

# **QUALITY ASSURANCE PROJECT PLAN**

**for**

## **TNT/TNB-FOCUSED BIOREMEDIATION PILOT STUDY AT BANGOR SITE F SOURCE AREA**

**Naval Base Kitsap-Bangor  
Kitsap County, WA**

Prepared by

U.S. ARMY CORPS OF ENGINEERS  
Engineer Research and Development Center and Seattle District



**FINAL**

**February 9, 2023**

## QAPP Worksheet #1 & 2: Title and Approval Page

(UFP-QAPP Manual Section 2.1)

<b>Document Title:</b>	Quality Assurance Project Plan for Bioremediation Pilot Test at Bangor Site F
<b>Site Location:</b>	Naval Base Kitsap-Bangor, Kitsap County, WA
<b>Preparation Date:</b>	September 29, 2021
<b>Lead Organization:</b>	Naval Facilities Engineering Command Northwest (NAVFAC NW)
<b>Investigative Organization:</b>	United States Army Engineer Research and Development Center (ERDC) and United States Army Corps of Engineers (USACE) Seattle District

### QAPP Approval Signatures:

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<b>Investigative Organization Project Chemist</b>	Alison M. Suess, Ph.D. Chemist USACE Seattle District
<b>Regulatory Agency Project Manger</b>	Christopher Maurer Washington State Department of Ecology (Ecology)
<b>Regulatory Agency Project Manger</b>	Harry Craig U.S. Environmental Protection Agency (EPA)

Plans and reports from previous investigations relevant to this project: See References.

## Executive Summary

USACE Seattle District and U.S. Army ERDC (collectively USACE) have completed multiple rounds of *in situ* bioremediation (ISB) pilot testing at Naval Base Kitsap-Bangor Site F, which collectively show (1) that ISB is capable of achieving explosives cleanup concentrations and (2) that implementing ISB could significantly reduce aquifer cleanup time and cost at Site F. The purpose of this study is to perform an ISB pilot to simulate a portion of a full-scale ISB remedy in the Site F aquifer, which would provide (1) full-scale bioremediation performance information for the Navy and the Navy's remediation contractor to use when developing the full-scale ISB design, and (2) extended ISB performance monitoring to directly answer remaining questions regarding the ability to achieve cleanup levels and longevity of treatment.

**USACE Preparation Work:** USACE will prepare the site, acquire fructose and sodium bicarbonate, and install a substrate metering system for injecting a fructose/sodium bicarbonate solution. USACE personnel will be available for maintenance and troubleshooting - and will perform the injections and groundwater monitoring.

**Preliminary Phase, Push-Pull Tests:** In the preliminary phase of the study, beginning March 2023, USACE will conduct push-pull tests (PPTs) to explore TNT/TNB transport characteristics in the Site F source area. A total of three PPTs will be performed in three separate wells near the source area (F-MW32, F-MW33, and F-MW21) using groundwater obtained from F-MW31 [containing approximately 700 micrograms per liter ( $\mu\text{g/L}$ ) as of January 2021]. The PPTs will yield aquifer dispersivity and TNT/TNB retardation factor estimates specific to the Site F aquifer near the explosives source area, which will support bioremediation performance assessments during the biostimulation event and during future full-scale bioremediation efforts at Site F.

**Phase I, *in situ* Bioremediation:** In the first ISB phase of the pilot study, beginning May 2023, USACE will establish an *in situ* bioreactor by injecting a large quantity of fructose-amended groundwater to stimulate growth and activity of indigenous explosives degrading microbes in the Site F aquifer. A portion of the water currently extracted from well F-EW3 will be diverted to the ISB test locations, fructose and bicarbonate will be added to F-EW3 groundwater, and then the amended F-EW3 groundwater will be injected into an existing monitoring well (F-MW33) and an existing extraction well (F-EW7). The injections will last approximately 60 days at each location. Extended monitoring will occur for approximately 1 year after injections are complete. A second round of fructose-amended groundwater injections is planned to occur in 2024 (ISB Phase II). During Phase II fructose-amended groundwater will be injected into F-EW7 using water obtained from F-EW1. Using water from F-EW1 (as opposed to F-EW3) will result in a different gradient, thereby increasing the portion of the aquifer receiving the carbon substrate-amended groundwater.

After the amended groundwater injection has occurred, and after reducing geochemical conditions have been achieved in the interrogated portion of the aquifer, extended ISB performance monitoring data will be collected to answer questions regarding: (1) ISB performance specific to TNT and TNB in the Site F source area and (2) the longevity of bioremediation treatment. An additional goal of the study is to assess the ability to achieve explosives cleanup levels in site groundwater using ISB; however, the ability to achieve cleanup levels during the test will be subject to field conditions encountered.

Any deleterious findings, though not anticipated, will empower Navy with required information to ensure the full-scale system is properly designed and implemented. Previous tests revealed aquifer acidification inhibited the degradation of other explosives (i.e., RDX) in the Site F aquifer. To ensure aquifer

acidification has no negative impacts on biodegradation, the injected solution will be buffered with sodium bicarbonate for both Phase I and Phase II. The buffer quantity required herein was based on excess acid production measured during previous biostimulation tests performed in the Site F aquifer.

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## Acronyms and Abbreviations

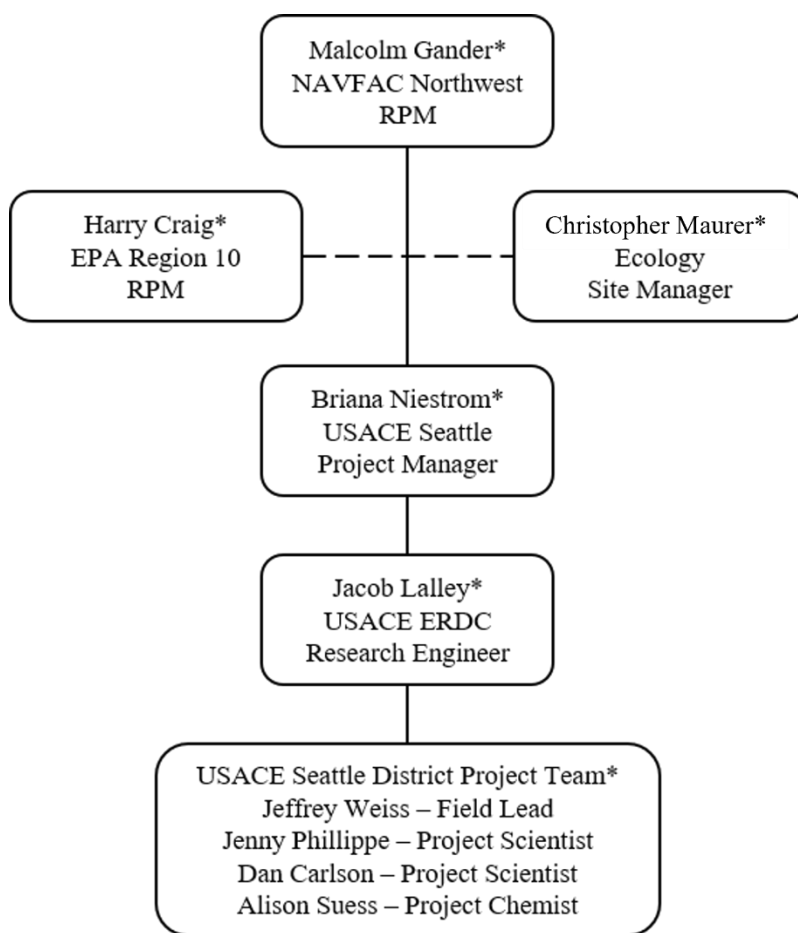
µg/L	micrograms per liter
µm	micrometer
1,3,5-TNB	1,3,5-trinitrobenzene
AHA	Activity Hazard Analysis
BTC	breakthrough curve
COC	chain of custody
DNT	2,4-dinitrotoluene
DoD	Department of Defense
Ecology	Washington State Department of Ecology
EPA	United States Environmental Protection Agency
ERDC	United States Army Engineer Research and Development Center
FD	field duplicate
gpm	gallons per minute
GW	groundwater
HDPE	high density polyethylene
HPLC	high-performance liquid chromatography
ISB	<i>in situ</i> bioremediation
MDL	method detection limit
mg/L	milligrams per liter
mL	milliliter
MS	matrix spike
MSD	matrix spike duplicate
NA	not applicable
NAVFAC	Naval Facilities Engineering Command
Navy	United States Navy
PPT	push-pull test
PSOHP	Project Safety and Occupational Health Plan
QAPP	Quality Assurance Project Plan
QC	quality control
QSM	Quality Systems Manual
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazinane
RL	reporting limit
RPD	relative percent difference
RPM	remedial project manager
Site F	Naval Base Kitsap, Bangor Site F
SOP	Standard Operating Procedure
TOC	total organic carbon
TNB	1,3,5-trinitrobenzene
TNT	2,4,6-trinitrotoluene
UFP-QAPP	Uniform Federal Policy Quality Assurance Project Plan
USACE	United States Army Corps of Engineers
VOA	volatile organics analysis
WLI	water level indicator



## QAPP Worksheet #3 & 5: Project Organization and QAPP Distribution

(UFP-QAPP Manual Section 2.3 and 2.4)

\*QAPP Recipient      Lines of Authority (solid)      Lines of Communication (dashed)



**Figure 1. Project Organization Chart**

## QAPP Worksheet #4, 7 & 8: Personnel Qualifications and Sign-off Sheet

(UFP-QAPP Manual Sections 2.3.2 – 2.3.4)

### Project Execution:

Name/Organization	Project Role	Contact Information
Malcolm Gander, RPM NAVFAC Northwest	Manage project for NAVFAC Northwest	malcolm.gander@navy.mil 206-321-5110
Briana Niestrom, Project Manager USACE – Seattle District	Responsible for project oversight, coordination, and execution for USACE Seattle District	Briana.C.Niestrom@usace.army.mil 206-764-3498
Jacob Lalley, Research Environmental Engineer, USACE – ERDC	Oversees technical work and deliverables for USACE-ERDC; primary Work Plan author	Jacob.M.Lalley@usace.army.mil 601-634-7480
Jeffrey Weiss, Geologist, Field Lead USACE – Seattle District	Leads fieldwork and contributes to data analysis and writing reports	Jeffrey.M.Weiss@usace.army.mil 206-764-3312
Jenny Phillippe, Physical Scientist, Project Scientist USACE – Seattle District	Coordinates USACE project teamwork and deliverables, contributes to data analysis and writing reports	Jennifer.E.Phillippe@usace.army.mil 206-764-6965
Dan Carlson, Physical Scientist, Project Scientist USACE – Seattle District	Coordinates USACE project teamwork and deliverables, contributes to data analysis and writing reports	Daniel.J.Carlson@usace.army.mil 206-764-6899
Alison Suess, Chemist, Project Chemist USACE – Seattle District	Primary QAPP author; Coordinates QAPP and sampling/data needs, contributes to data analysis and writing reports	Alison.M.Suess@usace.army.mil 206-764-3263

### Laboratory:

Name/Organization	Project Role	Contact Information
Tim Witrzek Environmental Monitoring and Technologies, Inc (EMT)	Primary lab contact: Federal Program Manager	847-324-3320 twitrzek@emt.com  Environmental Monitoring and Technologies, Inc. 509 N. 3rd Ave. Des Plaines, IL. 60016
Nicki Ryan EMT	Backup prime laboratory contact: Federal Project Manager	847-324-3326 nryan@emt.com
Jason Cristino EMT	Backup prime laboratory contact: Business Development – Federal Market	847-324-3309 jcristino@emt.com

### Project Review:

Name/Organization	Project Role	Contact Information
Harry Craig, RPM EPA Region 10	Provide regulatory oversight	Craig.Harry@epa.gov 503-326-3689
Christopher Maurer, Site Manager Ecology	Provide regulatory oversight	Cmau461@ecy.wa.gov 360-407-6913

Signatures and qualifications available upon request.

