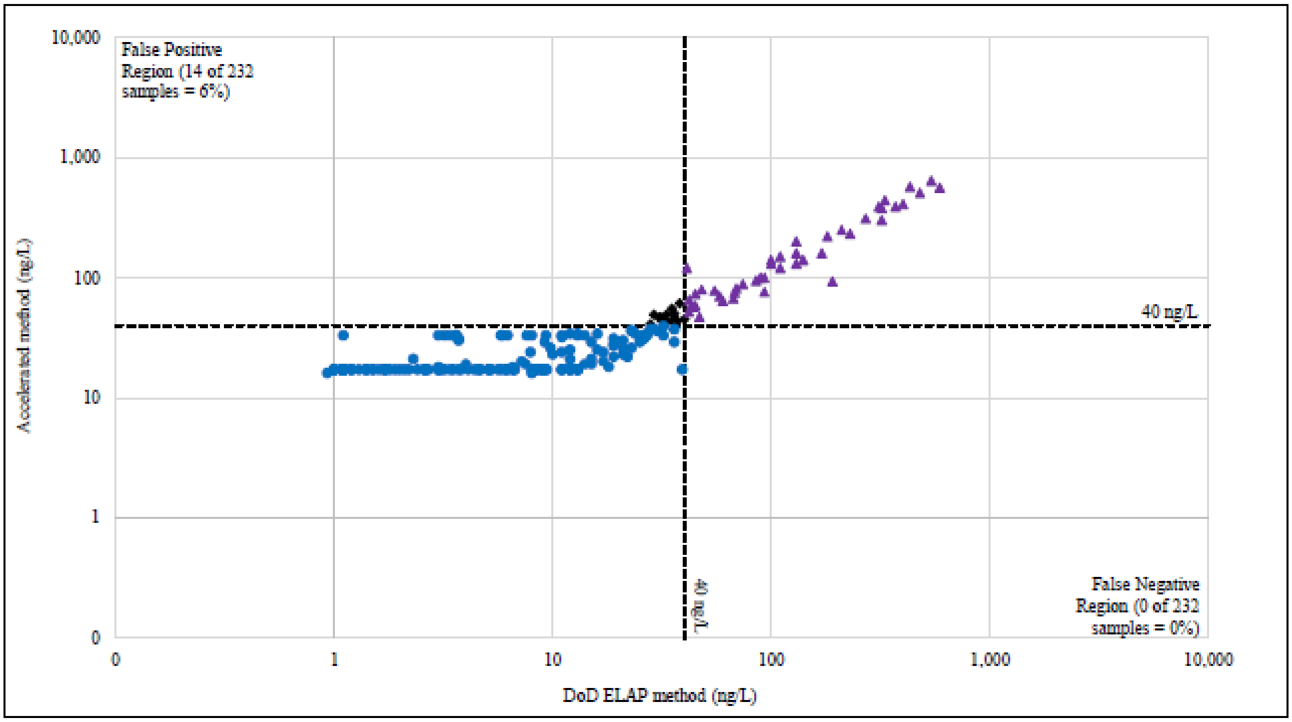
Matrix	Analyte	Sample Size	Classification	Total No.Pairs	Sample Proportion	P-Value	Reject Null Hypothesis at α = 0.05?	95% Lower Confidence Limit	95% Upper Confidence Limit
			Not Reliable	2	4%	0.12890	No	1%	14%
	PFHpA	59	Reliable	41	69%	0.99929	No	56%	81%
			Not Reliable	18	31%	1.00000	No	19%	44%
	PFHpS	43	Reliable	43	100%	0.00092	Yes	92%	100%
			Not Reliable	0	0%	0.01078	Yes	0%	8%
	PFHxA	65	Reliable	39	60%	1.00000	No	47%	72%
			Not Reliable	26	40%	1.00000	No	28%	53%
	PFHxS	83	Reliable	71	86%	0.52057	No	76%	92%
			Not Reliable	12	14%	0.93139	No	8%	24%
	Br-PFHxS	83	Reliable	79	95%	0.00334	No	88%	99%
			Not Reliable	4	5%	0.07300	No	1%	12%
	Total PFHxS	61	Reliable	58	95%	0.01319	Yes	86%	99%
			Not Reliable	3	5%	0.12896	No	1%	14%
	PFNA	53	Reliable	44	83%	0.73403	No	70%	92%
			Not Reliable	9	17%	0.96452	No	8%	30%
	PFPeA	72	Reliable	38	53%	1.00000	No	41%	65%
			Not Reliable	34	47%	1.00000	No	35%	59%
	PFPeS	35	Reliable	35	100%	0.00339	Yes	90%	100%
			Not Reliable	0	0%	0.02503	Yes	0%	10%

Notes:

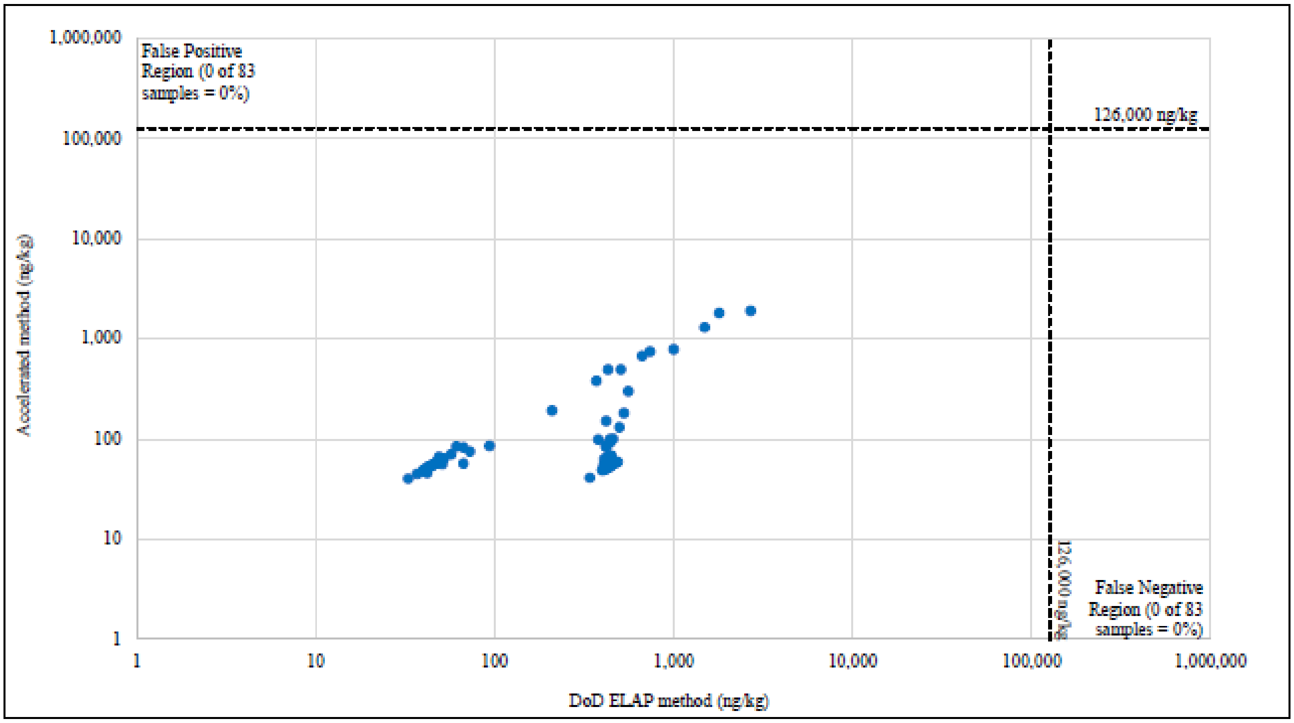
1. Reliability for groundwater determined using a decision value of 40 nanograms per liter (ng/L).
2. Reliability for soil determined using a decision value of 100 nanograms per kilogram (ng/kg). Indeterminate pairs with elevated DoD ELAP method detection limits were excluded.

Figure 7-3. Primary PFAS Compounds –Reliability Plots

PFOA - Groundwater - Reliability based on Action / No Action using decision value of 40 ng/L



PFOA - Soil- Reliability based on Action / No Action using decision value of 126,000 ng/kg



Legend

▲ Reliable - Both Action

● Reliable - Both No Action

---- Decision Value Line

◆ Not Reliable - DoD ELAP method No Action and Accelerated method Action (False Positive Case 1)

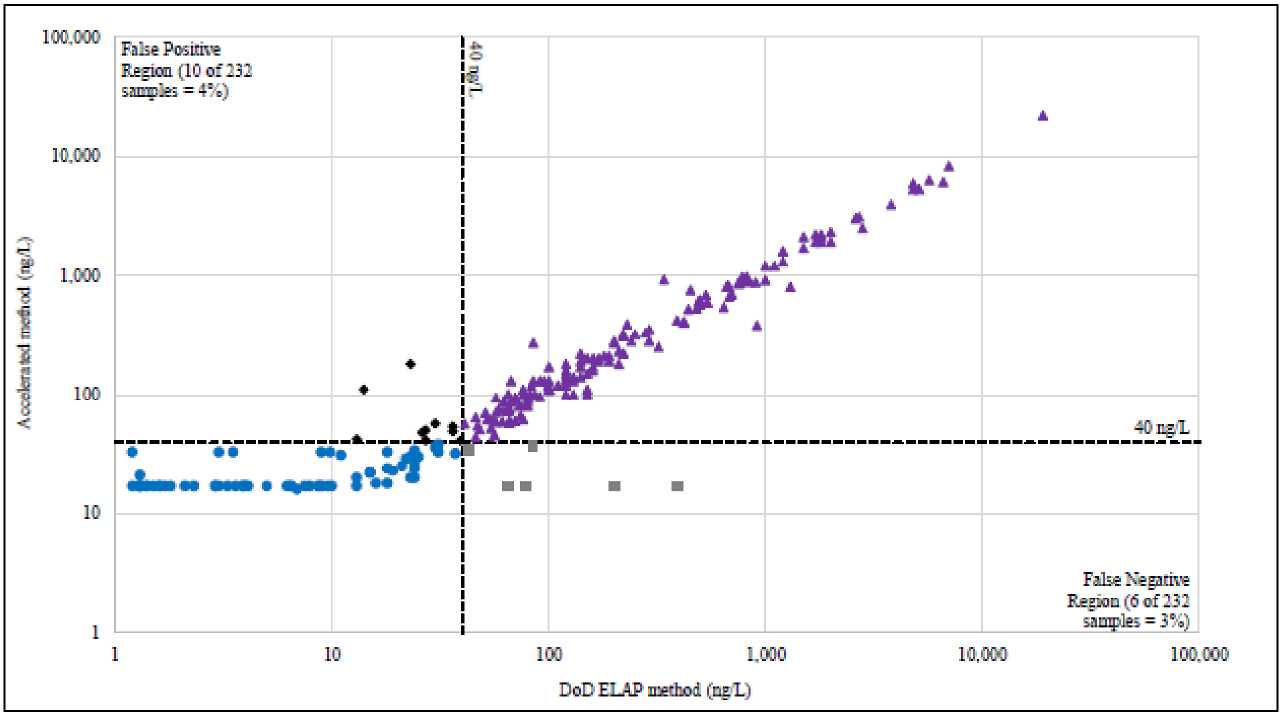
Abbreviations

ng/L = nanograms per liter

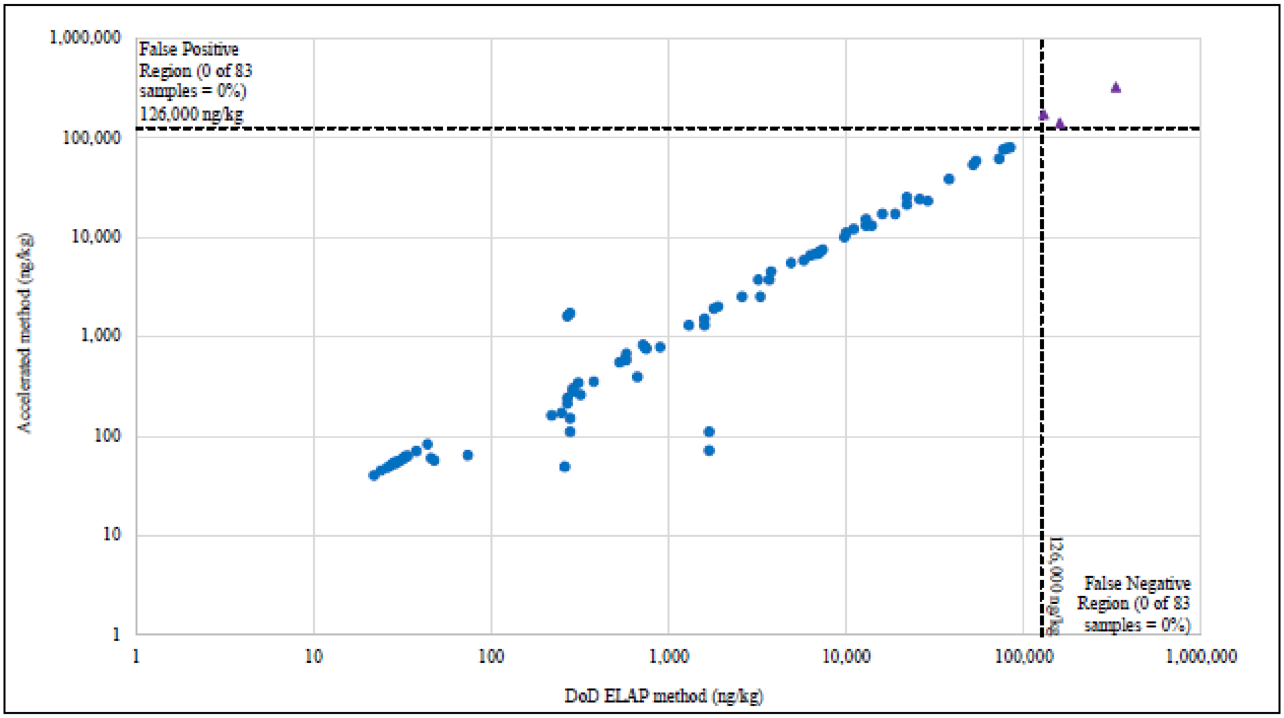
ng/kg = nanograms per kilogram

Figure 7-3A. Primary PFAS Compound - PFOA - Reliability Plots

PFOS - Groundwater - Reliability based on Action / No Action using decision value of 40 ng/L



PFOS - Soil- Reliability based on Action / No Action using decision value of 126,000 ng/kg



Legend

▲ Reliable - Both Action

● Reliable - Both No Action

---- Decision Value Line

◆ Not Reliable - DoD ELAP method No Action and Accelerated method Action (False Positive Case 1)

■ Not Reliable - DoD ELAP method Action and Accelerated method No Action (False Negative)

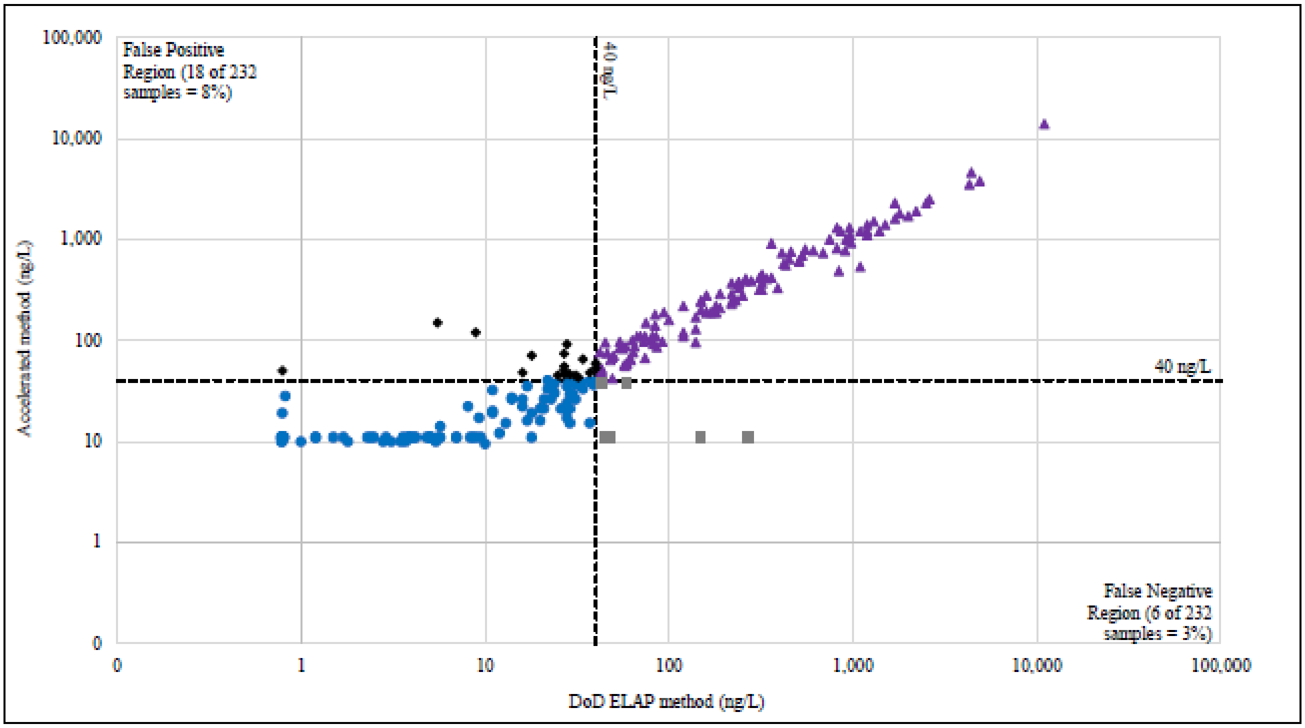
Abbreviations

ng/L = nanograms per liter

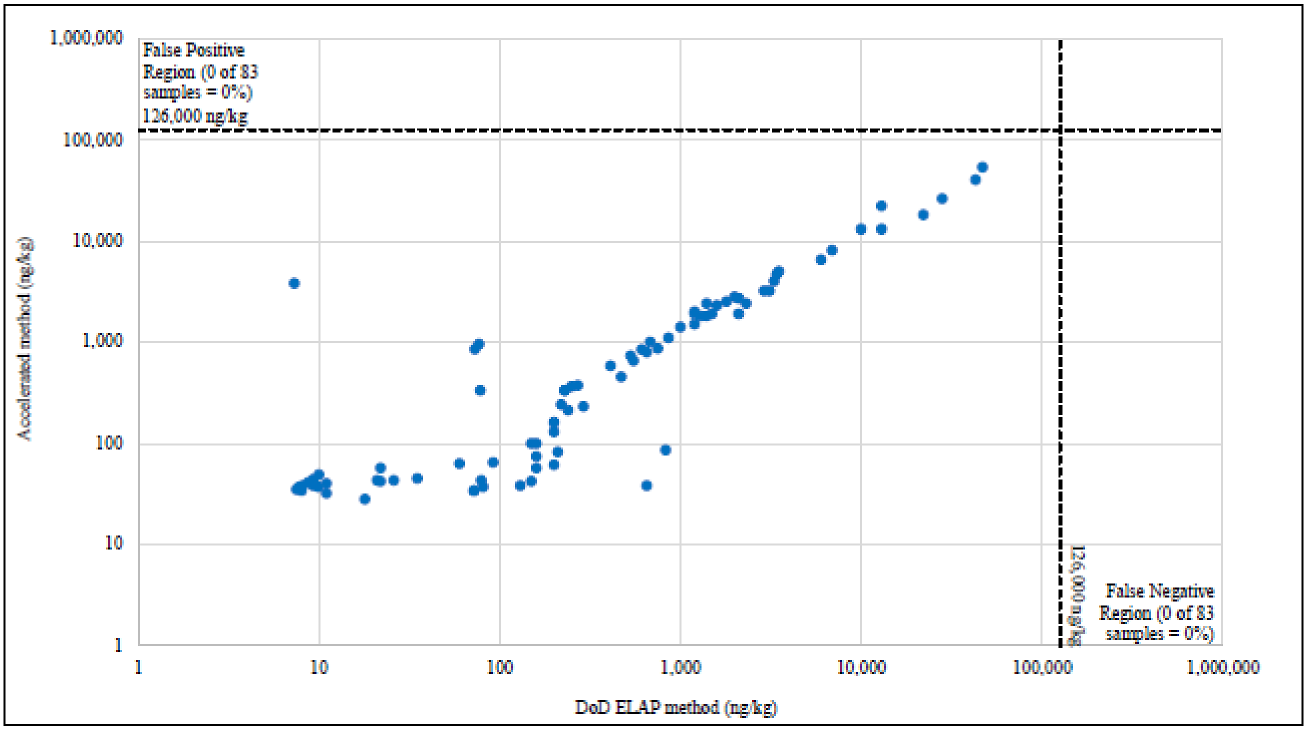
ng/kg = nanograms per kilogram

Figure 7-3B. Primary PFAS Compound - PFOS - Reliability Plots

T-PFOS - Groundwater - Reliability based on Action / No Action using decision value of 40 ng/L



T-PFOS - Soil- Reliability based on Action / No Action using decision value of 126,000 ng/kg



Legend

▲ Reliable - Both Action

● Reliable - Both No Action

---- Decision Value Line

◆ Not Reliable - DoD ELAP method No Action and Accelerated method Action (False Positive Case 1)

■ Not Reliable - DoD ELAP method Action and Accelerated method No Action (False Negative)

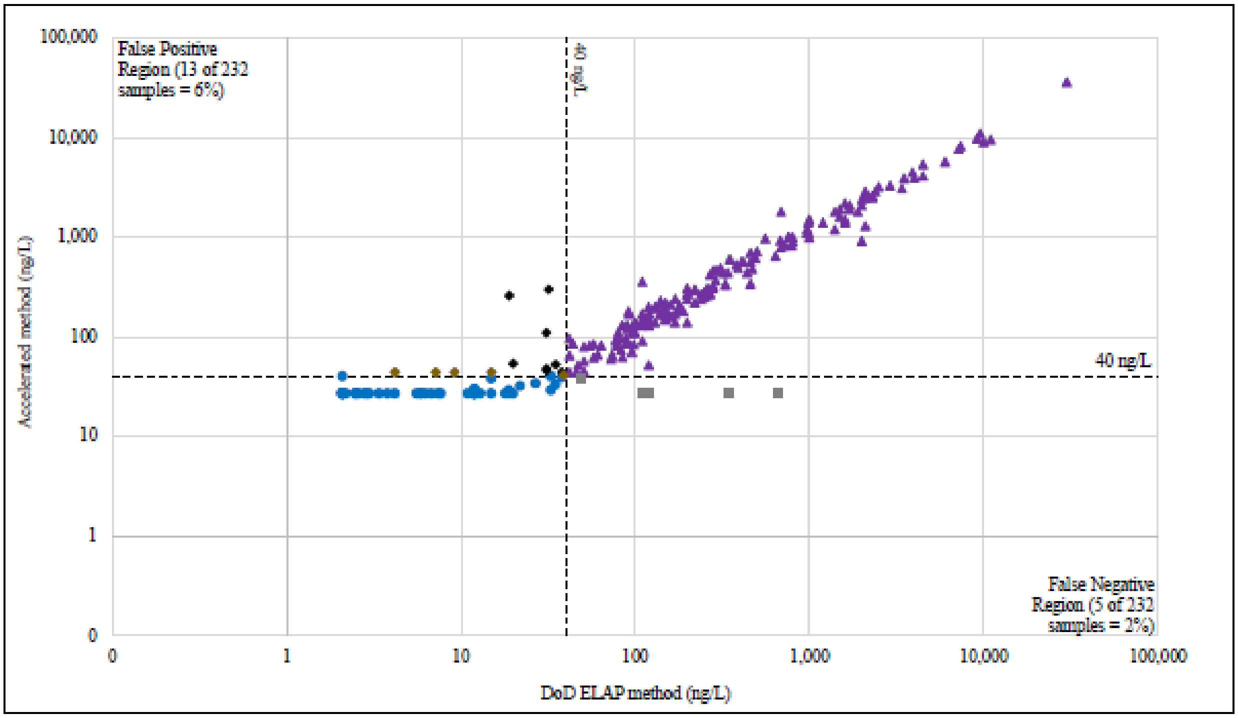
Abbreviations

ng/L = nanograms per liter

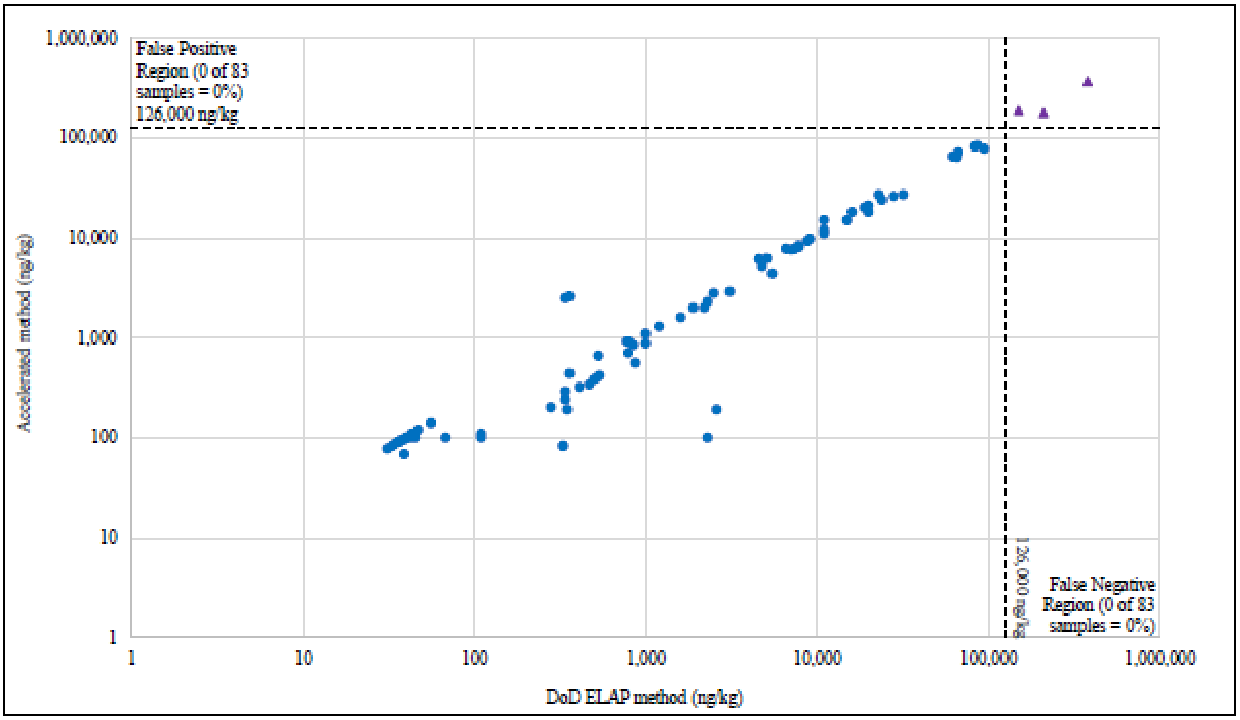
ng/kg = nanograms per kilogram

Figure 7-3C. Primary PFAS Compound - T-PFOS - Reliability Plots

Total PFOS - Groundwater - Reliability based on Action / No Action using decision value of 40 ng/L



