Field Sampling Plan

AOC-492

Real-Time Measurement Technology Demonstration Project
KRCEE

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Prepared by Argonne National Laboratory

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1.0 INTRODUCTION

1.1 General Background

The work described in this field sampling plan pertains to the demonstration of real-time characterization technologies applied to potentially contaminated surface soils in and around AOC-492, which is part of the Paducah Gaseous Diffusion Plant (PGDP).

1.2 Project Scope, Objectives, and Approach

This field sampling plan describes field activities associated with the demonstration of surface soil real-time characterization technologies. The field work will focus on surface soils in and around the AOC-492 area of the PGDP. The suite of real-time technologies includes logged gamma walkover surveys (GWS) for gamma-emitting radionuclides, *in situ* High Purity Germanium (HPGe) gamma spectroscopy for radionuclides, X-Ray Fluorescence (XRF) for metals including total uranium, and field test kits for polychlorinated biphenyls (PCBs).

The objectives of the field work and subsequent data analysis are:

- Demonstrate the applicability of real-time measurement technologies to the evaluation of the contaminants of concern at demonstration project levels in surface soils.

- Demonstrate the applicability of real-time measurement technologies to verifying that demonstration project goals have been achieved for surface soil exposure units.

- Demonstrate the applicability of real-time measurement technologies to supporting excavation for soils exceeding demonstration project goals.

- Demonstrate the applicability of real-time measurement technologies to verifying compliance with waste acceptance criteria in support of the disposition of excavated soils.

- Determine the performance characteristics of real-time technologies in the context of the Paducah site.

The overall approach of the proposed work is to deploy the real-time soil characterization technology suite at an area (AOC-492) believed to have at least some soils elevated above likely demonstration project levels. The entire area will be evaluated for the presence of contamination in surface soils through the application of GWS. Based on GWS data sets, the study area will be divided into sub-areas consistent with MARSSIM (Multi-Agency Radiation Survey and Site Investigation Manual, 2000) guidance. For those sub-areas believed to have contamination levels below demonstration project levels, real-time technologies in conjunction with traditional laboratory analyses will be used to demonstrate compliance with demonstration project levels. For those sub-areas with contamination levels above demonstration project levels, real-time technologies in conjunction with standard laboratory techniques will be used to demonstrate how these technologies can be used to guide excavation laterally and vertically through a re-evaluation of exposed dig faces. As appropriate, real-time data for excavated soils will be used to demonstrate compliance with waste acceptance criteria. During the course of the work, technology-specific quality control data collection will take place to help establish characterization technology performance in the context of Paducah soils.

1.3 Work Plan Organization

The remainder of the work plan is broken into seven sections. Section 2 discusses project organization, responsibilities, coordination, and schedule. Section 3 presents a Conceptual Site Model (CSM) for the AOC-492 area. Section 4 works through the data quality objective process for the proposed work. Section 5 describes the overall field data collection logic and associated field activities. Section 6 identifies decontamination necessary. Section 7 describes documentation and reporting requirements. Section 8 contains references.

2.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

2.1Project Coordination

The details of the proposed work were developed with the participation of representatives from the U.S. Department of Energy (DOE) and its contractors, Paducah Remedial Services, the State of Kentucky, the U.S. Environmental Protection Agency (EPA), and the Kentucky Research Consortium for Energy and the Environment (KRCEE) and its contractors. These participants form the real-time characterization work group.

This field sampling plan was prepared by KRCEE and its contractors.

The proposed work will be primarily performed by KRCEE and its contractors. The project manager for KRCEE is Steve Hampson and John Volpe is the Principal Investigator. The work will be conducted in close coordination with PRS.

2.2 Project Schedule

The proposed work is scheduled for late fall or winter, 2007. The exact timing is to be determined. The effectiveness of some of the real-time techniques can be significantly affected by the presence of saturated soils and/or standing water (particularly the GWS);

consequently the field work schedule may be adjusted to avoid weather conditions that could adversely affect the outcome of the field work.

3.0 CONCEPTUAL SITE MODEL

3.1Site Location

The AOC-492 area (also known as SMWU-492) is located southeast of the secured area of the PGDP (Figure 1), adjacent to the confluence of Outfall-11 and Little Bayou Creek.

3.2 Site History and Physical Setting

AOC-492 is adjacent to Outfall-11 and Little Bayou Creek (Figure 2). The proposed study boundary includes four distinct areas: AOC-492 itself, a buffer area surrounding AOC-492, portions of Outfall-11 including ditch bed and banks, and the north bank of Little Bayou Creek.

Historical samples within and adjacent to the AOC-492 footprint identified elevated uranium and total PCBs (Figure 3) as being present. A mound of soil has been described as being present in the vicinity of AOC-492. The height and dimensions of the mound are unknown at this time. The mound is assumed to be a soil pile whose origins are sediments from the outfall and/or creek. There are also anecdotal reports that surface soil contamination may exist without a visually-identifiable mounding of soil.