## QAPP Worksheet #6: Communication Pathways

(UFP-QAPP Manual Section 2.4.2)

Communication Driver	Organization and Role	Name and Contact Information	Procedure (timing, pathway, documentation, etc.)
<p>NAVFAC management for this project</p> <p>Regulatory agency interface</p> <p>Overall direction and Point of Contact for public</p>	NAVFAC Northwest RPM	<p>Malcolm Gander malcolm.gander@navy.mil 206-321-5110</p>	<p>Assures that the overall direction of the project is consistent with NAVFAC goals</p> <p>Communicates with regulatory agency</p> <p>Liaison with the Public and EPA</p>
<p>Schedule, budget and technical issues</p> <p>Coordinates USACE Seattle District meetings and funding</p>	USACE Project Manger	<p>Briana Niestrom Briana.C.Niestrom@usace.army.mil 206-764-3498</p>	<p>Coordinates meetings, tracks budget and schedule</p> <p>Consults Jacob Lalley regarding schedule, budget, and technical issues</p>
<p>Guides USACE project team to develop technical objectives and methods of execution</p> <p>Changes to schedule and budget; adaptive management during field work execution</p> <p>Project Final Report</p>	USACE ERDC Research Environmental Engineer	<p>Jacob Lalley Jacob.M.Lalley@usace.army.mil 601-634-7480</p>	<p>Contributes to and approves all technical project documents</p> <p>Coordinates with Briana Niestrom to pass along any schedule/budget changes proposed due to adaptive management</p> <p>Coordinates writing and review of Project Final Report, contributes to data analysis in Final Report</p>
<p>Project Safety and Occupational Health Plan (PSOHP) and Activity Hazard Analysis (AHA)</p> <p>Sampling Supplies</p> <p>Provide direction to field teams on sample collections, ensures compliance with PSOHP</p>	USACE Field Lead	<p>Jeff Weiss Jeffrey.M.Weiss@usace.army.mil 206-764-3312</p>	<p>Ensures PSOHP and AHA are approved prior to fieldwork</p> <p>Plans sampling supplies purchase.</p> <p>Daily communication with field team members during sampling events</p>

<p>Delivery of samples to laboratory</p> <p>Sampling activities summary, Project Final Report</p>			<p>Directs shipment of samples to the laboratory</p> <p>Writes field activities summary for Project Final Report with input from USACE technical team, contributes to data analysis in Final Report</p>
<p>Reviews Work Plan and QAPP</p> <p>Field sampling</p> <p>Data receipt</p> <p>Project Final Report</p>	USACE Project Scientists	<p>Jenny Phillippe Jennifer.E.Phillippe@usace.army.mil 206-764-6965</p> <p>Dan Carlson Daniel.J.Carlson@usace.army.mil 206-764-6899</p>	<p>Coordinates with Research Engineer and Chemist for review</p> <p>Assists with field sampling and coordinating team for field sampling</p> <p>Coordinates with Project Chemist to track data and data validation receipt and summarize results.</p> <p>Contributes to data analysis, writing, and review for Project Final Report</p>
<p>Reviews Work Plan and write QAPP with input from USACE technical team</p> <p>Laboratory and data validation</p> <p>Sampling coordination</p> <p>Data receipt</p> <p>Project Final Report</p>	USACE Project Chemist	<p>Alison Suess Alison.M.Suess@usace.army.mil 206-764-3263</p>	<p>Coordinates with technical team on Work Plan and QAPP and prepares final versions</p> <p>Coordinates and oversees laboratory work and data validation work</p> <p>Coordinates with Field Lead and Project Scientists to carry out sampling event</p> <p>Coordinates with Project Scientists to track data and data validation receipt and summarize results.</p> <p>Contributes to data analysis, writing, and review for Project Final Report</p>
Regulatory oversight	Ecology Site Manager	<p>Christopher Maurer cmau461@ecy.wa.gov 360-407-6913</p>	Provide oversight, including stakeholder meetings and review of the draft Work Plan, QAPP, and project report.

Regulatory oversight	EPA Region 10 RPM	Harry Craig Craig.Harry@epa.gov 503-326-3689	Provide oversight, including stakeholder meetings and review of the draft Work Plan, QAPP, and project report.
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**QAPP Worksheet #9: Project Planning Session Summary**  
*(UFP-QAPP Manual Section 2.5.1 and Figures 9-12)*

Not used.

## QAPP Worksheet #10: Conceptual Site Model

(UFP-QAPP Manual Section 2.5.2)

### Site Description:

Between approximately 1957 and 1972, wastewater produced during the demilitarization of ordnance items at Naval Base Kitsap, Bangor Site F (Site F, Figure 2) was discharged to an unlined wastewater lagoon and overflow ditch. The wastewater contained mostly 2,4,6-trinitrotoluene (TNT) and 1,3,5-trinitro-1,3,5-triazine (RDX) with lower concentrations of other explosives compounds, including 1,3,5-trinitrobenzene (TNB). Infiltration through approximately 15 meters of unsaturated soil to groundwater resulted in an RDX groundwater plume in the shallow aquifer that extends approximately 1,500 meters downgradient of the former lagoon. Because TNT and TNB are less mobile in groundwater, it has formed a much smaller plume present near the original lagoon source area. The maximum TNT concentration within the plume observed in recent years was 700 µg/L in monitoring well F-MW31 as of January 2021 and the maximum TNB concentrations recently observed were approximately 600 µg/L, also in F-MW31. The primary COCs driving remediation at Site F are TNT, RDX, and 2,4-dinitrotoluene (DNT) in soil and TNT, RDX, DNT, and TNB in groundwater.

The shallow aquifer at Site F consists of Vashon Advance Outwash sand, overlain by approximately 5 to 14 meters of Vashon Till and underlain by Lawton Clay. Outwash deposits are upward coarsening with very silty, fine sand at the base, overlain by medium to coarse sand throughout much of the unit, then grading to gravelly sand at the top. Saturated thickness of the shallow aquifer ranges from 18 to 30 meters across the site and has a horizontal hydraulic conductivity of 25 to 60 feet per day, based on a groundwater model calibrated to site conditions (Sealaska, 2015). The overlying Vashon till forms a low permeability “veneer” over the site, which limits the rate of infiltration to the shallow aquifer. The Lawton Clay aquitard has low permeability with vertical hydraulic conductivity in the  $1 \times 10^{-4}$  meters/day range. Groundwater flows at an approximate linear velocity of 37 – 43 meters/year in a northwest direction near the former lagoon source area, then in a northward direction further downgradient. The shallow aquifer discharges to seeps that feed tributaries flowing to the Hood Canal.

### Bioremediation Pilot at Bangor Site F:

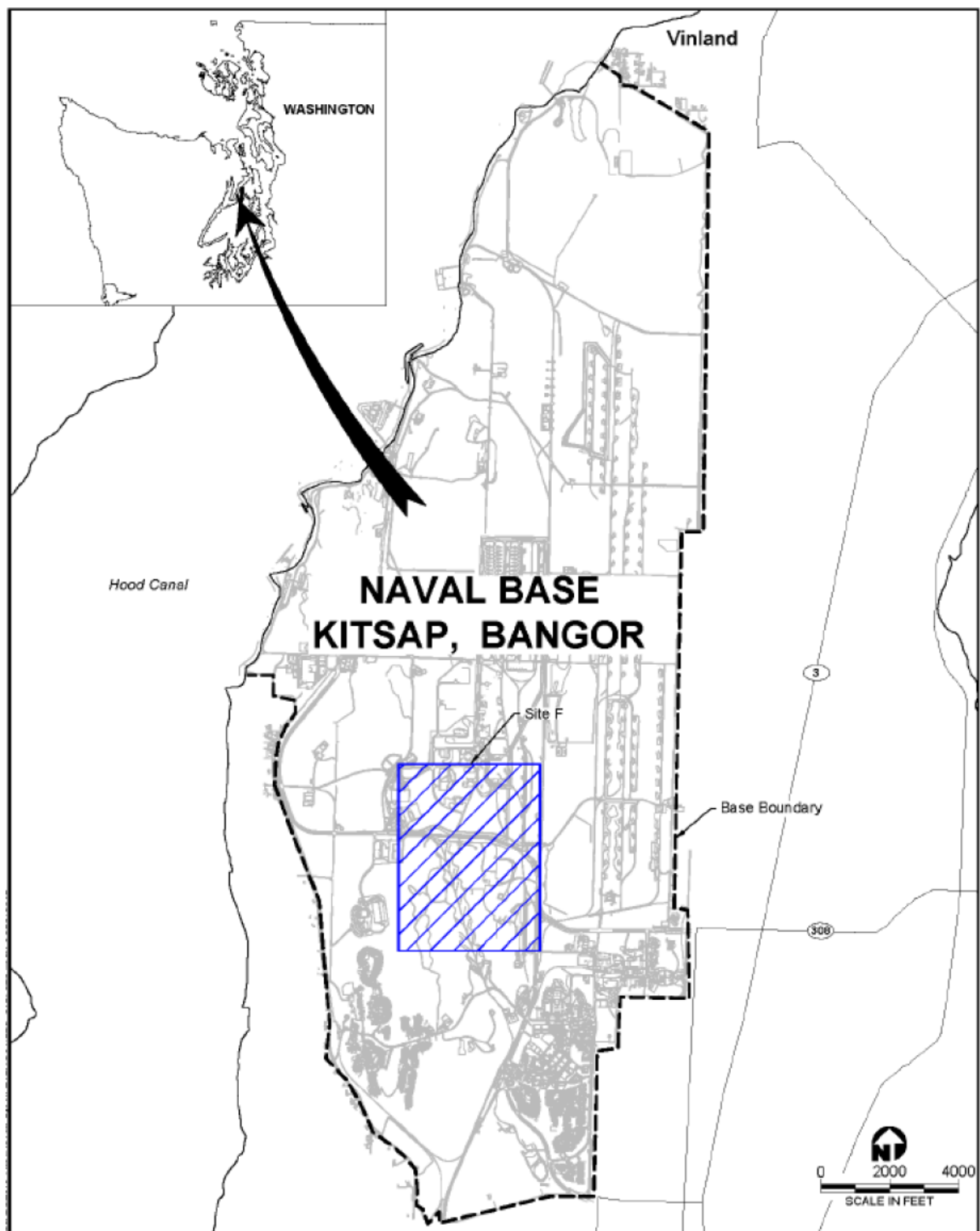
USACE Seattle District and U.S. Army ERDC (collectively USACE) have completed multiple rounds of *in situ* bioremediation (ISB) pilot testing at Site F, which collectively show (1) that ISB is capable of achieving RDX cleanup concentrations, and (2) that implementing ISB could significantly reduce aquifer cleanup time and cost at Site F. USACE previously developed and used a site-specific groundwater model to simulate performance of a full-scale bioremediation remedy at Site F (USACE 2014), which featured a number of new injection and extraction wells throughout the RDX plume that would circulate bioremediation amendment throughout targeted aquifer treatment areas. NAVFAC NW has expressed interest in performing an ISB pilot study to simulate a portion of a full-scale ISB remedy in the Site F aquifer, which would provide (1) full-scale bioremediation performance information for the Navy and the Navy’s remediation contractor to use when developing the full-scale ISB design, and (2) extended ISB performance monitoring to directly answer remaining questions regarding ISB performance specific to TNT and TNB in the Site F source area and longevity of treatment.



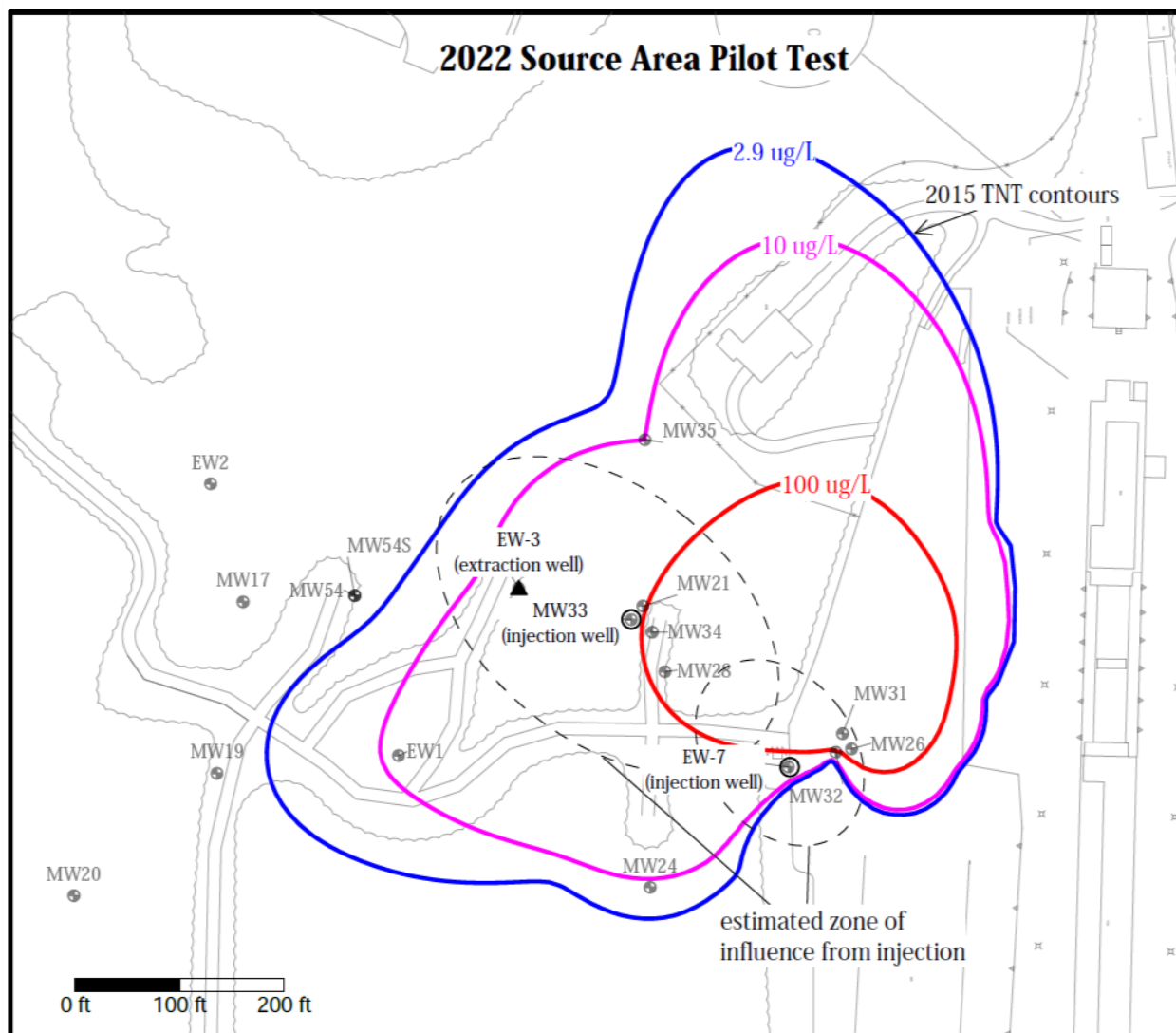
The ISB pilot study will first explore TNT and TNB transport characteristics in the Site F source area by performing short duration push-pull tests (PPTs). A total of three PPTs will be performed in three separate wells near the source area (F-MW32, F-MW33, and F-MW21) using groundwater obtained from F-MW31 (containing approximately 700 µg/L TNT and 600 µg/L TNB). The PPTs will yield aquifer dispersivity and TNT/TNB retardation factor estimates specific to the Site F aquifer, which will support bioremediation performance assessments during the biostimulation event and during future full-scale bioremediation efforts at Site F.

