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LETTER REPORT REGARDING ARSENIC BACKGROUND STUDY WORK PLAN NS MAYPORT FL
1/18/2008
TETRA TECH NUS

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Project Number 112G00436

Naval Facilities Engineering Command, Southeast
ATTN: Adrienne Wilson (Code EV4)
2155 Eagle Drive
North Charleston, South Carolina 29406

Reference: CLEAN IV Contract Number N62467-04-D-0055
Contract Task Order 0033

Subject: Arsenic Background Study Workplan
Naval Station Mayport, Mayport, Florida

Dear Ms. Wilson:

Tetra Tech NUS, Inc. (TtNUS) is pleased to submit the Arsenic Background Study Workplan at Naval Station (NAVSTA) Mayport, Florida. This workplan was prepared for the United States Navy, Naval Facilities Engineering Command Southeast (NAVFAC SE) under Contract Task Order (CTO) 0033 for the Comprehensive Long-term Environmental Action Navy (CLEAN) IV Contract Number N62467-04-D-0055. This workplan outlines the soil sampling requirements for background arsenic sampling. The overall objective of the field activities outlined in this workplan is to determine background arsenic concentrations at NAVSTA Mayport through hand augering and Direct Push Technology (DPT) soil sampling.

The data collected during field activities outlined in this workplan will provide the basis for establishing the background arsenic concentration for NAVSTA Mayport.

SITE BACKGROUND

Soils at NAVSTA Mayport are predominantly composed of dredge fill material. With the concentrations of arsenic in soils being fairly consistent throughout the facility's Solid Waste Management Units (SWMUs), the Navy proposes to use the results of this study to determine background arsenic concentrations at NAVSTA Mayport.

Past sampling at the NAVSTA Mayport SWMUs has yielded more than 800 soil samples that are depicted in Figure 1. These samples were collected over several years from surface and subsurface soil intervals. The surface depth interval is 0 to 1 foot below ground surface (bgs); all other depths below 1 foot represent subsurface soil. The arsenic concentrations detected to date in soil at the installation range from 15.6 to 0.006 (nondetect) milligrams per kilogram (mg/kg) with a combined surface and subsurface mean of 1.15 mg/kg (1.25 mg/kg for subsurface soil) and a combined median of 0.77 mg/kg. The Florida Department of Environmental Protection (FDEP) residential direct exposure Soil Cleanup Target Level (SCTL) for arsenic is 2.1 mg/kg. The FDEP industrial direct exposure SCTL for arsenic is 12 mg/kg.

Several areas at the installation that are located away from the SWMUs, and industrial operations have not been sampled. The relative magnitude of the arsenic concentrations in the SMWU areas compared to arsenic concentrations in the unsampled areas is unknown. It is anticipated that the arsenic concentrations in these previously unsampled areas are less than or equal to already measured arsenic concentrations.

SAMPLING PROGRAM OBJECTIVES

The objectives of the sampling program detailed in this plan are as follows:

1. Previously unsampled areas will be sampled to provide adequate spatial and statistical coverage for NAVSTA Mayport-wide arsenic concentrations in soil. Arsenic will be the only parameter analyzed.

2. Data sets for SWMU-area arsenic concentrations and arsenic concentrations from previously unsampled areas will be compared statistically to determine the relative magnitudes of arsenic concentrations in these two categories.

3. Two specific areas at the installation that are known to be native soil will be represented in the sampling scheme so arsenic concentrations for those areas can be compared to arsenic concentrations from the other areas containing dredged material.

Two primary questions will be answered in the statistical study:

1. Are arsenic concentrations from previously sampled areas significantly different, based on statistical analysis, than arsenic concentrations in previously unsampled areas?

2. Are arsenic concentrations from previously sampled areas significantly different, based on statistical analysis, than arsenic concentrations in the native soil areas?

If the answer to either of these questions is yes, additional study activities may be warranted.

To accomplish this, TtNUS will perform the following proposed sampling activities.

PROPOSED SITE ACTIVITIES

To support background arsenic site assessment activities throughout the base, TtNUS will collect soil samples using the techniques discussed below. Samples will be submitted to a fixed-base laboratory for arsenic analysis. Soil samples will be collected using hand augering and DPT methodologies at approximately 40 locations that were approved by the FDEP regulator and determined through statistical analysis and random or pseudo-random location selection (see Attachment 1). The soil sample locations are shown on Figure 2 of this workplan. Field activities will be conducted during an approximate 20-day period. Prior to the field activities, mobilization activities will be conducted. Tasks associated with mobilization include the following:

- Field Coordination (i.e., coordinating for site access, obtaining field equipment and consumables, etc.)
- Subcontractor Procurement and Coordination (DPT subcontractor and fixed-base laboratory)
- Utility Clearance
- Project “Kick-off” and Daily Health and Safety “Tailgate” Meetings

Health and Safety

Field activities shall be completed in accordance with the Health and Safety Plan (HASP) for Base Wide Background Soil Sampling (dated November 2007). A copy of the HASP will be kept on site at all times during field activities. Additional copies are available upon request for both TtNUS field personnel and subcontractors.

Soil Sampling

Soils across NAVSTA Mayport are believed to be uniform enough in geologic composition as to represent similar geochemistry regardless of location. The geochemistry, however, may vary with depth. Furthermore, risk assessments commonly subdivide soils samples into surface and subsurface groups because exposure scenarios are different for these groups. Consequently, only two potentially significant soil groups will be used in the study, surface and subsurface.

Soil samples will be collected from at least the 40 locations depicted on Figure 2. The first 4 feet of each boring will be hand augured or post-holed by the DPT subcontractor, if possible, to clear for underground utilities. It should be noted that hand auguring has been attempted at various locations at NAVSTA Mayport in the past. At some locations, it was difficult to penetrate the various layers of coquina shells at the site. Therefore, the subcontractor may have to use alternative methods for clearance of underground utilities. Decisions to use alternative soil sampling technology will be made by the TtNUS Field Operations Leader (FOL) in conjunction with the TtNUS Task Order Manager (TOM).

Two soil samples will be collected at each location to a maximum depth of approximately 10 feet. These will consist of one surface soil sample (0 to 1 foot) and one subsurface soil sample collected just above the water table. Surface soil will be collected using a hand auger. Subsurface soil will be collected using a stainless steel Macro-Core® soil sampler (4-foot section) beginning at 4 feet bgs and continuing in 4-foot vertical intervals until the maximum depth of 10 feet or the water table is encountered. Historical groundwater data indicate that the water table at NAVSTA Mayport is encountered at approximately 4.5 to 10 feet bgs. A closed-piston sampling method will be used to avoid cross-contamination between collection intervals. The Macro-Core® soil sampler will be decontaminated between each sample collection. Decontamination will be conducted in accordance to FDEP Standard Operating Procedure (SOP) FC1000.

Soil sampling procedures will be conducted in accordance with FDEP SOPs 001/01: FS3000: Soil Sampling and FS1000: General Sampling Procedures. Equipment rinsate blanks will also be collected. A summary of soil sampling activities is provided in Table 1. A copy of the soil boring and soil sampling logs are provided in Attachment 2. Soil displaced during each boring will be returned to the boring from which it was collected. No field duplicate samples will be collected.

Each soil sample location will be surveyed with a Trimble global positioning system (GPS) unit (or equivalent) that is capable of achieving a horizontal accuracy of less than 1 meter. It is anticipated that a Trimble GPS unit will be kept on site for the duration of the project. Horizontal datum should be surveyed in feet relative to the Florida State Plane Coordinate System, Florida State Plane North (North American Datum 1983). Following completion of the field sampling event, all survey data will be entered into the Environmental Geographic Information System (EGIS) database for NAVSTA Mayport.

Decontamination

The equipment used in field sampling activities will be decontaminated prior to and during sampling activities in accordance to FDEP SOP FC1000: Cleaning/Field Decontamination Procedures. Non-disposable equipment used for collecting samples will be decontaminated prior to beginning field sampling and between sample locations.

TABLE 1
SUMMARY OF SAMPLING ACTIVITIES
ARSENIC BACKGROUND STUDY WORKPLAN
NAVAL STATION MAYPORT, FLORIDA

Sample Type	Aqueous Samples	Soil Samples	Rinsate Blanks[1, 2]	Parameter	Analysis Method
Soil Samples	--	80	8	Arsenic	SW-846 6010B or 6020

1 = Pre- and post-equipment rinsate blanks will be collected each day. In accordance with FDEP SOP FQ1000, FQ1230, pre-cleaned and field-cleaned rinsate blanks will be collected for any equipment used in the collection of samples that is not certified pre-cleaned (i.e., 5 percent of the reported test matrix combination).

2 = The rinsate blanks listed will be aqueous samples collected for soil samples.

Soil Sampling Identification System

Each sample will be assigned a unique codified sample identification number. The unique nomenclature established for this sampling event is as follows:

1		2		3		4
MPTBG	-	EEXX	-	XX	-	MMDDYY

Sample Nomenclature for soil samples:

- MPTBG = NAVSTA Mayport, Background (BG)
- EEXX = SS for surface soil samples collected sequentially beginning with ‘SS01’ and SB for subsurface soil samples collected sequentially beginning with ‘SB01’
- XX = Depth of the bottom of interval at which sample was collected (feet bgs)
- MMDDYY = Month, day, and year of sample collection

Examples of the above are:

A soil sample collected on November 26, 2007, from SB05 at 8 feet bgs would be represented by MPTBG-SB05-08-112607.