The rectangle demarcating AOC-492 is approximately 220 square yards (188 m^2) in size. However, given its location relative to historical sampling that presumably targeted suspect soils, the current AOC-492 boundary is likely no more than a schematic indicating the approximate area of concern.

The observed contaminants in AOC-492 are assumed to be associated with sediments removed from the outfall and/or creek. Contaminants of concern for this area would presumably reflect contaminants potentially found within outfall or creek sediments. At least some of these contaminants may have been associated with activities at C-340, including uranium and certain metals used in the process of reducing UF6 to UF4 to U metal such as Mg and Ca.

Sedimentation is an integrating process from the perspective of laying-down contaminants of concern. It is expected that, in general, one would find contaminants co-located. In the case of the outfall bed, contaminants would likely occur in well-defined sedimentary layers. Contamination in the banks of the outfall and/or Little Bayou Creek would likely be associated with a “bathtub” ring, and would likely be spotty. Contamination in soils adjacent to banks is assumed to be associated with contaminated sediments removed from the outfall and/or creek and placed on top of native soils. Given the nature of the historical removal/placement process, contaminated footprints are expected to be fairly localized. Soil mounds would be of particular concern.

Because contamination is believed to be associated with contaminated sediments that were removed from the creek/outfall and placed along the banks and/or contamination deposited in bank walls and outfall bed through normal depositional processes, the likelihood of finding contamination is assumed to decrease as one moves laterally away from stream/outfall banks and channels.

Primary completed exposure pathways of concern are ingestion and direct exposure to contaminated soils. Secondary exposure pathways are remobilization of contaminants via erosion and deposition into Little Bayou Creek.

3.3 Previous Investigations

Three surface soil samples were collected within/adjacent to the AOC-492 footprint in 2001. These samples were analyzed for PCBs, radionuclides, and metals. Metals with concentrations above background included cadmium (up to 3.1 ppm), chromium (up to 1,040 ppm), copper (up to 84.7 ppm), and zinc (up to 662 ppm). Elevated radionuclides included U-238 (up to 383 pCi/g) and Tc-99 (up to 14 pCi/g). PCBs were present in detectable concentrations in all three samples, up to 44.1 ppm total PCBs. Figure 3 shows sample locations, identifiers, and U-238 activity concentration and total PCB concentrations. It is not known at this time whether these three samples were taken from a soil pile or from surrounding soils.

There were a number of sediment and creek/outfall bank samples pertinent to this area. Their locations are shown in Figure 4. All six sediment samples were analyzed for PCBs, and in all six cases PCBs were detected. In sediment samples, detectable levels of PCBs were typically less than 1 ppm, with the maximum total PCB value of 5.4 ppm occurring at LBD11, in Little Bayou Creek downstream from its confluence with Outfall 11. The only sediment sample analyzed for U-238 was OF11B with U-238 at 48 pCi/g. OF11B was also the only sediment sample in this area analyzed for SVOCs and metals. Zinc, chromium, and copper were all elevated somewhat above background, which is consistent with soil sample results from AOC-492. Two PAHs, fluoranthene and phenanthrene, were detected, but at levels very close to detection limits and well below 1 ppm. Five of the six samples were analyzed for VOCs; there were no VOCs detected.

The RC series soil samples provided insights into the conditions of the banks for one cross-section of Outfall 11. These samples were analyzed for PCBs and radionuclides. In the cross-section represented by the RC samples, total U was detected above background in every sample, and reported to range from 63 to 1,030 ppm. Likewise PCBs were detected in every sample with concentrations from 0.5 ppm up to 40 ppm.

The BSN series soil samples provided information about the buffer area surrounding AOC-492. These samples were analyzed for radionuclides, metals, PCBs, VOCs and SVOCs. The results for these locations were all around background (or non-detects in the case of PCBs, SVOCs and VOCs) with the exception of BSN011-21 which had 15 pCi/g of U-238, 4.09 pCi/g Tc-99, and 2.4 ppm total PCBs. BSN011-21 was in closest proximity to Outfall 11 of this set (approximately 20 feet off the center line of the creek), a result consistent with the conceptual model for the site. It is not known whether BSN011-21 was associated with a soil pile.

3.4 Potential Contaminants of Concern

Based on historical sampling associated with AOC-492 and immediate vicinity, uranium (U-238) and PCBs are the primary contaminants of concern (COC). For those samples with both PCB and uranium analyses, elevated PCBs were consistently collocated with elevated uranium.

Very low levels of Tc-99 and Pu-239 were observed in a handful of samples, but not at levels that would be drivers for decision-making. There was also limited evidence of elevated metals (in particular zinc, copper, cadmium, and chromium) in some samples; these were also collocated with elevated uranium. For the purposes of this demonstration Tc-99, Pu-239, and metals other than uranium are considered secondary contaminants of concern (i.e., present above background levels but not likely to drive decision-making).