Total PFOS - Soil- Reliability based on Action / No Action using decision value of 126,000 ng/kg



Legend

- ▲ Reliable - Both Action
- ● Reliable - Both No Action
- —— Decision Value Line
- ◆ Not Reliable - DoD ELAP method No Action and Accelerated method Action (False Positive Case 1)
- ◆ Not Reliable - DoD ELAP method No Action and Accelerated method Action (Step-out) (False Positive Case 2)
- ■ Not Reliable - DoD ELAP method Action and Accelerated method No Action (False Negative)

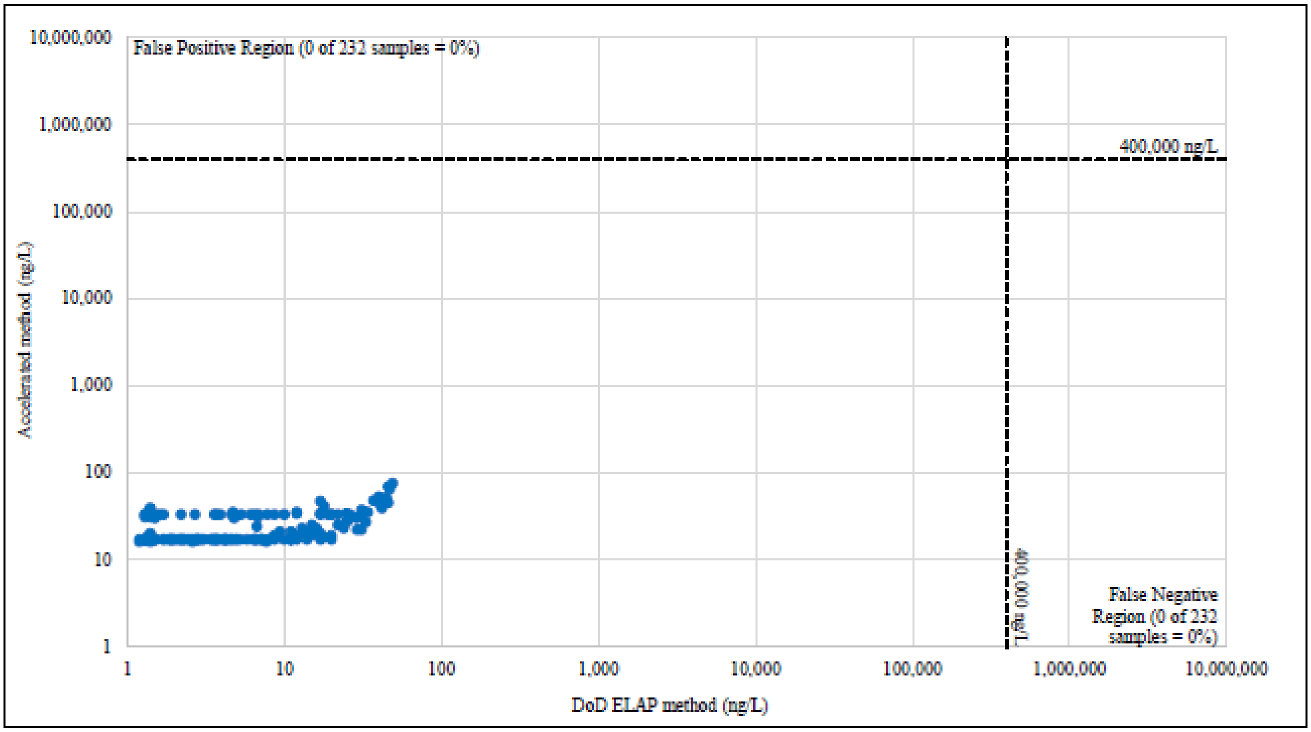
Abbreviations

ng/L = nanograms per liter

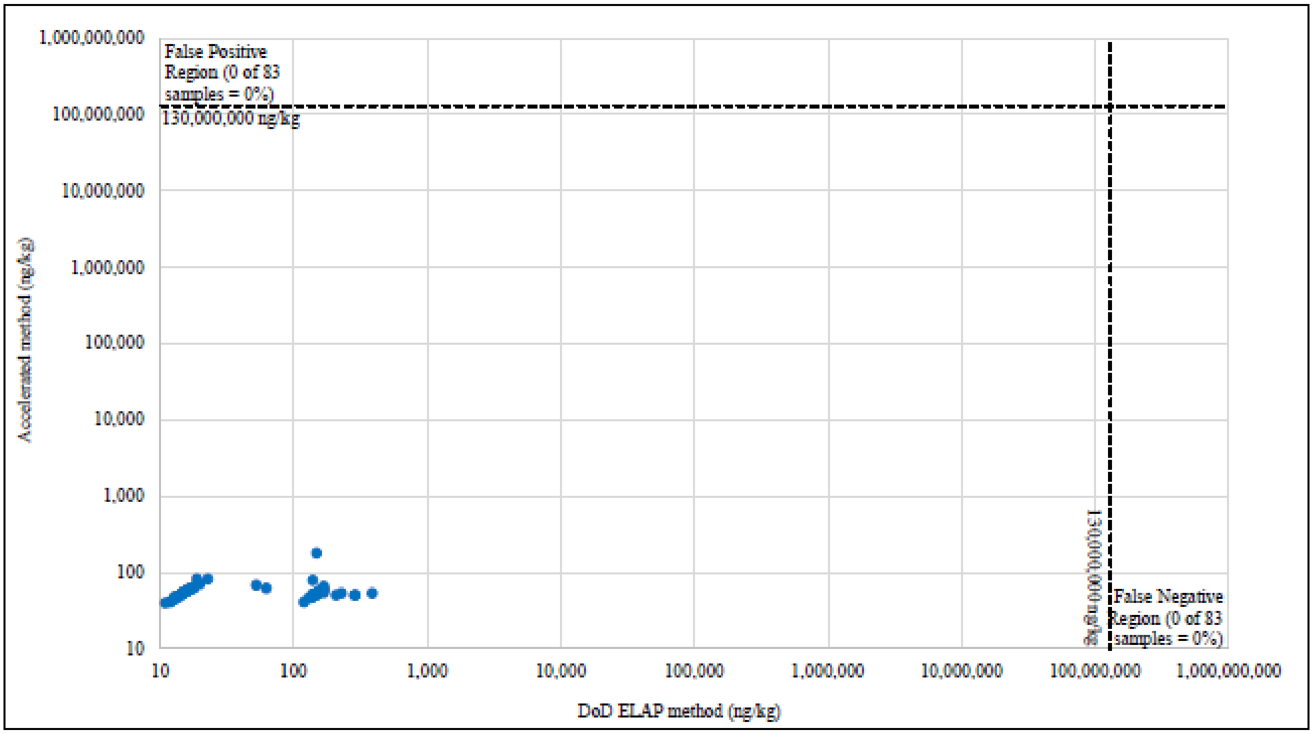
ng/kg = nanograms per kilogram

Figure 7-3D. Primary PFAS Compound - Total PFOS - Reliability Plots

PFBS - Groundwater - Reliability based on Action / No Action using decision value of 400,000 ng/L



PFBS - Soil- Reliability based on Action / No Action using decision value of 130,000,000 ng/kg



Legend

● Reliable - Both No Action

----- Decision Value Line

Abbreviations

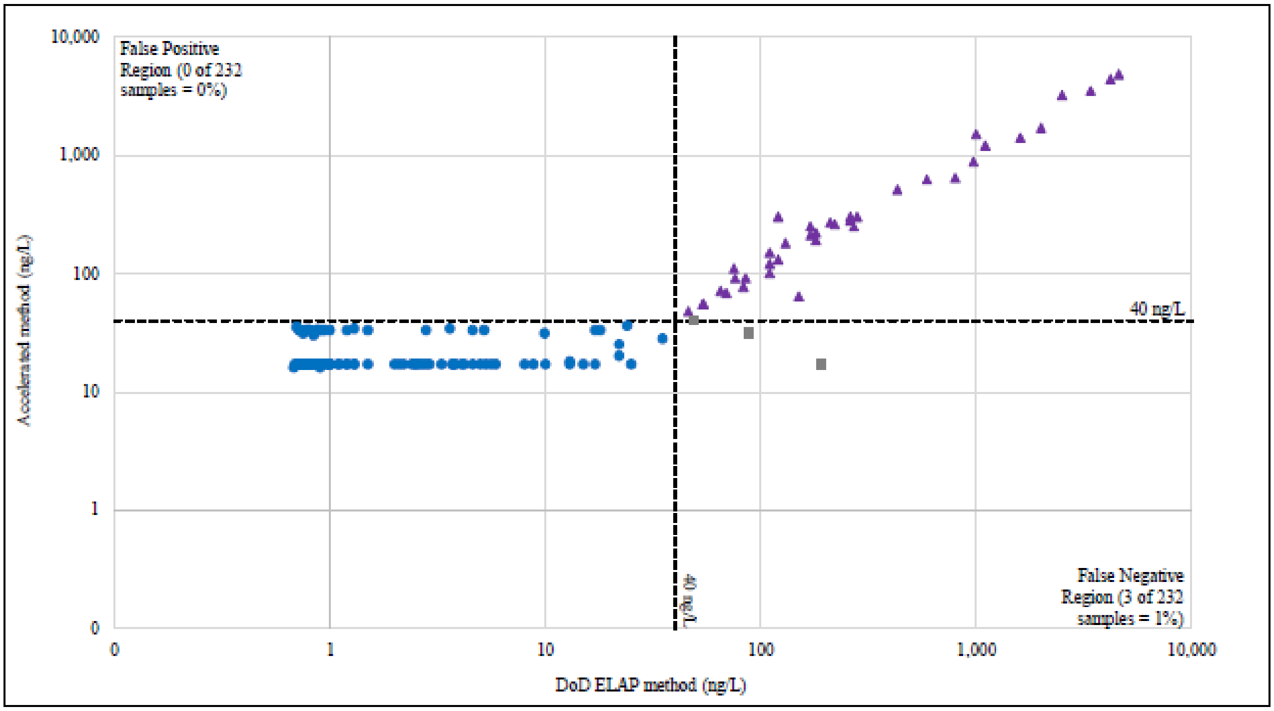
ng/L = nanograms per liter

ng/kg = nanograms per kilogram

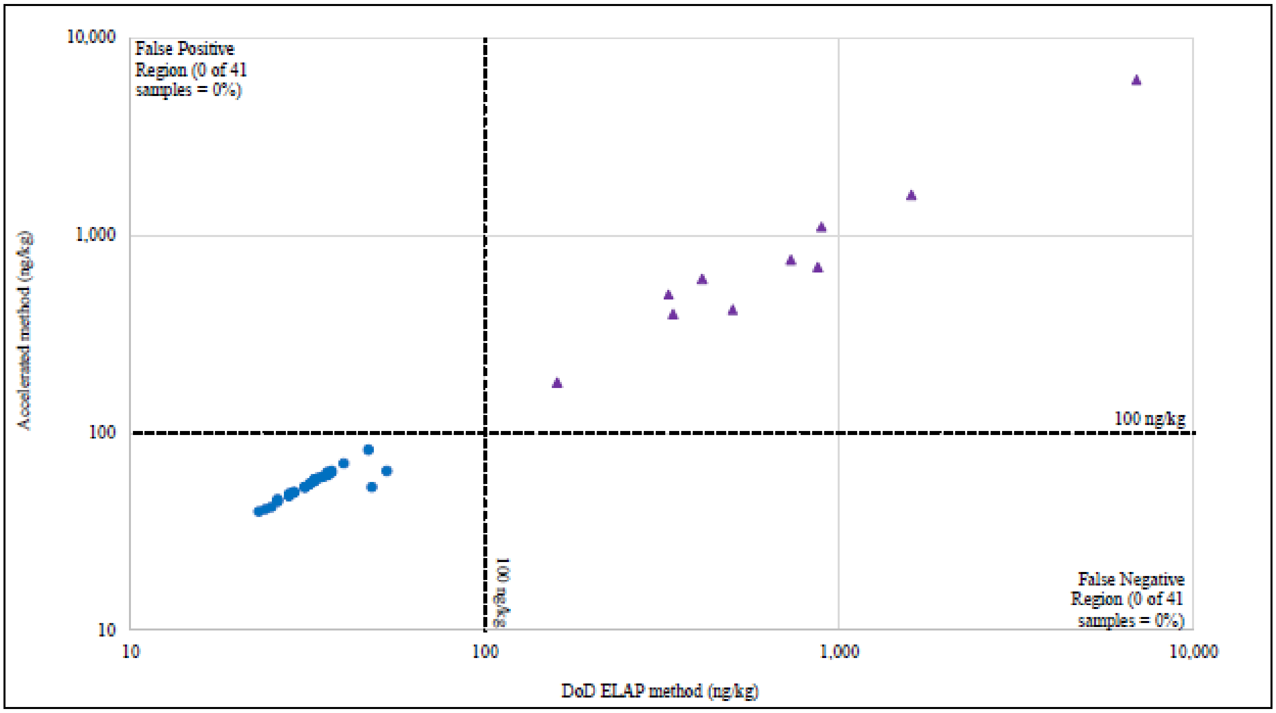
Figure 7-3E. Primary PFAS Compound - PFBS - Reliability Plots

Figure 7-4. Secondary PFAS Compounds – Reliability Plots

6-2FTS - Groundwater - Reliability based on Action / No Action using decision value of 40 ng/L



6-2FTS - Soil- Reliability based on Action / No Action using decision value of 100 ng/kg



Legend

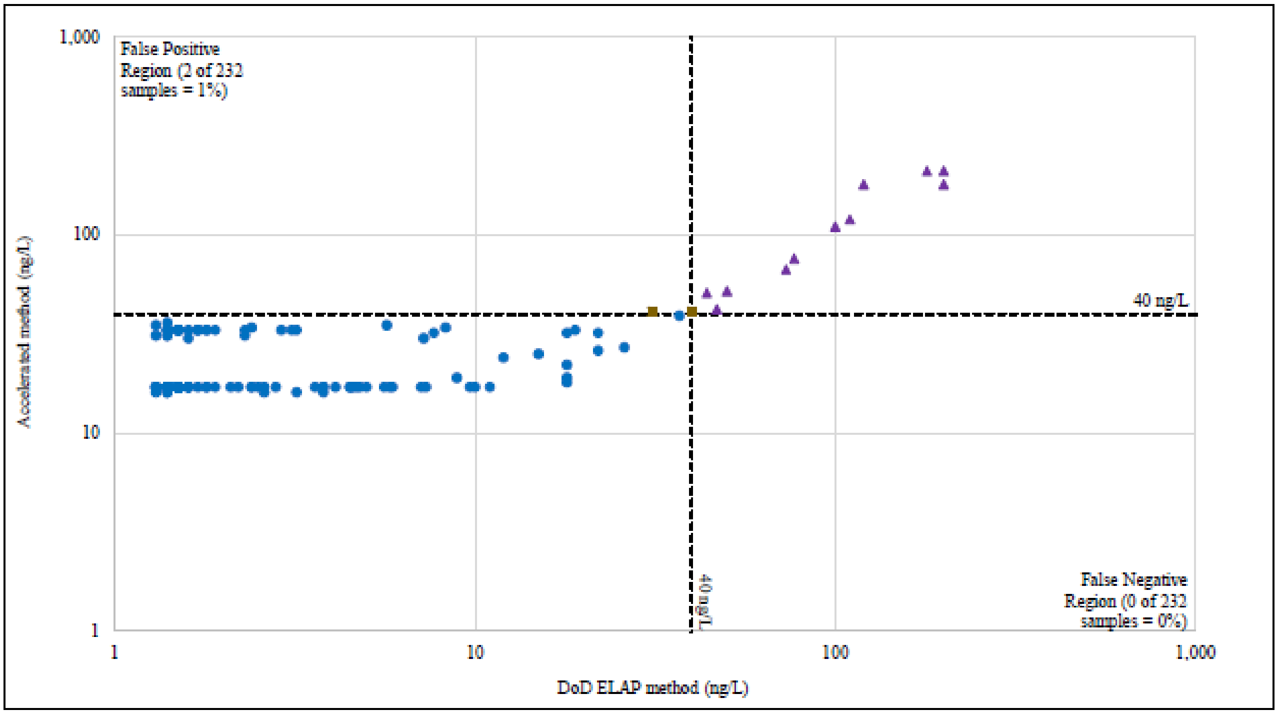
▲ Reliable - Both Action
● Reliable - Both No Action
---- Decision Value Line
■ Not Reliable - DoD ELAP method Action and Accelerated method No Action (False Negative)

Abbreviations

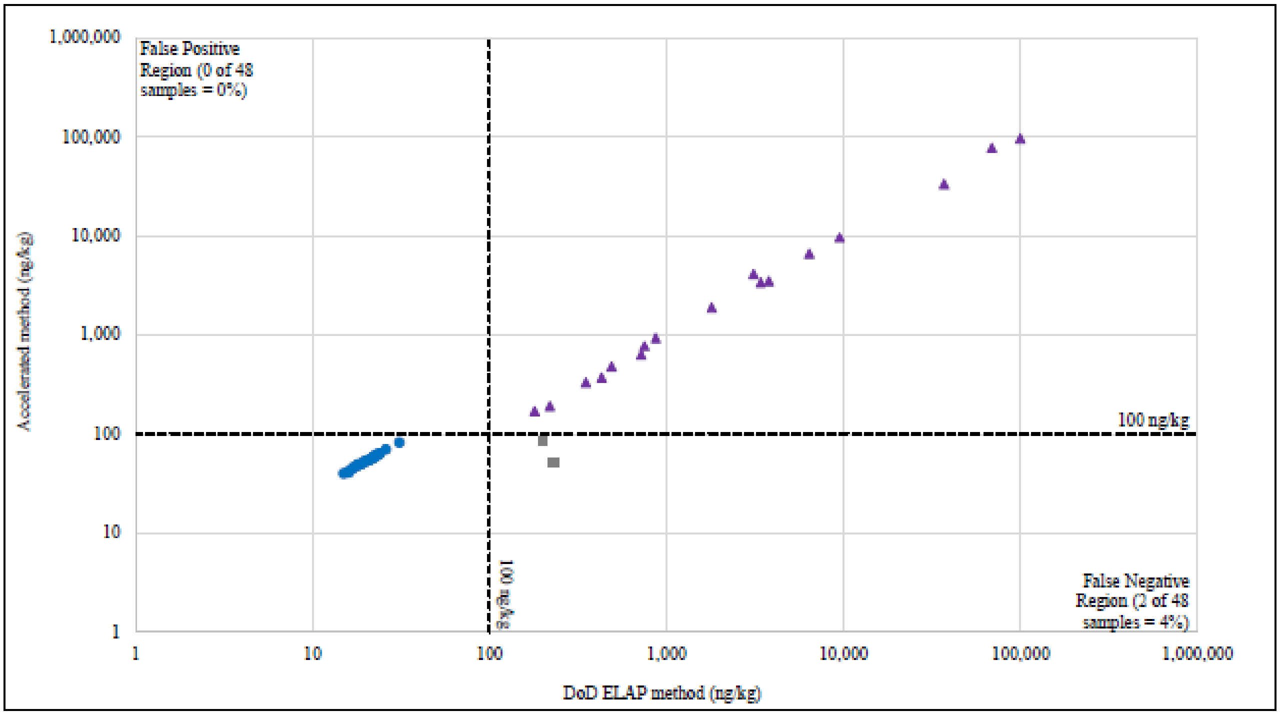
ng/L = nanograms per liter
ng/kg = nanograms per kilogram

Figure 7.4A. Secondary PFAS Compounds - 6-2FTS - Reliability Plots

8-2FTS - Groundwater - Reliability based on Action / No Action using decision value of 40 ng/L



8-2FTS - Soil- Reliability based on Action / No Action using decision value of 100 ng/kg



Legend

▲ Reliable - Both Action ● Reliable - Both No Action ---- Decision Value Line

◆ Not Reliable - DoD ELAP method No Action and Accelerated method Action (Step-out) (False Positive Case 2)

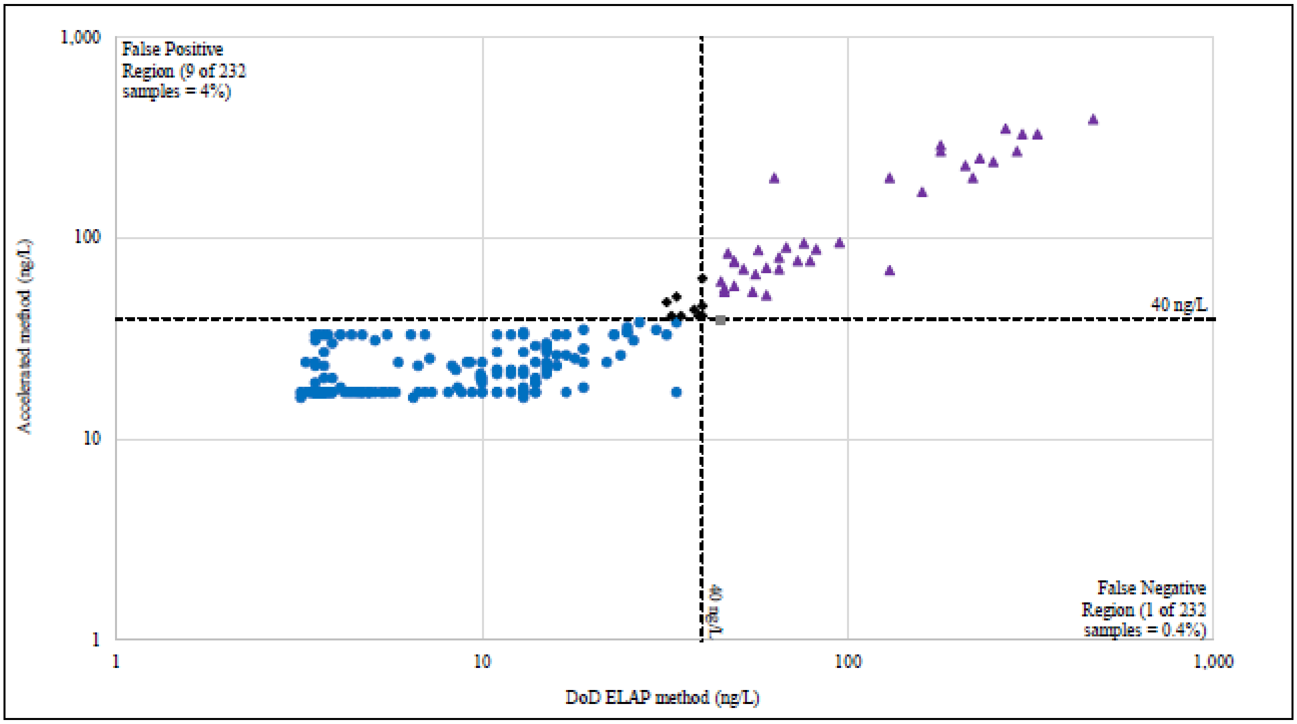
■ Not Reliable - DoD ELAP method Action and Accelerated method No Action (False Negative)