Sample Custody, Packaging, and Shipping

Custody of samples must be maintained and documented at all times. Chain-of-custody begins with the collection of the samples in the field. FDEP SOP 001/01 FS 1000 and TtNUS SOP SA-6.3 provide a description of the chain-of-custody procedures to be followed.

Samples will be packaged and shipped in accordance with FDEP SOP 001/01 FS1000: General Sampling and applicable sections of FS2200 and FS3000. The FOL will be responsible for completion of the following forms when samples are collected for shipping:

1. Sample labels
2. Chain-of-custody labels

3. Appropriate labels applied to shipping coolers
4. Chain-of-custody forms
5. Federal Express (or equivalent) air bills

FS1000 also identifies requirements for sample containers, holding times, and sample preservations.

Quality Control Samples

Quality control samples will be collected during the soil assessment event in general accordance to FDEP SOP 001/01 FQ1000: Field Quality Control Requirements. In general, rinsate blanks will be collected on any sampling equipment (hand auger, DPT soil sampler, etc.) that is brought to the field and is not certified clean or that is field-cleaned between samples. This will be done to document that the equipment was clean when brought to the site and that no cross-contamination is occurring between samples. At a minimum, equipment rinsate blanks will be collected at a rate of 5 percent for each analysis to be performed.

Record Keeping

In addition to chain-of-custody records associated with sample handling, packaging, and shipping, certain standard forms will be completed for sample description and documentation. These will include sample log sheets (for soil and groundwater samples), daily activities record, and logbooks.

The FOL will maintain a bound/weatherproof field notebook. The FOL, or designee, will record pertinent information related to sampling or field activities. This information may include sampling time, weather conditions, unusual events (e.g., well tampering), field measurements, site visitors, descriptions of photographs, etc. At the completion of field activities, the FOL shall submit to the TtNUS TOM all field records, data, field notebooks, logbooks, chain-of-custody receipts, sample log sheets, daily logs, etc.

Investigation Derived Waste Management

Because the samples collected are for a basewide arsenic background study and are, therefore, being collected from areas that are not contaminated, soil displaced during each boring will be returned to the boring from which it was collected. It is not anticipated that there will any investigation derived waste that will require containerization and disposal as a result of field activities associated with this study.

Reporting

Information obtained from field activities detailed in this work plan will be incorporated into the Final Arsenic Background Study Report.

If you have any questions with regard to this submittal, please feel free to contact me at (904) 730-4669, extension 222, or via e-mail at shina.ballard@tetratech.com.

Sincerely,

Shina A. Ballard
Task Order Manager

SB/dh

Attachments (4)

c: Mr. John Winters P.G., FDEP (2 copies, 1 CD)
Mr. C. Benedikt, USEPA (CD only)
Ms. D. Racine, NAVSTA Mayport (1 copy, 1 CD)
Mr. M. Halil P.E., CH2MHill (CD only)
Ms. D. Humbert, TtNUS (cover letter only)
Mr. M. Perry, TtNUS (unbound copy, CD)
NAVSTA Mayport Administrative Record
CTO 0033 Project File

PROFESSIONAL CERTIFICATION

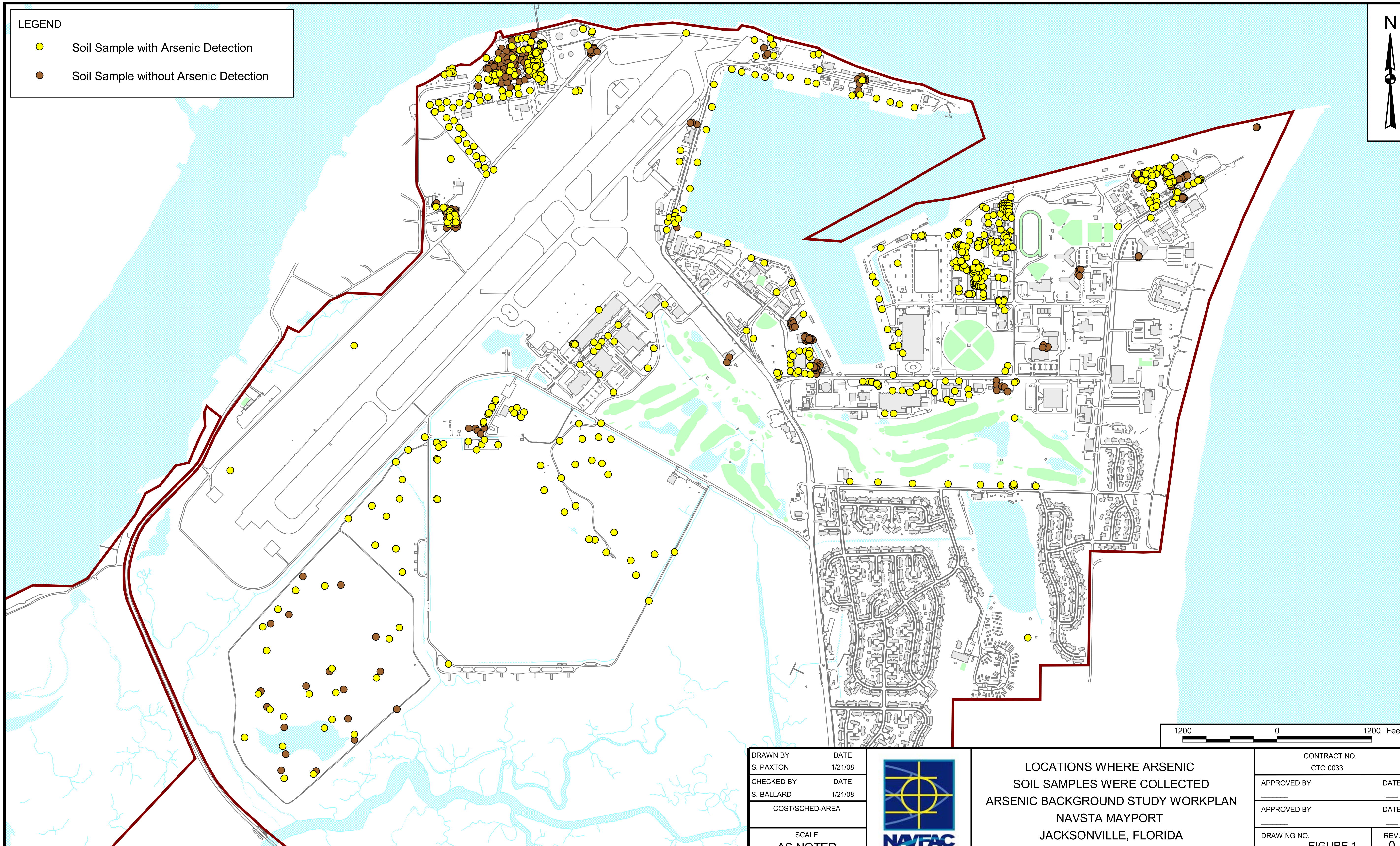
Arsenic Background Study Workplan
Various Locations throughout the Base
Naval Station Mayport, Florida

This Arsenic Background Study Workplan was prepared under the direct supervision of the undersigned geologist using geologic and hydrogeologic principles standard to the profession at the time the report was prepared in general conformance with the State of Florida Standard Operating Procedures. If conditions are determined to exist that differ from those described, the undersigned geologist should be notified to evaluate the effects of additional information on the assessment described in this report. This report was developed specifically for the referenced site and should not be construed to apply to any other site.

Joe Gibson, P.G.
Florida License Number PG-2356
January 18, 2008

FIGURES

P:\GIS\MAYPORT_NS\NAVSTA_MAYPORT_EVS.APR ARSENIC DETECTION LAYOUT 1/21/08 SP



DRAWN BY	DATE
S. PAXTON	1/21/08
CHECKED BY	DATE
S. BALLARD	1/21/08
COST/SCHED-AREA	
SCALE	
AS NOTED	

NAVFAC

LOCATIONS WHERE ARSENIC
SOIL SAMPLES WERE COLLECTED
ARSENIC BACKGROUND STUDY WORKPLAN
NAVSTA MAYPORT
JACKSONVILLE, FLORIDA

CONTRACT NO.	
CTO 0033	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO.	REV.
FIGURE 1	0

P:\GIS\MAYPORT_NS\NAVSTA_MAYPORT_EVS.APR REVISED PROPOSED LOCATION LAYOUT - HORIZONTAL 1/21/08 SP

DRAWN BY	DATE			CONTRACT NO.	
S. PAXTON	1/21/08		FORTY PROPOSED SOIL SAMPLE LOCATIONS	CTO 0033	
CHECKED BY	DATE	NAVFAC	ARSENIC BACKGROUND STUDY WORKPLAN	APPROVED BY	DATE
S. BALLARD	1/21/08		NAVSTA MAYPORT	APPROVED BY	DATE
COST/SCHED-AREA			JACKSONVILLE, FLORIDA		
SCALE				DRAWING NO.	REV.
AS NOTED				FIGURE 2	0

ATTACHMENT 1

USING STATISTICS TO CALCULATE THE ADDITIONAL SAMPLES NEEDED TO FULLY IDENTIFY THE ARSENIC CONCENTRATIONS IN SOIL ACROSS NAVAL STATION MAYPORT, FLORIDA

Using Statistics to Calculate the Additional Samples Needed to Fully Identify the Arsenic Concentrations in Soil across Naval Station Mayport, FL

Introduction

The purpose of this study is to establish the number and locations of additional soil sample needed to achieve a statistically meaningful sample population for arsenic concentrations in soil at Naval Station (NAVSTA) Mayport. The analytical results from these additional samples will be combined with the installation's existing arsenic concentration database and analyzed statistically to determine if there is a statistically significant difference in the arsenic concentrations detected in soils associated with Solid Waste Management Units (SWMUs) vs. soils collected located away from the SWMUs and industrial operations.