There was no significant evidence of PAH contamination, although in the case of the creek and outfall, this finding is based on only one sample.

There was no evidence of VOC contamination in the BSN series of samples or sediment samples from the creek.

4.0 DATA QUALITY OBJECTIVES

4.1 Problem Statement

The Paducah site has contaminated soils and sediments. The purpose of the proposed work is to demonstrate "real-time" (field-deployable) measurement technologies and associated processes – data management approaches, decision-making techniques, etc. – for surface and near surface soils and sediments that can optimize characterization and remediation performance (shortened schedules, reduced overall costs, improved decisions, reduced waste generation, etc.) at the site.

The scoping team consists of representatives from DOE, DOE contractors (PRS and Navarro), State of Kentucky, EPA Region 4, and KRCEE and its contractors. Members of the team include Rich Bonczek (DOE), Aric Cowne and Craig Jones (PRS), Leo Williamson and Ed Winner (State of Kentucky), Jon Richards and Dave Williams (U.S. EPA Region 4), John Volpe (KRCEE), Bruce Phillips (Navarro), and Steve Meiners and Bob Johnson (KRCEE contractors).

The current and the likely future uses of site areas outside the secured facility are recreational. Therefore the exposure scenario of concern is for a recreational user. To be consistent with soil piles work conducted to date, a teen recreational user scenario is used for risk evaluation purposes. Completed pathways include external radiation exposure, dermal exposure, inhalation, and ingestion of contaminants contained in surface soils. Run-off is also of concern and needs to be considered as a potential pathway for recreational users, with exposure to surface water and resulting sediments. The ultimate integrator of ecological risk is the surface water system (Little Bayou Creek and the Ohio River) defining the watershed that contains the site.

The 2000 risk-methods document (DOE 2000) includes risk-based levels in Table A.1 and Table A.4 for a teen recreational user scenario. Since "closure" of AOC492 is one goal of the RTD project, the risk-method document will be used as the source of "demonstration project levels." The demonstration project level taken from the risk-methods document for U-238 and daughters is 3.64 pCi/g (equivalent to 10.9 ppm total U assuming natural U) and 0.127 or 3.64 ppm total PCBs depending on whether high-risk or low-risk aroclors are of concern, respectively.

For the purposes of this demonstration, two types of demonstration project level requirements will be considered. The first is an average level ($DCGL_w$ or Derived Concentration Guideline Level) that must be achieved over an area the size of an exposure unit. The second is a "hot spot" or "elevated area" level that must be achieved over an area of size much smaller than an exposure unit. Consistent with MARSSIM, exposure units will be represented by final status survey units. MARSSIM defines three types of final status survey units, Class 1 units, Class 2 units, and Class 3 units. Class 1 units represent areas with contamination at levels known to exceed demonstration project level requirements, or areas where demonstration project level exceedances are likely to exist. Class 1 units can be up to 2,000 m^2 in size (approximately 0.4 acre). Class 2 units represent areas with contamination known to be present but less than demonstration project levels, or possibly present but unlikely to exceed demonstration project level requirements. Class 2 units can be up to 10,000 m^2 in size (approximately 2 acres). Class 3 units represent areas where it is highly unlikely contamination exists at levels that would be of concern. Class 3 units have no size limitation.

Consistent with the definitions used at Paducah, surface soils are defined as the top one foot of the soil. For the purposes of this demonstration, the "hot spot" criterion is applied to areas that are 25 m^2 in size, down to a depth of one foot. The "hot spot" criterion is defined consistent with DOE Order 5400.5's area factor equation. The acceptable hot spot concentration or activity concentration for a particular COC is given by:

Hot spot criterion = $DCGL_w$ * sqrt(survey unit area/hot spot area)

Assuming a Class 1 final status survey unit size of 2,000 m^2 and a hot spot area of 25 m^2, the area factor is 9. Note that for U-238, 9 is approximately equal to the generic area factor corresponding to a 25 m^2 area as listed in MARSSIM Table 5.6 (MARSSIM 2000). DOE Order 5400.5 also establishes a never-to-exceed criterion of 30 times the $DCGL_w$. Demonstration project levels and demonstration project hot spot levels for the AOC-492 primary contaminants of concern are listed in Table 1.

4.2 Required Decisions

There were a large number of potential goals, questions, and associated decisions identified for the real-time characterization demonstration project. In general the goals, questions, and their associated decisions can be grouped into five categories.

1) Can real-time technologies determine the general presence or absence of contamination for exposed surface soils?

2) Can real-time technologies verify that exposure units are free of contamination above prescribed demonstration project levels?

3) Can real-time technologies guide excavation work during soil removal to minimize soil waste volumes?