Abbreviations

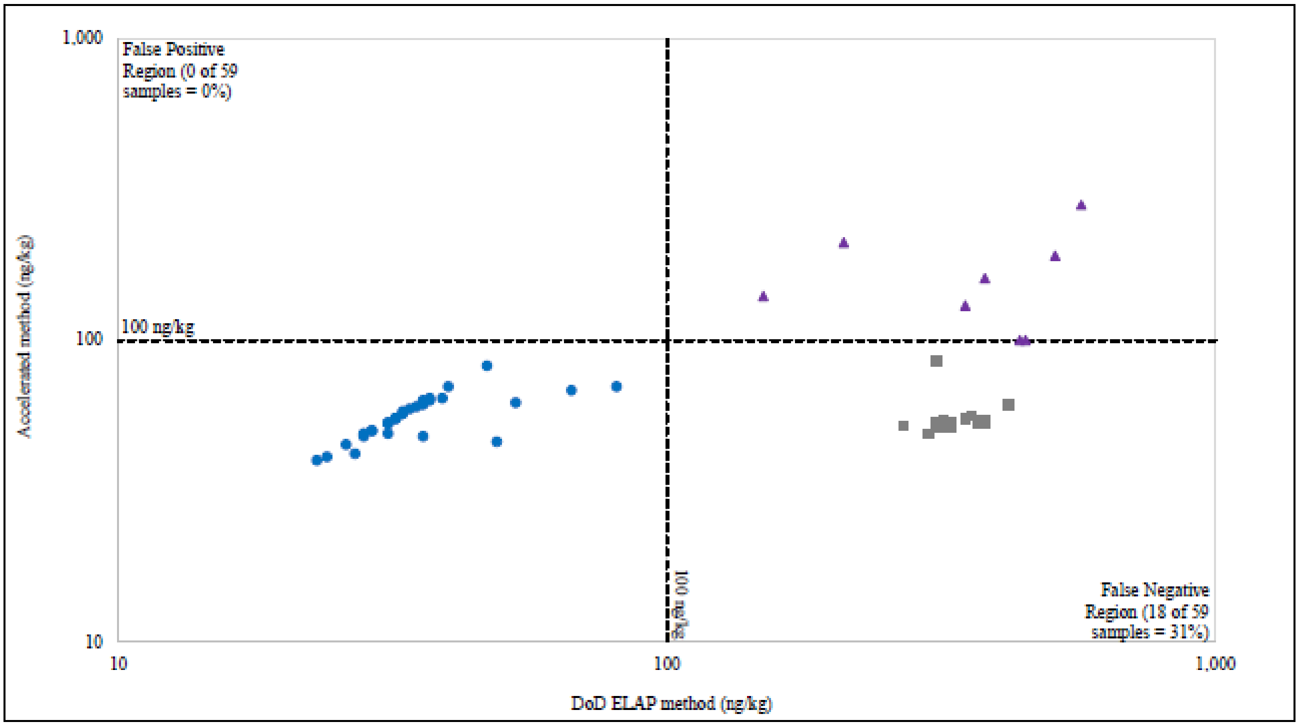
ng/L = nanograms per liter ng/kg = nanograms per kilogram

Figure 7-4B. Secondary PFAS Compounds - 8-2FTS - Reliability Plots

PFHpA - Groundwater - Reliability based on Action / No Action using decision value of 40 ng/L



PFHpA - Soil- Reliability based on Action / No Action using decision value of 100 ng/kg



Legend

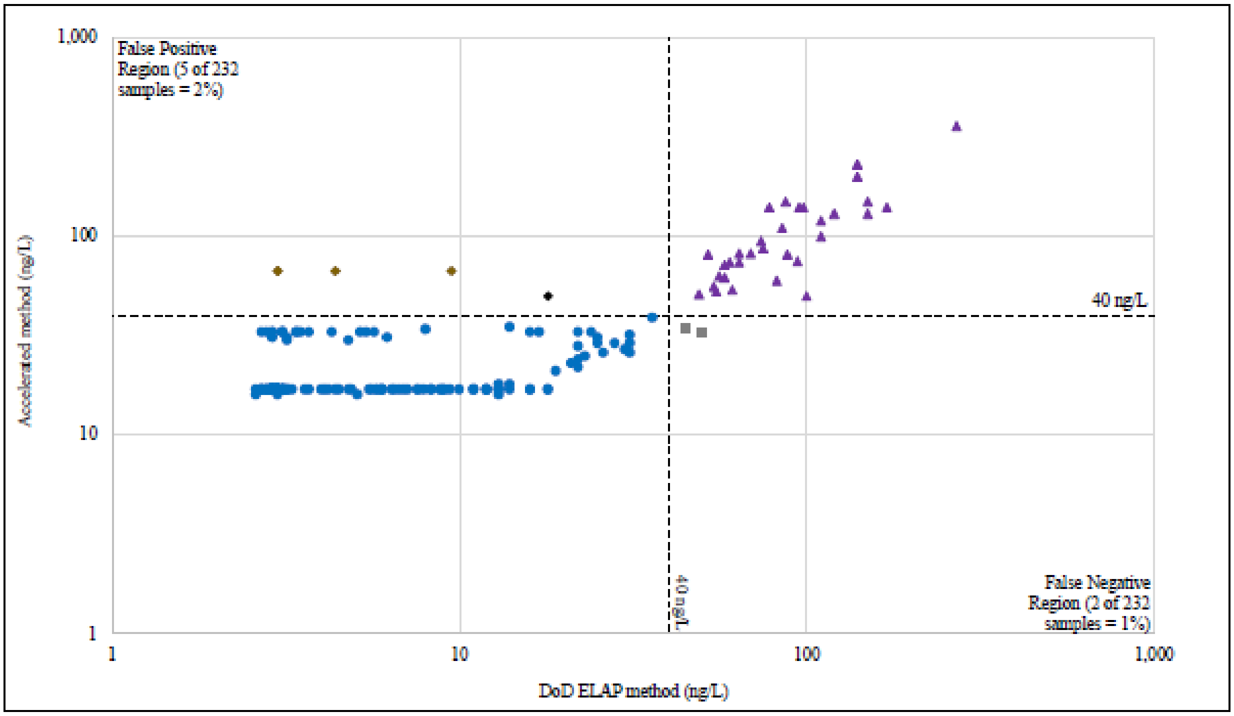
▲ Reliable - Both Action
● Reliable - Both No Action
---- Decision Value Line
◆ Not Reliable - DoD ELAP method No Action and Accelerated method Action (False Positive Case 1)
■ Not Reliable - DoD ELAP method Action and Accelerated method No Action (False Negative)

Abbreviations

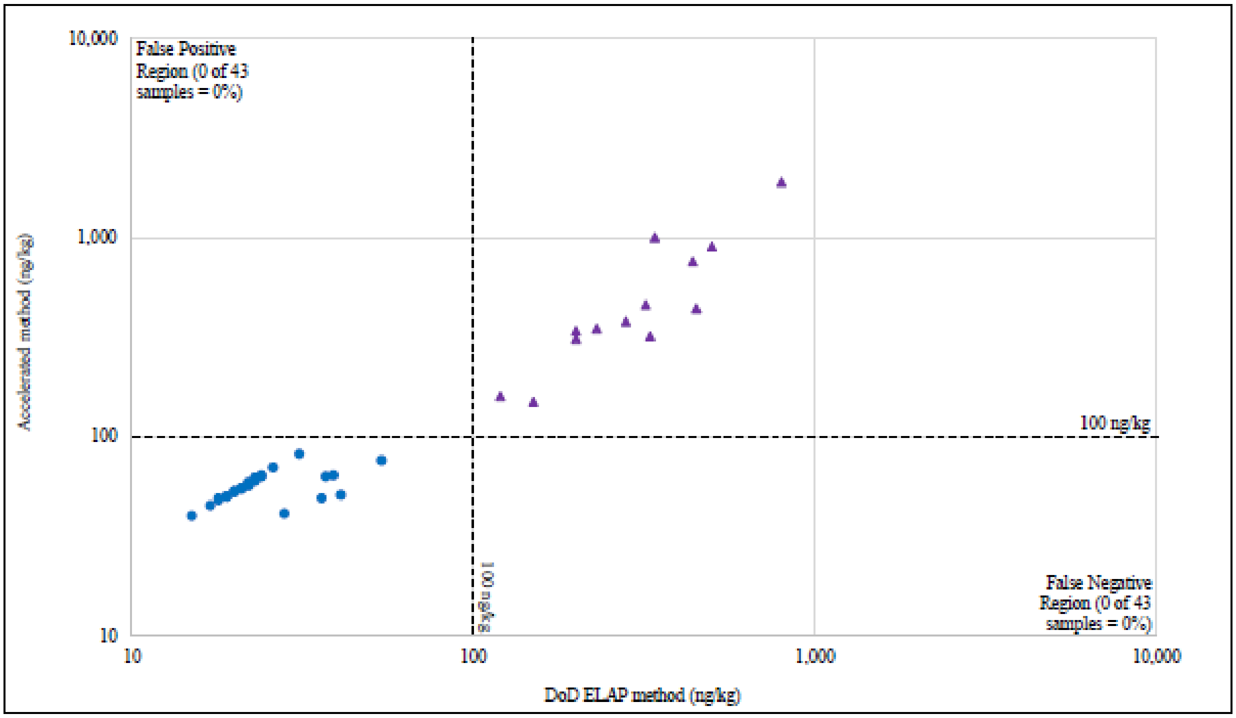
ng/L = nanograms per liter
ng/kg = nanograms per kilogram

Figure 7-4C. Secondary PFAS Compounds - PFHpA - Reliability Plots

PFHpS - Groundwater - Reliability based on Action / No Action using decision value of 40 ng/L



PFHpS - Soil- Reliability based on Action / No Action using decision value of 100 ng/kg



Legend

- ▲ Reliable - Both Action
- ● Reliable - Both No Action
- ---- Decision Value Line
- ◆ Not Reliable - DoD ELAP method No Action and Accelerated method Action (False Positive Case 1)
- ◆ Not Reliable - DoD ELAP method No Action and Accelerated method Action (Step-out) (False Positive Case 2)
- ■ Not Reliable - DoD ELAP method Action and Accelerated method No Action (False Negative)

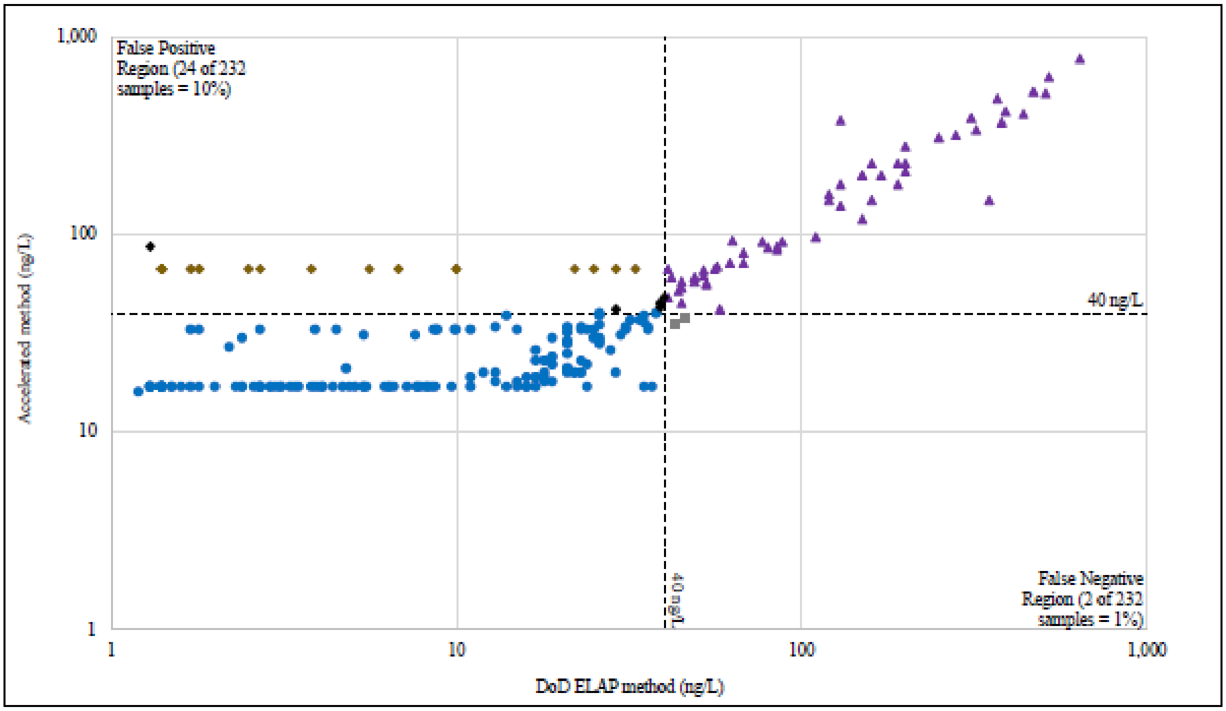
Abbreviations

ng/L = nanograms per liter

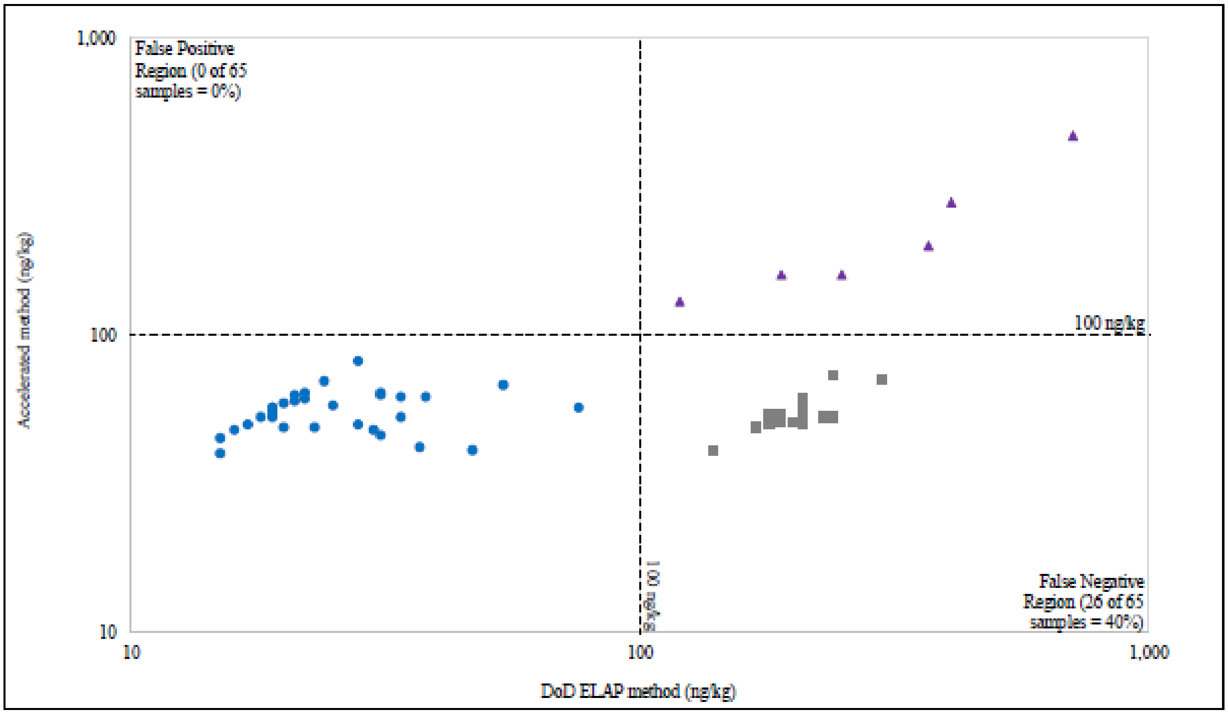
ng/kg = nanograms per kilogram

Figure 7-4D. Secondary PFAS Compounds - PFHpS - Reliability Plots

PFHxA - Groundwater - Reliability based on Action / No Action using decision value of 40 ng/L



PFHxA - Soil- Reliability based on Action / No Action using decision value of 100 ng/kg



Legend

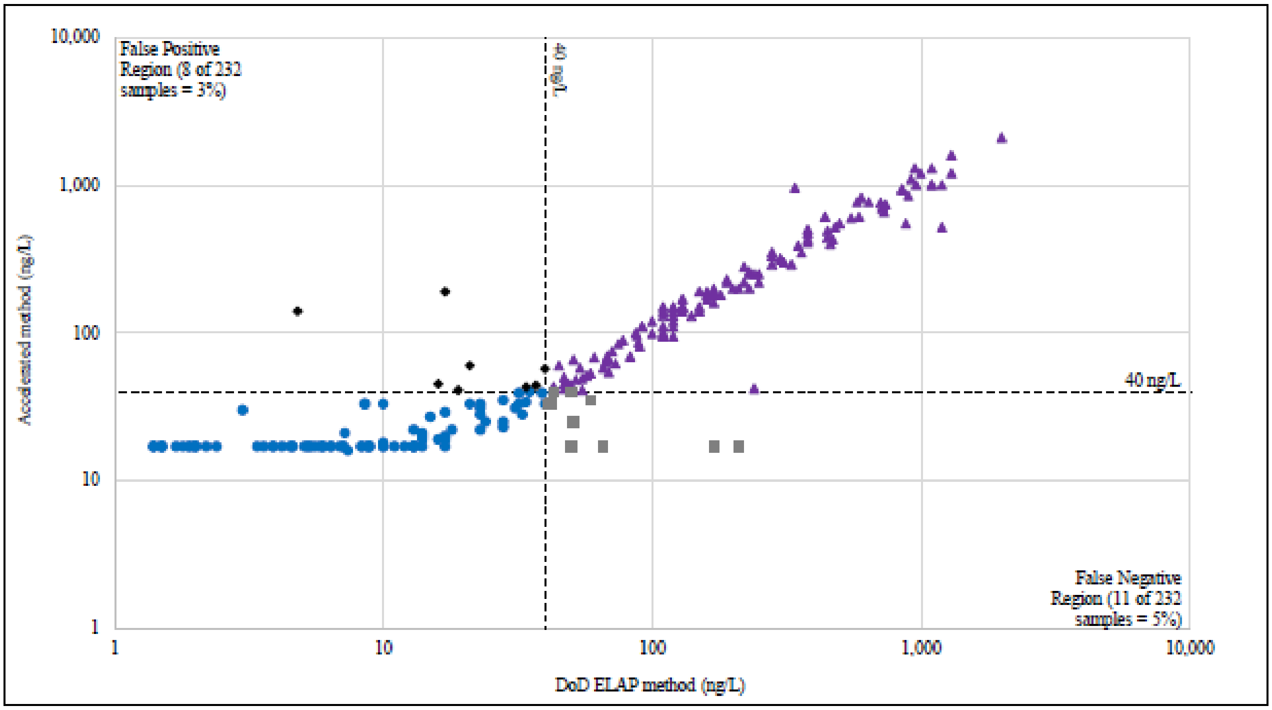
▲ Reliable - Both Action
● Reliable - Both No Action
—— Decision Value Line
◆ Not Reliable - DoD ELAP method No Action and Accelerated method Action (False Positive Case 1)
◆ Not Reliable - DoD ELAP method No Action and Accelerated method Action (Step-out) (False Positive Case 2)
■ Not Reliable - DoD ELAP method Action and Accelerated method No Action (False Negative)

Abbreviations

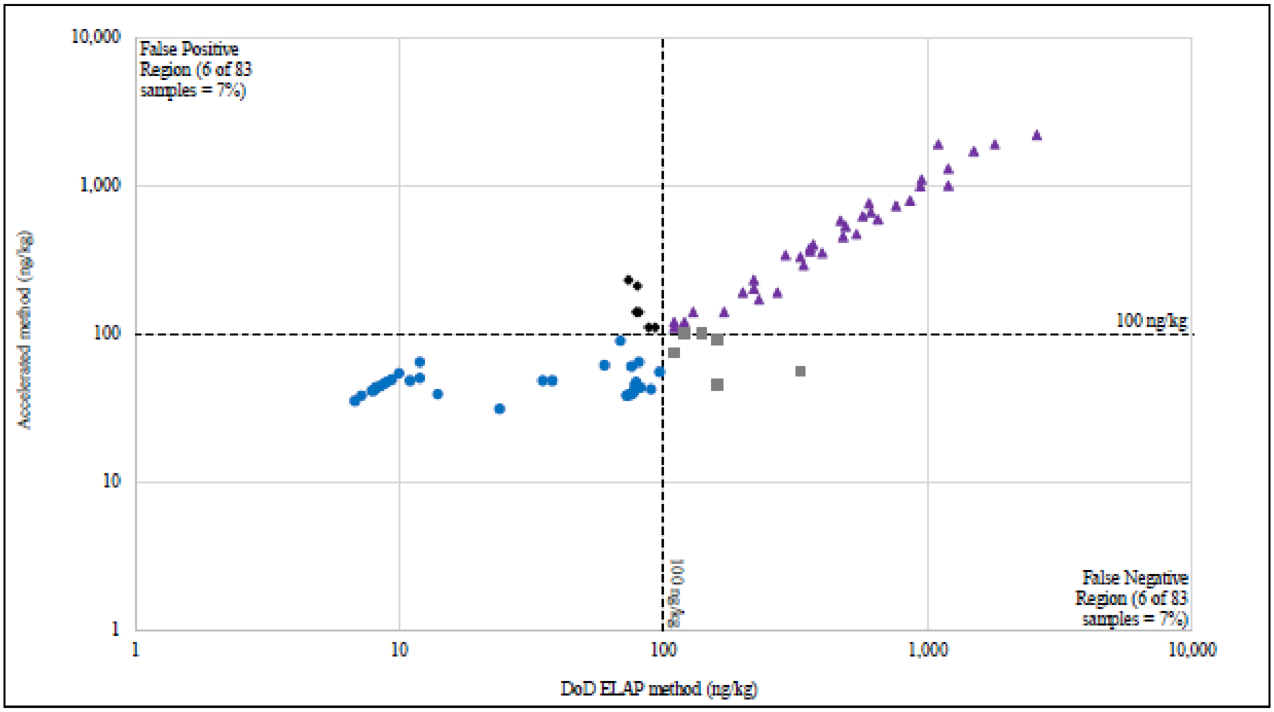
ng/L = nanograms per liter
ng/kg = nanograms per kilogram

Figure 7-4E. Secondary PFAS Compounds - PFHxA - Reliability Plots

PFHxS - Groundwater - Reliability based on Action / No Action using decision value of 40 ng/L



PFHxS - Soil- Reliability based on Action / No Action using decision value of 100 ng/kg



Legend

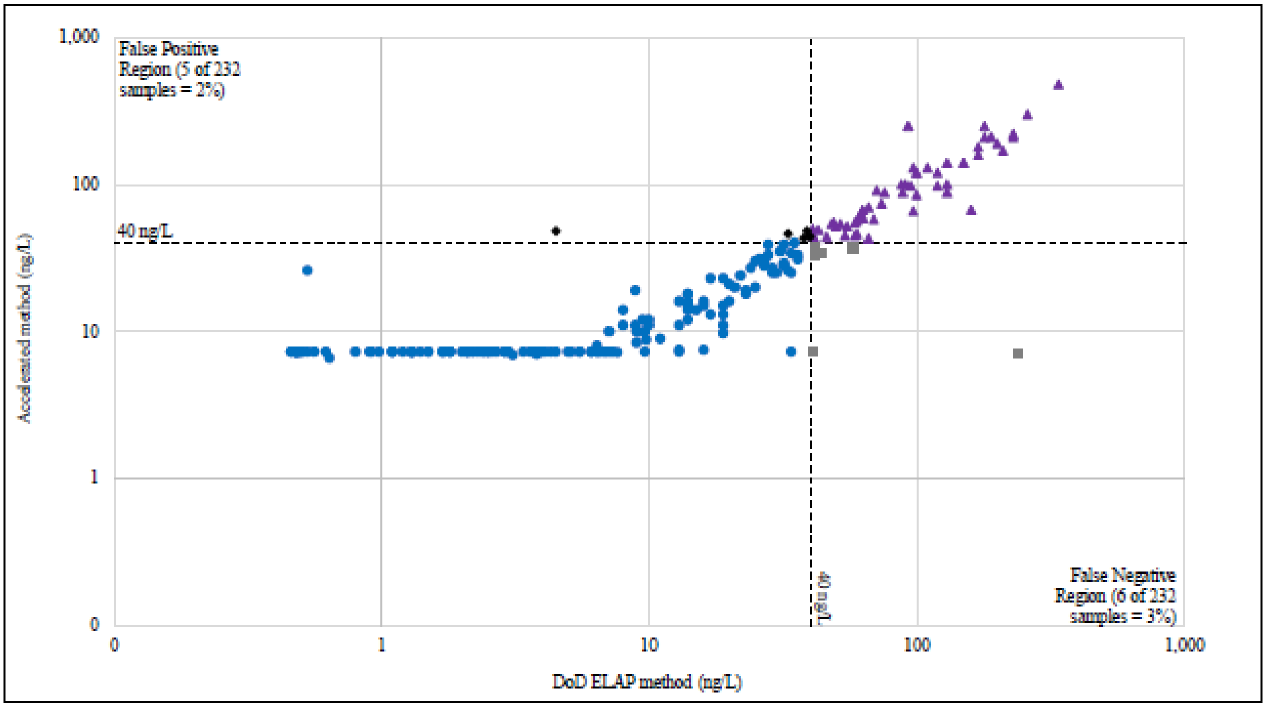
▲ Reliable - Both Action
● Reliable - Both No Action
---- Decision Value Line
◆ Not Reliable - DoD ELAP method No Action and Accelerated method Action (False Positive Case 1)
■ Not Reliable - DoD ELAP method Action and Accelerated method No Action (False Negative)

Abbreviations

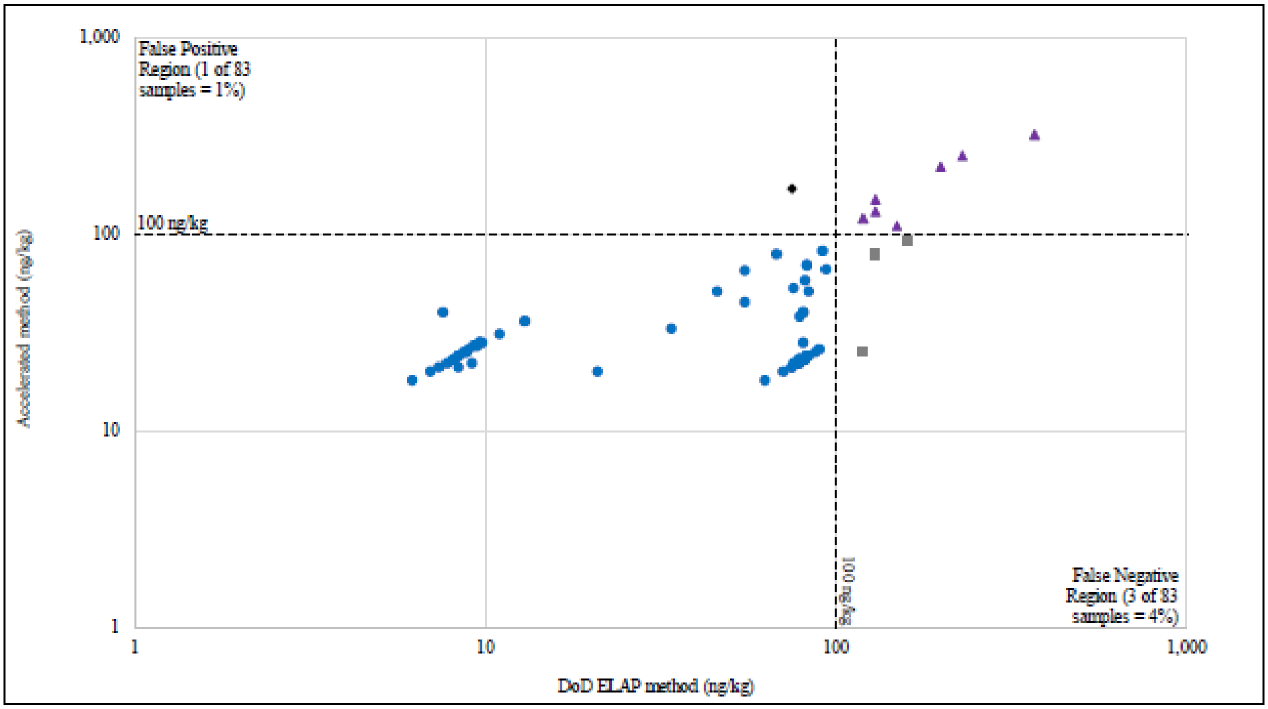
ng/L = nanograms per liter
ng/kg = nanograms per kilogram