The pilot study will then establish an *in situ* bioreactor by injecting a large quantity of fructose-amended groundwater to stimulate growth and activity of indigenous explosives degrading microbes in the Site F aquifer in Phase I. Figure 3 illustrates the anticipated zones of influence. A portion of the water currently extracted from well F-EW3 will be diverted to the ISB test locations, fructose and bicarbonate will be added to F-EW3 groundwater, and then the amended F-EW3 groundwater will be injected into an existing monitoring well (F-MW33) and an existing extraction well (F-EW7). The ability to adjust and continuously record the rate of F-EW3 groundwater injected, and the ability to adjust and continuously record the rate of fructose and bicarbonate solution metered into the into F-EW3 groundwater being injected is critical to test success. A second round of injections (Phase II) is anticipated to begin in 2024. During Phase II fructose-amended groundwater will be injected into F-EW7 using water obtained from F-EW1. Using water from F-EW1 (as opposed to F-EW3) will result in a different gradient, thereby increasing the portion of the aquifer receiving the carbon substrate-amended groundwater. Note: TNT concentrations for F-EW3, F-EW7, and F-MW33 were 13, 29, and 70 µg/L, respectively, as of January 2021.

After the amended groundwater injection has occurred, and after reducing geochemical conditions have been achieved in the interrogated portion of the aquifer, extended ISB performance monitoring data will be collected to answer questions regarding: (1) ISB performance specific to TNT and TNB in the Site F source area and (2) the longevity of bioremediation treatment. While the focus of the study is on TNT and TNB degradation, the impact biostimulation has on other explosives (e.g., RDX and 1,3-DNB) will also be explored. An additional goal of the study is to assess the ability to achieve TNT and TNB cleanup levels in site groundwater using ISB; however, the ability to achieve cleanup levels during the test will be subject to field conditions encountered. Any deleterious findings, though not anticipated, will empower Navy with required information to ensure the full-scale system is properly designed and implemented. Previous tests revealed aquifer acidification inhibited the degradation of RDX in the Site F aquifer. To ensure aquifer acidification has no negative impacts on biodegradation, the injected solution will be buffered with sodium bicarbonate. The buffer quantity required herein was based on excess acid production measured during previous biostimulation tests performed in the Site F aquifer.



**Figure 2. Bangor Site F Vicinity Map**



**Figure 3. Pilot Test Wells and Anticipated Radius of Influence**

## QAPP Worksheet #11: Project/Data Quality Objectives

*(UFP-QAPP Manual Section 2.6.1)*

<b>Step 1: State the Problem</b>	<b>Step 2: Identify the Goals of the Study</b>	<b>Step 3: Identify Information Inputs</b>	<b>Step 4: Define the Boundaries of the Study</b>	<b>Step 5: Develop the Analytic Approach</b>	<b>Step 6: Specify Performance or Acceptance Criteria</b>	<b>Step 7: Develop the Detailed Plan for Obtaining Data</b>
1) What are water levels in wells associated with the pilot test over the course of the test?	Water levels will contribute to analysis of groundwater gradient, flow direction, radius of influence of injections, and hydraulic conductivity of the aquifer between the injection well and monitoring wells.	Information from automated recording by pressure transducer and manual recordings using an electronic water level indicator will be used.	Water levels will be measured in the eight wells used during the test (F-EW1, F-EW3, F-MW31, F-MW32, F-MW35, F-MW21, and the injection wells F-EW7 and F-MW33) and two wells outside the anticipated area of influence (F-MW17 and F-MW24).	Pressure transducers will record the water level every 15 minutes to monitor the change in water level during the test.  Manual readings of the monitoring wells using an electronic water level indicator will be collected prior to installing the transducers and during every groundwater sampling event.	A difference greater than 0.1 ft will be documented and an additional manual water level will be collected.  See Worksheet #37.	See Worksheet #17 and 18.

<b>Step 1: State the Problem</b>	<b>Step 2: Identify the Goals of the Study</b>	<b>Step 3: Identify Information Inputs</b>	<b>Step 4: Define the Boundaries of the Study</b>	<b>Step 5: Develop the Analytic Approach</b>	<b>Step 6: Specify Performance or Acceptance Criteria</b>	<b>Step 7: Develop the Detailed Plan for Obtaining Data</b>
2) What is the water temperature in wells associated with the pilot test over the course of the test?	Temperature monitoring will contribute to analysis of groundwater flow direction, velocity, depth, and vertical anisotropy. Temperature is more sensitive to vertical anisotropy than the anion tracer.	Information from automated recording by temperature data loggers will be used.	Temperature will be measured in the eight wells used during the test (F-EW1, F-EW3, F-MW31, F-MW32, F-MW35, F-MW21, and the injection wells F-EW7 and F-MW33).	Temperature data loggers will record the temperature every 15 minutes to monitor the change in temperature during the test.	The temperature data will be plotted to look for drift after each monthly download. If there appears to be drift the temperature loggers will be removed and calibration checked.  See Worksheet #37.	See Worksheet #17 and 18.
3) What are the water quality parameters in wells associated with the pilot test over the course of the test?	Water quality monitoring will contribute to analysis of the time until reducing conditions start and the length reducing conditions last, which will affect the degradation of TNT and TNB.	Multiparameter water quality meter with flow through cell and Hach Iron II Test will be used to measure dissolved oxygen, conductivity, temperature, pH, and iron(II) concentration.	Water quality parameters will be recorded during sampling of the monitoring wells used during the test (F-EW1, F-EW3, F-MW31, F-MW32, F-MW35, F-MW21, and the injection wells F-EW7 and F-MW33).	Water quality parameters will be recorded each time the monitoring wells are sampled; see Worksheet 18 for the schedule.	See Worksheet #37.	See Worksheet #17 and 18.

<b>Step 1: State the Problem</b>	<b>Step 2: Identify the Goals of the Study</b>	<b>Step 3: Identify Information Inputs</b>	<b>Step 4: Define the Boundaries of the Study</b>	<b>Step 5: Develop the Analytic Approach</b>	<b>Step 6: Specify Performance or Acceptance Criteria</b>	<b>Step 7: Develop the Detailed Plan for Obtaining Data</b>
4) What are the concentrations of explosives analytes in wells associated with the pilot test over the course of the test?	Explosives monitoring will contribute to the analysis of TNT/TNB degradation.	Results obtained from laboratory analysis of the water samples using EPA Method 8330B will be used.	Samples will be obtained from the monitoring wells used during the test (F-EW1, F-EW3, F-MW31, F-MW32, F-MW35, F-MW21, and the injection wells F-EW7 and F-MW33).	Water samples for explosives analysis will be obtained each time the monitoring wells are sampled; see Worksheet 18 for the schedule.	See Worksheet #37.	See Worksheet #17 and 18.
5) What is the concentration of the anion (conservative tracer) in the PPT injection solution and in wells associated with the PPTs over the course of the test during the preliminary phase?	Anion monitoring will contribute to the analysis of aquifer dispersivity and TNT/TNB retardation coefficients during PPTs. See Worksheet #18, Equation 1	Results obtained from laboratory analysis of the water samples using EPA Method 300.0 will be used.	Samples will be obtained from the injection solution and from the wells used during the test (F-MW32, F-MW33, and F-MW21)	Water samples for anion analysis will be obtained from the PPT injection solution during injection, and each time the wells are sampled during the PPTs; see Worksheet 18 for the schedule.	See Worksheet #37.	See Worksheet #17 and 18.
6) What is the concentration of total organic carbon (TOC) in the injection solution and in wells associated with the pilot test over the course of the test?	TOC monitoring will contribute to the analysis of fructose dispersal and residence time in groundwater.	Results obtained from laboratory analysis of the water samples using EPA Method 9060 will be used.	Samples will be obtained from the injection solution and the monitoring wells used during the test (F-EW1, F-EW3, F-MW31, F-MW32, F-MW35, F-MW21, and the injection wells F-EW7 and F-MW33).	Water samples for TOC analysis will be obtained from the injection solution during injection, and each time the monitoring wells are sampled; see Worksheet 18 for the schedule.	See Worksheet #37.	See Worksheet #17 and 18.

<b>Step 1: State the Problem</b>	<b>Step 2: Identify the Goals of the Study</b>	<b>Step 3: Identify Information Inputs</b>	<b>Step 4: Define the Boundaries of the Study</b>	<b>Step 5: Develop the Analytic Approach</b>	<b>Step 6: Specify Performance or Acceptance Criteria</b>	<b>Step 7: Develop the Detailed Plan for Obtaining Data</b>
7) What are the concentrations of per- and polyfluoroalkyl substances (PFAS) in Site F groundwater wells in the vicinity of this test, and do those concentrations change over the course of this test?	Annual sampling of PFAS will indicate concentrations and changes over time.	Results obtained from annual sampling efforts by the Navy's contractor will be reviewed by USACE (CH2M HILL, 2021).	Samples will be obtained from the test (F-EW1, F-EW3, F-MW31, F-MW32, F-MW35, F-MW21, and injection wells F-EW7 and F-MW33).	USACE will compare concentrations of PFAS in Site F groundwater from the annual sampling events and evaluate if there were changes in concentrations over the course of the test.	See the dedicated Sampling and Analysis Plan (CH2M HILL, 2021).	See the dedicated Sampling and Analysis Plan (CH2M HILL, 2021).