The following are the statistical software packages that are used to determine the number and locations of the additional soil samples:

C Tech EVS-PRO – A graphical, parameter spacing tool that uses system-driven kriging algorithms with best fit variograms. This program considers the measured uncertainty in available data as well as spatial positions of the sampled locations. In doing so it computes proposed sample locations with a goal of limiting future concentration estimates to an acceptable level of uncertainty.

Visual Sample Plan (VSP) – A publicly available software tool that generates technically defensible sampling schemes for site characterization. This program computes the minimum number of samples necessary to detect a predetermined difference between a data set mean and a numerical level (an action level). This program may also be used to compute the number of samples required to detect a prescribed difference between two data sets. This program does not consider nor does it propose lateral or vertical positions of samples locations.

VSP, which was developed with the support of the U.S. EPA, was used to independently verify the number of samples generated by the EVS-PRO.

The following sections, which follow the Data Quality Objectives (DQO) process, present the approach used to select the required number of additional soil samples and their locations.

DQO Step 1 - State the Problem

Past sampling at the NAVSTA Mayport (SWMUs) has yielded more than 800 soil samples. These samples were collected over several years from surface and subsurface soil intervals. The surface depth interval is 0-2 feet (below ground surface) bgs; all other depths represent subsurface soil.

The arsenic concentrations detected to date in soil at the installation ranged 15.6 to 0.006 (non-detect) milligram/kilogram (mg/kg) with a combined surface and subsurface mean of 1.15 mg/kg (1.25mg/kg for subsurface soil) and a combined median of 0.77 mg/kg. The Florida Department of Environmental Protection (FDEP) Soil Clean-up Target Level (SCTL) for arsenic is 2.1 mg/kg.

Several areas at the installation that are located away from the SWMUs and industrial operations have not been sampled. The relative magnitude of the arsenic concentrations in the SMWU areas compared to arsenic concentrations in the unsampled areas is unknown. It is anticipated that the arsenic concentrations in these previously unsampled areas are less than or equal to already measured arsenic concentrations.

For the purposes of the statistical study that will follow the sampling effort, there are three different types of soil areas:

- Group 1: SWMU areas that have already been sampled.
- Group 2: Areas away from the SWMUs and industrial operations that have not been sampled.
- Group 3: Areas within Group 2 that represent native soil.

The study will proceed with the following steps:

- Previously unsampled areas will be sampled to provide adequate spatial and statistical coverage for NAVSTA Mayport-wide arsenic concentrations in soil.

- Data sets for SMWU area arsenic concentrations and arsenic concentrations from previously unsampled areas will be compared to determine the relative magnitudes of arsenic concentrations in these two categories.

- Two specific areas at the installation that are known to be native soil will be represented in the sampling scheme so arsenic concentrations for those areas can be compared to arsenic concentrations from the other areas.

Soils across NAVSTA Mayport are believed to be uniform enough in geologic composition as to represent similar geochemistry regardless of location. The geochemistry, however, may vary with depth. Furthermore, risk assessments commonly subdivide soils samples into surface and subsurface groups because exposure scenarios are different for these groups. Consequently, only two potentially significant soil groups will be used in the study, surface and subsurface.

Two primary questions will need to be answered in the statistical study:

- Are arsenic concentrations from already sampled areas significantly different, based on statistical analysis, than arsenic concentrations in previously unsampled areas?

- Are arsenic concentrations from already sampled areas significantly different, based on statistical analysis, than arsenic concentrations in the native soil areas?

If the answer to either of these questions is yes, additional study activities may be warranted. The additional actions to be taken will depend on the relative magnitudes of the Group 1 arsenic concentrations and the Group 2 and Group 3 arsenic concentrations.

DQO Step 2: State the Decisions

The decisions to be addressed in the study are:

- Determine whether arsenic concentrations from already sampled areas are statistically greater than arsenic concentrations in previously unsampled areas. If they are, additional study activities may be warranted; otherwise, conclude that no further action is required.

- Determine whether arsenic concentrations from already sampled areas are statistically greater than arsenic concentrations in the native soil areas. If they are, additional study activities may be warranted; otherwise, conclude that no further action is required.

DQO Step 3: Identify Inputs to the Decisions

The analyte of interest is arsenic. The analytical method to be used for arsenic measurement will be U.S EPA SW-846 6010B or SW-846 6020. Which method is actually used will depend on the selected laboratory; however, all practical efforts will be made to select a laboratory that uses the same analytical method that was used for previously analyzed samples. This is an important factor in ensuring that the data are comparable from the two sampling periods. Whichever laboratory is used, they will be required to comply with analytical method QC requirements. The precision and accuracy requirements for the arsenic data are:

- Laboratory matrix spike (MS) and duplicate samples will be analyzed at the rate of one MS and one duplicate per 20 field samples.

- Individual matrix spike (MS) arsenic recoveries shall be no less than 50 percent.

- Mean MS arsenic recoveries shall be in the range of 65 to 135 percent.

- If accuracy requirements are not met, the quality of the data will be considered to be substandard and corrective actions will be taken to repeat the analyses, recollect samples and analyze the replacement samples, or to discuss with regulators the appropriate course of action.

- Individual relative percent difference (RPD) values for laboratory duplicate samples should be no more than 50 percent for arsenic.

- If the precision (RPD) target is not met an evaluation will be conducted to determine whether the level of uncertainty is sufficient to compromise decision making. If it is, corrective action will be taken. The first step will be a discussion with regulators concerning the appropriate course of action.

- Collection of field duplicates is not recommended because it is more important to obtain spatial coverage and estimates of uncertainty across the sampled area than to obtain estimates of sampling precision in individual samples.

- Additional sample volume must be collected to accommodate QC sample analyses.

- Samples will be handled and stored the same way they were handled in the past. This will help to ensure comparability of data.

DQO Step 4: Identify the Study Boundaries

There are no temporal considerations of importance for sample collection. Arsenic concentrations in soil today are not expected to have changed significantly in the past decade nor are they expected to change significantly within the next decade. Nevertheless, a change in analytical method could cause an artificial difference to appear among data sets. This is addressed in DQO Step 3.

Soils investigated at NAVSTA Mayport were found to be geologically similar; therefore the need to separate soils into different groups because of geochemical differences is not anticipated. Past sampling patterns and areal coverage are the driving factors for this sampling effort. The intent is to collect samples from the surface and subsurface in previously unsampled areas and compare past data with these new data. The areas to be sampled are identified in Step 1 and on Figure 1.

Surface and subsurface soils are not considered to be geologically different but they are considered to be different with respect to risk exposure. Hence, development of the sampling plan will be designed to consider these depth intervals separately as well as together.

DQO Step 5: Specify the Analytic Approach

Once the data are compiled into what are considered to be representative data sets for the sampled areas, the following decision rules will be applied:

1. If mean arsenic concentrations in the previously unsampled areas are greater than 2.1mg/kg (SCTL), additional study activities may be warranted; otherwise, conclude that no further action is required.

2. If mean arsenic concentrations from already sampled areas are greater than arsenic concentrations in previously unsampled areas, additional study activities may be warranted; otherwise, conclude that no further action is required.

3. If mean arsenic concentrations from already sampled areas are greater than arsenic concentrations in the native soil areas, additional study activities may be warranted; otherwise, conclude that no further action is required.

DQO Step 6: Specify Error Tolerances

Previously unsampled areas are in locations where industrial activities are believed to have not occurred or at least not to the same degree that occurred in the SWMUs. Thus the areas to be sampled are expected to have arsenic concentrations that are less than or equal to those observed from previously sampled areas. The null hypothesis was chosen to be that the data to be collected will have a mean arsenic concentration less than the arsenic SCTL (2.1 mg/kg).

It is understood that spatial differences in arsenic concentrations, variations in sample collection technique, analytical uncertainty, etc., can cause arsenic concentration results to be somewhat uncertain. This is true whether examining an arsenic concentration for a single sample or a mean concentration for multiple samples. The inevitable conclusion is that any measurement of the mean arsenic concentration is almost certain to not be equal to the true mean concentration. Hence, the measured mean will either be greater than or less than the true mean. The problem is that there is no way to know whether it is greater than or less than the true mean. In statistical parlance, this leads to two types of decision error that can be made from a measurement. With the null hypothesis as stated above, a Type I error is erroneously deciding that the true mean concentration exceeds 2.1 mg/kg. This would occur when the measured mean value is greater than 2.1 mg/kg, but the true mean is less than 2.1 mg/kg. Type II error would be to erroneously decide that the mean arsenic concentration is less than 2.1 mg/kg.

This would occur when the measured mean concentration is less than 2.1 mg/kg, but the true mean concentration is greater than 2.1 mg/kg.

Statisticians have devised a way to manage this decision uncertainty. The general approach is to first recognize that either type of error is possible and that one type of error might actually be made. The goal is to collect enough samples to minimize each type of error to a tolerable level. It is recognized that the chance of making either error decreases as the number of samples collected increases. It is also recognized that the cost of sample collection and analysis increases with each additional sample. The “law” of diminishing returns says that only so many samples can be collected before no significant benefit is added by additional sample collection.