Figure 7-4F. Secondary PFAS Compounds - PFHxS - Reliability Plots

Br-PFHxS - Groundwater - Reliability based on Action / No Action using decision value of 40 ng/L



Br-PFHxS - Soil- Reliability based on Action / No Action using decision value of 100 ng/kg



Legend

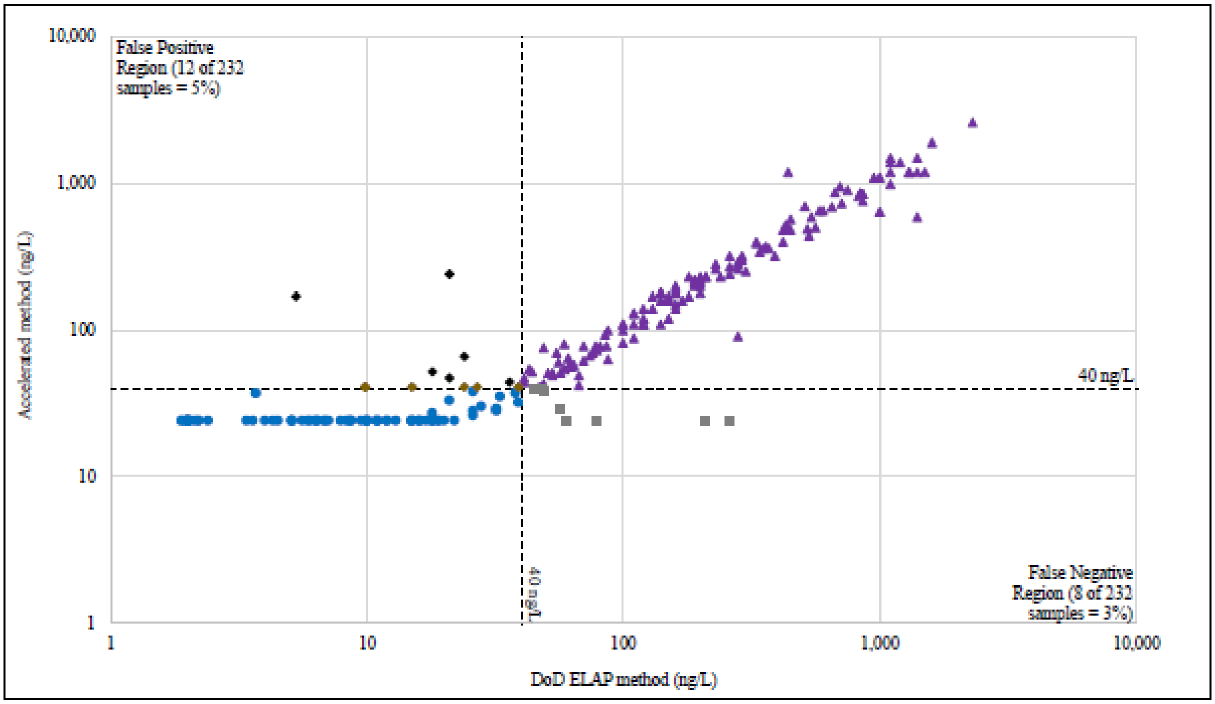
▲ Reliable - Both Action
● Reliable - Both No Action
--- Decision Value Line
◆ Not Reliable - DoD ELAP method No Action and Accelerated method Action (False Positive Case 1)
■ Not Reliable - DoD ELAP method Action and Accelerated method No Action (False Negative)

Abbreviations

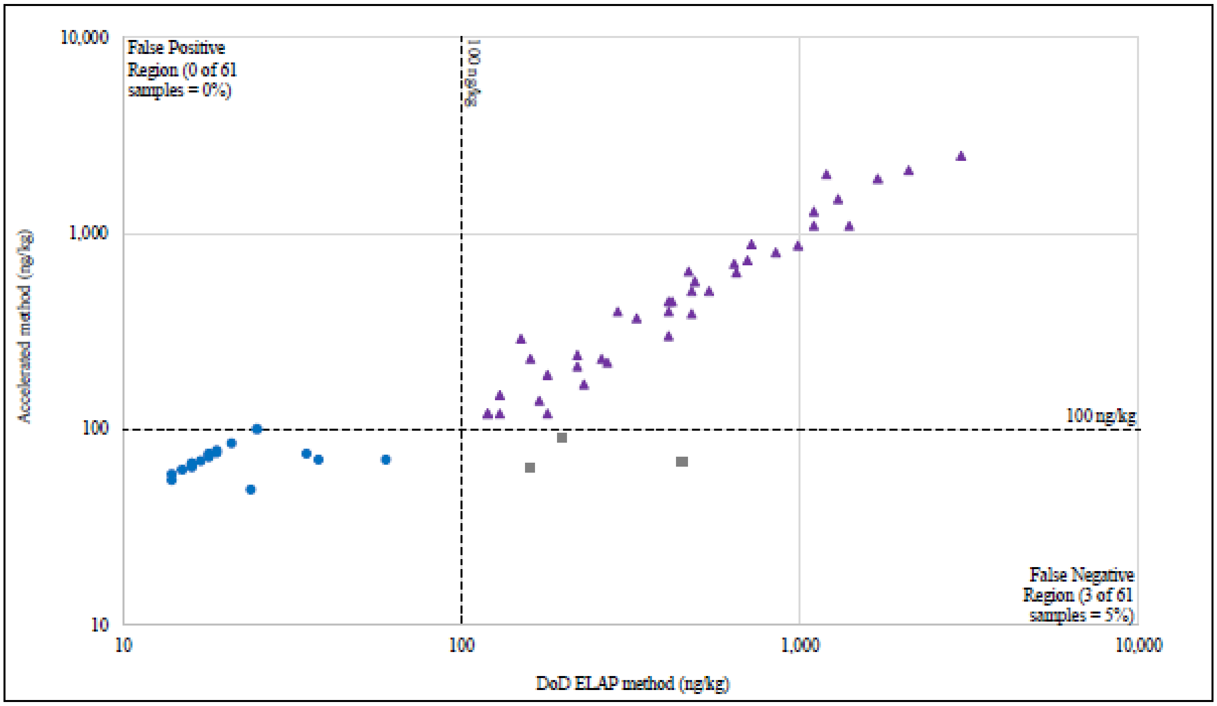
ng/L = nanograms per liter
ng/kg = nanograms per kilogram

Figure 7-4G. Secondary PFAS Compounds - Br-PFHxS - Reliability Plots

Total PFHxS - Groundwater - Reliability based on Action / No Action using decision value of 40 ng/L



Total PFHxS - Soil- Reliability based on Action / No Action using decision value of 100 ng/kg



Legend

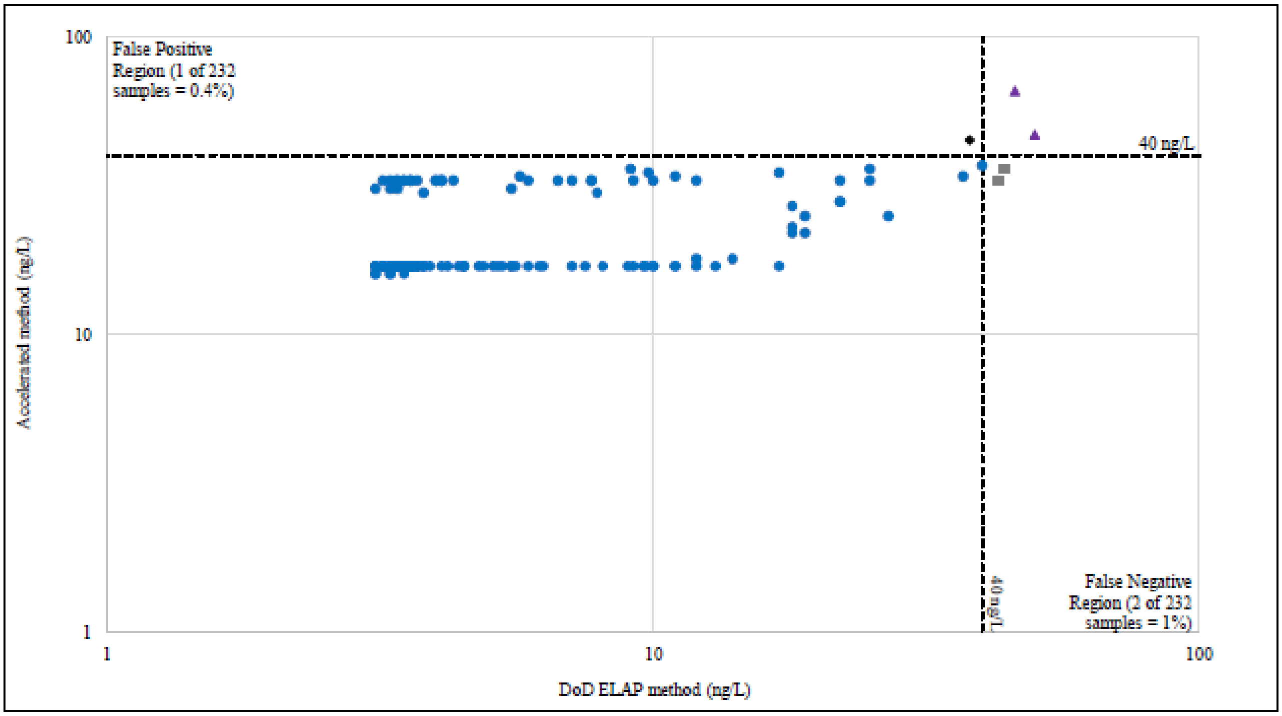
- ▲ Reliable - Both Action
- ● Reliable - Both No Action
- ---- Decision Value Line
- ◆ Not Reliable - DoD ELAP method No Action and Accelerated method Action (False Positive Case 1)
- ◆ Not Reliable - DoD ELAP method No Action and Accelerated method Action (Step-out) (False Positive Case 2)
- ■ Not Reliable - DoD ELAP method Action and Accelerated method No Action (False Negative)

Abbreviations

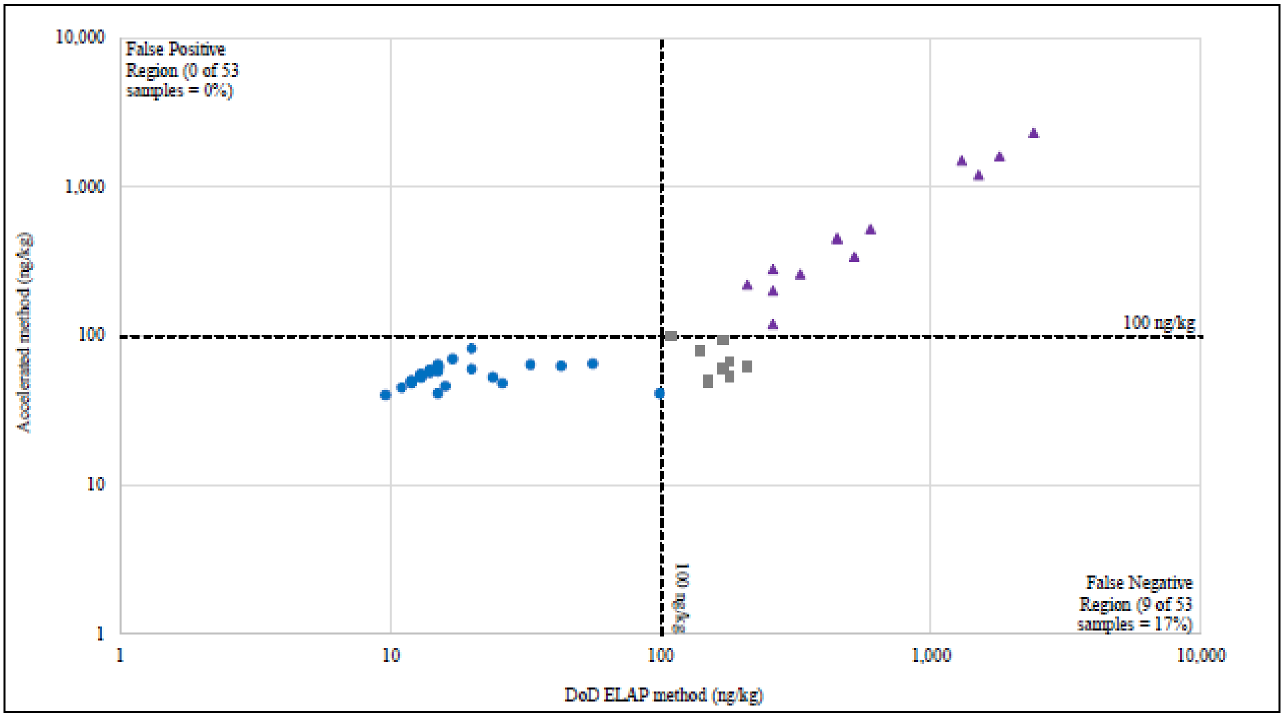
ng/L = nanograms per liter
ng/kg = nanograms per kilogram

Figure 7-4H. Secondary PFAS Compounds - Total PFHxS - Reliability Plots

PFNA - Groundwater - Reliability based on Action / No Action using decision value of 40 ng/L



PFNA - Soil- Reliability based on Action / No Action using decision value of 100 ng/kg



Legend

▲ Reliable - Both Action

● Reliable - Both No Action

---- Decision Value Line

◆ Not Reliable - DoD ELAP method No Action and Accelerated method Action (False Positive Case 1)

■ Not Reliable - DoD ELAP method Action and Accelerated method No Action (False Negative)

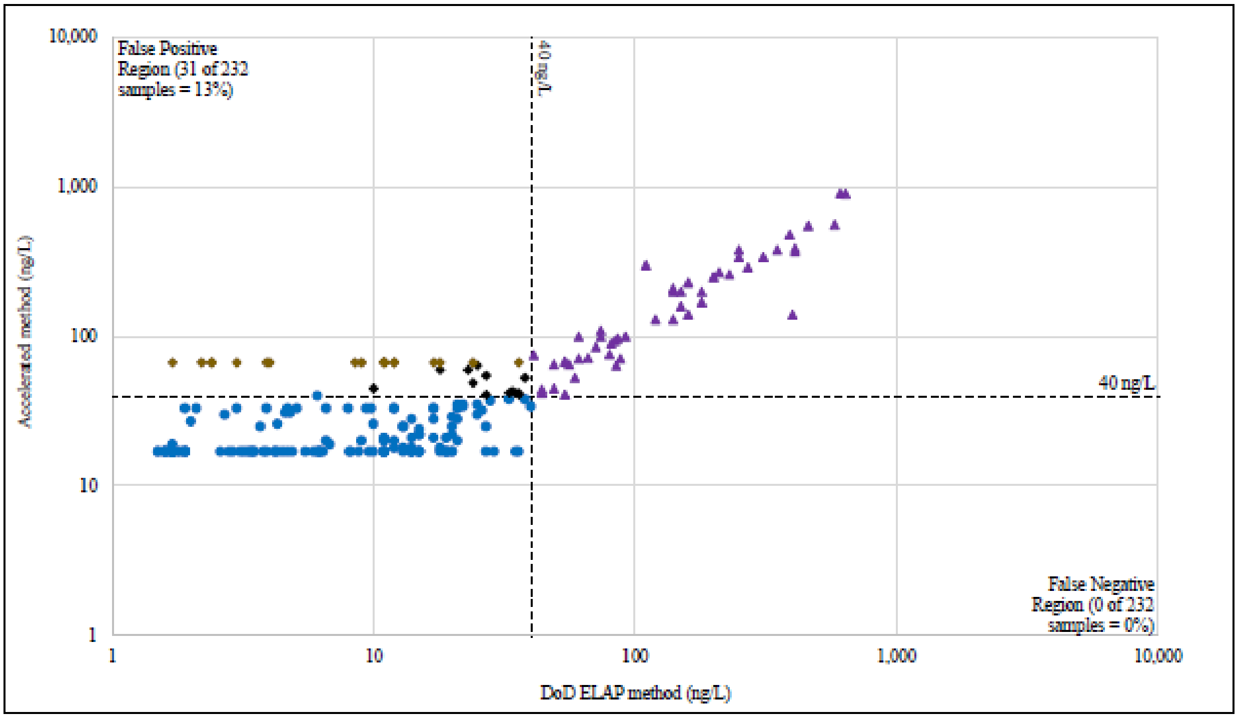
Abbreviations

ng/L = nanograms per liter

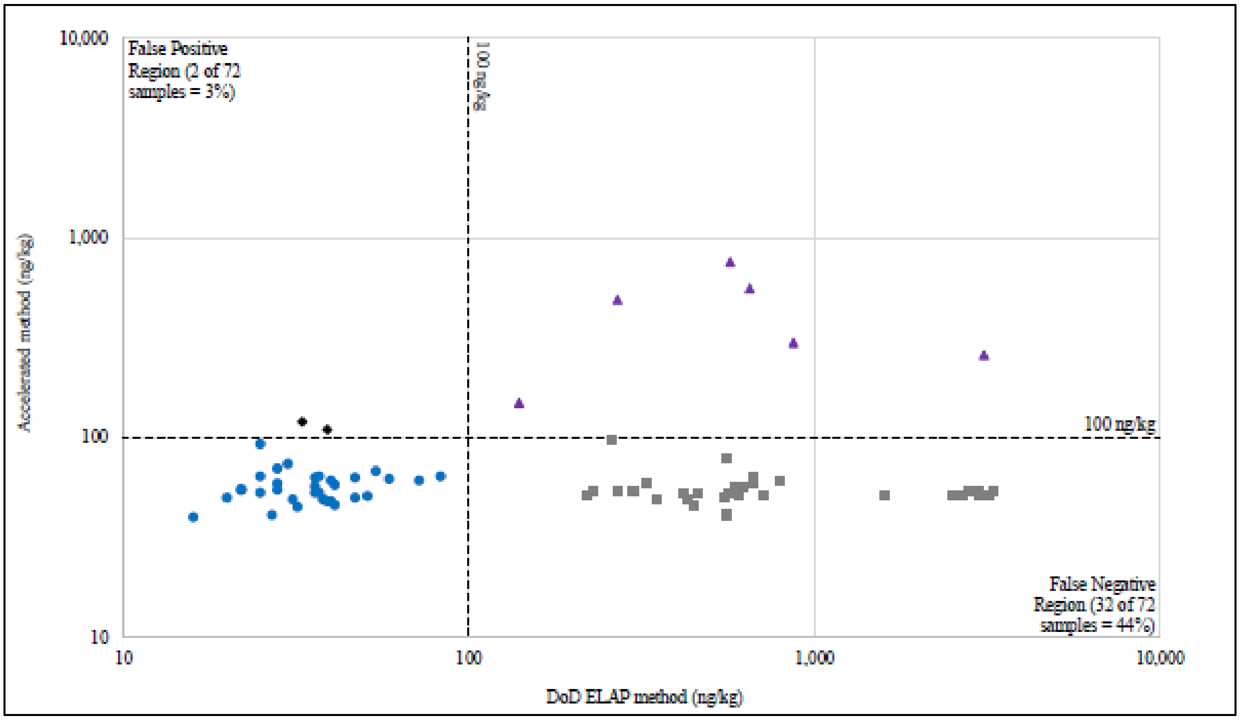
ng/kg = nanograms per kilogram

Figure 7-4I. Secondary PFAS Compounds - PFNA - Reliability Plots

PFPeA - Groundwater - Reliability based on Action / No Action using decision value of 40 ng/L



PFPeA - Soil- Reliability based on Action / No Action using decision value of 100 ng/kg



Legend

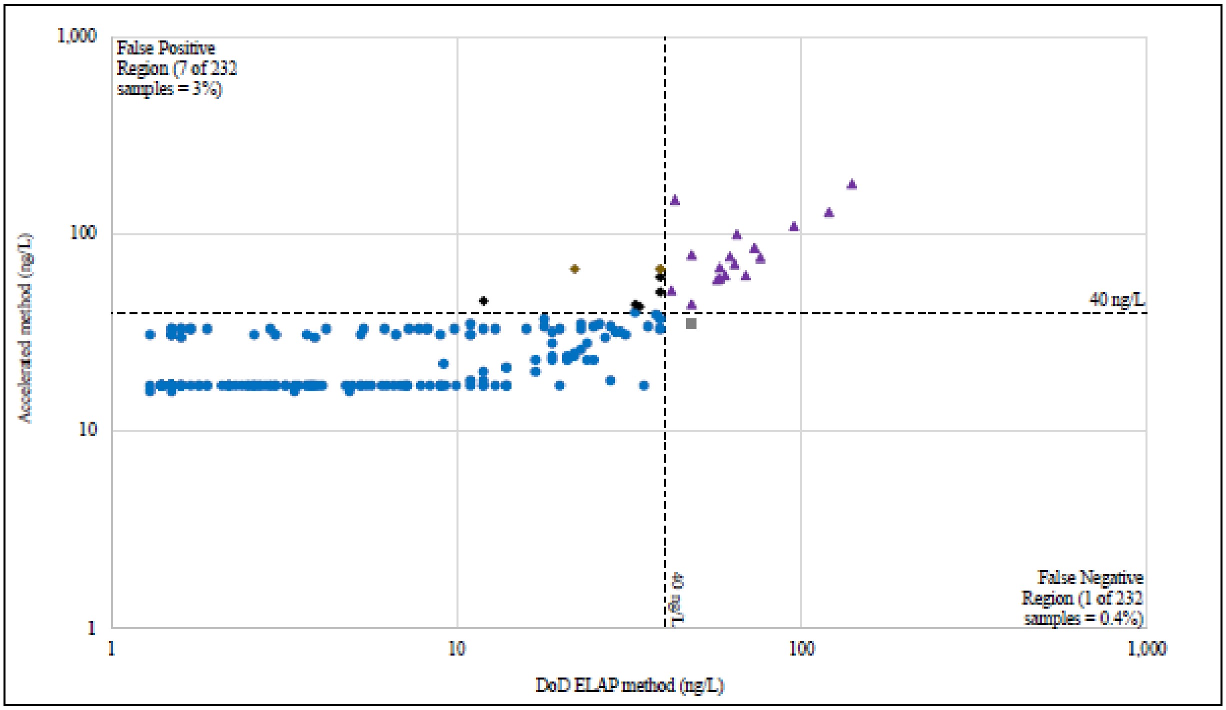
▲ Reliable - Both Action
● Reliable - Both No Action
—— Decision Value Line
◆ Not Reliable - DoD ELAP method No Action and Accelerated method Action (False Positive Case 1)
◆ Not Reliable - DoD ELAP method No Action and Accelerated method Action (Step-out) (False Positive Case 2)
■ Not Reliable - DoD ELAP method Action and Accelerated method No Action (False Negative)

Abbreviations

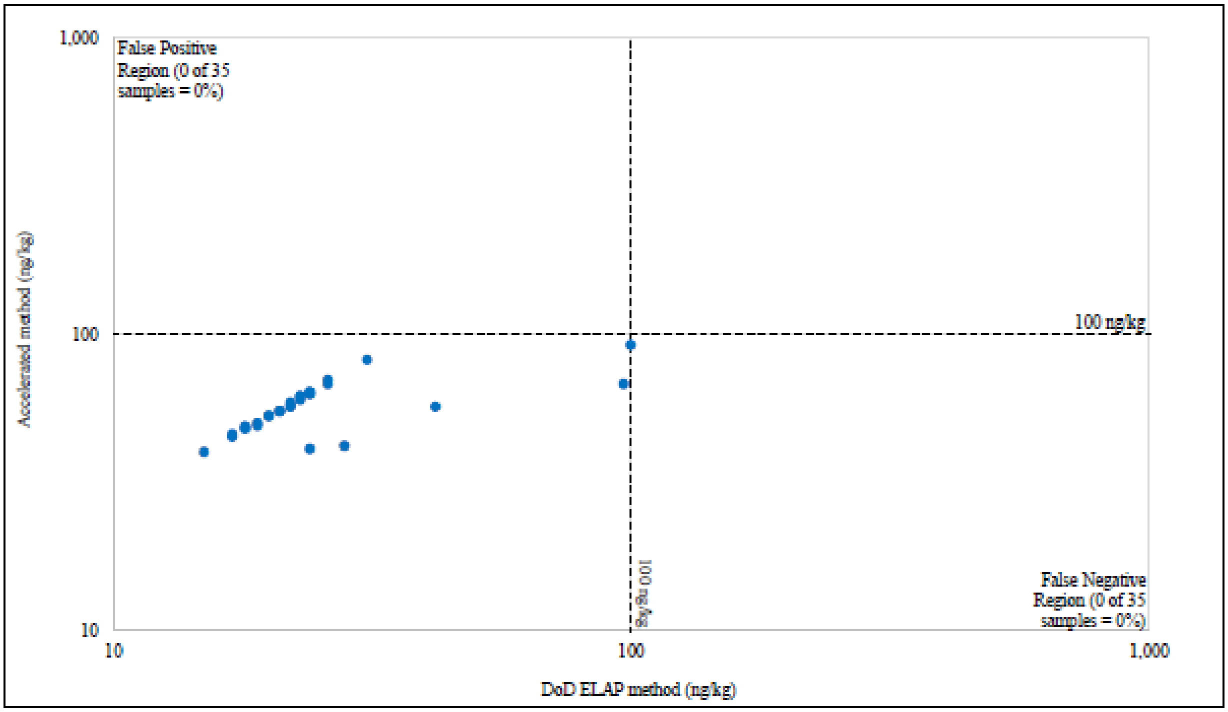
ng/L = nanograms per liter
ng/kg = nanograms per kilogram