4) Can real-time technologies support soil waste disposal decision-making?

5) What performance can be expected from real-time measurement technologies in the context of Paducah soil requirements? What is the optimal deployment strategy of these technologies for surface soils at Paducah? What QC is appropriate during deployment of these technologies?

4.3 Decision Inputs

The following information sources will serve as information inputs to the five general decisions/study questions that have been identified:

- Demonstration Project values for a teenager recreational user scenario from the risk methods document (DOE 2000)
- Existing soil sampling protocols used for SWOU and NSDD work
- Waste acceptance criteria for the U Landfill, along with existing associated protocols
- Previously collected and analyzed soil samples and their results
- Historical waste profile sampling results
- Logged gamma walk over survey with a NaI system
- *In situ* HPGe system measurements
- XRF system data (*in situ* readings, *ex situ* bagged sample readings, *ex situ* prepared sample readings)
- PCB test kits
- Standard off-site laboratory analyses of soil samples

Table 1 contains generic detection limits for the primary contaminants of concern at AOC-492 with the proposed technologies. Table 2 lists generic XRF detection limits for various metals.

4.4 Study Boundaries

The primary focus is on surface soils for AOC-492 and adjacent areas down to a depth of one foot; however the intent is to be able to transfer the technologies and methodologies to surface soils elsewhere at the Paducah site. The characteristics of interest are the average concentrations or activity concentrations of primary contaminants of concern in soils for AOC-492 and adjacent areas.

Figure 2 identifies the study area for the proposed work. The study area is 1.12 acres in size and includes AOC-492, which is 220 yd^2 (188 m^2). The study area was selected to include soils representing a range of potential contamination conditions. The study area includes locations with historical sampling that demonstrates contamination at levels of concern (vicinity of AOC-492), areas likely to be impacted at levels of concern (Outfall 11 and Little Bayou Creek banks), and areas unlikely to be contaminated at levels of concern (buffer area around AOC-492). This study will focus on the characterization of surface soils. In the event that excavation is required to achieve demonstration project levels, excavation will take place to a minimum depth of one foot with the option of pursuing contamination until demonstration project levels have been achieved. However, wetlands and the banks/bottom of the outfall and creek are outside the scope of this project from an excavation perspective.

The study area will be divided into three sub-areas following MARSSIM guidance. The Class 1 area will include areas where either historical sampling has indicated contamination at levels of concern or there is reason to believe contamination may be present at demonstration project levels of concern (e.g., banks of the outfall). The Class 2 area will include areas where there is the possibility for the presence of contamination but it is not believed likely that contamination is above demonstration project levels of concern. The Class 3 area will include areas where it is considered highly unlikely that contamination exists at demonstration project levels of concern. Figure 5 shows a general schematic for how the study area might be broken into these three areas.

The Class 1 area will be further potentially subdivided into Class 1 units whose size will not exceed 2,000 m^2. Based on current understanding of the site, there is expected to be one Class 1 unit. Class 2 survey units can be up to 10,000 m^2 in size. Based on the size of the study area, there will be one Class 2 survey unit. The balance of the study area will be represented by a Class 3 unit. MARSSIM places no size restrictions on Class 3 units.

The proposed real-time decision-making opportunities are as follows:

- finalize layout of final status survey units – within 24 hours of GWS data collection;
- determine whether and where biased discrete samples are required based on GWS data collection activities – within 24 hours of GWS data collection;
- decisions about whether excavation is required based on GWS, direct measurement, and/or discrete sampling results – within 24 hours of when GWSs are conducted, direct measurements are made, or soil samples are obtained;
- decisions about whether an area has met final status survey (FSS) demonstration project levels based on GWS, direct measurement, and/or discrete sampling results (i.e., backfill [from clean borrow area] can occur or additional excavation is required) – within a short time of when scans are conducted, direct measurements are made, or soil samples are obtained.

These decisions will be based on "real-time" data and verified through the use of standard laboratory analyses.

Decisions regarding the presence or absence of contamination in different areas of the study area will be made on the basis of:

- individual sample results,
- scan results, and/or
- direct reading results (e.g., if an individual result is above the demonstration project level for one or more contaminants of concern, then contamination is present at demonstration project levels of potential concern).

The sample support (e.g., the unit of soil the result is representative of) will vary for each source of information.

- For example, for *ex situ* analysis of individual samples this will be the soils contributing to the sample.

- If multi-increment sampling is used to form the sample, then the decision-making scale will be defined by the area covered by the sample increments.
- For *in situ* HPGe measurements, the field of view defines the scale of the decision. An un-collimated HPGe measurement taken from a height of one meter will produce an area-weighted average activity concentration representative of approximately 100 m^2.
- For an individual GWS data point, the field of view is roughly one m^2.
- For an *in situ* XRF reading, the measurement support will vary depending on whether an individual measurement is made or measurement aggregation is done. For the purposes of this work, XRF measurements and surface soil samples will be collect in such a way as to provide an approximate 1-m^2 sample support consistent with the field of view of individual GWS measurements.