## QAPP Worksheet #12: Measurement Performance Criteria

(UFP-QAPP Manual Section 2.6.2)

**Table 1. Measurement Performance Criteria for Water Samples**

Method (Analysis/Prep/Cleanup) Analyte <i>Surrogate</i>	MS/MSD, RPD	LCS/LCSD, RPD	Blank	Surrogate	Field Duplicate	Equipment Blanks
<b>Total Organic Carbon (SW-846 9060; NA)</b>						
TOC	% R laboratory-specific at time of analysis; RPD $\pm$ 20% of true value	% R laboratory-specific at time of analysis	No analytes detected > ½ RL and > 1/10 the amount measured in any sample or 1/10 the regulatory limit (whichever is greater).		$\leq$ 40% RPD	No analytes detected > ½ RL and > 1/10 the amount measured in any sample or 1/10 the regulatory limit (whichever is greater).
<b>Anions (EPA 300.0, NA)</b>						
Bromide	% R laboratory-specific at time of analysis; RPD $\leq$ 15%	% R laboratory-specific at time of analysis; RPD $\leq$ 15%	No analytes detected > ½ RL and > 1/10 the amount measured in any sample or 1/10 the regulatory limit (whichever is greater).		$\leq$ 40% RPD	No analytes detected > ½ RL and > 1/10 the amount measured in any sample or 1/10 the regulatory limit (whichever is greater).
<b>Explosives (EPA 8330B, NA)</b>						
RDX	laboratory-specific at time of analysis	laboratory-specific at time of analysis	No analytes detected > ½ RL and > 1/10 the amount measured in any sample or 1/10 the regulatory limit (whichever is greater).		$\leq$ 40% RPD	No analytes detected > ½ RL and > 1/10 the amount measured in any sample or 1/10 the regulatory limit (whichever is greater).
1,3,5-TNB						
1,3-DNB						
2,4,6-TNT						
2,4-DNT						
2,6-DNT						

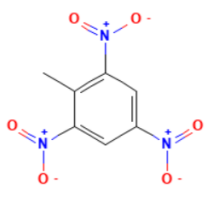
% R = percent recovery



**Table 2. Data Quality Indicators and Sampling/Analysis Error**

<b>Data Quality Indicator</b>	<b>QC Sample and/or Activity Used to Assess Measurement Performance</b>	<b>QC Sample Assesses Error for Sampling (S), Analytical (A) or Both (S&amp;A)</b>
Completeness	Percentage of measurements not rejected.	S&A
Precision	The degree of agreement between or among independent, similar, or repeated measures. Duplicate pairs such as MS/MSD, LCS/LCSD, laboratory duplicate, and field duplicate samples are evaluated for relative percent difference (RPD).	S&A
Accuracy	The amount of agreement between a measured value and the true value. Accuracy, expressed as %Recovery (%R), is by comparing MS/MSD, LCS/LCSD, and surrogate recoveries to the method limits.	A
Representativeness	Representativeness is a qualitative parameter that expresses the degree to which the sample data are characteristic of a population. Instrument/field blanks and sample preservation/temperature/holding times are among the factors considered.	S&A
Comparability	The degree of confidence with which one data set can be compared to another. Sampling field performance and analytical quality control is evaluated against QAPP requirements and results are flagged such that results are of known and documented quality.	S&A
Sensitivity	The ability of an analytical method or instrument to discriminate between measurement responses representing different concentrations. Analytical reporting and detection limits are evaluated against QAPP requirements.	A

**Table 3. Explosives Analyte Names, Abbreviations, CAS Numbers**

Analyte	Abbreviation	CAS Number
<b>Method 8330B Analytes</b>		
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine	HMX	2691-41-0
Hexahydro-1,3,5-trinitro-1,3,5-triazine	RDX	121-82-4
1,3,5-Trinitrobenzene	1,3,5-TNB	99-35-4
1,3-Dinitrobenzene	1,3-DNB	99-65-0
2,4,6-Trinitrotoluene	2,4,6-TNT	118-96-7
 <div> <div>227.13 g/mol</div> <div>C<sub>7</sub>H<sub>5</sub>N<sub>3</sub>O<sub>6</sub></div> </div>		
2,4-Dinitrotoluene	2,4-DNT	121-14-2
2,6-Dinitrotoluene	2,6-DNT	606-20-2

**QAPP Worksheet #13: Secondary Data Uses and Limitations**  
*(UFP-QAPP Manual Section 2.7)*

No secondary data used.

## QAPP Worksheet #14/16: Project Tasks & Schedule

(UFP-QAPP Manual Section 2.8.2)

Task Name	Duration	Start	Finish	Notes
<b>QAPP / Work Plan Preparation</b>	<b>(Work Days)</b>			
DQO meeting	1	7/20/2021	7/20/2021	
Preliminary Draft QAPP / Work Plan	25	10/1/2021	11/5/2021	
Preliminary Draft QAPP / Work Plan Internal Review	5	11/8/2021	11/12/2021	QAPP will be reviewed by USACE internally.
Revision of Preliminary Draft QAPP / Work Plan	5	11/15/2021	11/19/2021	
Stakeholders (Navy, Ecology, and EPA) Review Draft QAPP / Work Plan	20	6/8/2022	7/6/2022	
Meeting with stakeholders	1	7/6/2022	7/6/2022	
Revision of Draft QAPP / Work Plan	5	7/6/2022	7/20/2022	
Stakeholders Backcheck	5	7/13/2022	7/20/2022	
Final QAPP / Work Plan	--	7/27/2022	2/9/2023	Unforeseeable issues resulted in substantial project delays
Laboratory Task Order Award	NA	3/2023	9/2024	
<b>Field Work</b>	<b>(Total Days)</b>			
Push-Pull Tests	5	3/20/2023	3/24/2023	
PPT monitoring and sampling	5	3/20/2023	3/24/2023	
Substrate metering system installation and background sampling	10	4/17/2023	4/28/2023	To include sodium bicarbonate and fructose tank preparation.

<b>Task Name</b>	<b>Duration</b>	<b>Start</b>	<b>Finish</b>	<b>Notes</b>
Phase I ISB Location 1 injection	60	5/1/2023	6/30/2023	
Location 1 flush	6	6/30/2023	7/6/2023	
Transition of substrate metering system	4	7/7/2023	7/10/2023	
Phase I ISB Location 2 injection	60	7/10/2023	9/8/2023	
Location 2 flush	6	9/8/2023	9/14/2023	
Phase I ISB sampling and monitoring	252	9/15/2023	5/24/2024	To include 9 monthly sampling events
<b>Reporting</b>	<b>(Work Days)</b>			
Preliminary Draft Report	30	5/24/2024	7/8/2024	The report will include a data usability assessment based on the data validation report received
Internal Review of Preliminary Draft Report	5	7/9/2024	7/15/2024	
Revise Preliminary Draft Report	5	7/16/2024	7/22/2024	
Stakeholders Review of Draft Report	21	7/23/2024	8/21/2024	
Revise Draft report	5	8/22/2024	8/28/2024	
Final Report	1	8/29/2024	8/30/2024	

## QAPP Worksheet #15: Project Action Limits and Laboratory-Specific Detection/Quantitation Limits

(UFP-QAPP Manual Section 2.6.2.3 and Figure 15)

**Table 4. Detection and Quantitation Limit Definitions**

Limit	Definition
DL	Detection Limit: The smallest analyte concentration that can be demonstrated to be different from zero or a blank concentration with 99% confidence. At the DL, the false positive rate (Type I error) is 1%. A DL may be used as the lowest concentration for reliably reporting a detection of a specific analyte in a specific matrix with a specific method with 99% confidence.
LOD	Limit of Detection: The smallest concentration of a substance that must be present in a sample in order to be detected at the DL with 99% confidence. At the LOD, the false negative rate (Type II error) is 1%. A LOD may be used as the lowest concentration for reliably reporting a non-detect of a specific analyte in a specific matrix with a specific method at 99% confidence. A LOD is typically 2x to 4x the DL.
LOQ	Limit of Quantitation: The smallest concentration that produces a quantitative result with known and recorded precision and bias. For DoD/DOE projects, the LOQ shall be set at or above the concentration of the lowest initial calibration standard and within the calibration range.

**Table 5. Measurement Limits**

Analyte	Method (Analysis/Prep/Cleanup)	Cleanup Level	Project Quantitation Limit	LOQ	LOD	DL
<b>Total Organic Carbon (SW-846 9060; NA), mg/L</b>						
TOC		Not Applicable	Not Specified	1	0.8	0.4
<b>Anions (EPA 300.0; NA), µg/L</b>						
Bromide		Not Applicable	Not Specified	0.05	0.04	0.02
<b>Explosives (EPA 8330B, NA), µg/L</b>						
RDX		0.8	0.7	0.50	0.065	0.030
1,3,5-Trinitrobenzene		0.8	0.7	0.25	0.125	0.060
1,3-Dinitrobenzene		1.6	1.0	0.25	0.125	0.035
2,4,6-Trinitrotoluene		2.9	1.0	0.25	0.125	0.050
2,4-Dinitrotoluene		0.13*	0.25	0.25	0.125	0.050
2,6-Dinitrotoluene		0.13*	0.25	0.25	0.125	0.055
2-Amino-4,6-dinitrotoluene		Not Applicable	1.0	0.25	0.20	0.066
2-Nitrotoluene		Not Applicable	1.0	0.50	0.125	0.055
3,5-Dinitroaniline		Not Applicable	1.0	0.25	0.20	0.060
3-Nitrotoluene		Not Applicable	1.0	0.50	0.065	0.030

<b>Method (Analysis/Prep/Cleanup) Analyte</b>	<b>Cleanup Level</b>	<b>Project Quantitation Limit</b>	<b>LOQ</b>	<b>LOD</b>	<b>DL</b>
4-Amino-2,6-dinitrotoluene	Not Applicable	1.0	0.50	0.125	0.040
4-Nitrotoluene	Not Applicable	1.0	0.50	0.065	0.025
HMX	Not Applicable	1.0	0.50	0.125	0.060
Nitrobenzene	Not Applicable	1.0	0.50	0.065	0.030
Nitroglycerin	Not Applicable	1.0	0.50	0.125	0.050
PETN	Not Applicable	1.0	0.50	0.125	0.030
Tetryl	Not Applicable	1.0	0.50	0.125	0.050

<sup>1</sup> Full explosive analyte names and CAS numbers are provided in Worksheet 12, Table 2.

<sup>2</sup> The cleanup levels are 0.8 µg/L for RDX, 0.8 µg/L for 1,3,5-TNB, 1.6 µg/L for 1,3-DNB, 2.9 µg/L for 2,4,6-TNT, and 0.13 µg/L for DNT (EPA 1994a, 1994b). The cleanup level for DNT applies to the combined total of 2,4-DNT and 2,6-DNT.

<sup>3</sup> Explosives LOD/LOQ/DL shown are for a 1-L sample size concentrated to 1.0 mL during analysis.

## **QAPP Worksheet #17: Sampling Design and Rationale**

*(UFP-QAPP Manual Section 3.1.1)*

### **1. Site Preparation**

USACE personnel will prepare the site, acquire fructose and sodium bicarbonate, and install a metering system for injection solutions. USACE personnel will be available for maintenance, troubleshooting, and will perform the injections and groundwater monitoring.

### **2. Preliminary Phase: Push-pull Tests**

The preliminary phase of the ISB pilot study, beginning March 2023, USACE will perform push-pull tests (PPTs) to explore TNT/TNB transport characteristics in the Site F source area. A total of three PPTs will be performed in three separate wells near the source area (F-MW32, F-MW33, and F-MW21) using groundwater obtained from F-MW31 [containing approximately 700 micrograms per liter ( $\mu\text{g/L}$ ), as of January 2021]. The PPTs will yield aquifer dispersivity and TNT/TNB retardation factor estimates specific to the Site F aquifer, which will support bioremediation performance assessments during the biostimulation event and during future full-scale bioremediation efforts at Site F.

One background sample will be collected from the three wells prior to the PPTs using low-flow techniques. PPTs will include a single injection of 150-gallons of water obtained from F-MW31 and amended with 100 milligrams per liter ( $\text{mg/L}$ ) bromide tracer, followed by time-series groundwater sampling and analysis in that well. F-MW32, F-MW33, and F-MW21 have been selected as test locations. Prior to injection, water and bromide will be mixed thoroughly using a high-flow transfer pump, paddles, or other portable pumps (as necessary). Following mixing, the solution will be injected at approximately 5 gallons per minute ( $\text{gpm}$ ); if that rate is not possible, then injection will occur via siphon. Water will be injected at the highest possible rate without the well overflowing so that post-injection sampling for monitoring will have the highest concentrations of explosives. During injection, three samples of the injection solution will be collected at each well (9 samples total). Following injection, three times the injection volume will be extracted from each well (i.e., 450-gal) as quickly as possible – with a target extraction rate of 2  $\text{gpm}$ . During extraction, up to 15 groundwater samples will be collected from each well (up to 45 samples total); one sample for every 30 gallons extracted. USACE personnel will carry out monitoring and sampling as described in Worksheet #18. Each sample will be submitted for bromide and explosives analysis. Up to two samples per well (6 total) will also be submitted for TOC analysis. One of the TOC samples will be collected within the first 225-gallons and the second during the second 225-gallons. PPTs are expected to last 5 days, with groundwater monitoring being performed on the same days as PPTs.

USACE will perform field measurements of water quality parameters: dissolved oxygen, conductivity, temperature, and pH, and will test groundwater for Iron (II) with a Hach kit. The temperature in the screened areas of the PPT wells will be recorded to provide more information regarding injection delivery. Water levels will be measured with pressure transducers, and manual water level measurement will be performed prior to pressure transducer installation.

### **3. Phase I: *In situ* Bioremediation (ISB) and Long-term Monitoring**

In the first phase of ISB injections for the pilot study, beginning May 2023, USACE will perform an ISB pilot study and extended biostimulation performance monitoring. The ISB pilot study will biologically



activate the aquifer by injecting a large quantity of fructose-amended groundwater (obtained from F-EW3) to stimulate growth and activity of indigenous explosives degrading microbes in the Site F aquifer. The fructose-amended groundwater will be buffered with a sodium bicarbonate solution and will be injected into wells F-MW33 (Location #1) and F-EW7 (Location #2). The intent is to inject approximately 3.5 million gallons of groundwater, amended with 25 mM fructose and 10 mM sodium bicarbonate, split between Locations #1 and #2. The amended-water injection is expected to last a total of 139 days (60 days per location + a 6 day “flush” with unamended groundwater + 7 days for transitioning locations) and subsequent groundwater monitoring will be performed for approximately 338 days. This injection plan was designed, in part, to address the potential impact of biofouling. If the injection rate into F-MW33 begins to slow due to biofouling, the injection location can be changed to F-EW7. As an extraction well, F-EW7 is screened over a 30 foot interval (compared to F-MW33 which is screened over a 10 foot interval) and therefore, the impact of biofouling at this location will be minimized. While injections continue at F-EW7, the biofouling problem could be addressed, or the remainder of the injection can occur at the second location. Performance monitoring will occur before and after the biostimulation injection has occurred. A second round of fructose-amended groundwater injections is planned to occur in 2024 (ISB Phase II). During Phase II fructose-amended groundwater will be injected into F-EW7 using water obtained from F-EW1. Using water from F-EW1 (as opposed to F-EW3) will result in a different gradient, thereby increasing the portion of the aquifer receiving the carbon substrate-amended groundwater.