Figure 7-4J. Secondary PFAS Compounds - PFPeA - Reliability Plots

PFPeS - Groundwater - Reliability based on Action / No Action using decision value of 40 ng/L



PFPeS - Soil- Reliability based on Action / No Action using decision value of 100 ng/kg



Legend

▲ Reliable - Both Action

● Reliable - Both No Action

---- Decision Value Line

◆ Not Reliable - DoD ELAP method No Action and Accelerated method Action (False Positive Case 1)

◆ Not Reliable - DoD ELAP method No Action and Accelerated method Action (Step-out) (False Positive Case 2)

■ Not Reliable - DoD ELAP method Action and Accelerated method No Action (False Negative)

Abbreviations

ng/L = nanograms per liter

ng/kg = nanograms per kilogram

Figure 7-4K. Secondary PFAS Compounds - PFPeS - Reliability Plots

Table 7-7. Accuracy - Proportional Analysis Results and Confidence Intervals for the Primary PFAS Compounds

Matrix	Analyte	No. Detect Pairs [1]	Classification	No. Pairs	Sample Proportion	P-Value	Reject Null Hypothesis at $\alpha = 0.05$?	95% Lower Confidence Limit	95% Upper Confidence Limit
Groundwater	PFOA	114	Accurate	57	50%	1.00000	No	40%	60%
			Not Accurate	57	50%	1.00000	No	40%	60%
	PFOS	180	Accurate	129	72%	1.00000	No	64%	78%
			Not Accurate	51	28%	1.00000	No	22%	36%
	T-PFOS	186	Accurate	91	49%	1.00000	No	42%	56%
			Not Accurate	95	51%	1.00000	No	44%	58%
	Total PFOS	185	Accurate	116	63%	1.00000	No	55%	70%
			Not Accurate	69	37%	1.00000	No	30%	45%
	PFBS	45	Accurate	23	51%	1.00000	No	36%	66%
			Not Accurate	22	49%	1.00000	No	34%	64%
Soil	PFOA	21	Accurate	14	67%	0.99168	No	43%	85%
			Not Accurate	7	33%	0.99939	No	15%	57%
	PFOS	54	Accurate	50	93%	0.07690	No	82%	98%
			Not Accurate	4	7%	0.36145	No	2%	18%
	T-PFOS	58	Accurate	28	48%	1.00000	No	35%	62%
			Not Accurate	30	52%	1.00000	No	38%	65%
	Total PFOS	57	Accurate	52	91%	0.12528	No	81%	97%
			Not Accurate	5	9%	0.48879	No	3%	19%
	PFBS	0	Accurate	NA	NA	NA	NA	NA	NA
			Not Accurate	NA	NA	NA	NA	NA	NA

Notes:

1. Accuracy evaluated for detect pairs, excluding the outliers.
2. Accurate pairs were defined as detect pairs, in which the DoD ELAP method result and Accelerated method result were within +/-30% Percent Difference.
   Inaccurate pairs were defined as detect pairs, in which the DoD ELAP method result and Accelerated method result were more than +30% or less than -30% Percent Difference.
3. Percent Difference is calculated as the DoD ELAP method - the Accelerated method, divided by the DoD ELAP method. The DoD ELAP method is the denominator of the equation because it is the "gold standard" / reference method.

DoD ELAP = U.S. Department of Defense Environmental Laboratory Accreditation Program
PFOA = perfluoroocatnoic acid
PFOS = perfluorooctane sulfonate PFBS = perfluorobutane sulfonate

Table 7-8. Accuracy - Proportional Analysis Results and Confidence Intervals for the Secondary PFAS Compounds

Matrix	Analyte	No. Detect Pairs [1]	Classification	No. Pairs	Sample Proportion	P-Value	Reject Null Hypothesis at $\alpha = 0.05$?	95% Lower Confidence Limit	95% Upper Confidence Limit
Groundwater	6-2FTS	46	Accurate	36	78%	0.92551	No	64%	89%
			Not Accurate	10	22%	0.99516	No	11%	36%
	8-2FTS	25	Accurate	17	68%	0.99203	No	46%	85%
			Not Accurate	8	32%	0.99954	No	15%	54%
	PFHpA	107	Accurate	38	36%	1.00000	No	27%	45%
			Not Accurate	69	64%	1.00000	No	55%	73%
	PFHpS	52	Accurate	41	79%	0.91934	No	65%	89%
			Not Accurate	11	21%	0.99546	No	11%	35%
	PFHxA	121	Accurate	87	72%	0.99993	No	63%	80%
			Not Accurate	34	28%	1.00000	No	20%	37%
	PFHxS	166	Accurate	136	82%	0.88633	No	75%	87%
			Not Accurate	30	18%	0.99950	No	13%	25%
	Br-PFHxS	130	Accurate	106	82%	0.88809	No	74%	88%
			Not Accurate	24	18%	0.99893	No	12%	26%
	Total PFHxS	155	Accurate	135	87%	0.27359	No	81%	92%
			Not Accurate	20	13%	0.90593	No	8%	19%
	PFNA	17	Accurate	12	71%	0.96813	No	44%	90%
			Not Accurate	5	29%	0.99533	No	10%	56%
	PFPeA	107	Accurate	54	50%	1.00000	No	41%	60%
			Not Accurate	53	50%	1.00000	No	40%	59%
	PFPeS	56	Accurate	35	63%	0.99999	No	49%	75%
			Not Accurate	21	38%	1.00000	No	25%	51%
Soil	6-2FTS	10	Accurate	9	90%	0.54430	No	55%	100%
			Not Accurate	1	10%	0.73610	No	0%	45%
	8-2FTS	18	Accurate	16	89%	0.47966	No	65%	99%
			Not Accurate	2	11%	0.73380	No	1%	35%
	PFHpA	11	Accurate	3	27%	1.00000	No	6%	61%
			Not Accurate	8	73%	1.00000	No	39%	94%
	PFHpS	13	Accurate	4	31%	1.00000	No	9%	61%
			Not Accurate	9	69%	1.00000	No	39%	91%
	PFHxA	9	Accurate	3	33%	0.99995	No	7%	70%
			Not Accurate	6	67%	1.00000	No	30%	93%
	PFHxS	46	Accurate	39	85%	0.61520	No	71%	94%
			Not Accurate	7	15%	0.91602	No	6%	29%
	Br-PFHxS	15	Accurate	13	87%	0.60423	No	60%	98%
			Not Accurate	2	13%	0.81594	No	2%	40%

Matrix	Analyte	No. Detect Pairs [1]	Classification	No. Pairs	Sample Proportion	P-Value	Reject Null Hypothesis at α = 0.05?	95% Lower Confidence Limit	95% Upper Confidence Limit
	Total PFHxS	37	Accurate	32	86%	0.51279	No	71%	95%
			Not Accurate	5	14%	0.84022	No	5%	29%
	PFNA	19	Accurate	13	68%	0.98367	No	43%	87%
			Not Accurate	6	32%	0.99830	No	13%	57%
	PFPeA	13	Accurate	4	31%	1.00000	No	9%	61%
			Not Accurate	9	69%	1.00000	No	39%	91%
	PFPeS	1	Accurate	NA	NA	NA	NA	NA	NA
			Not Accurate	NA	NA	NA	NA	NA	NA

Notes:

1. Accuracy evaluated for detect pairs, excluding the outliers.
2. Accurate pairs were defined as detect pairs, in which the DoD ELAP method result and Accelerated method result were within +/-30% Percent Difference.
   Inaccurate pairs were defined as detect pairs, in which the DoD ELAP method result and Accelerated method result were more than +30% or less than -30% Percent Difference.
3. Percent Difference is calculated as the DoD ELAP method - the Accelerated method, divided by the DoD ELAP method. The DoD ELAP method is the denominator of the equation because it is the "gold standard" / reference method.

Table 7-9. Groundwater Statistical Equivalence Summary

Analyte	Dataset	No. Detect Pairs	Passing-Bablok Regression Equivalence [1]	Bland-Altman Lower and Upper Limits of Agreement [2]	TOST Symmetrical Equivalence Margin [3]	Lin's Concordance Coefficient [4]
PRIMARY PFAS COMPOUNDS						
PFOA	Outliers Removed	114	No (bias high)	- 64.8 ng/L + 34.7 ng/L	+ / - 15 ng/L	0.9714
	All Detect Pairs	116	No (bias high)	- 525 ng/L + 431 ng/L	+ / - 15 ng/L	0.3313
PFOS	Outliers Removed	180	No (bias high)	- 641 ng/L + 487 ng/L	+ / - 45 ng/L	0.9878
	All Detect Pairs	182	No (bias high)	- 766 ng/L + 568 ng/L	+ / - 45 ng/L	0.9901
T-PFOS	Outliers Removed	186	Not Applicable	- 570 ng/L + 487 ng/L	+ / - 35 ng/L	0.9710
	All Detect Pairs	188	Not Applicable	- 617 ng/L + 511 ng/L	+ / - 35 ng/L	0.9741
Total PFOS	Outliers Removed	185	No (bias high)	- 1,130 ng/L + 897 ng/L	+ / - 80 ng/L	0.9842
	All Detect Pairs	187	No (bias high)	- 1,350 ng/L + 1,040 ng/L	+ / - 85 ng/L	0.9858
PFBS	Outliers Removed	45	No (bias high)	- 23.6 ng/L + 9.4 ng/L	+ / - 10 ng/L	0.7116
	All Detect Pairs	47	Not Applicable	- 745 ng/L + 589 ng/L	+ / - 10 ng/L	0.0075
SECONDARY PFAS COMPOUNDS						
6-2FTS	Outliers Removed	46	No (bias high)	- 331 ng/L + 255 ng/L	+ / - 40 ng/L	0.9903
	All Detect Pairs	47	No (bias high)	- 668 ng/L + 515 ng/L	+ / - 40 ng/L	0.9604
8-2FTS	Outliers Removed	25	No (bias high)	- 35.5 ng/L + 20.2 ng/L	+ / - 10 ng/L	0.9649
	All Detect Pairs	26	Yes	- 758 ng/L + 606 ng/L	+ / - 15 ng/L	0.0121
PFHpA	Outliers Removed	107	No (bias high)	- 59.5 ng/L + 34.8 ng/L	+ / - 15 ng/L	0.9462
	All Detect Pairs	110	No (bias high)	- 539 ng/L + 447 ng/L	+ / - 15 ng/L	0.1468
PFHpS	Outliers Removed	51	No (bias high)	- 62.5 ng/L + 42.1 ng/L	+ / - 15 ng/L	0.8781
	All Detect Pairs	53	Not Applicable	- 694 ng/L + 550 ng/L	+ / - 15 ng/L	0.0880
PFHxA	Outliers Removed	121	No (bias high)	- 88.8 ng/L + 62.5 ng/L	+ / - 10 ng/L	0.9529
	All Detect Pairs	123	No (bias high)	- 491 ng/L + 406 ng/L	+ / - 15 ng/L	0.3682
PFHxS	Outliers Removed	166	No (bias high)	- 211 ng/L + 181 ng/L	+ / - 10 ng/L	0.9565
	All Detect Pairs	168	No (bias high)	- 386 ng/L + 318 ng/L	+ / - 15 ng/L	0.8746
Br-PFHxS	Outliers Removed	130	Yes	- 49.9 ng/L + 45.4 ng/L	+ / - 2 ng/L	0.9305
	All Detect Pairs	132	Yes	- 107 ng/L + 90.1 ng/L	+ / - 3 ng/L	0.7610
	Outliers Removed	155	No (bias high)	- 262 ng/L + 227 ng/L	+ / - 15 ng/L	0.9531

Analyte	Dataset	No. Detect Pairs	Passing-Bablok Regression Equivalence [1]	Bland-Altman Lower and Upper Limits of Agreement [2]	TOST Symmetrical Equivalence Margin [3]	Lin's Concordance Coefficient [4]
Total PFHxS	All Detect Pairs	157	No (bias high)	- 496 ng/L + 411 ng/L	+ / - 20 ng/L	0.8579
PFNA	Outliers Removed	17	Yes	- 16.8 ng/L + 8.8 ng/L	+ / - 10 ng/L	0.8122
	All Detect Pairs	18	Yes	- 985 ng/L + 767 ng/L	+ / - 10 ng/L	0.0704
PFPeA	Outliers Removed	107	No (bias high)	- 126 ng/L + 85.8 ng/L	+ / - 20 ng/L	0.9260
	All Detect Pairs	109	No (bias high)	- 513 ng/L + 410 ng/L	+ / - 20 ng/L	0.3904
PFPeS	Outliers Removed	56	No (bias high)	- 42 ng/L + 23.2 ng/L	+ / - 10 ng/L	0.8132
	All Detect Pairs	58	Yes	- 729 ng/L + 584 ng/L	+ / - 10 ng/L	-0.0009

Notes:

1. Passing-Bablok Regression tests whether there is sufficient evidence of bias with the Accelerated method with regard to the 1:1 (45 degree) line of agreement. If not, the null hypothesis is rejected that the two methods are not equivalent. This test is not applicable if either the Kendall's Tau Correlation or Cusum Linearity assumptions are not met.
2. The Bland-Altman test determines the upper and lower limits of agreement based upon the mean of the differences plus or minus 1.96 standard deviation
3. The two one-sided t-tests (TOST) was used to find the greatest symmetrical equivalence margin for which at least one of the two null hypotheses (upper and lower boundary) would be rejected. These null hypothesis state that the two methods are not equivalent at the respective boundary.
4. Lin's Concordance Coeffient is a measure as to how well the Accelerated method reproduces the results of the DoD ELAP method.
5. Bland-Altman Lower and Upper Limits of Agreement and TOST Symmetrical Equivalence Margin are in units nanograms per liter (ng/L).

Table 7-10. Soil Statistical Equivalence Summary

Analyte	Dataset	Group	No. Detect Pairs	Passing-Bablok Regression Equivalence [1]	Bland-Altman Lower and Upper Limits of Agreement [2]	TOST Symmetrical Equivalence Margin [3]	Lin's Concordance Coefficient [4]
PRIMARY PFAS COMPOUNDS							
PFOA	Outliers Removed	Combined	21	No (bias low)	- 279 ng/kg + 547 ng/kg	+/- 180 ng/kg	0.9231
		Pairs ≤ DoD ELAP Median of 410 ng/kg	11	Yes	- 179 ng/kg + 237 ng/kg	+/- 20 ng/kg	0.5825
		Pairs > DoD ELAP Median of 410 ng/kg	10	No (bias high)	- 220 ng/kg + 721 ng/kg	+/- 350 ng/kg	0.8825
	All Detect Pairs	--	23	No (bias low)	- 2,790 ng/kg + 3,840 ng/kg	+/- 280 ng/kg	0.2504
PFOS	Outliers Removed	Combined	54	Yes	- 12,800 ng/kg + 13,300 ng/kg	+/- 490 ng/kg	0.9922
		Pairs ≤ DoD ELAP Median of 6,050 ng/kg	27	Yes	- 909 ng/kg + 1,110 ng/kg	+/- 100 ng/kg	0.945
		Pairs > DoD ELAP Median of 6,050 ng/kg	27	No (bias low)	- 18,300 ng/kg + 19,100 ng/kg	+/- 2,000 ng/kg	0.9903
	All Detect Pairs	--	56	Yes	- 122,000 ng/kg + 146,000 ng/kg	+/- 700 ng/kg	0.5465
T-PFOS	Outliers Removed	Combined	58	No (bias high)	- 3,650 ng/kg + 2,890 ng/kg	+/- 340 ng/kg	0.9838
		Pairs ≤ DoD ELAP Median of 845 ng/kg	29	No (bias high)	- 359 ng/kg + 362 ng/kg	+/- 60 ng/kg	0.7521
		Pairs > DoD ELAP Median of 845 ng/kg	29	No (bias high)	- 5,290 ng/kg + 3,770 ng/kg	+/- 800 ng/kg	0.9804
	All Detect Pairs	--	60	Not Applicable	- 7,340 ng/kg + 7,820 ng/kg	+/- 310 ng/kg	0.9188
Total PFOS	Outliers Removed	Combined	57	Yes	- 14,200 ng/kg + 14,600 ng/kg	+ / - 250 ng/kg	0.9928
		Pairs ≤ DoD ELAP Median of 6,600 ng/kg	29	No (bias high)	- 1,470 ng/kg + 1,600 ng/kg	+ / - 110 ng/kg	0.9174
		Pairs > DoD ELAP Median of 6,600 ng/kg	28	No (bias low)	- 20,400 ng/kg + 21,000 ng/kg	+ / - 1,100 ng/kg	0.9911
	All Detect Pairs	--	59	Yes	- 126,000 ng/kg + 150,000 ng/kg	+ / - 450 ng/kg	0.595
PFBS	--	--	0	Not performed because there are not any detect pairs			
SECONDARY PFAS COMPOUNDS							
6-2FTS	Outliers Removed	--	10	Yes	- 504 ng/kg + 615 ng/kg	+ / - 180 ng/kg	0.9884
	All Detect Pairs	--	11	Yes	- 1,340 ng/lg + 1,920 ng/kg	+ / - 410 ng/kg	0.8888
8-2FTS	Outliers Removed	--	18	Yes	- 4,730 ng/kg + 4,640 ng/kg	+ / - 100 ng/kg	0.9963
	All Detect Pairs	--	19	Yes	- 23,900 ng/kg + 30,000 ng/kg	+ / - 200 ng/kg	0.8773
PFHpA	Outliers Removed	--	11	Not Applicable	-61.3 ng/kg + 462 ng/kg	+ / - 290 ng/kg	0.1385
	All Detect Pairs	--	12	Not Applicable	- 400 ng/kg + 993 ng/kg	+ / - 320 ng/kg	0.0488
PFHpS	Outliers Removed	--	13	No (bias high)	- 870 ng/kg + 442 ng/kg	+ / - 350 ng/kg	0.5684
	All Detect Pairs	--	15	Yes	- 1,620 ng/kg 1,780 ng/kg	+ / - 230 ng/kg	0.1023

Analyte	Dataset	Group	No. Detect Pairs	Passing-Bablok Regression Equivalence [1]	Bland-Altman Lower and Upper Limits of Agreement [2]	TOST Symmetrical Equivalence Margin [3]	Lin's Concordance Coefficient [4]
PFHxA	Outliers Removed	--	9	No (bias low)	- 66.3 ng/kg + 300 ng/kg	+ / - 180 ng/kg	0.6572
	All Detect Pairs	--	10	No (bias low)	- 319 ng/kg + 708 ng/kg	+ / - 240 ng/kg	0.2033
PFHxS	Outliers Removed	--	46	No (bias high)	- 311 ng/kg + 303 ng/kg	+ / - 30 ng/kg	0.9563
	All Detect Pairs	--	48	Yes	- 2,010 ng/lg + 2,370 ng/kg	+ / - 40 ng/kg	0.3796
Br-PFHxS	Outliers Removed	--	15	Yes	- 46.6 ng/kg + 66.2 ng/kg	'+ / - 30 ng/kg	0.9362
	All Detect Pairs	--	16	Yes	- 155 ng/kg + 221 ng/kg	+ / - 30 ng/kg	0.5282
Total PFHxS	Outliers Removed	--	37	Yes	- 379 ng/kg + 347 ng/kg	+ / - 40 ng/kg	0.9551
	All Detect Pairs	--	39	Yes	- 2,340 ng/kg + 2,780 ng/kg	+ / - 40 ng/kg	0.3644
PFNA	Outliers Removed	--	19	Yes	- 139 ng/kg + 272 ng/kg	+ / - 110 ng/kg	0.9817
	All Detect Pairs	--	21	Yes	- 2,820 ng/kg + 3,900 ng/kg	+ / - 150 ng/kg	0.2211
PFPeA	Outliers Removed	--	13	Not Applicable	- 1,250 ng/kg + 1,900 ng/kg	+ / - 350 ng/kg	0.0858
	All Detect Pairs	--	15	Not Applicable	- 1,160 ng/kg + 1,800 ng/kg	+ / - 340 ng/kg	0.0754
PFPeS	NA	--	1	Not performed because there is only one detect pair			

Notes:

1. Passing-Bablok Regression tests whether there is sufficient evidence of bias with the Accelerated method with regard to the 1:1 (45 degree) line of agreement. If not, the null hypothesis is rejected that the two methods are not equivalent. This test is not applicable if either the Kendall's Tau Correlation or Cusum Linearity assumptions are not met.
2. The Bland-Altman test determines the upper and lower limits of agreement based upon the mean of the differences plus or minus 1.96 standard deviations.
3. The two one-sided t-tests (TOST) was used to find the greatest symmetrical equivalence margin for which at least one of the two null hypotheses (upper and lower boundary) would be rejected. These null hypothesis state that the two methods are not equivalent at the respective boundary.
4. Lin's Concordance Coeffient is a measure as to how well the Accelerated method reproduces the results of the DoD ELAP method.
5. Bland-Altman Lower and Upper Limits of Agreement and TOST Symmetrical Equivalence Margin are in units nanograms per kilogram (ng/kg).

7.5.5 Primary PFAS Compounds

The results for the Primary PFAS compounds with screening levels are presented individually in this section. A more detailed discussion is provided in **Appendix M**. The statistical equivalence of the two methods was not always strong; however, the results presented in this section demonstrate that using the Accelerated Method for PFOA, PFOS, T-PFOS, Total PFOS, and PFBS analysis can produce reliable field decision-making.

7.5.5.1 PFOA

The Accelerated Method was found to be reliable for making field decisions for PFOA in groundwater in at least 90 percent of the sample pairs. The TOST hypothesis test for equivalence found the two methods to be equivalent to within +/- 40 ng/L when outliers were excluded. Lin's Concordance Correlation Coefficient also found the methods to be equivalent. Passing-Bablok and Bland-Altman regressions found some high bias in the Accelerated Method. In light of the fact that the few cases in which the Accelerated Method did not make reliable field decisions were false positives, this high bias leads to the conclusion that the Accelerated Method is satisfactory for investigating PFOA in groundwater and errs on the side of being protective to the environment.

The Accelerated Method was found to be reliable for making field decisions for PFOA in soil in every data pair. The TOST hypothesis test for equivalence found the two methods to be equivalent to within +/- 180 ng/L when outliers were excluded. Lin's Concordance Correlation Coefficient found the methods to be equivalent without the outliers. Passing-Bablok and Bland-Altman regressions found low bias in the Accelerated Method. That all of the observations were found to be reliable leads to the conclusion that the Accelerated Method is satisfactory for investigating PFOA in soil, even if some non-equivalence was found in the statistical equivalence testing.

7.5.5.2 PFOS

The Accelerated Method made reliable field decisions for PFOS in groundwater in 93 percent of the data pairs. The majority of the incorrect decisions were false positives. However, the two methods were not always accurate to within 30 ng/L, and the equivalence was not exhibited in two of the test methods (Passing-Bablok and Bland-Altman). The high rate of reliable decisions supports the conclusion that the Accelerated Method is satisfactory for investigating PFOS in groundwater, even if the accuracy and statistical equivalence testing exhibited differences.

In soil, the Accelerated Method was found to be reliable for making field decisions for PFOS in every data pair. The TOST hypothesis test for equivalence test found the two methods to be equivalent to within +/- 490 ng/kg when outliers were excluded. Lin's Concordance Correlation Coefficient found the methods to be equivalent without the outliers. The Passing-Bablok regression indicated equivalence, but the Bland-Altman regression found low bias in the Accelerated Method. That all of the observations were found to be reliable leads to the conclusion that the Accelerated Method is satisfactory for investigating PFOS in soil, even if the Accelerated Method might occasionally under-estimate the PFOS concentrations.

7.5.5.3 T-PFOS

The Accelerated Method made reliable field decisions in 90 percent of the data pairs for T-PFOS in groundwater. The majority of the incorrect decisions were false positives. Although the two methods were not always accurate to within 30 ng/L, the statistical equivalence evaluation found a measure of equivalence. The Bland-Altman regression showed some high bias with the Accelerated Method. In summary, the Accelerated Method is satisfactory for investigating T-PFOS in groundwater and errs on the side of being protective to the environment.

For soil, the Accelerated Method made accurate field decisions with all of the data pairs for T-PFOS. Lin's Concordance Correlation Coefficient showed statistical equivalence, and TOST indicated equivalence at +/- 340 ng/kg for the dataset excluding outliers. Bland-Altman and the Passing-Bablok regressions indicated that the Accelerated Method was biased high. In summary, the Accelerated Method is satisfactory for the analysis of T-PFOS in soil because it is reliable in making field decisions. Any lack of statistical equivalence with this method in soil is on the side of protection of the environment.

7.5.5.4 Total PFOS

The Accelerated Method made the correct field decision for 92 percent of the data pairs for total PFOS in groundwater. Lin's Concordance Correlation Coefficient showed a strong linear correlation, and TOST indicated equivalence at +/- 80 ng/kg for the dataset excluding outliers. Bland-Altman and the Passing-Bablok regressions indicated that the Accelerated Method was biased high. In summary, the Accelerated Method is satisfactory for the analysis of total PFOS in groundwater because it is reliable in making field decisions. Any lack of statistical equivalence with this method would be to err on the side of protection of the environment.