Conclusions about the presence or absence of contamination at this scale do not necessarily imply soil removal is or is not necessary for a particular area.

Decisions supporting excavation work will be made on the basis of sample units and the average contaminant concentrations observed in those units. For soils, a unit is defined as the smallest area about which a dig/no dig decision will be made. For the NSDD work, 35'x35' units (approximately equivalent to 100 m^2) were used. One of the objectives of this effort is to determine appropriate unit sizes when real-time data are available. As a starting point, the proposed work will use the definition of a hot spot, 25 m^2, as the definition of a unit. The depth of the unit will be one foot.

Decisions regarding the contamination status of FSS units for demonstration project closure purposes will be made on the average concentration contaminant concentration observed in the FSS unit and the presence or absence of contamination above hot spot demonstration project criteria averaged over 25 m^2.

Decision regarding the status of excavated soil with respect to waste acceptance criteria will be based on real-time results to the extent possible using general protocols defined by existing site documents.

Conclusions regarding real-time technology deployment optimization and real-time measurement performance will be based on real-time measurement technology results as measured by the proposed work and associated quality control information.

Data collection will be confined to a limited time (approximately two weeks) in the field.

4.5 Decision Rules

The parameters of interest are those primary contaminants of concern that appear in the conceptual site model description.

There are three separate demonstration project levels for each COC, an average level that must be met over an area defined by a FSS unit, a "hot spot" demonstration project level applied to a much smaller area, and a never-to-exceed level as defined by DOE Order 5400.5. The average demonstration project level will be based on teen recreational user, as defined in the risk methods document (DOE 2000). For the purposes of this project, the hot spot demonstration project criteria for each of the COCs will be based on an area factor analysis consistent with DOE Order 5400.5. The size of a hot spot will be set to 25 m^2 (as identified by DOE Order 5400.5), i.e., the hot spot demonstration project criterion will be achieved on average over 25 m^2. For a Class 1 unit this results in an area factor equal to 9. Consistent with DOE Order 5400.5, the never-to-exceed level is set to 30 times the demonstration project level. Table 1 contains demonstration project levels and hot spot demonstration project criteria for the primary AOC-492 contaminants of concern.

The decision rules for the first four decisions are as follows:

Decision Statement #1: Is contamination present at levels of potential concern?

If any individual sample result or direct measurement is above the demonstration project level or represents a detectable above-background result when detection limits are greater than demonstration project levels for an AOC-492 primary COC, then contamination is present potentially at demonstration project levels of concern

Decision Statement #2: Is contamination present at levels that require excavation?

If sample results or direct measurements return a result greater than 30 times the demonstration project level for the primary AOC-492 COCs, then an action will need to be taken (i.e., either soil removal or additional investigation).

If sample results or direct measurements that are representative of the hot spot area definition give an average result above the hot spot demonstration project criterion for a COC, then an action will need to be taken.

If the average results from samples or direct measurements taken from a FSS unit exceed the unit-averaged demonstration project levels as previously defined, then an action will need to be taken (i.e., either selective soil removal or additional investigation).

Decision Statement #3: Does the exposed surface meet the demonstration project risk standards required for demonstration project "closure" of action?

A final status survey unit will be considered as having met demonstration project risk standards suitable for a no action demonstration project closure if the following conditions are met:

- All sample/direct measurement results are less than 30 times the demonstration project level for primary COCs.
- Results averaged over 25 m^2 are less than the hot spot demonstration project criteria (9 times the demonstration project level for primary COCs).
- Results averaged over final status survey units are less than demonstration project levels for the primary COCs.

Decision Statement #4: Does excavated soil meet waste acceptance criteria for expected disposition facility?

If an individual sample result or direct measurement consistent with waste profile protocols exceeds facility-specific WAC standards, an action will need to be taken.

The fifth decision pertains to the most effective deployment of the real-time technologies at Paducah, and their observed performance. No one decision statement captures the variety of performance parameters and deployment strategies that will be evaluated as part of the proposed work. Data will be collected to answer questions regarding real-time measurement technology detection limits, error rates (false positive and false negative), comparability to standard laboratory techniques, interfering factors, practical deployment considerations, and deployment costs.

4.6. Acceptable Decision Errors

The null hypothesis for FSS units in the study area is that contamination exists above demonstration project levels that require action. With this baseline assumption, two types of decision errors are possible: a Type I error where the null hypothesis is true but rejected (i.e., contamination at demonstration project levels of concern inadvertently left behind) and a Type II error where the null hypothesis is false but accepted (i.e., soils with contamination below demonstration project levels of concern inadvertently removed for disposal). The Type I error is a human health risk error and is of primary importance. The Type II error results in unnecessary costs.