VSP Approach A (Corresponds to Decision Rule 1)

After recognizing that either type of error can be made, it is customary to establish the tolerable probabilities for making each error. For this study, the following rationale was used to establish the tolerable probabilities. It was first recognized that there is a concentration region close to the mean within which it is acceptable to ignore decision errors. Because a typical RPD value for duplicate samples is less than 50 percent, the action level was multiplied by about 50 percent to yield 3.15 mg/kg. Within the concentration range of 2.1 to 3.15 mg/kg, the tendency will be to error on the side of not taking corrective action even if the true mean concentration exceeds 2.1 mg/kg. The rationale for this is that more than 800 samples have already indicated that the true mean is less than 2.1 mg/kg.

The range of 2.1 to 3.15 mg/kg is called the Gray Region and 3.15 mg/kg is called the upper bound of the Gray Region (UBGR). The action level, 2.1 mg/kg, is the lower bound of the Gray Region (LBGR). At this point we ask ourselves the following question: If the true concentration were infinitesimally less than 2.1 mg/kg, what would be the tolerance for concluding that the mean concentration exceeds 2.1 mg/kg? Because the true mean is not that different than the STCL, the tolerance is relatively high. The study team set this tolerance at 20 percent. This means that if the statistical study could be repeated many times, 20 percent of the time the team would tolerate taking corrective action even though the true mean arsenic concentration was slightly less than 2.1 mg/kg. Now we ask: If the true mean concentration were infinitesimally greater than 3.15 mg/kg what would be the tolerance for not taking corrective action? Because the true mean in this scenario is slightly greater than the upper end of the region where we agreed that decision errors are not very serious, the tolerance is also relatively high. However, the study team set the tolerance for this error at 10 percent because the UBGR is already greater than the 2.1 mg/kg action level.

The last statistical value to be established was the estimated standard deviation of the data to be collected. The planning team reasoned that the standard deviation is likely to be less than the standard deviation of the available data. Using available subsurface soil data (more than 300 data concentration values) the computed standard deviation was 1.82 mg/kg. Subsurface soil data were used because they represent the greater standard deviation of the surface and subsurface data. This is a conservative approach that causes the number of required samples to be artificially inflated.

VSP Approach B (Corresponds to Decision Rules 2 and 3)

In this scenario the intent is to determine whether the mean arsenic concentrations of two data sets differ by more than a prescribed amount (called delta). The planning team decided that a difference of less than about half of the standard deviation of available data, or 0.9 mg/kg, was too difficult to detect. Furthermore, the mean subsurface soil arsenic concentration was 1.25 mg/kg and adding 0.85 mg/kg to 1.25 mg/kg yields the 2.1 mg/kg action level. The team wanted to be confident that exceedances of the action level are reasonably detectable.

The LBGR was set at 0.85 mg/kg. This means that the minimum detectable difference between the current mean of 1.25 mg/kg and the mean of the new data should be at least 0.85 mg/kg. Because the baseline assumption, however, is that the actual mean for the new data will not be greater than 2.1 mg/kg, some latitude is allowed for the mean to be as great as 3.15 without much concern for concluding that the site is not contaminated when in fact it is contaminated, based on regulatory standards. This is the upper gray region boundary concentration in VSP Approach A. With this upper concentration limit and a current mean of 1.25 mg/kg, the width of the gray region for differences between mean is 3.15 mg/kg – 1.25 mg/kg = 1.9 mg/kg. Thus the gray region for differences between means runs from 0.85 mg/kg to 1.9 mg/kg where 1.9 mg/kg is the upper bound of the gray region (UBGR) for differences between data set means. Alpha and beta were maintained as above: alpha = 10 percent at the LBGR; beta = 20 percent at the UBGR.

If the difference between data set means is 1.9 mg/kg, this would equate to the actual concentration of the newly sampled areas being 1.25 mg/kg + 1.9 mg/kg = 3.15 mg/kg when these areas are considered to be more contaminated than the previously sampled areas. If the newly sampled areas are less contaminated then previously sampled areas, the mean arsenic concentration of the newly sampled areas would be 1.25 mg/kg – 1.9 mg/kg = -0.65 mg/kg, Of course, this result (a negative concentration) is untenable and simply indicates that the current mean arsenic concentration is close to non-detect values.

Step 7: Optimize the Design

Two approaches were taken to devise the proposed sampling plan. The first approach used EVS-PRO to krig the data and estimate arsenic concentrations for areas not previously sampled as described below in the GIS Approach. The VSP approach relies primarily on statistical inferences based on decision error tolerances developed in Step 6, above.

EVS-PRO Approach

The following optimization approach was taken to arrive at the sampling distribution presented in Figure 1. First, the available surface and subsurface soil results were combined into a single data set. The results were plotted spatially to show surface soil spatial coverage and subsurface soil spatial coverage.

There were fewer subsurface soil data collected (337 samples) than surface soil data (550 samples). Furthermore, the plotted subsurface soil data represented less spatial coverage across the study area than the surface soil data. While most sample locations with a subsurface sample also have an associated surface soil sample, the converse is not always true, thus causing the discrepancy between spatial coverages. Since it is planned that for each newly proposed sample location, both a subsurface and a surface sample would be collected, it was decided to focus the kriging efforts on the subsurface soil data as a “worst case scenario” to maximize the improvement in overall spatial coverage for both data sets.

The subsurface soil data were kriged to obtain estimates of arsenic concentrations where samples had not been collected previously. Based on the kriged data, areas representing the greatest degree of uncertainty in the estimated concentrations were identified. EVS-PRO defines uncertainty as a function of predicted concentration levels and the resulting confidence levels of those predictions where uncertainty is high at locations where concentrations are predicted to be relatively high, but the confidence in that prediction is low.

The modeling software was then used to add a number of points to the spatial plot to reduce the estimated uncertainties. The software allows the user to specify two primary factors during this optimization: 1) the factor within which the estimated concentration is expected to agree with the true concentration and 2) the confidence level of this estimate.

The primary objective was to obtain at least an 80 percent confidence that all estimated concentrations were within a factor of 1.7 of the true value for at least 90 percent of the area covered by NAVSTA Mayport. In this case, it was assumed that knowing any arsenic concentration to within a factor of 1.7 of the true concentration would be acceptable.

The factor of 1.7 represents a relative percent difference (RPD) of approximately 50 percent [200% x (1.7x – x)/(1.7x+x) = 52%]. This value (i.e., 50 percent) is commonly used as the upper end of the target acceptance range for field duplicate sample precision and also represents a relative standard deviation (RSD) of approximately 37 percent. These conservative input error limits were used because the interpolated arsenic concentrations generated by the kriging model were based on sparsely distributed samples in some of the areas. This can result in large concentration estimate errors that will not be measurable until the data are collected.

Another reason for using conservative input values is that some sampling locations may not be accessible because the ground surface could be unstable or obstacles could be present. The sampling team will be able to move a sample location up to 100 feet away from the designated location without effecting spatial distribution. This 100 feet limit represents less than the radius of influence of each new sample location in the kriging model. This approach was taken to fine tune the kriging model because some of the computer generated sampling locations were placed on a runway or in a building.

Confidence plots were generated for the original 337 subsurface soil samples using a factor of 1.7. Subsequent plots were then generated using factors of 1.5, 1.85, and 2.0 for comparison purposes. The results of these plots are presented in Figure 2.

Confidence plots were then generated using the original 337 subsurface soil samples plus an additional 40 samples as designated by the modeling software based on the areas of greatest uncertainty. The placement of some locations were modified just enough to avoid known obstacles such as buildings, runways, and roads. Proposed locations that the modeling software placed within the Turning Basin were relocated to the two “native soil” areas. These plots were generated using factors of 1.5, 1.7, 1.85, and 2.0 for comparison purposes. The results are presented in Figure 3.

An additional objective was to ensure that at least seven samples were collected from the two “native soil” areas. Seven samples were chosen because the study team’s experience with similar projects indicated that five to seven samples often provide enough data to make defensible decisions when the true mean concentration differs from the action level by at least 50 percent. Figure 1 shows that this objective was achieved.

VSP Approach A (Corresponds to Decision Rule 1)

Using the inputs from DQO Step 6, VSP (Version 4.4b) was used to compute the minimum number of samples that should be collected to meet the specified decision performance. The outputs are provided in Attachment A along with explanatory text and graphs to support the text.

The VSP software uses the following equation (when ignoring analytical uncertainty) to compute the required number of samples:

$$n = \frac{2s^2\left(z_{1\text{-}\alpha} + z_{1\text{-}\beta}\right)^2}{\Delta^2} + \frac{z_{1\text{-}\alpha}^2}{4}$$

In this equation, n is the minimum number of samples required to yield the desired decision making confidence; s is the expected standard deviation of the data; alpha (α) and beta (β) are the Type I and Type II error tolerance values; and z is the standard normal deviate. Delta (Δ) is the width of the gray region.

The arsenic concentrations for the available data were not normally distributed. Therefore, the VSP software was run in the “non-parametric” mode. This mode makes very few assumptions about the distribution of the data.

Run 1:

Analytical uncertainty was ignored because it is commonly understood to be much less than the sampling uncertainty. Sampling uncertainty is the inherent variability in concentration from one sample to another. The VSP software computed that at least 29 samples should be collected to meet the decision specifications.