The Accelerated Method made accurate field decisions with all of the data pairs for Total PFOS in soil. Lin's Concordance Correlation Coefficient showed statistical equivalence, and TOST indicated equivalence at +/- 250 ng/kg for the dataset excluding outliers. The Passing-Bablok regression also supported statistical equivalence. The Bland-Altman regression indicated that the Accelerated Method was biased low. In summary, the Accelerated Method is satisfactory for the analysis of total PFOS in soil because it is reliable in making field decisions. Some measure of statistical equivalence was observed in the equivalence testing.

7.5.5.5 PFBS

For PFBS, there were no non-reliable observations in the groundwater dataset used in this analysis. The statistical equivalence testing produced mixed results. For this site, the Accelerated Method was sufficient for PFBS in groundwater because the concentrations were low in every sample compared to the screening level.

In soil, there were no detect pairs. For this reason, accuracy testing and statistical equivalence testing could not be performed. Only reliability testing was possible. The reliability evaluation, using a screening limit of 130,000,000 ng/kg, did not produce any non-reliable observations in the dataset used in this analysis. All of the data measurements called for no action.

7.5.6 Secondary PFAS Compounds

The Accelerated Method was reliable in making field decisions for at least 90 percent of the data pairs for nine of the 11 Secondary PFAS compounds in groundwater. The two exceptions were PFHxA (89 percent) and PFPeA (87 percent). The Accelerated Method did not exhibit accuracy with respect to the DoD ELAP Method. Only for total PFHxS was the Accelerated Method able to match the DoD ELAP Method within a % difference of +/- 30 percent for more than 85 percent of the portion of data pairs, and no compound achieved 90 percent.

The TOST statistical equivalence margins were +/- 40 ng/L or less for these compounds in groundwater. Lin's Concordance Correlation Coefficient was 0.8122 or higher for all of the datasets with the outliers removed and was 0.9 of higher for eight of the 11 Secondary PFAS compounds. The Passing-Bablok regression found evidence to conclude that the two methods were not equal for most of the compounds, usually due to a high bias. The details of the statistical tests are provided in the tables in **Appendix M**. Due to the high sample portions of reliable outcomes, the Accelerated Method appears to be satisfactory for the analysis of the Secondary PFAS compounds in groundwater.

In soil, the Accelerated Method also performed satisfactorily in making field decisions if the surrogate screening level for these compounds was the same as that for PFOA and the PFOS isomers: 126,000 ng/kg. In such a case, all of the pairs for all 11 compounds would have agreed that no action was necessary, resulting in 100 percent reliability for all of the Secondary PFAS compounds.

Only for five of the compounds was the Accelerated Method able to match the DoD ELAP Method in soil within a % difference of +/- 30 percent for more than 85 percent of the portion of data pairs, and only 6-2FTS achieved 90 percent (**Table 6-2**). None of the compounds yielded an LCL greater than 71 percent.

The TOST statistical equivalence margins were between +/- 30 ng/kg and +/- 350 ng/kg for these compounds in datasets with outliers removed. The best compounds (margins of +/- 40 ng/kg or tighter) were PFHxS, Br-PFHxS, and total PFHxS. Lin's Concordance Correlation Coefficient was 0.9362 or higher for six of the ten datasets with the outliers removed. The Passing-Bablok regression found insufficient evidence to conclude that the two methods were not equal for five of the eight compounds for which the test was valid. Two of the three for which evidence was found that the methods were not equal were due to a high bias; an error on the side of being protective. The details of the statistical tests are provided in the tables in **Appendix M**. If a screening level comparable to PFOS or PFOA were to be adopted for the Secondary PFAS compounds, the high sample portions of reliable field decisions would make the Accelerated Method satisfactory for the analysis of the Secondary PFAS compounds in soil.

7.6 SUMMARY AND CONCLUSIONS

7.6.1 Base Level Statistics

The data derived from the base level statistical evaluation indicate that the large majority of the compounds achieved the performance goals and that, in aggregate, the Accelerated Method matched well with the DoD ELAP Method. Comparing the data with and without the outliers reveals that the removal of the outliers improved the statistical comparisons.

In aggregate, the Accelerated Method should provide adequate accuracy and precision to be used as a screening method for making field-based intermediate decisions. Where these goals were not met, the statistical goals were in most cases only marginally exceeded. Exceptions to this, which are limited to the Secondary PFAS compounds, include PFBA and several compounds (PFHpA, PFPeA, and PFHpS) in soil present at significant exceedances with respect to the performance goals. Knowing these limitations, the DQOs for a given project should be set according to the performance of this method so that there is an adequate level of confidence for the project-specific decisions.

7.6.2 Advanced Level Statistics

Reliable field decisions can be made using the Accelerated Method for the evaluation of PFAS in groundwater and soil. For the Primary PFAS compounds, the Accelerated Method led to the same field decision as the DoD ELAP Method for 90 percent of the data pairs or more for each of the five compounds in groundwater based on the data analyzed in this study with an LCL of 85 percent or higher. In soil, there were no data pairs for which the Accelerated Method and the DoD ELAP Method differed in a field decision. The Accelerated Method also demonstrated reliability with the compounds for which there is no current screening level; the Secondary PFAS compounds were compared to 40 ng/L and 100 ng/kg threshold, as this is typically twice the MDL for water and soils, respectively.

The accuracy of the Accelerated Method was better in soil than in groundwater for the Primary PFAS compounds. However, only PFOS and total PFOS in soil exhibited a rate of 90 percent or more sample pairs matching at +/- 30 percent on a percent difference basis. Percent difference is used for statistical equivalence when one method is considered the accurate measure; the DoD ELAP Method statistical equivalence was tested using four methods including Passing-Bablok, Bland-Altman, TOST, and Lin’s Concordance Correlation Coefficient. Deming’s orthogonal regression was also attempted, but the applicability criteria for running the test were rarely met. In almost all cases, the tests showed better accuracy and equivalence when statistical outliers were excluded. The results of the Bland-Altman and TOST tests should be interpreted in terms of whether the margins of agreement or equivalence are acceptable. Lin’s Concordance Correlation Coefficient was strong for all of the Primary PFAS compounds in soil and groundwater, except for PFBS in groundwater, where the correlation was only moderate. Of the Primary PFAS compounds, Passing-Bablok only found statistical equivalence for PFOS and total PFOS, and only in soil.

8.0 STRATIGRAPHIC FLUX RESULTS

Mass flux measures plume strength at a given time and location. Mass flux (J) is given by the product of hydraulic conductivity (K), horizontal gradient (i), and contaminant concentration in groundwater (C), such that:

$$J = K\ i\ C \tag{1}$$

Where:

J = Mass Flux (M/TL^2)
K = Hydraulic Conductivity (L/T)
i = Horizontal Hydraulic Gradient (L/L)
C = Concentration in groundwater (M/L^3)

Mass discharge is given by the sum of the mass flux measurements orthogonal to the direction of plume migration with interpolation and summation across all of the monitoring points:

$$MD = \Sigma KiAC \tag{2}$$

Where:

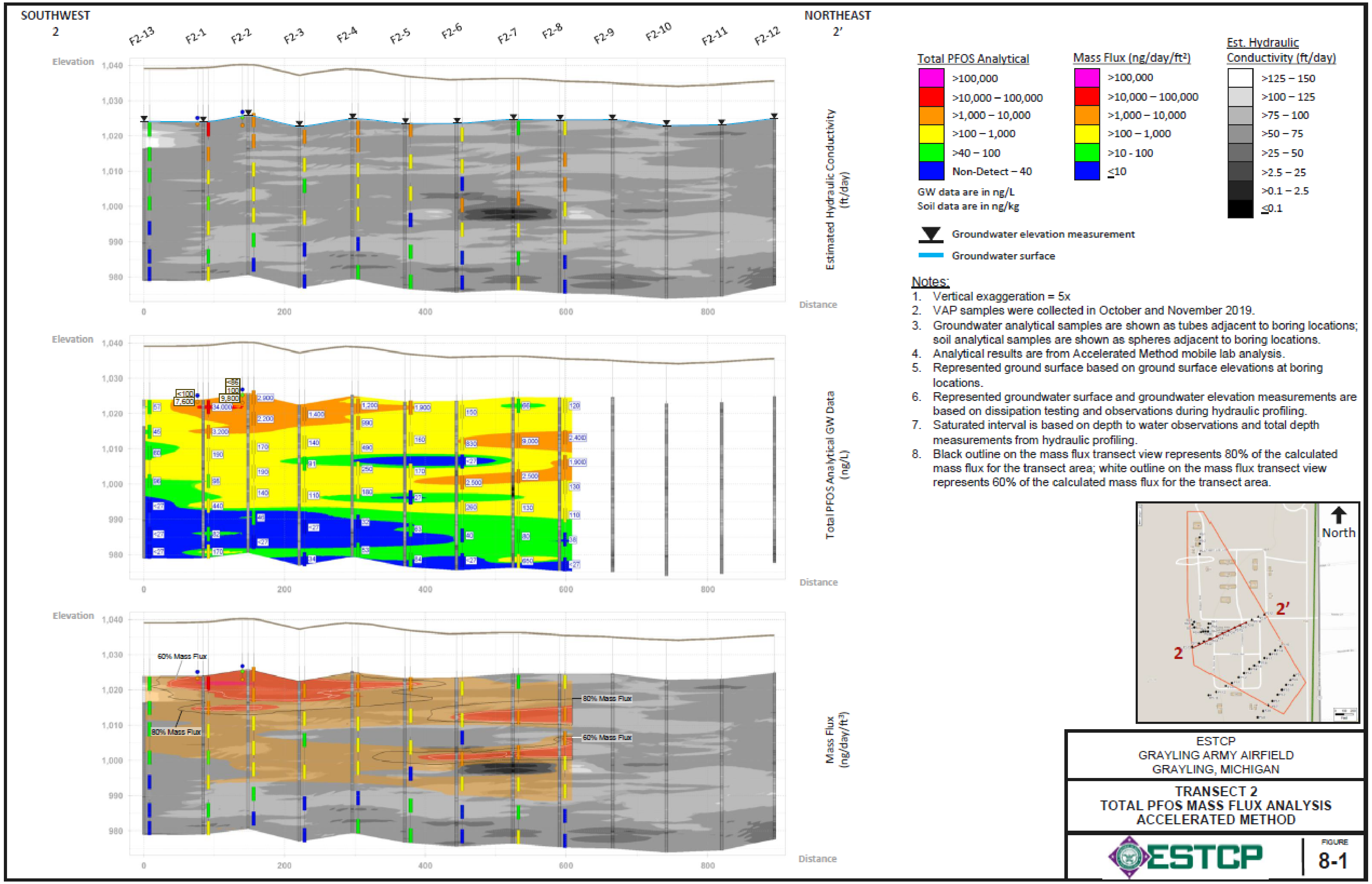
MD = total contaminant discharge across the control plane (M/T)
A = representative area of each monitoring point (L^2)

The higher the resolution of K and C measurements, the more representative the estimate of K and C spatial distribution when applied to mapping mass flux. For the GAAF, the high-resolution permeability data collected with the HPT (Est K) and the concentration data collected with VAP borings were evaluated using the 3D model EVS to facilitate mass flux evaluation. Once assembled in a 3D model, the interpolated data fields for conductivity and concentration are multiplied together, along with horizontal groundwater gradient, to produce a heat map that illustrates an estimate of mass flux on 2D cross-sections. The three transects at GAAF were modeled independently to provide a 3D evaluation of mass flux along successive planes within the aquifer. This approach provides insight to mass movement, plume maturity, plume morphology, and allows for future evaluation of remedy approach, location, and design.

8.1 FLUX TRANSECTS

While the relative permeability for the site exhibits spatial variability, it is dominated by advective transport (Est K primarily between 30 and 200 ft/day) with only a few zones suggesting lower-permeability slow advection. The relative homogeneity of the GAAF hydrostratigraphy, coupled with the limited effective range of the Est K, results in a stratigraphic flux model with distribution similar to that of a model based on the VAP concentration alone. This is unusual, as most sites have a larger range of K, typically spanning two to five orders of magnitude. To refine the analysis, the mass flux figure includes contours showing where 60 and 80 percent of the mass flux occur within each of the cross-sections.

The 2D cross-sections for each transect using the DoD ELAP Method are provided as **Figures 5-10** through **5-15**. For comparison, mass flux cross-sections were also prepared using the Accelerated Method results, provided as **Figures 8-1** through **8-6**.



Notes:

1. Vertical exaggeration = 5x
2. VAP samples were collected in October and November 2019.
3. Groundwater analytical samples are shown as tubes adjacent to boring locations; soil analytical samples are shown as spheres adjacent to boring locations.
4. Analytical results are from Accelerated Method mobile lab analysis.
5. Represented ground surface based on ground surface elevations at boring locations.
6. Represented groundwater surface and groundwater elevation measurements are based on dissipation testing and observations during hydraulic profiling.
7. Saturated interval is based on depth to water observations and total depth measurements from hydraulic profiling.
8. Black outline on the mass flux transect view represents 80% of the calculated mass flux for the transect area; white outline on the mass flux transect view represents 60% of the calculated mass flux for the transect area.

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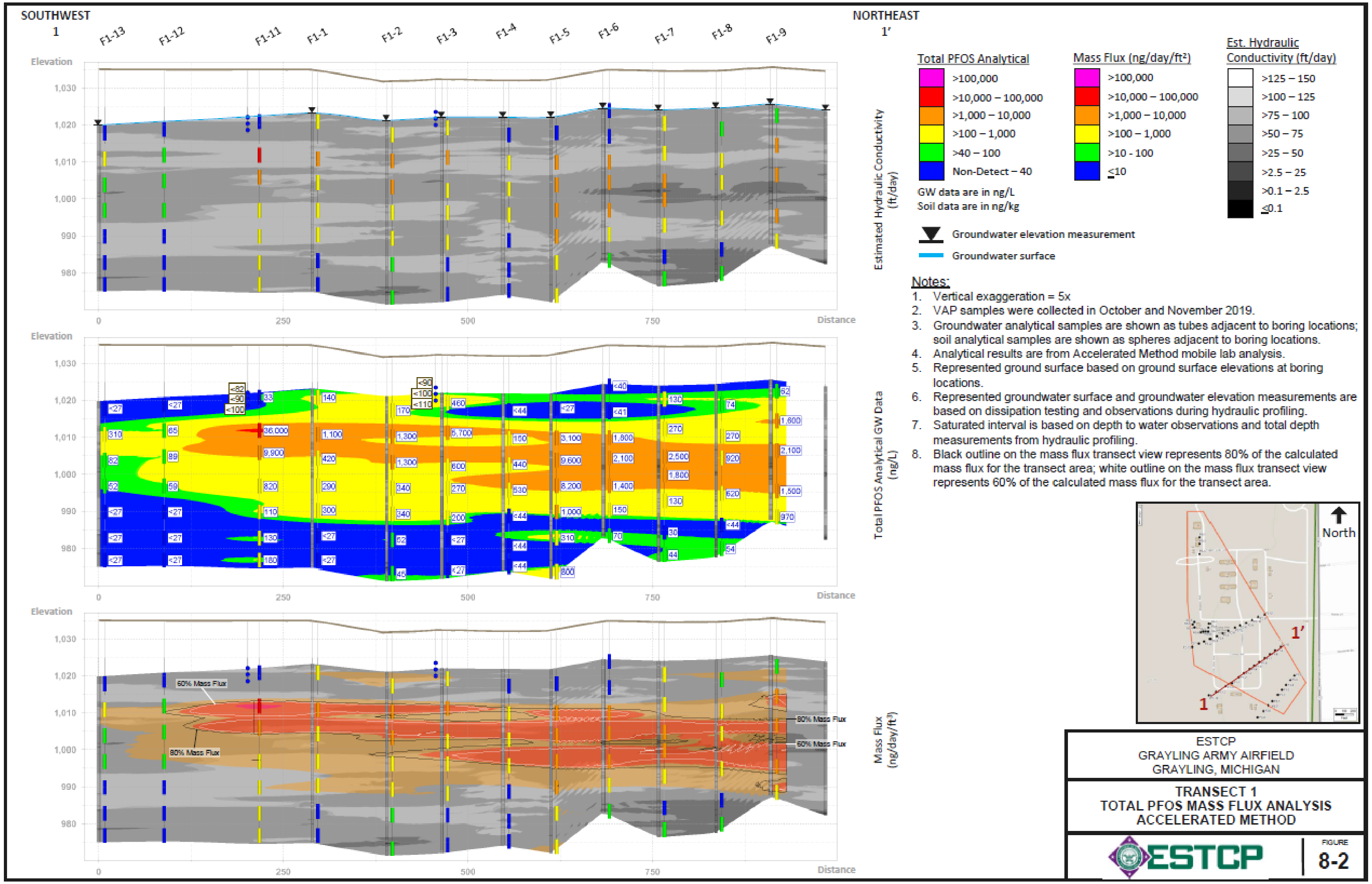
GRAYLING, MICHIGAN

TRANSECT 2
TOTAL PFOS MASS FLUX ANALYSIS
ACCELERATED METHOD

FIGURE
8-1

Figure 8-1. Transect 2 Total PFOS Mass Flux Analysis Accelerated Method



Notes:

1. Vertical exaggeration = 5x
2. VAP samples were collected in October and November 2019.
3. Groundwater analytical samples are shown as tubes adjacent to boring locations; soil analytical samples are shown as spheres adjacent to boring locations.
4. Analytical results are from Accelerated Method mobile lab analysis.
5. Represented ground surface based on ground surface elevations at boring locations.
6. Represented groundwater surface and groundwater elevation measurements are based on dissipation testing and observations during hydraulic profiling.
7. Saturated interval is based on depth to water observations and total depth measurements from hydraulic profiling.
8. Black outline on the mass flux transect view represents 80% of the calculated mass flux for the transect area; white outline on the mass flux transect view represents 60% of the calculated mass flux for the transect area.

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TRANSECT 1
TOTAL PFOS MASS FLUX ANALYSIS
ACCELERATED METHOD

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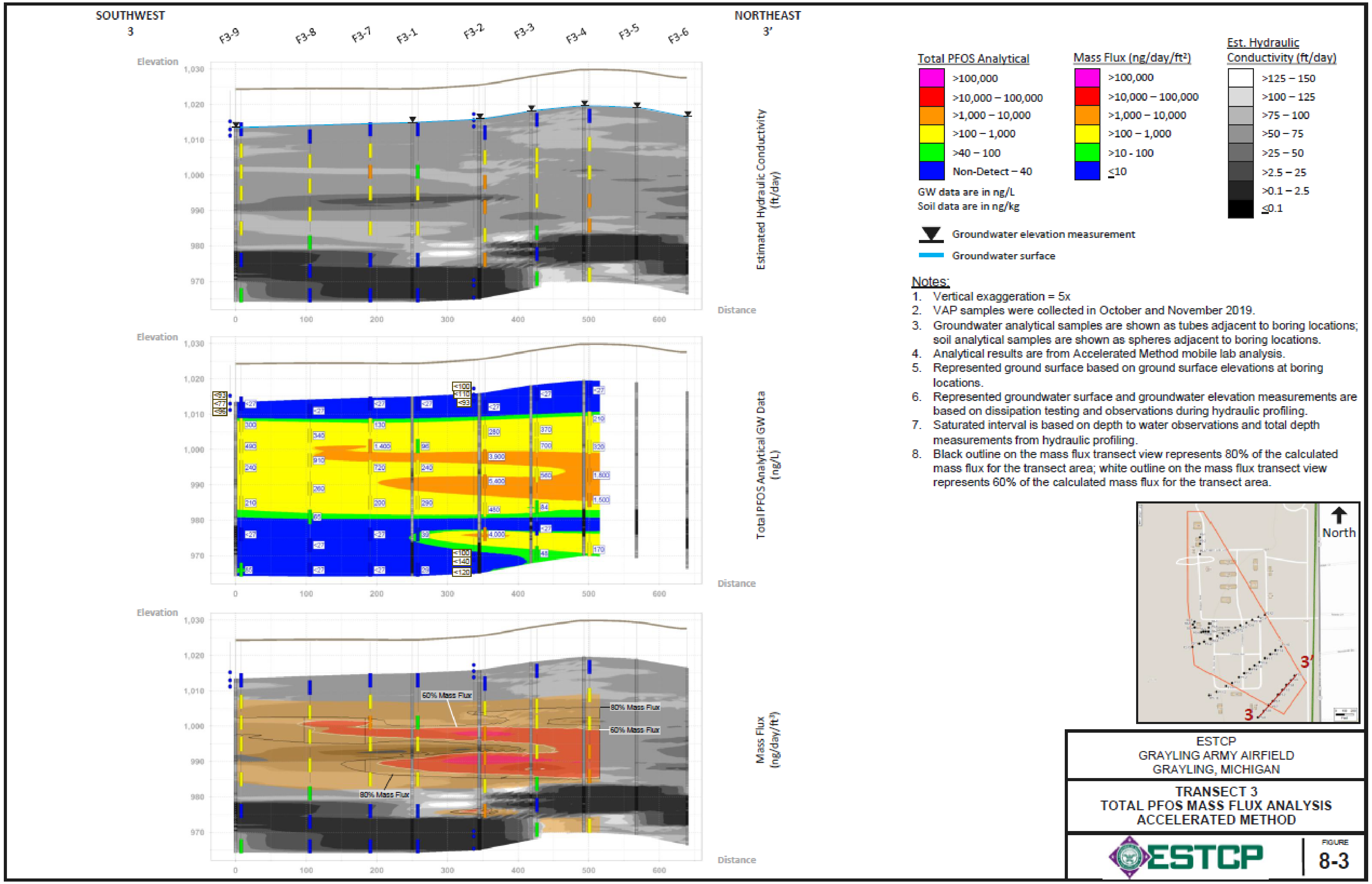
FIGURE
8-2

Figure 8-2. Transect 1 Total PFOS Mass Flux Analysis Accelerated Method



Notes:
1. Vertical exaggeration = 5x
2. VAP samples were collected in October and November 2019.
3. Groundwater analytical samples are shown as tubes adjacent to boring locations; soil analytical samples are shown as spheres adjacent to boring locations.
4. Analytical results are from Accelerated Method mobile lab analysis.
5. Represented ground surface based on ground surface elevations at boring locations.
6. Represented groundwater surface and groundwater elevation measurements are based on dissipation testing and observations during hydraulic profiling.
7. Saturated interval is based on depth to water observations and total depth measurements from hydraulic profiling.
8. Black outline on the mass flux transect view represents 80% of the calculated mass flux for the transect area; white outline on the mass flux transect view represents 60% of the calculated mass flux for the transect area.

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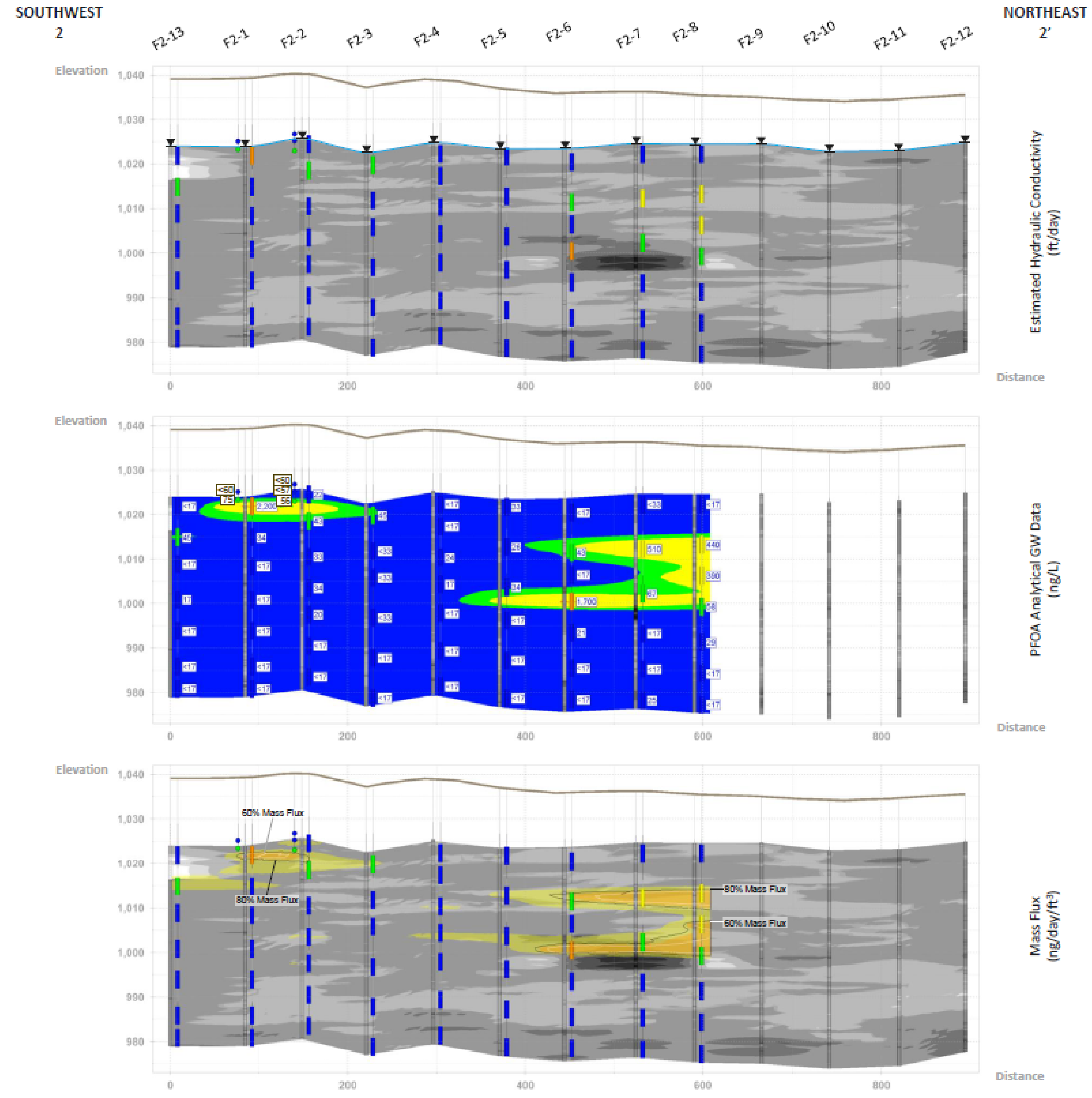
TRANSECT 3
TOTAL PFOS MASS FLUX ANALYSIS
ACCELERATED METHOD

ESTCP

FIGURE
8-3

Figure 8-3. Transect 3 Total PFOS Mass Flux Analysis Accelerated Method



PFOA Analytical
- 🟪 >100,000
- 🟥 >10,000 – 100,000
- 🟧 >1,000 – 10,000
- 🟨 >100 – 1,000
- 🟩 >40 – 100
- 🟦 Non-Detect – 40

GW data are in ng/L
Soil data are in ng/kg

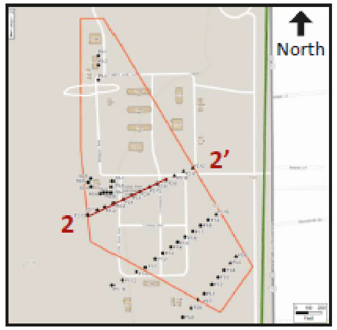
Mass Flux (ng/day/ft²)
- 🟪 >100,000
- 🟥 >10,000 – 100,000
- 🟧 >1,000 – 10,000
- 🟨 >100 – 1,000
- 🟩 >10 - 100
- 🟦 ≤10

Est. Hydraulic Conductivity (ft/day)
- ⬜ >125 – 150
- ▨ >100 – 125
- ▨ >75 – 100
- ▨ >50 – 75
- ▨ >25 – 50
- ▨ >2.5 – 25
- ⬛ >0.1 – 2.5
- ⬛ ≤0.1

▼ Groundwater elevation measurement

— Groundwater surface

Notes:
1. Vertical exaggeration = 5x
2. VAP samples were collected in October and November 2019.
3. Groundwater analytical samples are shown as tubes adjacent to boring locations; soil analytical samples are shown as spheres adjacent to boring locations.
4. Analytical results are from Accelerated Method mobile lab analysis.
5. Represented ground surface based on ground surface elevations at boring locations.
6. Represented groundwater surface and groundwater elevation measurements are based on dissipation testing and observations during hydraulic profiling.
7. Saturated interval is based on depth to water observations and total depth measurements from hydraulic profiling.
8. Black outline on the mass flux transect view represents 80% of the calculated mass flux for the transect area; white outline on the mass flux transect view represents 60% of the calculated mass flux for the transect area.