The proposed work includes an average and hot spot demonstration project criteria. The hot spot demonstration project criteria are set at nine times the no-action criteria. The FSS unit-averaged level is set to the risk-based no-action demonstration project criteria. In the case of the hot spot demonstration project criteria, the upper bound of the gray region is set to the hot spot demonstration project criteria. In the case of the FSS-unit averaged criteria, the upper bound of the gray region is set to the demonstration project level. The upper bound of the gray region can be interpreted as the value above which one must identify soil as contaminated with the specified Type I error rate.

The lower bound of the gray region (something less than the demonstration project level) can be interpreted as the value below which one must identify soil as clean with the specified Type II error rate. In this context, the lower bound of the gray region is the general demonstration project level of contamination one would expect to be present if one were in "clean" areas. Since this is often unknown for any particular site, it often is set, arbitrarily, at half the demonstration project level. Sample numbers derived from this assumption may be either too many or too few depending on contamination realities in the field. One of the advantages of real-time techniques is that they can provide some insight into both the variability and average level of contamination present while work is underway, allowing a much more definitive determination of the lower bound of the gray region and sample numbers required.

For the SWOU work Plans, the Type 1 error rate was set to 0.1 and the Type II error rate to 0.2. For the purposes of the proposed work, these are minimum error targets that will be achieved, if technically possible. However, it is expected that actual error rates will be significantly lower, depending on the performance of the fielded characterization technologies and the nature of contamination encountered. The goal will be to achieve error rates that are as low as reasonably possible.

4.7 Optimized Data Collection Strategy

The proposed data collection will take place in one field effort planned for the fall or winter of CY2007. The field effort is organized into five major activities:

1) Determine the presence or absence of contamination at demonstration project levels of potential concern in surface soils for the entire study area.
2) Support demonstration project closure of Class 2 and Class 3 final status survey units, and for the Class 1 unit once excavation is complete, if possible. Note that not all areas exceeding demonstration project levels or hot spot demonstration project criteria within the Class 1 area may be accessible for excavation. In this scope of work excavation will not be conducted in the banks or bottom of the outfall or creek, or in areas designated as wetlands. Consequently it may not be possible to achieve closure for the Class 1 area if significant residual contamination is in either banks or wetlands.
3) Support excavation of soil from areas that either exceed hot spot demonstration project criteria or result in the average of a final status survey unit exceeding the no-action demonstration project criteria, with the exception of banks, stream/outfall bottom sediments, and areas designated as wetlands.
4) Demonstrate that removed soils meet waste acceptance criteria.
5) Collect sufficient QC information to demonstrate real-time measurement technology performance.

The subsections below provide an overview of the planned activities, along with their rationale. Additional technology-specific detail is presented in Section 5.0 of this field sampling plan. In addition, technology-specific Standard Operating Procedures (SOPs) will be prepared and available prior to the initiation of field work.

4.7.1 Determining Presence/Absence of Contamination

Field work will begin with a logged gamma walkover survey (GWS) of the study area surface with a density of at least one measurement per square meter. A FIDLER NaI detector will be used with 2-second acquisition times. Data will be captured along with coordinate information recorded in Kentucky State Plane Coordinates (NAD 83 feet). The FIDLER detector will respond to uranium contamination in the top few inches of soil. The purpose of the GWS survey is to provide information about the presence or absence of gamma-emitting radionuclides in surface soils.

The resulting GWS data set will be downloaded and mapped with other GIS information available for the AOC-492. The GWS data points will be posted on a study area map, and color-coded using an appropriate legend. The GWS data sets will also have a moving-window average applied with the window size set to 25 m^2. Moving window averages can be an effective means for controlling measurement error and short-scale heterogeneity in GWS results when one is looking for spatial patterns in GWS data sets. The raw and moving window-averaged data sets will be visually evaluated for evidence of obvious spatial trends and/or the presence of clearly elevated areas. A 25-m^2 moving window averaging area was selected to match hot spot size definition.

Based on the GWS data, up to 20 locations will be selected for biased measurements using *in situ* XRF readings and *in situ* HPGe measurements. These locations will be biased towards locations that exhibit elevated GWS readings in the expected range of the instrument's response to demonstration project level activity concentrations (likely close to detection limits for the instrument) to the demonstration project level for hot spots. If possible, they will also be scattered across the study area to the extent possible. The purpose of these 20 locations is to provide data that can assist in the quantitative interpretation of FIDLER detector results. The rationale for 20 is that this is a sufficient number for performing a regression between FIDLER NaI detector cpm readings and U-238 activity concentrations, if that turns out to be of value. Twenty locations are also sufficient to allow an estimate of lower investigation levels that can be applied to FIDLERI detector data for the specified Type I error rate for the hot spot demonstration project criteria. A lower investigation level sets a cpm threshold that, as long as readings are below the investigation level, one can be confident the demonstration project level was not exceeded. Twenty locations set a starting point for developing a relationship between FIDLER NaI detector results and U-238 activity concentrations in surface soils. Other data collection activities that are part of this field effort will also produce data pairs (i.e., a FIDLER reading with a sample or measurement from the reading location) that will augment the initial twenty.