VSP outputs for this approach are provided in Attachment A.

Run 2:

After computing the number of samples using these inputs, another computation was done. The standard deviation of existing subsurface data is 1.82 mg/kg. It is commonly recognized that being able to detect a difference less than a single standard deviation between a mean concentration and a numerical criterion frequently is not cost-effective. Therefore the computation was rerun using 1.8 mg/kg as the width of the gray region boundary. This yielded UBGR = 2.1 mg/kg + 1.8 mg/kg = 3.9 mg/kg. The number of samples computed was 10. This helps to confirm that approximately 29 samples should be sufficient. This provides some perspective on the previously computed 29 samples.

VSP outputs for this approach are not included in this report.

VSP Approach B (Corresponds to Decision Rules 2 and 3)

Based on the specifications of DQO Step 6, the VSP software computed the minimum number of samples to be 32. This is an indication that discriminating between data set means is likely to be more difficult than discriminating between the mean concentration of a data set and the 2.1

mg/kg action level. Given that the data to be collected are expected to have a lower mean arsenic concentration than previously collected data, this is not a serious deficiency.

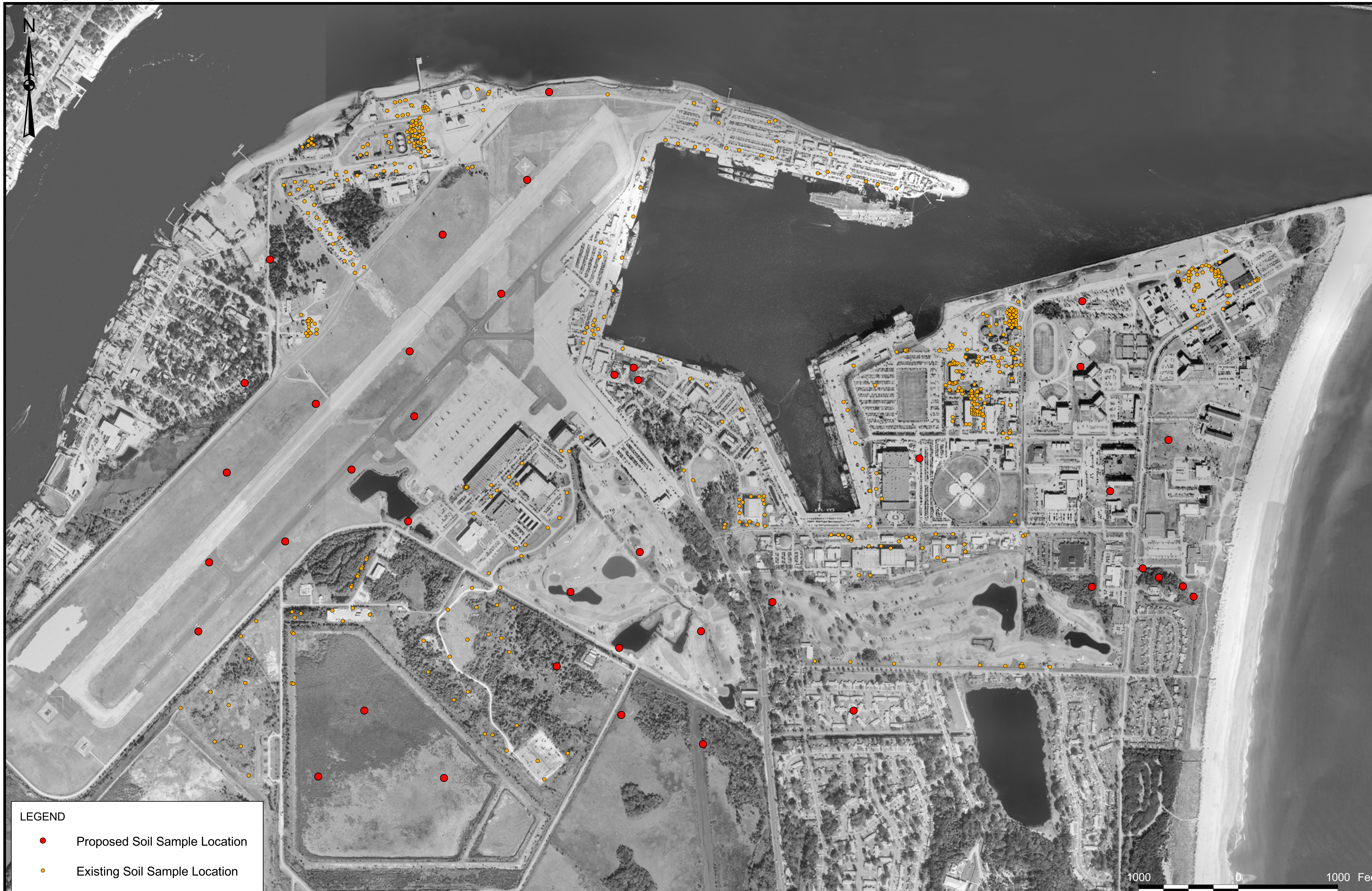
VSP outputs for this approach are provided in Attachment B.

Sampling Plan Synopsis

Based on the VSP and EVS-PRO computations, it is evident that about 30 to 40 samples would be sufficient to support all three decision rules (assuming the input assumptions hold). Because both surface and subsurface soils must be represented, the total number of soil samples should be 60 to 80, with half of the samples collected in the surface soil and the other half in the subsurface soil. The surface soil interval is 0 to 2 feet bgs; the subsurface soil interval is 2 to 8 feet bgs. In the subsurface, it is desirable to represent all possible depths without collecting the entire 2 to 8 foot bgs interval at each location. Therefore, the subsurface soil at each sample location will be divided into three 2-foot intervals (2-4 feet, 4-6 feet, and 6-8 feet) and samples will be alternatively collected from one of the subsurface intervals. Every location will be sampled in the 0-2 foot interval. This strategy will yield two soil samples at each location, a surface sample and a subsurface sample drawn from one of the three possible 2-foot subsurface intervals.

Because the number of additional soil sample locations calculated by EVS (40) and VSP (32) represent the minimum number required to satisfy the goals of this study, it was decided that 80 samples will be collected at the 40 locations specified by the EVS software. All samples will be stored, prepared for analysis, and analyzed in as similar a manner to previous operations as practicable.