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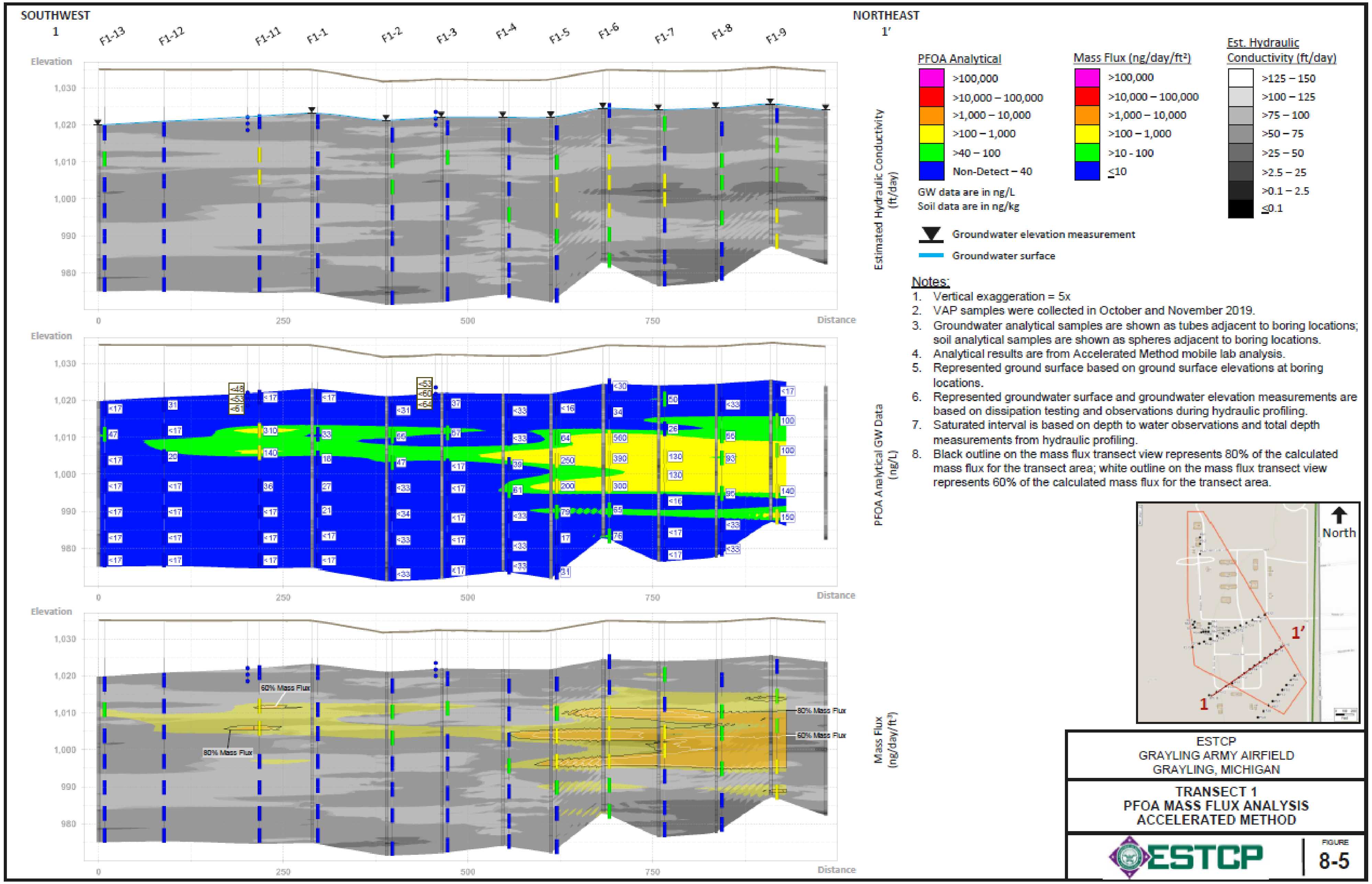
TRANSECT 2
PFOA MASS FLUX ANALYSIS
ACCELERATED METHOD

ESTCP

FIGURE
8-4

Figure 8-4. Transect 2 PFOA Mass Flux Analysis Accelerated Method



Notes:

1. Vertical exaggeration = 5x
2. VAP samples were collected in October and November 2019.
3. Groundwater analytical samples are shown as tubes adjacent to boring locations; soil analytical samples are shown as spheres adjacent to boring locations.
4. Analytical results are from Accelerated Method mobile lab analysis.
5. Represented ground surface based on ground surface elevations at boring locations.
6. Represented groundwater surface and groundwater elevation measurements are based on dissipation testing and observations during hydraulic profiling.
7. Saturated interval is based on depth to water observations and total depth measurements from hydraulic profiling.
8. Black outline on the mass flux transect view represents 80% of the calculated mass flux for the transect area; white outline on the mass flux transect view represents 60% of the calculated mass flux for the transect area.

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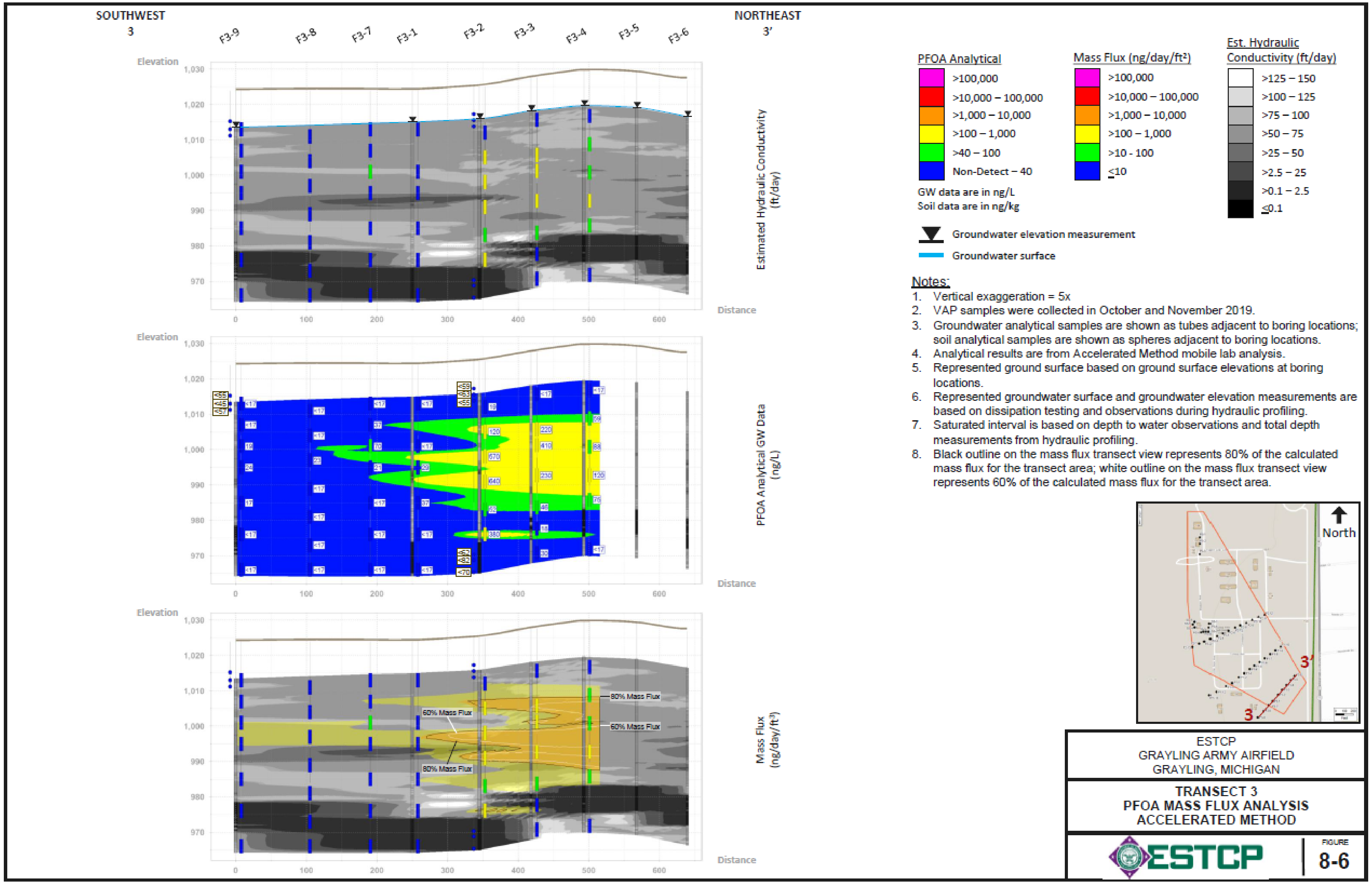
TRANSECT 1
PFOA MASS FLUX ANALYSIS
ACCELERATED METHOD

ESTCP
FIGURE
8-5

Figure 8-5. Transect 1 PFOA Mass Flux Analysis Accelerated Method



Notes:
1. Vertical exaggeration = 5x
2. VAP samples were collected in October and November 2019.
3. Groundwater analytical samples are shown as tubes adjacent to boring locations; soil analytical samples are shown as spheres adjacent to boring locations.
4. Analytical results are from Accelerated Method mobile lab analysis.
5. Represented ground surface based on ground surface elevations at boring locations.
6. Represented groundwater surface and groundwater elevation measurements are based on dissipation testing and observations during hydraulic profiling.
7. Saturated interval is based on depth to water observations and total depth measurements from hydraulic profiling.
8. Black outline on the mass flux transect view represents 80% of the calculated mass flux for the transect area; white outline on the mass flux transect view represents 60% of the calculated mass flux for the transect area.

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TRANSECT 3
PFOA MASS FLUX ANALYSIS
ACCELERATED METHOD

ESTCP
FIGURE
8-6

Figure 8-6. Transect 3 PFOA Mass Flux Analysis Accelerated Method

8.1.1 DoD ELAP Method Results

The PFOS flux analysis for Transect 2, nearest to the source areas, shows two distinct flux hotspots downgradient of the two source areas representing 80 percent of the mass flux that occurs on the transect. Both occur in advective sands and interbedded sands and silts. The PFOA distribution on Transect 2 is similar to that of PFOS (with two hotspots), although at orders of magnitude less than the PFOS estimated mass flux. The PFOS mass flux on Transect 1, within the center of the study area, is commingled but is focused on more permeable zones at depths between 25 and 40 feet bgs. Transect 3 shows a larger vertical distribution of mass flux, with complex stratification extending to depths up to 50 feet bgs.

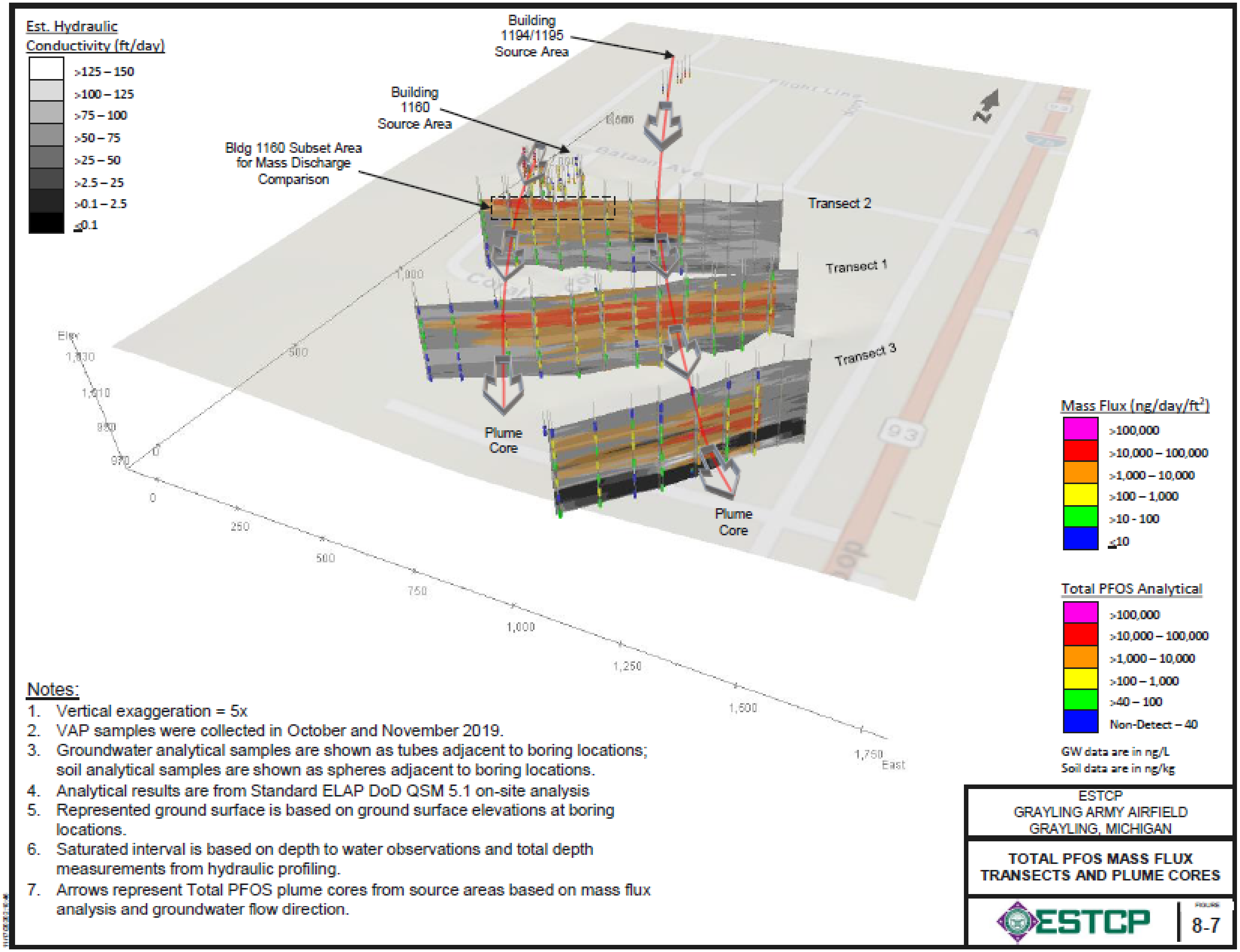
A 3D view of total PFOS flux along all three transects is provided as **Figure 8-7** and illustrates the gradual depth increase of the plume as it moves towards the eastern site boundary. A 3D view of PFOS flux along all three transects, provided as **Figure 8-7**, illustrates the gradual depth increase of the plume as it moves towards the eastern site boundary. The core of the plume originating from the source near Building 1160 is evident on Transects 1 and 2 moving south from the source area. However, as noted above, Transect 3 does not extend far enough to the southwest to show the plume originating near Building 1160. The plume core originating near Building 1194/95 is evident on all three transects. Very little mass flux occurs at depth along the transects where the permeability of the soil decreases and the concentrations are lower.

8.1.2 Accelerated Method Results

The Accelerated Method versions of the mass flux cross-sections are provided as **Figures 8-1** through **8-6**. Visual comparison of these results with the DoD ELAP Method results (**Figures 5-10** through **5-15**) enables a determination of whether the interpretation and field decisions would be the same and provides another measure of the utility of the Accelerated Method. As noted in **Section 7.5** above, statistically, the Accelerated Method results lead to the same field decision as the DoD ELAP Method results approximately 90 percent of the time. The standard and accelerated cross-sections are similar and show little difference in overall interpretation of mass distribution and mass flux with a few notable differences:

- Transect 2: Significant differences are noted at Boring F2-6 that create a different interpretation of the PFOS plume morphology and mass flux. Using the DoD ELAP Method, the PFOS concentrations at the 27- to 31- and 33- to 37-foot intervals are 660 and 210 ng/L (respectively), whereas using the Accelerated Method, the results are <27 and 2,500 ng/L. This result creates a vertically bifurcated plume at this interval where the DoD ELAP Method data suggest a consistent core. The PFAS results for the 33-37-foot interval using the Accelerated Method where noted as a statistical outlier as described further in **Section 7.3.1**.

- Transect 3: The total PFOS result from the Accelerated Method at F3_4_25-29 is 1,800 ng/L compared to 690 ng/L from the DoD ELAP Method, which results in a vertically bifurcated plume on the accelerated result (**Figure 5-12**). Also note that, within the same boring, the DoD ELAP Method detected higher concentrations at depth (350 and 110 ng/L) versus the <27 ng/L at both intervals reported using the Accelerated Method, which leads to less lateral extent of the yellow concentration band.



Notes:
1. Vertical exaggeration = 5x
2. VAP samples were collected in October and November 2019.
3. Groundwater analytical samples are shown as tubes adjacent to boring locations; soil analytical samples are shown as spheres adjacent to boring locations.
4. Analytical results are from Standard ELAP DoD QSM 5.1 on-site analysis
5. Represented ground surface is based on ground surface elevations at boring locations.
6. Saturated interval is based on depth to water observations and total depth measurements from hydraulic profiling.
7. Arrows represent Total PFOS plume cores from source areas based on mass flux analysis and groundwater flow direction.

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TOTAL PFOS MASS FLUX
TRANSECTS AND PLUME CORES

ESTCP
FIGURE
8-7

Figure 8-7. Total PFOS Mass Flux Transect and Plume Cores

In total, there were three Accelerated Method results out of 234 considered outliers for groundwater (VAP-F2-1 15-19, VAP-F3-8 33-37, and VAP-F3-8 25-29). Overall, this result shows that using the additional throughput and shorter TATs of the Accelerated Method does not substantially change the outcome of the investigation. The general shape and magnitude of core PFOS concentrations are quite similar. The increased throughput using the Accelerated Method is better suited and more cost-effective for adaptive PFAS investigations.

8.2 MASS DISCHARGE AND SOURCE MASS LOADING EVALUATION

The nodal data from the mass flux model were summed to estimate a total mass discharge along each transect. The analysis assumes an equidistant grid cell spacing in the model, transects perpendicular to groundwater flow, and an average hydraulic gradient of 0.005 ft/ft from available groundwater flow measurements. **Table 8-1** summarizes the estimated mass discharge for Total PFOS and PFOA using the DoD ELAP and Accelerated Methods.

The groundwater discharge on Transects 1 and 2 are similar based on the ratio of flow to cross-sectional area, indicating that the average K is similar on both sections. The groundwater discharge on Transect 3 is lower by approximately 20 percent relative to cross-sectional area, indicating lower K, consistent with the CSM.

As **Table 8-1** indicates, the PFOS mass discharge is greatest on Transect 1, which is also the longest transect and spans sections of both groundwater plumes. The lowest PFOS mass discharge is along Transect 3, which is the furthest from the source areas, covers the smallest cross-section area, and does not intersect the core of the plume from the Building 1160 source. Of note, although Transects 2 and 3 are similar cross-sectional areas, and Transect 2 intersects both plumes, the PFOA mass discharge is higher at Transect 3 located furthest downgradient. The increasing concentrations of PFOA with distance are likely due to the higher relative mobility of PFOA compared to PFOS. The PFOA distribution supports the conclusion of a mature plume with the highest concentrations shifted downgradient of a largely depleted source area (i.e., Building 1160). As noted above, this conclusion is also supported by the age of the source area (at least 30 years) and source sampling that shows an order of magnitude lower concentration of PFAS in groundwater/pore-water than observed downgradient at Transects 1 and 2.

Similar to the mass flux evaluation, the comparison of the mass discharge calculated from mobile laboratory data using the DoD ELAP Method to the Accelerated Method suggest little difference in the interpretation – typically a few milligrams/day (mg/d). The largest difference occurs for total PFOS at Transect 3, which is 98 versus 81 mg/day (17 percent). This difference is associated with the generally higher concentrations observed at a number of samples across Transect 3 from the Accelerated Method.

Table 8-1. Summary of PFAS Mass Discharge Estimates

Location	GW Gradient	Cross Sectional Area	GW Discharge forCross Sectional Area	Total Mass Discharge for Cross Sectional Area			
				Total PFOS		PFOA	
				DoD ELAP Method	Accelerated method	DoD ELAP Method	Accelerated method
	ft/ft	ft^2	gpm	mg/day	mg/day	mg/day	mg/day
Transect 1	0.005	43,543	78.87	229	221	14	13
Transect 2		28,312	51.57	126	124	6	4
Transect 3		23,604	35.46	81	98	10	11
Building 1160 Source Area		4,549	8.60	61	71	1.1	0.6

Notes:
ft/ft = foot per foot
ft^2 = square foot
gpm = gallon per minute
mg/day = milligram per day
PFOA = perfluorooctanoic acid
PFOS = perfluorooctane sulfonate

Mass discharge calculations in this workbook reflect maximum concentrations from parent/duplicate sample pairs

8.2.1 Building 1160 Source Mass Loading

Although the lysimeter borings and soil borings were proximal (~2 to 3 feet apart), the concentrations in soil observed at each boring and at similar depths varied considerably. For example, the 5.5 to 6 foot bgs sample interval yielded a total PFOS concentration of 560,000 ng/kg at SB-SS-6 but was 11,000 ng/kg at LS-1R. A similar result was observed at LS-3R/SB-SS-5 at 3.5 to 4 feet bgs (6,500/190,000 ng/kg). These results reflect the heterogeneity of the PFAS source distribution in vadose zone soil. Also, note that the objective of the source work completed at Building 1160 was to measure source strength, not to delineate; therefore, the footprint of the Building 1160 source area is unknown. The locations and results of the soil, SPLP, pore-water, and shallow groundwater samples are summarized on **Figure 5-6** for total PFOS and **Figure 5-7** for PFOA. Lysimeter and SPLP analytical reports are provided as part of **Appendix J**. In general, the concentrations of PFOS observed in pore-water and SPLP samples were similar to shallow groundwater concentrations below the source area, except for pore-water at LS-2R, which was 96 ng/L for pore-water versus 2,400 ng/L in shallow groundwater. This may be due to dilution from the high rate of simulated rainfall applied to this location during sampling (2 inches/30 minutes).

As shown on **Figures 5-6** and **5-7**, the lysimeter results and the SPLP results provide similar concentrations for PFOS leachate (except for LS-2R). The average concentration indicated by the lysimeter results is 3,700 ng/L. The nine SPLP samples collected from the source area provide an average PFOS concentration of 2,800 ng/L. The current mass discharge (M/T) from the source can be estimated based on an assumption of source area, the average annual net recharge accounting for evapotranspiration losses for the region (8.3 inches [USGS 1997]), and the estimated leaching concentration such that:

$$\text{Area (ft}^2\text{)} * \text{Recharge (ft}^3\text{)} * \text{Concentration (ng/ft}^3\text{)}$$

Using the average lysimeter PFOS results as the representative leaching concentration, and assuming an area of source to be approximately 5000 ft^2, the mass discharge through the source area is approximately 0.4 gram per year or 1.1 mg/day.