USACE personnel will carry out monitoring and sampling of the injection water and groundwater as described in Worksheet #18. In Phase I ISB, the injection water will be analyzed for TOC and explosives from the Method 8330B analytes list. Groundwater from monitoring wells will be analyzed for TOC and explosives from the Method 8330B analytes list. USACE will perform field measurements of water quality parameters: dissolved oxygen, conductivity, temperature, and pH, and will test groundwater for Iron (II) with a Hach kit. Water levels will be measured with pressure transducers, and manual water level measurement will be performed prior to pressure transducer installation and during every groundwater sampling event.

#### **4. Assessing Pilot Performance and TNT/TNB Degradation**

Data will be evaluated using multiple approaches in order to accomplish project objectives. The first approach will involve using tracer-corrected time course TNT/TNB concentrations measured during PPTs and standard PPT data analysis methods (Schroth et al. 2001) to extract a localized retardation coefficients to support bioremediation performance assessments during Phase II. After Phase I ISB injections, extended ISB performance monitoring data will be collected to answer questions regarding: (1) ISB performance specific to TNT and TNB in the Site F source area and (2) the longevity of bioremediation treatment. Collectively, this large-scale bioremediation pilot will provide additional performance data to inform design and performance monitoring of a future full-scale ISB system. Collectively, this large-scale bioremediation pilot will provide additional performance data to inform design and performance monitoring of a future full-scale ISB system.

#### **5. Per- and Polyfluoroalkyl Substances Assessment**

The Navy’s long term monitoring contractor will sample groundwater from Site F wells and analyze the samples for per-and polyfluoroalkyl substances (PFAS). The PFAS sampling occurred in April 2022 and will occur annually thereafter (CH2M Hill, 2021). The PFAS sampling is addressed in a separate Sampling and Analysis Plan (CH2M Hill). The Navy’s contractor will analyze for 18 PFAS analytes, including PFOS, PFOA, and PFBS, using liquid chromatography tandem mass spectrometry (LC-

MS/MS) compliant with DoD Quality Systems Manual Table B-15. The contractor's laboratory holds DoD and state accreditation. Third party data validation will be performed.

PFAS sampling is to be conducted in the test and injection wells before and after the pilot study by another contractor under another task order. USACE will compare the concentrations of the analyzed PFAS obtained from the Navy's annual sampling over the course of the test and will describe the results and any changes in concentrations over the course of the test. This analysis will be included in the final report.

Results from the April 2022 PFAS sampling event indicate very low levels of PFAS in the area of the pilot test. In F-MW21, the sum of all PFAS detections (two compounds) was 5.58 parts per trillion (ppt), and in F-MW54S, there was one PFAS compound detection (1.29 ppt). In F-MW31, five PFAS compounds were detected at a combined concentration of approximately 15 ppt. In F-MW31, the sum of PFOS and PFOA (Perfluorooctane sulfonic acid and Perfluorooctanoic acid) was 4.07 ppt, which is below the Environmental Protection Agency (EPA) Lifetime Health Advisory (LHA) of 70 ppt, and also below their respective Regional Screening Levels (RSLs) as recently promulgated by EPA. PFOS and PFOA were not detected in F-MW21 and F-MW54S. PFAS precursors N-Ethyl perfluorooctane sulfonamido acetic acid (EtFOSAA) and N-Methyl perfluorooctane sulfonamido acetic acid (MeFOSAA) were not detected in the Site F explosives source area; therefore, precursor biotransformation is not expected to pose an issue. The following table summarizes PFAS analytical results from the April 2022 sampling event:

Station ID	F-MW21		F-MW31		F-MW54S		Tap Water Regional Screening Levels (NG/L)
Sample ID	NBKB-F-MW21-0422		NBKB-F-MW31-0422		NBKB-F-MW54S-0422		
Sample Date	4/20/2022		4/21/2022		4/21/2022		
Chemical Name							
PFAS (NG/L)							
4,8-dioxa-3H-perfluorononanoic acid (ADONA)	2.6	U	2.22	U	2.65	U	none
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9CI-PF3ONS)	2.6	U	2.22	U	2.65	U	none
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11CI-PF3OUDs)	2.6	U	2.22	U	2.65	U	none
N-Ethyl Perfluorooctanesulfonamidoacetic Acid (NEtFOSAA)	2.6	U	2.22	U	2.65	U	none
N-Methyl Perfluorooctanesulfonamidoacetic Acid (NMeFOSAA)	2.6	U	2.22	U	2.65	U	none
Hexafluoropropylene oxide dimer acid (HFPO-DA)	2.6	U	2.22	U	2.65	U	6
Perfluorobutanesulfonic acid (PFBS)	2.6	U	2.22	U	1.29	J	600
Perfluorodecanoic Acid (PFDA)	2.6	U	2.22	U	2.65	U	none
Perfluorododecanoic Acid (PFDoA)	2.6	U	2.22	U	2.65	U	none
Perfluoroheptanoic acid (PFHpA)	2.6	U	1.68	J	2.65	U	none
Perfluorohexanesulfonic acid (PFHxS)	3.65	J	6.6		2.65	U	39
Perfluorohexanoic Acid (PFHxA)	2.6	U	2.47	J	2.65	U	none
Perfluorononanoic acid (PFNA)	2.6	U	2.22	U	2.65	U	5.9
Perfluorooctane sulfonic acid (PFOS)	2.6	U	1.21	J	2.65	U	4
Perfluorooctanoic acid (PFOA)	1.93	J	2.86	J	2.65	U	6
Perfluorotetradecanoic Acid (PFTeDA)	2.6	U	2.22	U	2.65	U	none
Perfluorotridecanoic Acid (PFTriDA)	2.6	U	2.22	U	2.65	U	none
Perfluoroundecanoic Acid (PFUnA)	2.6	U	2.22	U	2.65	U	none
Notes:							
NA = Not analyzed							
J = The analyte was positively identified: the associated numerical value is the approximate concentration of the analyte in the sample.							
U = The analyte was analyzed for, but was not detected above the reported sample quantitation limit.							
Detected Analyte							

## QAPP Worksheet #18: Sampling Locations and Methods

(UFP-QAPP Manual Section 3.1.1 and 3.1.2)

### 1. Preliminary Phase: PPTs

**Water Level Monitoring:** USACE will monitor water level using an electronic water level indicator prior to performing PPTs.

**PPT Injection Samples:** USACE personnel will collect three water samples from the PPT injection solution periodically throughout injection (Table 9). USACE will perform field measurements of groundwater parameters: dissolved oxygen, conductivity, temperature, and pH, and will test PPT injection solution for Iron (II) with a Hach kit. USACE will collect samples for laboratory analysis of total organic carbon (TOC), explosives, and anions.

**Groundwater Monitoring Samples:** USACE personnel will collect groundwater monitoring samples from the three wells used during the test (F-MW32, F-MW33, and F-MW21). USACE will collect samples for laboratory analysis of TOC, explosives from the Method 8330B analytes list, and anions (bromide). Resulting breakthrough curves (BTC) can be analyzed using published methodologies to determine estimates for longitudinal dispersivity and TNT/TNB retardation factors (Schroth et al. 2001). Equations 1 and 2 can be used to determine the longitudinal dispersivity in the area near the test wells.

$$\hat{r}_{max} = \sqrt{\frac{V_{inj}}{\pi b n R} + r_w^2} \quad \text{Equation 1}$$

where  $V_{inj}$  is the injected volume of PPT solution,  $b$  is the aquifer thickness,  $n$  is the effective porosity,  $R$  is the solute retardation factor,  $r_w$  is the well radius, and  $r_{max}$  is the final frontal position of the injection solution.

$$\frac{C}{C_0} = \frac{1}{2} \operatorname{erfc} \left\{ \left( \frac{V_{ext}}{V_{inj}} - 1 \right) / \left[ \frac{16}{3} \frac{\alpha_L}{\hat{r}_{max}} \left( 2 - \left| 1 - \frac{V_{ext}}{V_{inj}} \right|^{\frac{1}{2}} * \left( 1 - \frac{V_{ext}}{V_{inj}} \right) \right) \right] \right\}^{1/2} \quad \text{Equation 2}$$

where  $V_{ext}$  is the cumulative extracted volume and  $\alpha_L$  is the aquifer longitudinal dispersivity.

According to Schroth et al. 2001, the tracer frontal position at the end of the injection phase,  $r_{max,tr}$ , is computed from Equation 1 based on known values for  $V_{inj}$ ,  $b$ ,  $n$ , and  $R = 1$ . Then, Equation 2, with  $r_{max} = r_{max,tr}$  is fit to the tracer BTC to obtain and estimate for  $\alpha_L$ . Then, Equation 3 can be used to determine an estimate for the retardation factor ( $R^*$ ) for the sorbing solute:

$$R^* = \left( \frac{\hat{r}_{max,tr}}{\hat{r}_{max,sol}} \right)^2 \quad \text{Equation 3}$$

The following method for estimating retardation factors for a sorbing solute from a PPT extraction BTC is thus: 1) determine  $r_{max,tr}$  from Equation 1 and  $\alpha_L$  from the tracer extraction phase BTC using Equation 2; 2) keeping  $\alpha_L$  fixed in Equation 2, estimate the sorbing solute frontal position at the end of the injection

phase  $r_{\max, \text{sol}}$  by fitting Equation 2 to the sorbing TNT/TNB BTC; 3) use Equations 2 and 3 to estimate the TNT/TNB retardation factors.

**Groundwater Parameters:** USACE personnel will collect groundwater parameters from the test wells prior to conducting the PPTs. USACE personnel will perform field measurements of groundwater parameters: dissolved oxygen, conductivity, temperature, and pH, and will test groundwater for Iron (II) with a Hach kit.

**Groundwater Monitoring Methods:** See Worksheet #21, Field SOPs, for methods.

**Analytical Methods:** Samples will be analyzed for TOC using SW-846 Test Method 9060A. Samples will be analyzed for the anion tracer (bromide) using EPA Method 300.0. Explosives and transformation product concentrations will be determined by high performance liquid chromatography (HPLC) using EPA Method 8330B. At a minimum, the laboratory required method detection limit (MDL) shall be 0.25 microgram/liter ( $\mu\text{g/L}$ ) and the reporting limit (RL) shall be 1.0  $\mu\text{g/L}$ . One field duplicate will be collected for every 10 samples. One matrix spike (MS) and matrix spike duplicate (MSD) sample will be collected for every 20 samples. See Worksheets #12, #15, and #20 for further detail.

## 2. Phase I: ISB and Long-term Monitoring

**Water Level Monitoring:** USACE will install pressure transducers in the eight wells used during the test (F-EW1, F-EW3, F-MW31, F-MW32, F-MW35, F-MW21, and the injection wells F-EW7 and F-MW33) as well as two background wells outside the anticipated area of influence of the test (F-MW17 and F-MW24), and record the water level every 15 minutes to monitor the change in water level during the test. The pressure transducers will be installed a minimum of two weeks prior to injection starting to collect background water levels. The data loggers will be downloaded once a week during the injection and once a month during the monitoring period. Manual readings of the monitoring wells using an electronic water level indicator will be collected prior to installing the transducers and during every groundwater sampling event.

**Injection Samples:** USACE personnel will collect three water samples from the injection water periodically throughout injection (Table 10). USACE will perform field measurements of groundwater parameters: dissolved oxygen, conductivity, temperature, and pH, and will test water for Iron (II) with a Hach kit. USACE will collect samples for laboratory analysis of TOC and explosives from the Method 8330B analytes list for all injection samples.

**Groundwater Temperature Monitoring:** USACE personnel will install temperature loggers every three feet in the screened portion of the injection and monitoring wells. The temperature loggers will be installed at least one month prior to the injections in in test wells (F-EW1, F-EW3, F-MW31, F-MW32, F-MW35, F-MW21, and the injection wells F-EW7 and F-MW33). The loggers will record the water temperature every 15 minutes and the data will be downloaded once a week during the injection and once a month during the monitoring period.