For each of the selected locations, one 30-second static reading with the FIDLER detector over the location of interest will be obtained and recorded.

From each of the selected locations a set of *in situ* XRF readings will be obtained. Each location will have five 30-second readings collected systematically across one square meter of exposed surface centered on the location above which the NaI reading was obtained. The purpose is to obtain a representative average total U value across the square meter which is approximately the field of view of a static FIDLER NaI reading, to provide a measure of the degree of spatial variability one would expect in XRF measurements at this scale, and also to determine whether there are other collocated heavy metals present that should be considered as potential contaminants of concern for the AOC-492 study area (note that elevated zinc, chromium, copper, and cadmium have been observed in historical samples). Information regarding spatial variability of total uranium is useful for estimating the number of measurement aggregates that should generally be used when doing *in situ* XRF measurements.

Un-collimated *in situ* HPGe measurements will be obtained over each location from a height of 15 cm. A height of 15 cm will provide a field of view roughly equivalent to 2 m^2. Measurement times will not exceed 20 minutes. The purposes of the HPGe measurements are to determine whether there are other elevated gamma-emitting radionuclides contributing to GWS results besides U-238, and to further quantify the activity concentration of U-238 present at the spatial scale of a hot spot.

After the *in situ* HPGe and XRF measurements have been obtained, a composite five-increment soil sample (ICSS) will be obtained from the location, with the increment soil samples (ISS) systematically distributed from the one-meter area centered on the location, with the increment locations corresponding to the locations of the XRF *in situ* measurements. ICSS from each location will initially undergo minimal sample prep (i.e., air drying, removal of organic material and stones).

Ten ICSS will be selected and bagged after minimal sample prep. Individual bags will be hand kneaded to break up soil aggregates, and then each bag will have ten 30-second XRF measurements through the bag walls, five on each side.

All soil ICSS will then undergo standard preparation. The ten ICSS initially bagged and measured will be re-bagged. The ten 30-second measurement process will be repeated for each of these bagged samples. All of the ICSS will then be split, and each split labeled. One half of the splits will be sent off-site for standard laboratory analysis including beta scintillation, alpha spectroscopy, gamma spectroscopy, and metals analysis. The other half will be analyzed on-site by XRF cup measurements (120-second acquisition times) and PCB test kits.

The measurement results from the XRF and HPGe will be used to determine investigation levels for GWS data sets. These include a lower investigation level below which there should be relatively low false negative errors for identifying the presence of U-238 at its hot spot demonstration project criteria, and an upper investigation level above which there is a high level of confidence that the hot spot demonstration project criteria have been exceeded. The purpose of the investigation levels is to provide a means for quantitatively evaluating GWS data regarding the presence or absence of contamination at demonstration project levels of concern with decision-making errors at the specified rates (or better).

The GWS data will re-interpreted using these investigation levels to identify locations within the study area that potentially have U-238 contamination at demonstration project levels of concern versus areas that do not. In particular, the GWS data and investigation levels will be used to finalize the spatial definition of Class 1, Class 2 and Class 3 areas.

Table 3 summarizes the number of measurements required by this part of the proposed field effort.

4.7.2 Supporting Final Status Unit Closure

Real-time data collection will take place in the Class 2 and Class 3 units identified by the previous step. The GWS data should have already demonstrated that U-238 hot spots are unlikely to exist, and that average concentrations are likely below the required FSS unit average concentration level. Closure sampling in the FSS units will focus on showing compliance with FSS unit average requirements, and demonstrating compliance with hot spot demonstration project criteria for those chemical and radiological contaminants that are not identifiable by GWS.

In the case of hot spot demonstration project compliance, the spatial density of data collection is directly related to the size of hot spot of concern. At a large site such as Paducah, not all areas present hot spot concerns. For example, in areas where the presumed source of soil contamination was air deposition, hot spots are not a significant issue. MARSSIM recommends 100% coverage when looking for hot spots in Class 1 units, 10% - 100% coverage for Class 2 units, and judgmental, targeted coverage in Class 3 units, as necessary.

4.7.2.1Class 1 Unit

As portrayed in Figure 5, the Class 1 unit in the study area is approximately 1,200 yd^2 (1,000 m^2) in size. A GWS with 100% coverage and a data density of approximately 1 measurement per m^2 will have been conducted for this area. Based on this GWS, areas will have been identified as likely exceeding no-action demonstration project levels and/or hot spot demonstration project levels and requiring soil excavation. Data collection to support selective excavation for these areas is discussed in a later section. The following discussion pertains to those portions of the Class 1 unit that are either not excavated, or represent exposed surfaces in areas where excavation has been conducted and residual contamination levels are believed to be at demonstration project acceptable levels. Conceptually, final status survey work begins after excavation work is complete. In a real-time data collection effort such as this, FSS data collection will take place concurrently with excavation work. This leverages the ability of real-time techniques to identify potential FSS concerns while excavation capabilities are still present in the field.