To refine the comparison of the source mass discharge from the Building 1160 area and the mass discharge on Transect 2, the mass discharge on Transect 2 was estimated for a subset of the nodal data centered around the apparent core of the PFOS plume originating near Building 1160 (Boring F2-1 with a concentration of 31,000 ng/L PFOS). The subset mass discharge area is shown on **Figure 5-1**. As noted above, the estimated mass discharge from the Building 1160 source area is estimated at 1.1 mg/day. The mass discharge from the subset area on Transect 2 is estimated to be approximately 61 mg/day, substantially higher than the source loading estimate. This is also consistent with the order of magnitude increase in groundwater concentration moving downgradient of the source area and suggests two potential interpretations:

1. The source area is depleted of PFOS mass relative to the initial loading provided to the aquifer during and immediately following release. This is consistent with the age of the release (>30 years) and sandy soils, which promote flushing of the vadose zone.
2. The source is larger than assumed, and/or at higher concentration than estimated based on the four borings completed in the presumed release area. Tracing the apparent core of the plume originating near Building 1160 back to the source area (**Figure 5-1**) suggests that additional PFAS mass may be present west of the area investigated.

8.2.2 Soil-Groundwater Partitioning

Anderson et al. (2019) have used data from ongoing site investigations at U.S. Air Force sites to evaluate primary factors associated with PFAS partitioning from source area soils to groundwater. The primary basis of comparison for the study was soil-to-groundwater concentration ratio ($\gamma_{Soil\text{-}GW}$), which was then regressed against select soil and chemical properties such as clay content and total organic carbon. Based on this approach, partitioning ratios were developed for collocated soil to SPLP results, collocated soil to pore-water results, and the maximum concentration collected in a vadose zone to groundwater at the water table and summarized in **Table 8-2**.

Table 8-2. Summary of Total PFOS Partitioning Ratios – USEPA Method 537, DoD QSM 5.3

Partitioning Ratios – PFOS (USEPA Method 537, DoD QSM 5.3)			
Sample	**Collocated Soil to SPLP (max)**	**Collocated Soil to Pore-Water**	**Max Soil to Groundwater**
LS-1R (SS-6)	17	14	267
LS-3R [LS-4R] (SS-5)	25	38	475
LS-2R (SS-4)	26	531	36

The ratios derived for SPLP and lysimeter data are similar and range from 14 to 38, except for LS-2R. At location LS-2R, the pore-water concentration was very low relative to the collocated soil and may be anomalous. The ratios of maximum soil concentration to shallow groundwater are higher and reflect the seasonal and intermittent nature of vadose zone source mass loading and dilution due to (relatively) clean groundwater flowing into the source area from upgradient. LS-2R is located on the downgradient side of the Building 1160 source area, and groundwater concentrations are higher relative to collocated soil samples.

8.3 SUMMARY

Based on the mobile lab field application approach outlined above in **Section 2.0** and the stratigraphic flux analysis results provided above, the following provides a summary of the key takeaways:

<u>Hydrostratigraphy:</u> The HPT data collected within the Building 1160 source area and downgradient illustrate alternating sequences of slightly higher and lower permeability intervals that mark shifting conditions associated with glacial retreat and outwash. The Est K provided by the HPT typically ranges from 35 to >75 ft/day through the upper 60 feet of aquifer, with lower-permeability silty and clayey sediments encountered in isolated zones and at depth near the GAAF southeast boundary (Transect 3).

- Within the range of the HPT tool (0.1 to 75 ft/day), the evaluation of the grain size data correlates well to HPT Est K. Where Est K was observed at 75 ft/day or greater, the actual K of the aquifer may be higher by a factor of 2 or more based on the range of K derived from sieve analyses.

Source Characterization: Soil samples were collected from source area borings to evaluate source strength as well as at key locations downgradient to evaluate potential mass storage within the capillary fringe and low-permeability zones.

- High concentrations of PFOS were observed in the vadose zone on the west side of Building 1160 (up to 560,000 ng/kg).
- Pore-water collected with ceramic cup suction lysimeters and collocated soil SPLP results yielded similar concentrations for PFOS leachate.
- For downgradient soil sampling locations, PFOS and PFOA were not detected in the capillary fringe samples likely due to the shallow, unconfined conditions and sandy soil that promotes vadose flushing during groundwater recharge.

Mass Flux: The hydrostratigraphy at the site is dominated by advective transport with only a few zones, suggesting lower-permeability slow advection. Mass flux along each transect was estimated based on the HPT Est K and the total PFOS and PFOA concentration data provided by the mobile lab using the DoD ELAP Method results.

- The relative homogeneity of the GAAF hydrostratigraphy, coupled with the limited effective range of the Est K, results in a stratigraphic flux model with distribution similar to that of a model based on the VAP concentration alone.
- The total PFOS mass flux nearest to the source areas show two distinct flux hotspots downgradient of the two source areas (Building 1160 and Building 1195) representing 80 percent of the mass flux that occurs on the transect.
- The core of the total PFOS plume originating from the source near Building 1160 is evident on Transects 1 and 2 moving southeast from the source area. However, Transect 3 does not extend far enough to the southwest to show the plume. The Building 1194/95 area source plume core is evident on all three transects.
- Moving downgradient, the mass distribution becomes more commingled and vertically distributed at depth as the plumes approach the southeast GAAF boundary.
- The PFOA distribution on the transects is similar to that of PFOS, although at one to two orders of magnitude lower than the PFOS estimated mass flux.

Mass Discharge: The mass discharge at the Building 1160 source area was estimated based on an assumed areal extent of impacts, the average annual groundwater recharge, and the average pore-water concentration from lysimeter sampling.

- Results show that the source mass discharge is significantly lower than the mass discharge estimated from the HPT/VAP results along Transect 2, consistent with the higher concentrations observed in shallow groundwater downgradient relative to the source area.
- The evaluation suggests that the source area is: 1) larger, or at a higher concentration, than estimated based on the results of this study or 2) that the source area is relatively depleted of PFAS mass, and the majority of the associated mass is currently located downgradient. The latter would be consistent with the age of the release (>30 years).

- Using an approach similar to that of Andersen et al. (2019), the ratio of SPLP to collocated soil concentration and lysimeter/soil are similar and range from 14 to 38. Ratios of maximum soil concentration to shallow groundwater are higher and reflect the seasonal and intermittent nature of source mass discharge and dilution due to (relatively) clean groundwater flowing into the source area from upgradient.

Mass Flux/Mass Discharge Analytical Method Comparison: The nodal data from the EVS mass flux model were summed to estimate a total mass discharge along each transect using both the mobile lab DoD ELAP Method analytical results and those from the Accelerated Method.

- Comparison of the DoD ELAP and Accelerated Method mass flux cross-sections shows that they are similar with some local variation on Transects 2 and 3 that modify the plume core and mass flux interpretation.
- Similarly, comparison of the mass discharge calculated from DoD ELAP and Accelerated Methods are not substantially different, typically within 5 percent. The exception is the PFOS concentration on Transect 3, where the Accelerated Method suggests a 17 percent increase in mass discharge. This difference is associated with the generally higher concentrations observed at several samples across Transect 3.
- These result show that Accelerated Method does not substantially change the interpretations that would be made in the field under an adaptive stratigraphic flux approach. The fact that the concentration distributions, mass flux distributions, and mass discharge estimates are similar underscores the utility of the approach. The higher throughput and faster analysis associated with the Accelerated Method make the approach better suited and more cost-effective for adaptive PFAS investigations than the DoD ELAP Method.

9.0 RECOMMENDATIONS FOR APPLICATIONS IN REMEDIAL INVESTIGATION

The following section offers recommendations for application of the mobile lab approach for PFAS RI work. The primary elements considered for these recommendations are the project-specific DQOs, sampling strategies, and overall project costs.

9.1 DOD ELAP METHOD APPROACH

Given the relatively low throughput and higher cost per sample associated with the mobile laboratory's DoD ELAP Method, the following characteristics of projects would benefit most from this analytical program:

- Sample production fewer than 15 samples per day
- DQOs that require definitive analytical data because the project team needs to make final decisions (as opposed to intermediate) that carry a high risk (and cost) if the decision is incorrect
- Fast TATs are required to accelerate project tasks and minimize project costs related to expensive deep drilling or remediation operations. The balance is the relatively high unit sample cost versus the cost of equipment standby. In these examples, it is assumed that next-day results, as opposed to a 3-day TAT at a fixed lab, will allow project work to progress more efficiently and with minimized down time.

Although the cost per analysis may be higher than that of a fixed lab for fast-turnaround work, the overall project costs can be greatly reduced by streamlining the site activities. Examples of these projects would be as follow:

- Deep bedrock groundwater sampling programs in which expensive drilling and sampling techniques are being deployed. In some cases, the monitoring systems are built as the drilling tooling is retrieved from the borehole. These sampling programs often do not produce more than 10 samples per day and, to provide maximum certainty regarding where in the borehole to set monitoring intervals, a definitive dataset is often deemed critical. If a fixed lab were to be used for providing these definitive data, there would be significant down time and expenses incurred while the project team waited for the analytical data.
- Sampling and analytical programs associated with a remediation program that is segregating clean from impacted soil as the remedy is in production. Here, definitive data are needed for compliance reasons and to prevent the project team from having to wait several days for definitive data from a fixed lab, which can lead to significant costs.

9.2 ACCELERATED METHOD

Given the relatively high throughput and lower cost of this screening method, the following are characteristics of projects that would benefit most from this analytical program:

- Sample production more than 20 samples per day

- DQOs that will allow for a screening level of analysis to support the decisions being made by the project team. These decisions are intermediate (not final) in nature, and the risk associated with making an incorrect decision is low enough that the more economical screening-level analysis is warranted. This concept of using screening data for making intermediate decisions was established by the Uniformed Federal Policy for Quality Assurance Project Plans (UFP-QAPP; USEPA 2005).

As illustrated with the DoD ELAP analytical program, the benefit of streamlining and compressing project schedules is that it can greatly reduce project costs. Examples of these projects would be as follow:

- Shallow high-resolution site characterization (HRSC) soil and groundwater investigation targeting source zones and related downgradient plumes or large-scale investigations with multiple drill rigs. These sampling programs can produce a high volume of soil and groundwater samples and rely on timely data to guide sampling teams as they evaluate source area impacts and characterize the distribution of contamination. The Accelerated Method is designed to accommodate both matrices using a single calibration curve and hence will not experience down time associated with any recalibration when the sampling team switches matrix. The sampling systems often involve nimble drilling platforms that can quickly move on and off boreholes as the sampling team reacts to the incoming data. As with other screening analytical techniques, the data need to be corroborated via definitive analytical data (DoD ELAP Method). The definitive data serve the purpose of verifying the accuracy of the screening data, providing full list of Table B-15 composition and samples to support final decision-making such as delineation and risk assessment. This example is further illustrated in **Section 9.3**, in which cost and performance are assessed.
- Optimization of on-site treatment system. On-site treatment processes must manage a wide range of contaminant concentrations and soil characteristics. Access to rapid analytical testing would provide the feedback to evaluate whether treatment objectives are met, enabling one to segregate soils that meet objectives from those that do not, providing a feedback loop to optimize treatment process. Examples could include on-site thermal, soil washing, or even excavation management. Having timely and accurate data to measure the performance over short intervals is critical to quickly and cost-effectively achieve optimal performance.

9.3 COST AND PERFORMANCE COMPARISON TO FIXED LABORATORY ANALYSIS

The following discussion is intended to provide a holistic comparison of costs related to application of the mobile lab definitive (DoD ELAP) and Accelerated Methods for screening. The examples illustrate different mobile lab strategies to cost-effectively conduct near real-time adaptive HRSC characterization. Note that this approach has several advantages over conventional remedial investigations, which consist of several iterative phases of work plans, investigation, data evaluation, and reporting. Conventional RIs often require 5 years to complete, which adds administrative costs that only increase the total cost of the investigation process. Application of the stratigraphic flux approach provides a flux-based CSM that can rank and prioritize sources, map migration pathways relative to site stratigraphy, and enable better decisions regarding source control/treatment to mitigate off-site migration and protect drinking water receptors.

This approach is consistent with the objectives of the Air Force Phase I RI program that is being implemented in its first tranche of RIs.

Adaptive TRIAD investigations often rely on field screening or direct sensing methods such as the membrane interface probe (MIP) for chlorinated solvents or the ultraviolet optical screening test (UVOST) for petroleum hydrocarbon non-aqueous phase liquids (NAPLs). These tools provide qualitative screening for gross impacts at sources, but do not speciate individual compounds or have the sensitivity to delineate groundwater impacts at concentrations relevant to maximum contaminant levels (MCLs). Mobile labs have been applied for the characterization of chlorinated solvents and 1,4-dioxane, providing sensitivity and selectivity to quantify individual compounds both at sources and for groundwater delineation to MCL levels. Currently, no real-time screening tool offers the combination of selectivity and sensitivity needed to meet both objectives at AFFF release sites except the PFAS mobile lab. While fixed laboratory analysis can be rushed on accelerated TATs, access to results is limited based on lab capacity and shipping, which leads to 3- to 5-day TATs at best.

In the follow discussion, we compare three modes of completing adaptive characterization at AFFF-related investigations:

1. All fixed lab services with DoD ELAP Method and quick TAT analyses
2. All mobile lab with definitive DoD ELAP Method analyses
3. Collaborative approach - Accelerated Method screening/DoD ELAP Method fixed lab confirmation analyses.

The work in each case involves an HRSC program conducted using an adaptive work strategy. The total number of samples is 400; this sample count is kept constant so that the work product is essentially the same in that the same level of site understanding is gained by each of the three scenarios. The variables that change with the changing lab programs are the staff and drilling resources and the duration of the programs. The factors are applied to enable comparison of the total cost of investigation.

9.3.1 Scenario #1 – All Fixed Lab Analyses

The total site investigation cost for this scenario is $322,600, and the cost per sample is $514. The cost per sample includes the analytical and shipping costs.

Pro:

- All data are definitive.

Cons:

- Adaptability is less than optimal due to 3-day wait for results, which will limit efficiencies, especially in the latter stages of the program.
- This scenario carries the highest risk of losing samples in transit to lab.
- This scenario requires the highest level of effort for sampling logistics with shipping all samples to the lab.

- The cost for this scenario is $90K higher than Scenario #3.
- The duration of the project is 16 days, plus 3 days for final results.

9.3.2 Scenario #2 – All Mobile Lab Definitive Analyses

The total site investigation cost for this scenario is $291,200, and the cost per sample is $450. The cost per sample includes mobilization and 31 days of on-site analysis by the mobile lab. The duration of the project is limited based on the average capacity of the mobile lab of 13 samples per day.

Pros:

- All data are definitive.
- Next-day results are available, maximizing the adaptive nature of sampling work.

Con:

- This scenario carries the longest duration and is limited by capacity of the mobile lab.

9.3.3 Scenario #3 – Collaborative Screening/Definitive Analyses

The total site investigation cost for this scenario is $233,800, and the cost per sample is $292. The cost per sample includes shipping and fixed lab analysis at regular TAT plus mobile lab mobilization and 16 days for on-site analyses and provisions for data comparison/statistics. Twenty percent of the samples are duplicated for fixed lab analysis when final decisions are required, including surficial soil samples for risk assessment and delineation of soil and groundwater impacts. This also includes 5 percent duplicates for QA/QC on the accelerated method.

Pros:

- This scenario carries the lowest cost. It costs $90K less than Scenario #1 and almost $60K less than Scenario #2.
- This scenario carries the shortest duration, as there is no lag for final results.
- This scenario provides the fastest TATs. It allows for maximum adaptability.

Cons:

- This scenario provides 80 definitive level results compared to 400 in other scenarios.
- Extra effort is needed to compare screening and definitive data.

9.4 SUMMARY

The forgoing examples illustrate the total costs and cost per sample for completing an adaptive HRSC project using fixed lab, mobile lab for DoD ELAP Method, and a collaboration approach using fixed lab and the mobile lab for screening. **Table 9-1** summarizes the assumptions and costs related to the implementation of the three scenarios.

Table 9-1. Mobile Lab Investigation Cost Scenarios Summary

Item	Duration of work (days)	# samples	Cost Units	# Units	Cost per Unit	Cost	Pros	Cons
Cost Scenario #1 Definitive Off-site - Prescriptive and adaptive phase with fixed lab, quick turns - 25 samples per day							Pros	Cons
Full 24 compound List								
Item	Duration of work (days)	# samples	Cost Units	# Units	Cost per Unit	Cost		
								Two days TAT for cost, closer to three with shipping
Drilliing mobe/demobe			LS	2	$2,500	$5,000		
Drilling - 2 rigs	16	NA	days	16	$4,600	$73,600	All data definitive	Limited adaptability
Sampling	16	400	day/2 staff	16	$2,400	$38,400		Reduced sampling time due to sample shipping
Definitive Analytical, 2-day TAT	NA	400	sample	400	$500	$200,000		Risk of losing samples
Shipping		400	per coooler	16	$350	$5,600		
25 samples collected per day, need time at end of day to write COCs, package and send samples								
					Total For Investigation	$ 322,600.00		
					Cost per sample - includes sampling and analytical	$514		
Cost Scenario #2 - Definitive On-site - Dynamic sampling with onsite DoD ELAP Method - 13 samples per day							Pros	Cons
Full 24 compound List								
Item	Duration of work (days)	# samples	Cost Units	# Units	Cost per Unit	Cost		Moderate cost
Drilliing mobe/demobe			LS	1	$2,500	$2,500		
Drilling 1 rig	31	NA	days	31	$2,300	$71,300	All data definitive Results in less than 24 hours	Duration of project limited by lab throughput
Sampling	31	400	day/staff	31	$1,200	$37,200		
Lab mobe/demobe			LS	1	$3,500	$3,500		
Definitive Analytical - 13/day	31	400	sample	31	$5,700	$176,700		
13 samples collected per day, to match lab productivity								
					Total For Investigation	$ 291,200.00		
					Cost per sample - includes sampling and analytical	$ 450.50		
Cost Scenario #3 - Screening/Definitive - Dynamic sampling with onsite lab screening/definitive Methods - 25 samples per day							Pros	Cons
PFOS/PFOA and several additional site-specific PFAS								
Item	Duration of work	# samples	Cost Units	# Units	Cost per Unit	Cost	Lowest cost	Limited definitive data
								Risk of losing samples that are sent to fixed lab
Drilliing mobe/demobe			LS	2	$2,500	$5,000		
Drilling - 2 rigs	Duration of work (days)	NA	days	16	$4,600	$73,600	Shortest duration	Most up-front planning needed
Sampling	16	400	day/2 staff	16	$2,400	$38,400	Most adaptive approach	More effort to compare data sets
Lab mobe/demobe			LS	1	$3,500	$3,500		
Screening Analytical - 25/day	16	400	sample	16	$5,500	$88,000		
Definitive Analytical (20%)	NA	80	sample	80	$200	$16,000		
Shipping - every two days		400	per coooler	8	$350	$2,800		
Data Comparison/statistics				1	$6,500	$6,500		
25 samples collected per day, accelerated method can keep up with this.								
					Total For Investigation	$ 233,800.00		
					Cost per sample - includes sampling and analytical	$ 292.00		

All scenarios collect 400 samples

In conclusion, the scenarios above result in the following points regarding using the three different analytical approaches to support an HRSC program:

- Scenario #3: The collaborative approach provides the lowest cost solution for conducting an adaptive HRSC investigation. It provides sampling coverage equal to those of the other two scenarios and with sufficient definitive data to address the compliance requirements for the site. Because this approach can provide data on the same day, the collaborate approach facilitates the most adaptive result. Based on a $90k cost difference between Scenarios 1 and 3, this approach could facilitate more than 6 extra days of sampling, or 550 samples total; 38 percent more than Scenario 1 at the same total cost. This costing does not consider the other project costs that can be minimized via reduced down time and standby costs associated with other site activities (e.g., drilling, sampling, remediation equipment) that may be waiting for time-sensitive data. These costs savings can be significant and have been demonstrated to be in the range of 30 to 50 percent (USEPA 2001).

- Scenario #1: All Fixed-Lab Definitive Analyses. This scenario represents the most expensive of the three approaches and, due to the longer TATs of the fixed lab, it would be difficult to conduct an efficient adaptive work strategy for the entire project. Adaptive work strategies often have a set number of prescriptive sampling locations as well as “step-out” locations that represent the adaptive portion of the work. During the earlier portions of the program, where both the prescriptive and “step-out” locations are being sampled, this delay in obtaining results would be manageable; however, as one reaches the latter portion of the field work, where there are no more prescriptive locations, the sampling team would likely experience delays as they wait for the information to determine if they have to step out further to fully delineate the contamination.

- Scenario # 2: All Definitive Mobile Lab Analyses. Given the parameters of this site work, this scenario is less costly than scenario #1 but is approximately $60K more than scenario #3. This scenario is the longest in duration. As mentioned above, the mobile lab in definitive analyses mode is more suited to sampling projects where the sampling load is fewer than 15 samples per day and the decisions being made at the site need to be final in nature.

In summary, for the given set of project conditions, Scenario #3 – Collaborative Approach will likely provide the best value for conducting this type of investigation. Each project will have its own unique set of conditions therefore it is strongly recommended that the project planning phases include an exercise such as this to ensure that the most appropriate analytical program is used. Considering the scale of RIs at DoD facilities, the collaborative approach is best suited to enable the real-time, adaptive characterization while also providing definitive data required for risk assessment, delineation and final decision making. The collaborative approach is planned for further evaluation at four Air Force Phase I PFAS RIs, which are designed to delineate AFFF-related impacts, evaluate source strength, and enable earlier decision making regarding source treatment and hydraulic containment strategies.

10.0 LESSONS LEARNED

Demonstration of the PFAS mobile lab at Camp Grayling provided lessons learned that can benefit practitioners who are considering its application as part of PFAS remedial investigations. Key lessons learned are presented in the following sections.

10.1 IMPLEMENTATION

The key to maximizing the benefit of the of the mobile lab is planning and workflow when implementing the DoD ELAP method. Because the definitive method requires calibration before switching between media (i.e., soil and water testing), it is critical to minimize switching media to minimize downtime for calibration. The team recognized this early on and it was an important factor in improving throughput and testing production rates._After the first week, during which both water and soil samples were analyzed, the laboratory analyzed only water samples during weeks 2, 3, and 4 and did not switch back to soil analyses until the last week, when the soil sample results became priority for the project team. This allowed the lab to continue operations without the need for multiple calibrations.

10.2 ANALYTICAL

10.2.1 DoD ELAP Method

The primary lessons learned associated with the implementation of the DoD ELAP Method were associated with the laboratory procedures and method parameters that impacted the productivity and data quality of the analytical work.

Productivity: During the early stages of this work, the analytical team encountered and subsequently solved several challenges that were causing delays in the program. Specifically, these matters fall under the following three items: 1) management of sediment in samples; 2) SPE capacity and 3) prioritization/sequencing of sample analyses (as discussed above in section 10.1, Implementation).

The first challenge encountered as part of this work was associated with the high levels of sediment present in the groundwater samples. As mentioned earlier in this report, this sediment caused significant delays in the solid phase extraction step of the analytical procedure and it is also believed that the sediment caused a matrix affect that led to QC outages. The analytical team dealt with this problem by allowing the samples to settle overnight however, it was deemed that a more efficient way to overcome the sediment was to have a centrifuge capable of handling 125mL containers present in the lab. This centrifuge has since been added to the laboratory's equipment.

Related to this sediment issue, were the delays caused by the turbid water as they were brought through the SPE process. To overcome this, capacity was added to the SPE system by reconfiguring the equipment within the manifold and adding a second SPE manifold; this led to an increase of approximately 100 percent (from ten to 20) in the number of samples that could be extracted in a given analytical batch.

Overall, the improvements made to the analytical program led to an increase in productivity for preliminary results from six samples per day during week 1 to a maximum of 17 samples per day during week 4 of the program.

Data Quality and Method Improvements: Although the analytical work was conducted largely within the QA/QC parameters set forth for this work, the analytical team observed that certain compounds for certain QC tests were falling outside of the acceptable tolerances. The most frequent outages were associated with the EIS recoveries for several compounds (i.e., MPFBA, MDPDoA and M2PFTeDA); this caused excessive rework for the laboratory team and delays with reporting. Recommended solutions for overcoming these EIS challenges include modifying extraction solvent ratios and re-assignment of EISs to compounds with more similar structure. Additionally, to improve overall performance, more frequent multiple reaction monitoring (MRM) optimizations are recommended along with reconfiguring the LC/MS/MS system to include a diverter valve which will divert unwanted matrix before and after elution of the compounds of interest. Further details are provided in Section 6-5, Recommendations for Method Improvements. Several of these method improvements have been successfully implemented since the time of this work.

10.2.2 Accelerated Method

The primary lesson learned associated with the Accelerated Method was related to the likelihood of needing lower detection limits for future projects. The water detection limits for this method are higher than that of the DoD ELAP Method and what fixed labs are offering. The Accelerated Method detection limits were deemed adequate for this work which was using the DoD's OSD screening levels as the benchmark for decision making. However, as this PFAS problem evolves there will likely be scenarios at future sites where lower levels of detection will be needed. Currently, the Accelerated Method protocol is such that data below the LOQ are not reported. In the future, and where needed, having the ability to report down the MDL will likely be needed to satisfy project needs. The primary cause for the elevated LOQs for this work was attributed to background contamination found in the solvents and materials used for this work. To solve this, Pace has been working (since the time of this analytical work) with several suppliers of these solvents and materials to obtain the cleanest products possible to allow for lower limits of detection. Additional information regarding recommendation for method improvements for this method are provided in Section, 6.5 Recommendations for Future Method Improvements.

10.3 METHOD COMPARISON AND VALIDATION

Traditionally, the validation of a screening method against a definitive method is often limited to correlation statistics and RPD calculations. Because the success of real-time characterization using a mobile lab is measured by the decisions made in the field, the team included three additional metrics: a reliability in making decisions, visual comparison of interpreted mass flux, and calculated mass discharge metrics. The results of these additional evaluations were found to be very powerful for further supporting the utility and reliability of the Accelerated Method, as compared to the DoD ELAP Method. Essentially, they provide an extra level of confidence for practitioners who are thinking of using this technology for their PFAS site work.

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