**Groundwater Monitoring Samples:** USACE personnel will collect groundwater monitoring samples from the eight wells used during the test (F-EW1, F-EW3, F-MW31, F-MW32, F-MW35, F-MW21, and the injection wells F-EW7 and F-MW33) (Tables 7 and 10). A total of 13 rounds of samples, including one background round prior to injection, will be collected from all 8 wells used during the test over the course of Phase I ISB. USACE will collect samples for laboratory analysis of TOC and explosives from the Method 8330B analytes list.

The PPT and Phase I ISB sample schedules are based on USACE knowledge at the time of UFP-QAPP finalization. USACE does not anticipate any deviations to the PPT sample schedule. Results from PPTs could prompt optimization in the Phase I ISB sampling schedule to ensure the best data possible is obtained to meet data quality objectives. Any alterations to the Phase I ISB sampling schedule will be proposed to all UFP-QAPP recipients in advance of Phase I ISB sampling.

**Groundwater parameters:** USACE personnel will collect groundwater parameters, using methods described in Worksheet #21, from the test wells prior to collecting groundwater samples and several times during and after the injection. USACE personnel will perform field measurements of groundwater parameters: dissolved oxygen, conductivity, temperature, and pH, and will test groundwater for Iron (II) with a Hach kit.

**Groundwater Monitoring Methods:** See Worksheet #21, Field SOPs, for methods.

**Analytical Methods:** Samples will be analyzed for TOC using SW-846 Test Method 9060A. Explosives and transformation product concentrations will be determined by high performance liquid chromatography (HPLC) using EPA Method 8330B. RDX concentrations will also be determined using EPA Method 8330B. At a minimum, the laboratory required method detection limit (MDL) shall be 0.25 microgram/liter ( $\mu\text{g/L}$ ) and the reporting limit (RL) shall be 1.0  $\mu\text{g/L}$ . One field duplicate will be collected for every 10 samples. One matrix spike (MS) and matrix spike duplicate (MSD) sample will be collected for every 20 samples. See Worksheets #12, #15, and #20 for further detail.

**Table 6. PPT Sampling Schedule**

Phase	Date	GW Monitoring Sample Location and Analytes	Groundwater Quality Parameter Monitoring Performed?
Prior to PPTs	Prior to 3/20/23	Test Wells (TOC, Anions, and Explosives)	Yes, Test Wells
PPT Location 1	3/20/23	F-MW32 (TOC, Anions, and Explosives)	Yes, F-MW32
PPT Location 2	3/22/23	F-MW33 (TOC, Anions, and Explosives)	Yes, F-MW33
PPT Location 3	3/24/23	F-MW21 (TOC, Anions, and Explosives)	Yes, F-MW21

1. Test Wells: F-MW32, F-MW33, and F-MW21

**Table 7. Phase I ISB Injection and Sampling Schedule**

Phase	Start Date	End Date	GW Monitoring Sample Location and Analytes	Groundwater Quality Parameter Monitoring Performed?
GW Monitoring (Background Sampling – conducted during PPTs)	4/2023	4/2023	Test and Injection Wells (TOC and Explosives)	Yes, Test and Injection Wells
Location 1 Injection	5/1/2023	6/30/2023	NA	NA
Location 1 Flush	6/30/2023	7/6/2023	NA	NA
Move metering system to Location 2	7/7/2023	7/10/2023	NA	NA
Location 2 Injection	7/10/2023	9/8/2023	NA	NA
Location 2 Flush	9/8/2023	9/14/2023	NA	NA
Sampling Event #1	9/15/2023	9/18/2023	Test and Injection Wells (TOC and Explosives)	Yes, Test and Injection Wells
Sampling Event #2	10/16/2023	10/17/2023	Test and Injection Wells (TOC and Explosives)	Yes, Test and Injection Wells
Sampling Event #3	11/20/2023	11/21/2023	Test and Injection Wells (TOC and Explosives)	Yes, Test and Injection Wells
Sampling Event #4	12/18/2023	12/19/2023	Test and Injection Wells (TOC and Explosives)	Yes, Test and Injection Wells
Sampling Event #5	1/15/2024	1/16/2024	Test and Injection Wells (TOC and Explosives)	Yes, Test and Injection Wells
Sampling Event #6	2/19/2024	2/20/2024	Test and Injection Wells (TOC and Explosives)	Yes, Test and Injection Wells
Sampling Event #7	3/18/2024	3/19/2024	Test and Injection Wells (TOC and Explosives)	Yes, Test and Injection Wells
Sampling Event #8	4/15/2024	4/16/2024	Test and Injection Wells (TOC and Explosives)	Yes, Test and Injection Wells
Sampling Event #9	5/23/2024	5/24/2024	Test and Injection Wells (TOC and Explosives)	Yes, Test and Injection Wells

1. Injection Wells: Location 1 is F-MW33 and Location 2 is F-EW7

2. Test Wells: F-MW31, F-MW32, F-MW35, F-MW21, F-EW1, F-EW3

## QAPP Worksheet #19 & 30: Sample Containers, Preservation, and Hold Times

*(UFP-QAPP Manual Section 3.1.2.2)*

**Laboratory:**

**Prime Contract Lab: Analytes**

Environmental Monitoring and Technologies, Inc.

509 N. 3rd Ave., Des Plaines, IL. 60016

Primary POC: Tim Witrzek, twitrzek@emt.com, 847-324-3320

**Sample Delivery Method:** FedEx

**Table 8. Containers, Preservation, and Holding Time Requirements**

Laboratory Performing Analysis	Matrix	Analyses	Extraction; Cleanup; Analysis Method Numbers	Sample Containers <sup>1</sup>	Sample Minimum Volume	Preservation (depends on holding time)	Maximum Holding Time (extraction/analysis)
EMT	Water	TOC	EPA 9060A	one 40-mL VOA vial with HCl	40 mL	HCl	28 days
		Anions	EPA 300.0	one 250-mL HDPE	50 mL	none	28 days
		Explosives	EPA 8330B	two 1-L amber glass	1 L (2 L preferred for breakage)	none	7 days to extract/40 days to analysis



## QAPP Worksheet #20: Field QC Summary

(UFP-QAPP Section 3.1.1 and 3.1.2)

**Table 9. PPT Sample Quantities**

Phase	Analytes	Number of sampling events	Number of sample location	Sample locations	Number of Field Samples (no FD or MS/MSD)	Number of Matrix Spike/Matrix Spike Duplicates (MS/MSD)	Number of Field Duplicates (FD)	Number of Total Samples (With FD and MS/MSD)
Background Sampling	Explosives	1	8	PPT Wells	8	1/1	1	11
	Anions	1	3	PPT Wells	3	1/1	1	6
	TOC	1	8	PPT Wells	8	1/1	1	11
PPT Injection Water Sampling	Explosives	3	3	PPT Wells	9	1/1	1	12
	Anions	3	3	PPT Wells	9	1/1	1	12
PPT Extraction Solution	Explosives	15	3	PPT Wells	45	3/3	5	56
	Anions	15	3	PPT Wells	45	3/3	5	56
	TOC	2	3	PPT Wells	6	1/1	1	9
Provisional Samples	Explosives	N/A	N/A	PPT Wells	N/A	N/A	N/A	4
	Anions	N/A	N/A	PPT Wells	N/A	N/A	N/A	4
	TOC	N/A	N/A	PPT Wells	N/A	N/A	N/A	1
<b>Total Explosives</b>								<b>83</b>
<b>Total Anions</b>								<b>78</b>
<b>Total TOC</b>								<b>21</b>

1. Field Duplicate (FD) samples will be collected at a rate of 1 per every 10 field samples.

2. Matrix Spike/Matrix Spike Duplicate (MS/MSD) samples will be collected at a rate of 1 pair per every 20 field samples.

3. PPT Wells are F-MW32, F-MW33, and F-MW21.

**Table 10. Phase I ISB Sample Quantities**

Phase	Analytes	Number of sampling events	Number of sample location	Sample locations	Number of Field Samples (no FD or MS/MSD)	Number of Matrix Spike/Matrix Spike Duplicates (MS/MSD)	Number of Field Duplicates (FD)	Number of Total Samples (With FD and MS/MSD)
Injection Water Sampling	Explosives	3	1	Injection Sampling Port	3	1/1	1	6
	TOC	3	1	Injection Sampling Port	3	1/1	1	6
ISB Long-term GW Monitoring	Explosives	9	8	Test Wells, Injection Well	72	4/4	8	88
	TOC	9	8	Test Wells, Injection Well	72	4/4	8	88
Provisional Samples	Explosives	N/A	N/A	Test Wells, Injection Well	N/A	N/A	N/A	18
	TOC	N/A	N/A	Test Wells, Injection Well	N/A	N/A	N/A	18
<b>Total Explosives</b>								<b>112</b>
<b>Total TOC</b>								<b>112</b>

1. Field Duplicate (FD) samples will be collected at a rate of 1 per every 10 field samples.

2. Matrix Spike/Matrix Spike Duplicate (MS/MSD) samples will be collected at a rate of 1 pair per every 20 field samples.

3. Injection Wells: F-MW33, F-EW7

4. Test Wells: F-MW31, F-MW32, F-MW35, F-MW21, F-EW1, F-EW3

## QAPP Worksheet #21: Field SOPs

(UFP-QAPP Manual Section 3.1.2)

### 1. USACE Groundwater Collection and Analysis Procedures

Background samples will be collected with a submersible pump using low-flow sampling techniques (subsequent samples will be collected at a low-flow rate after purging for an adequate amount of time, which is determined by the stabilization time during background sampling). The low flow sampling will be conducted in accordance with the USEPA “*Low Stress (low flow) purging and sampling procedure for the collection of groundwater sampled from monitoring wells*” (EPA 1997). Water levels will be monitored during low-flow sampling. Stabilization parameters pH, specific conductivity, temperature, dissolved oxygen, and oxidation reduction potential will be measured using an in-line flow cell (QED MicroPurge® Flow Cell Model MP20 or similar instrument) that will be calibrated each morning prior to use. Turbidity, while not considered a stabilization parameter, will also be measured. Fe (II) will be measured using a Hach Iron (Ferrous) Color Disc Test Kit, Model IR-18C following stabilization.

The initial flow rates will be closely monitored during purging. Well purge flow rates will be calculated by dividing volume purged by elapsed time. After determining the optimum flow rate, the controller will be adjusted, or throttled to the desired pump flow rate. For low-flow sampling, the flow rate should be no greater than 500 milliliters/minute. Micropurge flow cell data will be recorded every two minutes while monitoring for stabilization prior to sample collection.

At each well, low-flow purging will continue until three consecutive measurements of the stabilization parameters meet stabilization requirements. Stabilization parameter requirements are as follows:

pH	+/- 0.2 units
Specific Conductivity	+/- 0.020 mS/cm
Temperature	+/- 0.2 °C
DO	+/- 0.2 mg/l
ORP	+/- 20 mV

Samples of injected test solutions and groundwater for laboratory analysis will be collected in amber glass or HDPE bottles as appropriate, shipped on ice, and stored at 2-6 °C until analysis.

Explosives analyte concentrations will be determined by high performance liquid chromatography (HPLC) using EPA Method 8330B. Samples will be analyzed for bromide using EPA Method 300.0. Samples will be analyzed for TOC using SW-846 Test Method 9060A.

Samples will be packaged in insulated coolers for shipment to the lab. Each cooler will be lined with plastic bubble wrap for shock absorption, and sample bottles will be individually protected by bubble wrap to protect against breakage. Each sample bottle will be placed in its own plastic Ziploc bag. A large plastic garbage bag will be used inside the cooler to contain the sample bottles in case of breakage. All samples will be placed in the shipping coolers and denoted on the Chain of Custody (COC) form accompanying each cooler. A photo of each completed COC form will be taken. Completed COC forms will be taped to the inside of each cooler lid. The coolers will be shipped via standard overnight FedEx service to the analytical laboratory. The sampling team lead shall call or email the laboratory POC each

day samples are shipped in order to alert the lab to samples to arrive the next day. The laboratory POC shall call or email USACE, confirming receipt of each shipment.

The nearest FedEx shipment location is the FedEx Office Print and Ship Center in Silverdale, Washington at 10854 NW Myhre Pl, Silverdale, WA 98383. The business is open 7:30 AM to 9:00 PM during the week, with the latest drop-off time for express shipments at 4:05 PM. Coolers will be shipped to the appropriate lab, cooled from 2-6 °C with wet ice, in a timeline that will meet the sample holding times, under chain of custody control.

Instructions for sample handling and custody are listed in Worksheet #26/27.