P:\GIS\MAYPORT_NS\NAVSTA_MAYPORT_EVS.APR PROPOSED LOCATION LAYOUT 4/06/07 AJ



DRAWN BY A. JANOCHA DATE 4/06/07

CHECKED BY T. JOHNSTON DATE 4/06/07

COST/SCHED-AREA

SCALE AS NOTED

NAVFAC

ALL SOIL SAMPLES
WITH 40 PROPOSED SAMPLE LOCATIONS
NAVSTA MAYPORT
MAYPORT, FLORIDA

CONTRACT NO. CTO 0033

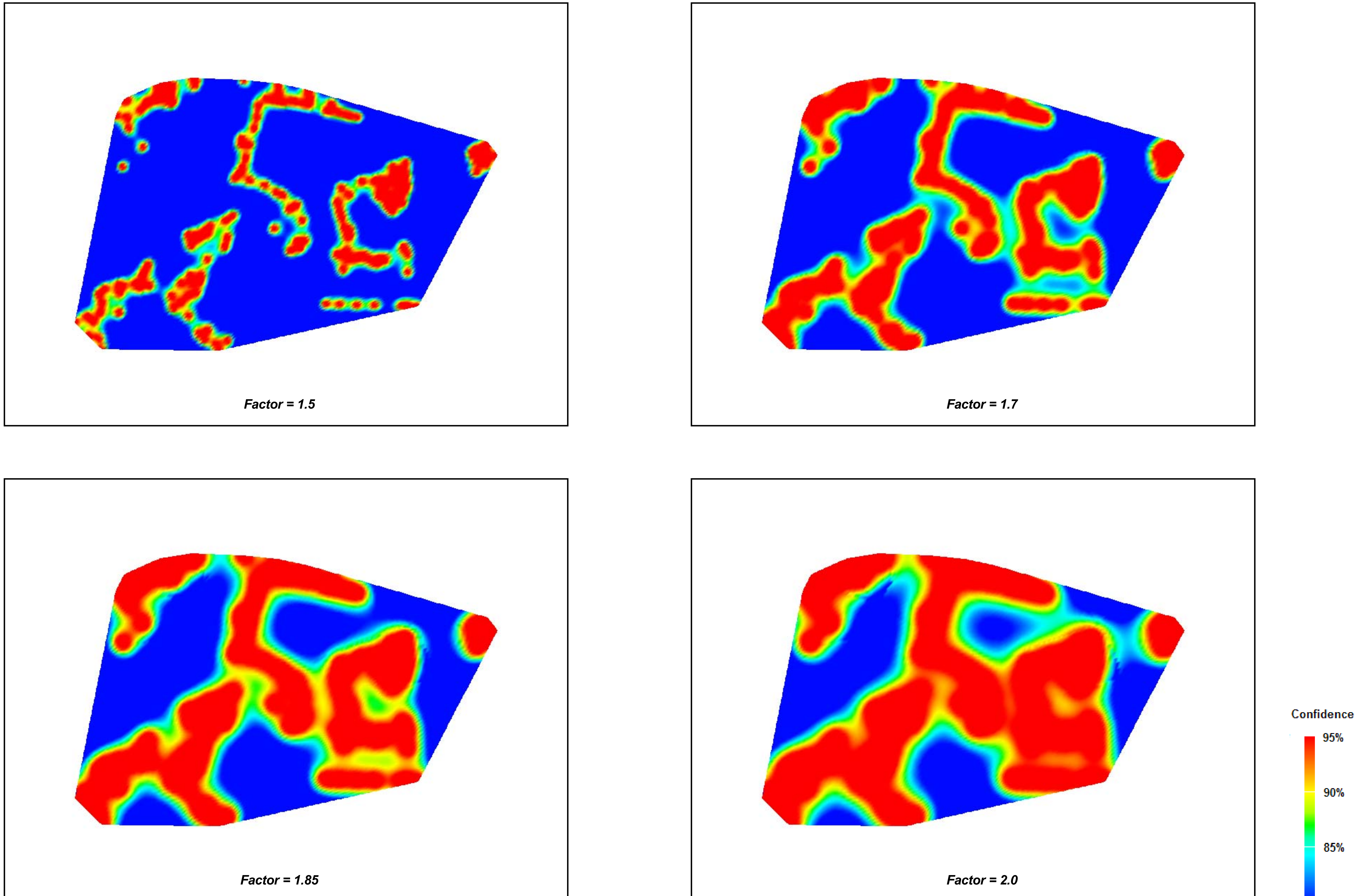
APPROVED BY DATE

APPROVED BY DATE

DRAWING NO. FIGURE 1

REV 0

P:\GIS\MAYPORT_NS\NAVSTA_MAYPORT_EVS.APR SB ORIGINAL SAMPLES LAYOUT 4/06/07 AJ



NOTE: Each panel shows, as a function of location, the confidence that the predicted concentration will be within a designated factor of the true value. The factors are shown on each panel (e.g., Factor = 1.5 and Factor = 1.7).

N

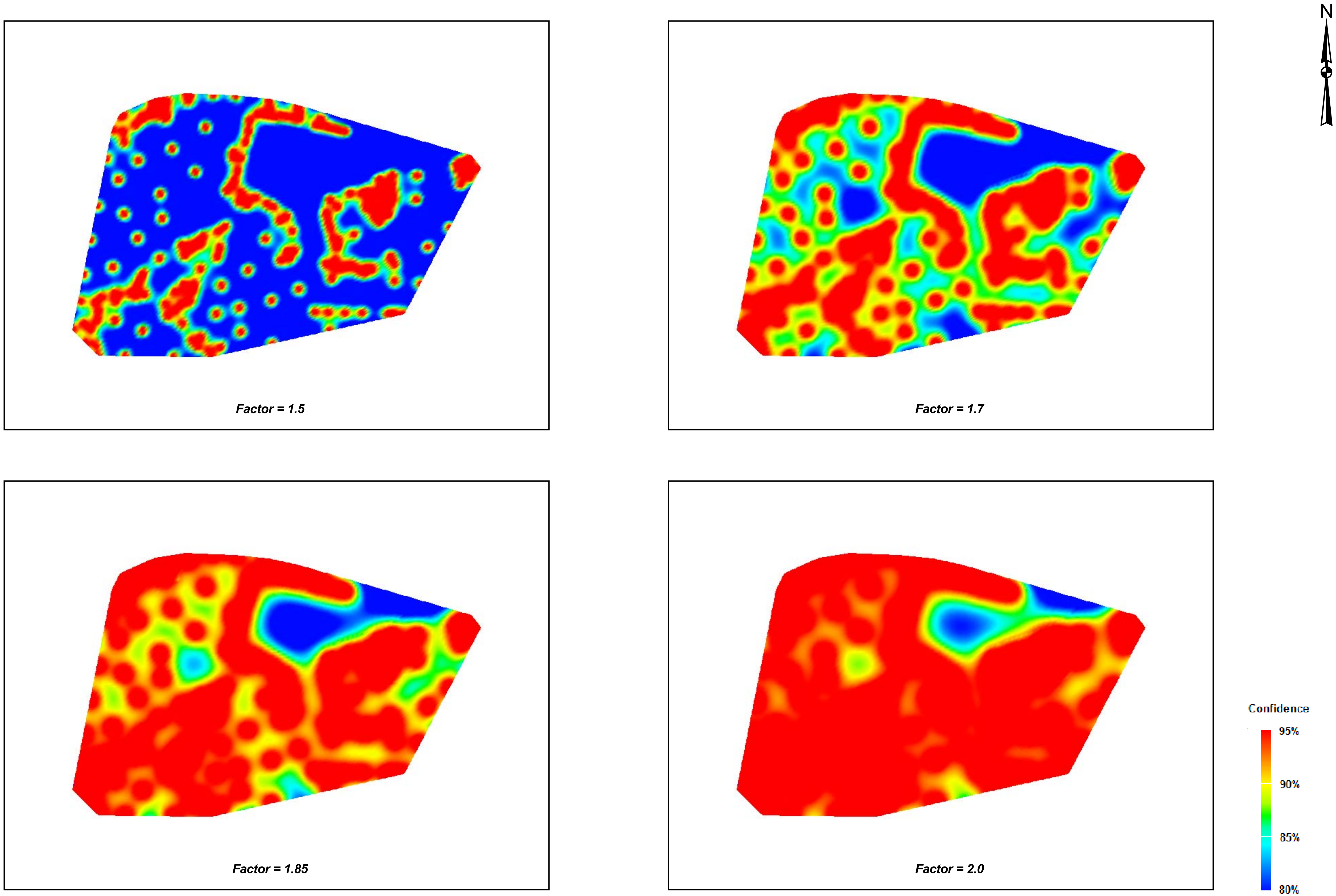
DRAWN BY: A. JANOCHA	DATE: 3/30/07
CHECKED BY: T. JOHNSTON	DATE: 4/06/07
COST/SCHED-AREA	
SCALE: AS NOTED	

NAVFAC

CONFIDENCE MAP FOR ORIGINAL SUBSURFACE SOIL SAMPLES
NAVSTA MAYPORT
MAYPORT, FLORIDA

CONTRACT NO. CTO 0033	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 2	REV 0

P:\GIS\MAYPORT_NS\NAVSTA_MAYPORT_EVS.APR SB 40 ADDITIONAL SAMPLES LAYOUT 4/06/07 AJ



NOTE: Each panel shows, as a function of location, the confidence that the predicted concentration will be within a designated factor of the true value. The factors are shown on each panel (e.g., Factor = 1.5 and Factor = 1.7).

DRAWN BY	DATE
A. JANOCHA	4/06/07
CHECKED BY	DATE
T. JOHNSTON	4/06/07
COST/SCHED-AREA	
SCALE	AS NOTED

CONFIDENCE MAP FOR ORIGINAL SUBSURFACE SOIL SAMPLES
WITH 40 PROPOSED SAMPLE LOCATIONS
NAVSTA MAYPORT
MAYPORT, FLORIDA

CONTRACT NO.	CTO 0033
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO.	FIGURE 3
REV	0

Attachment A

VSP Approach A

Random sampling locations for comparing a median with a fixed threshold (nonparametric - MARSSIM)

Summary

This report summarizes the sampling design used, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design developed.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean or median to a fixed threshold
Type of Sampling Design	Nonparametric
Sample Placement (Location) in the Field	Simple random sampling
Working (Null) Hypothesis	The median(mean) value at the site is less than the threshold
Formula for calculating number of sampling locations	Sign Test - MARSSIM version
Calculated total number of samples	29
Number of samples on map [a]	0
Number of selected sample areas [b]	0
Specified sampling area [c]	5000.00 ft^2
Total cost of sampling [d]	$15500.00

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[d] Including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.

Primary Sampling Objective

The primary purpose of sampling at this site is to compare a site median or mean value with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the median(mean) value at the site is less than the threshold. The alternative hypothesis is that the median(mean) value is equal to or exceeds the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative one, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach

A nonparametric random sampling approach was used to determine the number of samples and to specify sampling locations. A nonparametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that typical parametric assumptions may not be true.

Both parametric and non-parametric equations rely on assumptions about the population. Typically, however, non-parametric equations require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than if a non-parametric equation was used.

Locating the sample points randomly provides data that are separated by many distances, whereas systematic samples are all equidistant apart. Therefore, random sampling provides more information about the spatial structure of the potential contamination than systematic sampling does. As with systematic sampling, random sampling also provides information regarding the mean value, but there is the possibility that areas of the site will not be represented with the same frequency as if uniform grid sampling were performed.

Number of Total Samples: Calculation Equation and Inputs
The equation used to calculate the number of samples is based on a Sign test (see PNNL 13450 for discussion). For this site, the null hypothesis is rejected in favor of the alternative one if the median(mean) is sufficiently larger than the threshold. The number of samples to collect is calculated so that if the inputs to the equation are true, the calculated number of samples will cause the null hypothesis to be rejected.

The formula used to calculate the number of samples is:

$$n = 1.20\left[\frac{\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2}{4(SignP - 0.5)^2}\right]$$

where

$$SignP = \Phi\left[\frac{\Delta}{\left(s_{sample}^2 + \frac{s_{analytical}^2}{r}\right)^{1/2}}\right]$$

$\Phi(z)$ is the cumulative standard normal distribution on $(-\infty,z)$ (see PNNL-13450 for details),
n is the number of samples,
S is the estimated standard deviation of the measured values including analytical error,
Δ is the width of the gray region,
α is the acceptable probability of incorrectly concluding the site median(mean) exceeds the threshold,
β is the acceptable probability of incorrectly concluding the site median(mean) is less than the threshold,
$Z_{1-\alpha}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is $1-\alpha$,
$Z_{1-\beta}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is $1-\beta$.