## **2. Sample Collection Equipment**

- Well Keys
- Field notebook
- Laboratory provided sample containers and labels
- Coolers with ice
- Chain of custody
- Pump
- Battery for pump
- 1 Liter measuring cup
- Dedicated sample tubing
- Alconox ®
- Distilled water
- Multiparameter water quality meter (pH, ORP, DO, conductivity, temperature)
- Turbidity meter
- Iron test kit with ferrous iron reagent
- Electronic water level meter
- Ziploc® bags
- Packaging tape
- Bubble wrap
- Garbage bags
- Paper towels
- Nitrile gloves
- 5 gallon bucket

## **3. Decontamination and Investigation-Derived Waste**

Certified clean sample jars will be provided from the laboratory. Dedicated sample pumps will be used in each well, so there will be no reusable sampling equipment that would require decontamination.

Well purge water (approximately 5 gallons per sample) will be put into 1,500-gallon poly tanks onsite and then run through the site treatment system.

Personnel protective equipment and other solid wastes (paper towel, e.g.) will be placed in trash bags and disposed of in a dumpster.

## **4. Field Documentation**

### **a. Photographs**

Digital photographs will be taken to document sample locations. The subject of each photograph is the sampling location and the collection activity associated with the sample. Digital photographs will be provided electronically to the USACE PM with the associated field logbook information. Information about each photograph will be recorded in the field logbook. The information will include:

- Date and time;
- Subject;
- Purpose for photograph being taken;
- Number of photograph;

### **b. Field Logbooks**

Permanently bound field books with waterproof paper will be used as field logbooks because of their compact size, durability, and secure page binding. The pages of the logbook will be numbered consecutively and will not be removed for any reason. Logbooks will document the procedures performed by field personnel. Each entry will be dated and contain legible, accurate, and complete documentation of the sampling activities. Documentation in the field logbook will be at a level of detail sufficient to explain and reconstruct field activities without relying on recollection by the field team members.

Entries in the logbook or other relevant sampling forms for sampling events will include, but not necessarily be limited to, the following:

- Project name, location, and number
- Field crew personnel, subcontractors, other personnel names
- Safety briefing and day schedule plan conducted
- Rationale for collecting the sample
- Date and time of sampling
- Sample numbers
- Cross-reference of numbers for duplicate and blank samples
- Media sampled
- Geographical location of the sampling area
- Method of sampling, including procedures, equipment, and any departure from the procedures specified in the management plan.
- Rationale for any deviations from management plan procedures and documentation
- Sample preservation
- Type and quantity of container used for each sample.
- Weather conditions at the time of sampling and previous events that may influence the representative nature of a sample - at a minimum, the temperature, approximate wind speed and direction, and sky cover
- Photographic information - a brief description of what was photographed and why, the date and time, the compass direction of the picture, and digital file name
- Analyses requested
- Disposition of the sample (i.e., where the sample is being shipped)
- Airbill number of sample shipment, when applicable

- Other pertinent observations, such as the presence of other persons on the site (those associated with the job or members of the press, special interest groups, or passersby) and actions by others that may affect performance of site tasks
- Type of health and safety clothing and type of equipment used
- Name(s) of sampling personnel.

Additional details may be recorded in the field logbook for all sampling locations.

## **5. Sample Numbering**

Every sample collected in the field will be labeled and accompanied by a chain-of-custody form when delivered to the laboratory for analysis. Information on the sample label shall contain, at a minimum, sample identification number, analysis requested, and sampling date and time. All samples collected will be assigned a unique identification code based on a consistent sample designation scheme.

Sample numbers are generally assigned as follows:

22F-TNT-P(PPT or ISB)-(sample location (i.e., injection or well)-sample number-QC if applicable; where:

22F-TNT is for Bangor Site F, 2022 TNT Pilot Study, and P is for Phase (i.e., PPT or ISB).

Examples:

22F-TNT-PPT-MW32-09: TNT Pilot Study, PPT, Sample from F-MW32, Sample #9

22F-TNT-ISB-INJ-02: TNT Pilot Study, Phase I ISB, Sample from injection solution, Sample #2

22F-TNT-ISB-MW32-02-FD: TNT Pilot Study, Phase I ISB, Sample from F-MW32, Sample #2, field duplicate

22F-TNT-ISB-MW32-02-MS: TNT Pilot Study, Phase I ISB, Sample from F-MW32, Sample #2, matrix spike

22F-TNT-ISB-MW32-02-MSD: TNT Pilot Study, Phase I ISB, Sample from F-MW32, Sample #2, matrix spike duplicate

Samples designated in the field for MS/MSD will be collected at triple the required mass or volume. “MS or MSD” will be indicated on the sample label and chain-of-custody.

## **6. Cooler Packing for Shipping**

### **At the sampling location:**

1. Samples should be iced as soon as they are sampled. Place the collected samples in a cooler with ice. Samples may be prepared for shipping at the sample location, or later at a convenient location, as long as samples are iced throughout.

### **When using wet ice – How to prepare the samples and cooler for shipment:**

1. So that leaks will not escape the cooler, seal the cooler drain with tape on the inside of the cooler, if it is not already sealed.
2. Line the bottom and sides of the cooler with thick bubble wrap.

3. Place a large, heavy-duty trash bag inside the cooler. All samples and ice will go inside this trash bag.
4. Double-bag ice inside gallon-sized Ziploc bags. Each cooler should have 4 to 5 bags of ice. Ice from water is preferred to gel packs because the gel packs are very hard when frozen and may break bottles, and also due to chemical contamination concerns with some sample types. If the ice was used earlier in the day during sampling, it is good practice to top off the ice bags with additional ice, pouring out any water, to ensure the samples stay cold during shipping.
5. Place all sample bottles in individual Ziploc bags. Place the bagged samples inside bubblewrap sleeves, or wrap with bubblewrap and secure with rubber bands or tape.
6. Put the bagged, bubble-wrapped samples and the double-bagged ice inside the trash bag in the cooler. Each sample should be in contact with ice. A common way to arrange the contents is to lay 2 bags of ice on the bottom of the cooler, put the samples on top of the ice, and then put additional bags of ice on top of the samples, and also vertically between the bottles. Arrangement may vary so that all samples will fit in the cooler.
7. Place an additional piece of bubblewrap on top of the samples.
8. Gather the ends of the trash bag together, fold over several times, and seal with tape. All samples and ice will be sealed in the trash bag, so any leaks should not escape the cooler.
9. If there is too much extra space, stuff bubblewrap around the trash bag to limit motion inside the cooler.

**At the shipping location (for example, FedEx store):**

1. Sign off the chain of custody (COC) with the date and time you are relinquishing the samples to the shipping company. Include the airbill number/tracking number on the COC. It is good practice to take a picture of the COC and email it to the laboratory, along with the tracking number.
2. Place the signed COC in a Ziploc bag and tape it to the inside of the cooler lid.
3. Shut the cooler. Seal the cooler by wrapping filament tape around the cooler. Wrap the filament tape around the cooler on the right and left sides, with two layers of tape on each wrapping.
4. Cut two ~8-10 inch pieces of custody tape. Use the pieces of custody tape to seal the cooler lid to the cooler body, placing the pieces of tape at the front right and back left of the cooler.
5. Fill out the airbill, then keep the top copy of the airbill and return it to the Visa card holder who provided the shipping company account number. Scan a copy and email, if needed.
6. Attach the rest of the airbill to the cooler handle, or tape to the top lid of the cooler.
7. If shipping biological specimens (and assuming they are non-infectious), put a label on the cooler that says "exempt animal specimen." This label can simply be a piece of paper taped to the cooler. Put on the same side as any other labels.

## **QAPP Worksheet #22: Field Equipment Calibration, Maintenance, Testing, and Inspection**

*(UFP-QAPP Manual Section 3.1.2.4)*

### **Multiparameter Water Quality Meter**

1. Before each use inspect the instruments to ensure there are no signs of damage or wear that requires repair.
2. Check the battery life of the meter and ensure the battery will last for the entire sampling event.
3. If the instrument has been calibrated during the previous week then check the calibration of the pH, and conductivity using the calibration confidence solution. If the calibration is outside of the range listed on the confidence solution, then calibrate according to manufacturer's directions.
4. Calibrate the pH and conductivity a minimum of once a week according to the manufacturer's directions.
5. Use a three-point calibration for the pH.
6. Calibrate the dissolved oxygen daily according to the manufacturer's directions.
7. Record the daily calibration checks and calibration of the sampling logs.
8. Record any anomalies, such as if a probe is not calibrating.
9. Store equipment correctly with probes in the correct solution recommended by manufacturer.
10. Ensure equipment is decontaminated, dry and properly stored with all parts and manuals after each use.
11. Store equipment in a dry location that does not have temperature extremes.

### **Water Level Indicator (WLI)**

1. Before each use check the batteries on the WLI by pressing the test button.
2. Inspect the instrument for damage especially along the cable for exposed wires.
3. Inspect the instrument for dirt or debris that may contaminate a well.
4. After each use clean off the portion of the WLI that was in the well and decontaminate the bottom five feet of the WLI.
5. Store WLI in a dry location.



**QAPP Worksheet #23: Analytical SOPs**  
(UFP-QAPP Manual Section 3.2.1)

SOP #	Matrix/Analytical Group	Title, Date, and URL (if available)	Modified for Project? Y/N
EMT	TOC in Water EPA 9060A	EMT-SOP-I-063. Total Organic Carbon Using the Shimadzu TOC-LCPH/CPN Analyzer Rev. 15, 01/08/2021	N
	Anions in Water EPA 300.0	EMT-SOP-I-063. Inorganic Ions by Ion Chromatography Rev. 14 March 24, 2021	N
	Explosives in Water EPA 8330B	EMT-SOP-O-8330. Analysis of Explosives by Method 8330B Rev 11 December 14, 2020.	N

## **QAPP Worksheet #24: Analytical Instrument Calibration**

*(UFP-QAPP Manual Section 3.2.2)*

Analytical instrument calibration will be performed according to laboratory SOPs, and according to the principles of the DoD Quality Systems Manual (QSM) for DoD ELAP-accredited methods.

## **QAPP Worksheet #25: Analytical Instrument and Equipment Maintenance, Testing, and Inspection**

*(UFP-QAPP Manual Section 3.2.3)*

Analytical instrument and equipment maintenance, testing, and inspection will be performed according to the laboratory quality manual.

EMT: Quality Assurance Manual, Rev 18, Nov. 18, 2019.

## **QAPP Worksheet #26 & 27: Sample Handling, Custody, and Disposal**

*(UFP-QAPP Manual Section 3.3)*

**Sampling Organization:** USACE Seattle District

**Laboratory Address and Scope:**

**Prime Contract Lab: Analytes**

Environmental Monitoring and Technologies, Inc.

509 N. 3rd Ave.

Des Plaines, IL. 60016

Primary POC: Tim Witrzek, [twitrzek@emt.com](mailto:twitrzek@emt.com), 847-324-3320

**Method of Sample Delivery (shipper/carrier):** FedEx

### **1. Sample Delivery**

Samples will be packed in coolers using bubble wrap along with ice packs, blue ice, or crushed ice for transport to the laboratory. A temperature blank will be placed in each sample cooler. All samples will be accompanied by chain-of custody forms. Chain-of-custody records will be maintained by the Field Lead to document and verify sample transfer to laboratory.

### **2. Sample Custody**

After sample collection, samples will be maintained in the custody of field personnel until formally transferred to the laboratory or storage area. For the purposes of this work, custody will be defined as follows:

- Samples will be in plain view of the field personnel.
- Samples will be stored inside an appropriate container that is in plain view of the field personnel.
- Samples will be stored inside any locked space such as a cooler, locker, car, truck, or trailer to which field personnel have the only immediately available key(s) or lock combination.

Custody records will be maintained for all samples recovered. Custody records are defined as formal chain-of-custody forms. The information on the chain-of-custody form shall contain, at a minimum, the following:

- Project Name
- Sample identification number
- Date and time of sample collection
- Sample location identification and/or description
- Sample matrix type
- Signatures sample handlers
- Type of analyses requested
- Number of containers used to hold the sample

- Temperature blank listed on form (if using)
- Method of shipment
- Signatures indicating relinquishment and acceptance of samples including date and time of sample transfer
- Phone number and name of person to whom results should be reported

If samples leave the custody of the designated person as defined above, custody seals will be affixed to the sample or shipping containers. The custody seals will contain, at a minimum, the name and title of the person responsible for the samples, the signature of that person, and the date when the custody seal was applied.

The Field Lead will be responsible for sample tracking and chain-of-custody procedures in the field. The Field Lead, or designee, will prepare field notebook entries prior to removing samples from sampling equipment. At the end of the work day, chain-of-custody forms will be prepared by the Field Lead, or designee, prior to transfer of the samples into shipping coolers. All information on the chain-of-custody forms will be cross-checked against field notebook entries and sample labels prior to sample transfer.

### **3. Laboratory Custody Procedures**

A designated sample custodian at the laboratory will accept custody of the shipped samples from the carrier and enter the preliminary information about the samples into a sample receipt log, including the initial of the person delivering the samples and the status of the custody seals on the coolers (i.e., broken versus unbroken), if affixed. The custodian responsible for sample log-in will follow the laboratory's SOP for opening the coolers, checking cooler temperature, checking the contents, and verifying that the information on the chain-of-custody agrees with the samples received.

### **4. Laboratory Sample Disposal**

The laboratory will dispose of samples in accordance with their appropriate waste streams.

## **QAPP Worksheet #28: Analytical Quality Control and Corrective Action**

*(UFP-QAPP Manual Section 3.4 and Tables 4, 5, and 6)*

Quality control and corrective actions will follow laboratory SOPs and, if the analysis is according to the DoD ELAP accreditation, the principles of the DoD Quality Systems Manual (QSM) for each method.

## QAPP Worksheet #29: Project Documents and Records

*(UFP-QAPP Manual Section 3.5.1)*

Project Documents and Records			
Record	Generation	Verification	Storage Location/Archival
Work Plan	Project Chemist (Alison Suess)	Research Environmental Engineer (Jacob Lalley)	Project File
UFP-QAPP	Project Chemist (Alison Suess)	Research Environmental Engineer (Jacob Lalley)	Project File
Health and Safety Plan	Field Lead (Jeff Weiss) and Project Scientist (Jenny Phillippe/Dan Carlson)	USACE Seattle District Safety Office	Project File
Field Sampling Report	Field Lead (Jeff Weiss) or Project Scientist (Jenny Phillippe/Dan Carlson)	Project Scientist (Jenny Phillippe/Dan Carlson) or Field Lead (Jeff Weiss)	Project File
Laboratory Reports	Laboratory Staff	Project Chemist (Alison Suess)	Project File
Data Validation Report	Data Validation (Laboratory Subcontract) Staff	Project Chemist (Alison Suess)	Project File
Final Data Report	Project Scientist (Jenny Phillippe/Dan Carlson), Field Lead (Jeff Weiss), and Project Chemist (Alison Suess)	Research Environmental Engineer (Jacob Lalley)	Project File

## QAPP Worksheet #31, 32 & 33: Assessments and Corrective Action

*(UFP-QAPP Manual Sections 4.1.1 and 4.1.2)*

### Assessments:

Assessment Type	Responsible Party & Organization	Number/Frequency	Assessment Deliverable
Work Plan and QAPP Stakeholder Review	Project Manager (Briana Niestrom)	Once	Comments from Reviewers, Responses and Revisions from USACE
Field Sampling Daily Safety Briefs and Checks	Field Lead (Jeff Weiss)	Each day of sampling	Field Sampling Report
Assessment of Laboratory Data and Data Validation Reports	Project Chemist (Alison Suess)	Upon receipt of reports	Incorporated into Final Data Report
Data Usability Assessment	Project Team (See Worksheet #37)	Once	Incorporated into Final Data Report
Final Data Report Stakeholder Review	Project Manager (Briana Niestrom)	Once	Comments from Reviewers, Responses and Revisions from USACE



## QAPP Worksheet #34: Data Verification and Validation Inputs

(UFP-QAPP Manual Section 5.2.1 and Table 9)

### Planning Documents/Records:

Item	Verification (Completeness)	Validation (Conformance to Specifications)
Approved Work Plan	X	
Approved QAPP	X	

### Field Records:

Item	Verification (Completeness)	Validation (Conformance to Specifications)
Field Logs	X	
Field Sampling Report	X	

### Analytical Data Package:

Item	Verification (Completeness)	Validation (Conformance to Specifications)
Case narrative	X	X*
Sample receipt records	X	X*
Sample chronology (i.e. dates and times of receipt, preparation, & analysis)	X	X*
Standards Traceability	X	X*
Instrument calibration records	X	X*
Definition of laboratory qualifiers	X	X*
Results reporting forms	X	X*
QC sample results	X	X*
Raw data	X	
Electronic data deliverables: A1/A3 compatible with ADR	X	X*

\*Stage 2B data validation will be performed.

## QAPP Worksheet #35: Data Verification Procedures

*(UFP-QAPP Manual Section 5.2.2)*

Records Reviewed	Requirement Documents	Process Description	Responsible Person, Organization
Work Plan and QAPP	Work Plan and QAPP	Stakeholders will review the QAPP and provide comments. USACE will respond to comments and incorporate revisions to the QAPP if necessary.	Project Manager (Briana Niestrom)
Field logbooks	QAPP	Verify that records are present and complete for each day of field activities. Verify that all planned samples including field QC samples were collected and that sample collection locations are documented. Verify that meteorological data were provided for each day of field activities. Verify that changes/exceptions are documented and were reported in accordance with requirements. Verify that any required field monitoring was performed and results are documented.	Daily – Field Lead (Jeff Weiss)  At conclusion of field activities - Project Chemist (Alison Suess)
Chain-of-custody forms (CoCs)	QAPP	Verify the completeness of chain-of-custody records. Examine entries for consistency with the field logbook. Check that appropriate methods and sample preservation have been recorded. Verify that the required volume of sample has been collected and that sufficient sample volume is available for QC samples (e.g., MS/MSD). Verify that all required signatures and dates are present. Check for transcription errors.	Daily – Field Lead (Jeff Weiss)  At conclusion of field activities - Project Chemist (Alison Suess)
Laboratory Deliverable	QAPP, Field Logbooks or Field Sampling Report	Verify that the laboratory deliverable contains all records specified in the QAPP. Check sample receipt records to ensure sample condition upon receipt was noted, and any missing/broken sample containers were noted and reported according to plan. Compare the data package with the CoCs to verify that results were provided for all collected samples. Review the narrative to ensure all QC exceptions are described. Check for evidence that any required notifications were provided to project personnel as specified in the QAPP. Verify that necessary signatures and dates are present.	Before release - Laboratory Staff  Upon receipt - Project Chemist (Alison Suess)
Data Validation Deliverable	QAPP, Laboratory Reports	Verify that the data validation deliverable contains all records specified in the QAPP. Compare the deliverable to the laboratory report and CoCs to verify that results were provided for all collected samples. Review the narrative to ensure that all QC exceptions and flagged data are described.	Before release – Data Validation Staff  Upon receipt - Project Chemist (Alison Suess)

## QAPP Worksheet #36: Data Validation Procedures

(UFP-QAPP Manual Section 5.2.2)

Data will be validated by EMT's data validation subcontractor, LDC, Inc., as part of the Task Order for the laboratory work. EMT will provide Level 4 laboratory reports.

Data Validator: LDC, Inc.

Analytical Group	Matrix	Stage	Validation Criteria
TOC (EPA 9060A)	Water	100% Stage 2B (SV2EM)	Validation performed in accordance with the laboratory analytical methods and the DoD QSM (DoD, 2019). DoD General Data Validation Guidelines (DoD, 2018) and EPA National Functional Guidelines (EPA, 2020) will be used for general guidance.
Anions (EPA 300.0)	Water	100% Stage 2B (SV2EM)	Validation performed in accordance with the laboratory analytical methods and the DoD QSM (DoD, 2019). DoD General Data Validation Guidelines (DoD, 2018) and EPA National Functional Guidelines (EPA, 2020) will be used for general guidance.
Explosives (EPA 8330B)	Water	100% Stage 2B (SV2EM)	Validation performed in accordance with the laboratory analytical methods and the DoD QSM (DoD, 2019). DoD General Data Validation Guidelines (DoD, 2018) and EPA National Functional Guidelines (EPA, 2020) will be used for general guidance.

The following data qualifiers will be applied during data validation by a third party. Potential impacts on project-specific data quality objectives will be discussed in the data validation report.

**Table 11. Data Qualifiers and Definitions**

Qualifier	Definition
U	The analyte was not detected and was reported as less than the LOD or as defined by the customer. The LOD has been adjusted for any dilution or concentration of the sample.
J	The reported result was an estimated value with an unknown bias.
J+	The result was an estimated quantity, but the result may be biased high.
J-	The result was an estimated quantity, but the result may be biased low.
N	The analysis indicates the presence of an analyte for which there was presumptive evidence to make a "tentative identification."
NJ	The analyte has been "tentatively identified" or "presumptively" as present and the associated numerical value was the estimated concentration in the sample.
UJ	The analyte was not detected and was reported as less than the LOD or as defined by the customer. However, the associated numerical value is approximate.
X	The sample results (including non-detects) were affected by serious deficiencies in the ability to analyze the sample and to meet published method and project quality control criteria. The presence or absence of the analyte cannot be substantiated by the data provided. Acceptance or rejection of the data should be decided by the project team (which should include a project chemist), but exclusion of the data is recommended.

## QAPP Worksheet #37: Data Usability Assessment

(UFP-QAPP Manual Section 5.2.3 including Table 12)

This worksheet documents procedures that will be used to perform the data usability assessment. The data usability assessment is performed at the conclusion of data collection activities, using the outputs from data verification and data validation. It is the data interpretation phase, which involves a qualitative and quantitative evaluation of environmental data to determine if the project data are of the right type, quality, and quantity to support the decisions that need to be made. It involves a retrospective evaluation of the systematic planning process, and, like the systematic planning process, involves participation by key members of the project team. The data usability assessment evaluates whether underlying assumptions used during systematic planning are supported, sources of uncertainty have been accounted for and are acceptable, data are representative of the population of interest, and the results can be used as intended, with the acceptable level of confidence.

### **Identify personnel (organization and position/title) responsible for participating in the data usability assessment:**

Project Manager – Briana Niestrom

Research Environmental Engineer – Jacob Lalley

Project Scientist – Jenny Phillippe

Project Scientist – Dan Carlson

Project Chemist – Alison Suess

Field Lead – Jeff Weiss

### **Describe how the usability assessment will be documented:**

The data usability assessment will be documented as a section of the final report.

### **Summarize the data usability assessment process including statistics, equations, and computer algorithms that will be used to analyze the data:**

<b>Step 1</b>	<b>Review the project's objectives and sampling design:</b> Review the DQOs defined during systematic planning to make sure they are still applicable. Review the sampling design for consistency with stated objectives. This provides the context for interpreting the data in subsequent steps.
<b>Step 2</b>	<b>Review the data verification and data validation outputs:</b> Review available QA reports, including the data verification and data validation reports. Perform basic calculations and summarize the data (using graphs, maps, tables, etc.). Look for patterns, trends, and anomalies (i.e., unexpected results). Review deviations from planned activities (e.g., number and locations of samples, holding time exceedances, damaged samples, non-compliant PT sample results, and SOP deviations) and determine their impacts on the data usability. Evaluate implications of unacceptable QC sample results.
<b>Step 3</b>	<b>Verify the assumptions of the selected statistical method:</b> Verify whether underlying assumptions for selected statistical methods are valid. Common assumptions include the distributional form of the data, independence of the data, dispersion characteristics, homogeneity, etc. Depending on the robustness of the statistical method, minor deviations from assumptions usually are not critical to statistical analysis and data interpretation. If serious deviations from assumptions are discovered, then another statistical method may need to be selected.

<b>Step 4</b>	<b>Implement the statistical method:</b> Implement the specified statistical procedures for analyzing the data and review underlying assumptions.
<b>Step 5</b>	<b>Document data usability and draw conclusions:</b> Determine if the data can be used as intended, considering implications of deviations and corrective actions. Discuss data quality indicators. Assess the performance of the sampling design and identify limitations on data use. Update the conceptual site model and document conclusions. Summarize data usability in the final report.

## References

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- EPA (U.S. Environmental Protection Agency). 1994a. EPA Superfund Record of Decision: Bangor Naval Submarine Base, EPA ID: WA5170027291, OU 02, Silverdale, Washington. September 1994.
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- USACE. 2014. Groundwater Modeling at Naval Base Kitsap Bangor Site F Report. 16 June 2014.

## **Appendix A**

### **Response to Comments**

## Washington State Department of Ecology Review Comments and Responses

From: Maurer, Christopher (ECY) <[cm461@ecy.wa.gov](mailto:cm461@ecy.wa.gov)>

Sent: Wednesday, June 29, 2022 12:47 PM

To: Gander, Malcolm J CIV USN NAVFAC NW SVD WA (USA) <[malcolm.j.gander.civ@us.navy.mil](mailto:malcolm.j.gander.civ@us.navy.mil)>; Craig, Harry <[Craig.Harry@epa.gov](mailto:Craig.Harry@epa.gov)>

Subject: [Non-DoD Source] FW: Site F Source Area Pilot Test Draft Work Plan and QAPP (USN - Bangor Subase)  
- Ecology comments

Malcolm,

I have reviewed the above documents and have the following comments:

- 1) Workplan – Section 4.9 and Appendix B and QAPP – Worksheet 17 – while both documents refer to EPA's PFAS Regional Screening Levels in their narrative, numerical values for the screening levels should be included in the tables listing the results of the April groundwater sampling.
- 2) (editorial) Please replace Mahbub Alam's name with my own – Christopher Maurer – in both documents.

Chris M.

Response 1. Numerical values for the EPA's PFAS Regional Screening Levels have been included in the table in QAPP Worksheet #17.

Response 2. The editorial changes have been made