Note: MARSSIM suggests that the number of samples should be increased by at least 20% to account for missing or unusable data and uncertainty in the calculated value of n. VSP allows a user-supplied percent overage as discussed in MARSSIM (EPA 2000, p. 5-33).

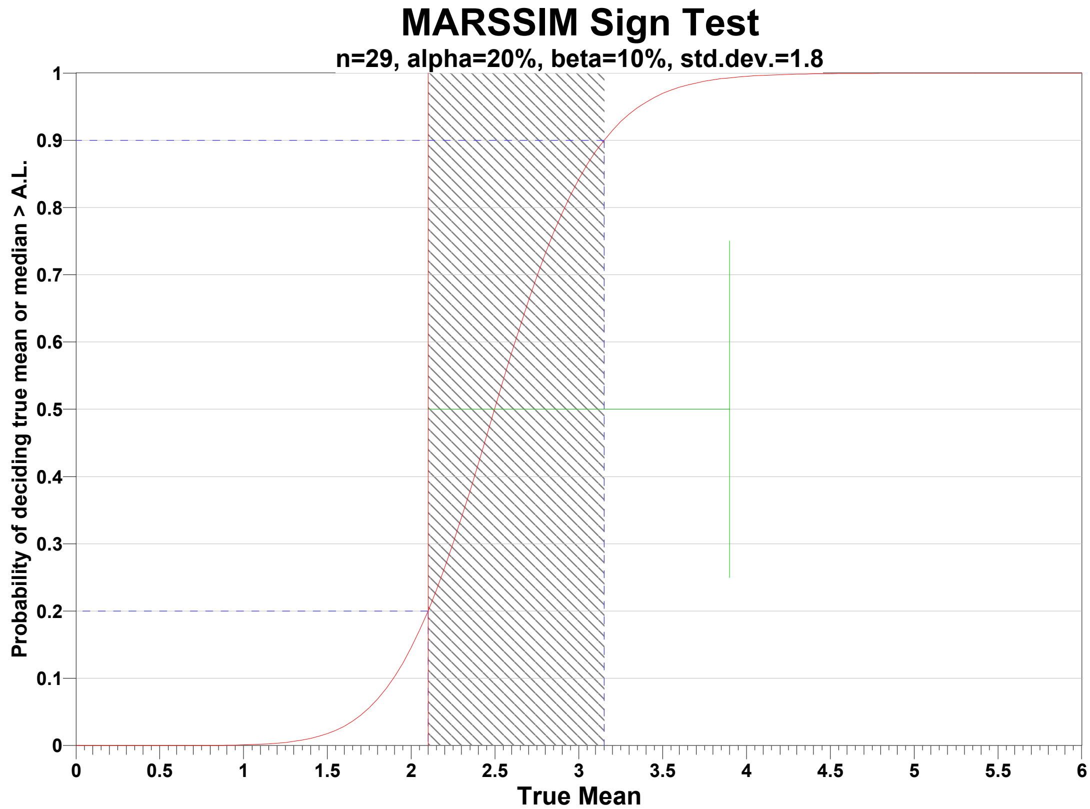
The values of these inputs that result in the calculated number of sampling locations are:

Analyte	n[a]	Parameter					
		S	Δ	α	β	$Z_{1-\alpha}$ [b]	$Z_{1-\beta}$ [c]
	29	1.8	1.05	0.2	0.1	0.841621	1.28155

[a] The final number of samples has been increased by the MARSSIM Overage of 20%.
[b] This value is automatically calculated by VSP based upon the user defined value of α.
[c] This value is automatically calculated by VSP based upon the user defined value of β.

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true median(mean) values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the lower horizontal dashed blue line is positioned at α on the vertical axis; the upper horizontal dashed blue line is positioned at $1-\beta$ on the vertical axis. The vertical green line is positioned at one standard deviation above the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at α and the upper bound of Δ at $1-\beta$. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions
The assumptions associated with the formulas for computing the number of samples are:
1. the computed sign test statistic is normally distributed,
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected randomly.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the sample locations were selected using a random process.

Sensitivity Analysis
The sensitivity of the calculation of number of samples was explored by varying s, UBGR, β and α and examining the resulting changes in the number of samples. The following table shows the results of this analysis.

Number of Samples							
AL=2.1		**α=10**		**α=15**		**α=20**	
		s=3.6	**s=1.8**	**s=3.6**	**s=1.8**	**s=3.6**	**s=1.8**
UBGR=110	**β=5**	4750	1192	3988	1001	3430	861
	β=10	3645	915	2981	748	2501	628
	β=15	2981	748	2384	599	1958	491
UBGR=120	**β=5**	1192	303	1001	255	861	219
	β=10	915	232	748	190	628	160
	β=15	748	190	599	153	491	125
UBGR=130	**β=5**	533	138	448	116	386	100
	β=10	410	106	335	87	281	74
	β=15	335	87	268	70	220	58

s = Standard Deviation
UBGR = Upper Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ < action level
α = Alpha (%), Probability of mistakenly concluding that μ > action level
AL = Action Level (Threshold)

Cost of Sampling
The total cost of the completed sampling program depends on several cost inputs, some of which are fixed, and others that are based on the number of samples collected and measured. Based on the numbers of samples determined above, the estimated total cost of sampling and analysis at this site is $15500.00, which averages out to a per sample cost of $534.48. The following table summarizes the inputs and resulting cost estimates.

COST INFORMATION			
Cost Details	**Per Analysis**	**Per Sample**	**29 Samples**
Field collection costs		$100.00	$2900.00
Analytical costs	$400.00	$400.00	$11600.00
Sum of Field & Analytical costs		**$500.00**	**$14500.00**
Fixed planning and validation costs			$1000.00
Total cost			**$15500.00**

Recommended Data Analysis Activities
Post data collection activities generally follow those outlined in EPA's Guidance for Data Quality Assessment (EPA, 2000). The data analysts will become familiar with the context of the problem and goals for data collection and assessment. The data will be verified and validated before being subjected to statistical or other analyses. Graphical and analytical tools will be used to verify to the extent possible the assumptions of any statistical analyses that are performed as well as to achieve a general understanding of the data. The data will be assessed to determine whether they are adequate in both quality and quantity to support the primary objective of sampling.

Because the primary objective for sampling for this site is to compare the site median(mean) value with a threshold value, the data will be assessed in this context. Assuming the data are adequate, at least one statistical test will be done to perform a comparison between the data and the threshold of interest. Results of the exploratory and quantitative assessments of the data will be reported, along with conclusions that may be supported by them.

Attachment B

VSP Approach B

Random sampling locations for comparing two population means or medians (site and reference) [nonparametric]

Summary
This report summarizes the sampling design used, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design developed.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean or median to a reference area mean or median
Type of Sampling Design	Nonparametric
Sample Placement (Location) in the Field	Simple random sampling
Working (Null) Hypothesis	The difference between the medians(means) is less than or equal to the threshold
Formula for calculating number of sampling locations	Wilcoxon rank sum test
Calculated total number of samples for each survey and reference area [a]	32
Number of samples on map [b]	0
Number of selected sample areas [c]	0
Specified sampling area [d]	5000.00 ft^2
Total cost of sampling [e]	$32.00

[a] Based on the analyte with the highest minimum number of survey unit samples.
[b] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[c] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[d] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[e] Costs for one sampling area, including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.

Primary Sampling Objective
The primary purpose of sampling at this site is to compare a site median or mean value with a reference area median or mean value. This is achieved by testing the difference between the site and reference area medians(means). The working hypothesis (or 'null' hypothesis) is that the difference between the site median(mean) and the reference area median(mean) is less than the threshold. The alternative hypothesis is that the difference is equal to or exceeds the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative one, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A nonparametric random sampling approach was used to determine the number of samples and to specify sampling locations. A nonparametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that typical parametric assumptions may not be true.

Both parametric and non-parametric equations rely on assumptions about the population. Typically, however, non-parametric equations require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than if a non-parametric equation was used.

Locating the sample points randomly provides data that are separated by many distances, whereas systematic samples are all equidistant apart. Therefore, random sampling provides more information about the spatial structure of the potential contamination than systematic sampling does. As with systematic sampling, random sampling also provides information regarding the mean value, but there is the possibility that areas of the site will not be represented with the same frequency as if uniform grid sampling were performed.

Number of Total Samples: Calculation Equation and Inputs

The equation used to calculate the number of samples is based on a Wilcoxon Rank Sum test. For this site, the null hypothesis is rejected in favor of the alternative one if the difference between the site and reference area median(mean) is sufficiently larger than the threshold. The number of samples to collect is calculated so that if the inputs to the equation are true, the calculated number of samples will cause the null hypothesis to be rejected.

The formula used to calculate the number of samples is:

$$n = m = 1.16\left[\frac{2\left(S_{sample}^2 + \frac{S_{analytical}^2}{r}\right)}{\Delta^2}\left(z_{1-\alpha} + z_{1-\beta}\right)^2 + 0.25 z_{1-\alpha}^2\right]$$

where

n	is the number of samples for the site and is equal to m,
m	is the number of samples for the reference area and is equal to n,
S	is the estimated standard deviation of the measured values including analytical error,
Δ	is the width of the gray region,
α	is the acceptable probability of incorrectly concluding the difference between the medians(means) exceeds the threshold,
β	is the acceptable probability of incorrectly concluding the difference between the medians(means) is less than the threshold,
$Z_{1-\alpha}$	is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is 1-α,
$Z_{1-\beta}$	is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is 1-β.

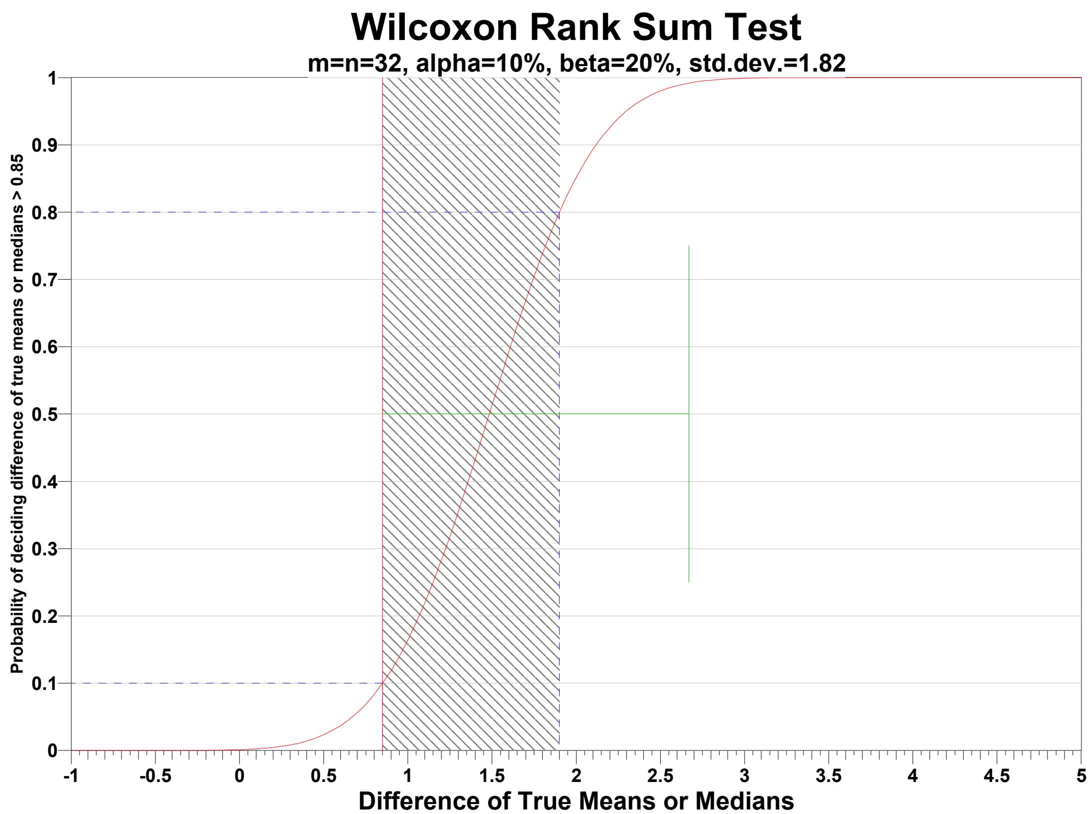
The values of these inputs that result in the calculated number of sampling locations are:

Analyte	n	Parameter					
		S	Δ	α	β	$Z_{1-\alpha}$ [a]	$Z_{1-\beta}$ [b]
	32	1.82	1.05	0.1	0.2	1.28155	0.841621

[a] This value is automatically calculated by VSP based upon the user defined value of α.
[b] This value is automatically calculated by VSP based upon the user defined value of β.

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty (the probability that the difference between the site median(mean) and the reference area median(mean) exceeds the threshold) on the vertical axis versus a range of possible true differences between the medians(means) on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the lower horizontal dashed blue line is positioned at α on the vertical axis; the upper horizontal dashed blue line is positioned at 1-β on the vertical axis. The vertical green line is positioned at one standard deviation above the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at α and the upper bound of Δ at 1-β. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions

The assumptions associated with the formulas for computing the number of samples are:

1. the data from each area (site and reference area) originate from symmetric (but not necessarily normal) populations,
2. the variances of the site and reference populations are equal,
3. the variance estimate, S^2, is reasonable and representative of the populations being sampled,
4. the population values are not spatially or temporally correlated, and
5. the sampling locations will be selected randomly.

The first four assumptions will be assessed in a post data collection analysis. The last assumption is valid because the sample locations were selected using a random process.

Sensitivity Analysis

The sensitivity of the calculation of number of samples was explored by varying the standard deviation, upper bound of gray region (% of action level), beta (%), probability of mistakenly concluding that μ < action level and alpha (%), probability of mistakenly concluding that μ > action level and examining the resulting changes in the number of samples. The following table shows the results of this analysis.

Number of Samples							
AL=0.85		α=5		α=10		α=15	
		s=3.64	s=1.82	s=3.64	s=1.82	s=3.64	s=1.82
UBGR=110	β=15	202	51	151	38	121	31
	β=20	174	44	127	32	99	25
	β=25	151	39	108	28	82	21
UBGR=120	β=15	202	51	151	38	121	31
	β=20	174	44	127	32	99	25
	β=25	151	39	108	28	82	21
UBGR=130	β=15	202	51	151	38	121	31

	β=20	174	44	127	32	99	25
	β=25	151	39	108	28	82	21

s = Standard Deviation
UBGR = Upper Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ < action level
α = Alpha (%), Probability of mistakenly concluding that μ > action level
AL = Action Level (Threshold)

Cost of Sampling
The total cost of the completed sampling program depends on several cost inputs, some of which are fixed, and others that are based on the number of samples collected and measured. Based on the numbers of samples determined above, the estimated total cost of sampling and analysis at this site is $32.00, which averages out to a per sample cost of $1.00. The following table summarizes the inputs and resulting cost estimates.

COST INFORMATION			
Cost Details	**Per Analysis**	**Per Sample**	**32 Samples**
Field collection costs		$1.00	$32.00
Analytical costs	$0.00	$0.00	$0.00
Sum of Field & Analytical costs		**$1.00**	**$32.00**
Fixed planning and validation costs			$0.00
Total cost [a]			**$32.00**

[a] Total cost for one sampling area.

Recommended Data Analysis Activities
Post data collection activities generally follow those outlined in EPA's Guidance for Data Quality Assessment (EPA, 2000). The data analysts will become familiar with the context of the problem and goals for data collection and assessment. The data will be verified and validated before being subjected to statistical or other analyses. Graphical and analytical tools will be used to verify to the extent possible the assumptions of any statistical analyses that are performed as well as to achieve a general understanding of the data. The data will be assessed to determine whether they are adequate in both quality and quantity to support the primary objective of sampling.

Because the primary objective for sampling for this site is to compare the difference between the site and reference area median(mean) values with a threshold value, the data will be assessed in this context. Assuming the data are adequate, at least one statistical test will be done to perform a comparison between the data and the threshold of interest. Results of the exploratory and quantitative assessments of the data will be reported, along with conclusions that may be supported by them.

ATTACHMENT 2

FIELD DATA SHEETS

Tetra Tech NUS, Inc.

DAILY ACTIVITIES RECORD

PROJECT NAME: ______________________ **PROJECT NUMBER:** ______________

CLIENT: ______________________ **LOCATION:** ______________

DATE: ______________________ **ARRIVAL TIME:** ______________

Tt NUS PERSONNEL: ______________________ **DEPARTURE TIME:** ______________

CONTRACTOR: ______________________ **DRILLER:** ______________

ITEM	QUANTITY ESTIMATE	QUANTITY TODAY	PREVIOUS TOTAL QUANTITY	CUMULATIVE QUANTITY TO DATE

COMMENTS: ____

APPROVED BY:

______________________ ______________________

Tt NUS REPRESENTATIVE DRILLER

DATE: ______________

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: ______________________ BORING NUMBER: ______________________
PROJECT NUMBER: ______________________ DATE: ______________________
DRILLING COMPANY: ______________________ GEOLOGIST: ______________________
DRILLING RIG: ______________________ DRILLER: ______________________

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION			USCS *	Remarks	PID/FID Reading (ppm)			
					Soil Density/ Consistency or Rock Hardness	Color	Material Classification			Sample	Sampler BZ	Borehole**	Driller BZ**
													0

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Remarks: ____ Drilling Area Background (ppm): ______

Converted to Well: Yes ________ No ________ Well I.D. #: ______________________

Tetra Tech NUS, Inc.

SOIL & SEDIMENT SAMPLE LOG SHEET

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Project Site Name: ____________________
Project No.: ____________________

[] Surface Soil
[] Subsurface Soil
[] Sediment
[] Other: ____________________
[] QA Sample Type: ____________________

Sample ID No.: ____________
Sample Location: ____________
Sampled By: ____________
C.O.C. No.: ____________

Type of Sample:
[] Low Concentration
[] High Concentration

GRAB SAMPLE DATA:

	Depth Interval	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Date:			
Time:			
Method:			
Monitor Reading (ppm):			

COMPOSITE SAMPLE DATA:

	Time	Depth Interval	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Date:				
Method:				
Monitor Readings (Range in ppm):				

SAMPLE COLLECTION INFORMATION:

Analysis	Container Requirements	Collected	Other

OBSERVATIONS / NOTES:

MAP:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):