The Class 1 unit will be divided into approximately forty 25-m^2 areas. The actual number will be dependent on the final layout of survey units within the study area. The question for each of these 25-m^2 areas is whether contaminant concentrations exceed the hot spot demonstration project criteria for total PCBs as identified in Table 1 (U-238 hot spot demonstration project level concerns should have been adequately addressed by GWS data). A composite five-increment soil sample (ICSS) will be collected from each 25-m^2 area, with increment soil samples (ISS) distributed systematically across each 25-m^2 area. Each ISS will sample soils down to a depth of 1 foot. The purpose of multi-increment sampling within each 25-m^2 area is to obtain a sample that would be more representative of the true average contaminant concentrations for each area than a single sampling location would provide.

Each homogenized ICSS will be split into two equal portions. One half of the ICSS split will be labeled and archived. The other half of the ICSS split will be combined with ICSS splits from four other 25-m^2 areas to form a 5-sample ICSS composite soil sample (CSS) (at most 8 composite samples in all). The 5 ICSS forming the CSS should be from adjacent 25-m^2 areas. The CSS will be thoroughly homogenized. The CSS will be split again after preparation and labeled, with one set of CSS splits sent for off-site analysis by traditional methods and the second set analyzed for PCBs using test kits and metals via XRF cup analysis on-site (120-second acquisition). The purpose of the off-site analysis in this case is to provide verification, comparability and performance information for the real-time analytical techniques.

The analytical results from the real-time analysis will be reviewed for PCB demonstration project hot spot concerns. If one or more composite results exceeds 20% of the hot spot demonstration project criteria for either U-238 or total PCBs as provided in Table 1, each archived ICSS split from samples contributing to those composites will be analyzed by real-time methods to determine if and which location(s) is (are) above the hot spot demonstration project criteria. Each archived ICSS split will be split once more prior to analysis, with each ICSS split labeled and one set analyzed on-site by XRF and PCB test kit, and the second set of ICSS splits submitted for off-site confirmatory analysis. If one or more of the ICSS split results exceeds the hot spot demonstration project criteria for U-238 and/or PCBs based on on-site analytical results, then the unit "fails". No further action will be taken as part of this field effort. In a "real" deployment of this approach, the 25-m^2 areas exceeding the demonstration project hot spot criteria would require excavation and subsequent re-sampling to verify that demonstration project criteria had been achieved. If none of the split results exceeds the demonstration project level for a COC, then the set of 25-m^2 areas contributing to the original composite are cleared of demonstration project hot spot concerns.

If none of the original composite results exceeds 20% of the hot spot level for a COC, then the exposure unit passes the hot spot evaluation.

The average of the composite samples will be calculated. If the average of the composite samples is less than the no-action demonstration project criteria, then the conclusion will be that the FSS unit is in compliance with its demonstration project criteria. If the average is above the no-action demonstration project criteria, then the exposure unit fails. No further action will be taken as part of this field effort. In a "real" deployment of this approach, the exposure unit would need to undergo selective excavation of those areas above demonstration project requirements. It is expected that with 200 individual sample locations contributing to the composite soil samples, the observed error rates will be much lower than the minimum error rates identified by the DQO process. A statistical evaluation of the data will be conducted to establish that this, in fact, was the case.

4.7.2.2 Class 2 Unit

As portrayed in Figure 5, the Class 2 unit in the study area is approximately 900 yd^2 (800 m^2) in size. A GWS with 100% coverage and a data density of approximately 1 measurement per m^2 will have been conducted for this area. The definition of a Class 2 unit is that there are no obvious concerns (prior to sampling) associated with contamination above relevant criteria, so the presumption would be that the GWS had not identified any areas of concern within the Class 2 unit (if the GWS had, those areas would have been included in the Class 1 unit, not the Class 2). The additional assumption is that Class 2 data collection will take place concurrently with or prior to excavation work, allowing the opportunity to address unexpected contamination that might be encountered during the FSS process.

The Class 2 unit will be divided into approximately thirty two 25-m^2 areas. The actual number will be dependent on the final layout of survey units within the study area. The question for each of these 25-m^2 areas is whether contaminant concentrations exceed the hot spot demonstration project criteria for total PCBs as identified in Table 1 (U-238 demonstration project hot spot concerns should have been adequately addressed by GWS data). A five-sample ICSS will be collected from each 25-m^2 area, with the ISS distributed systematically across each 25-m^2 area. Each ISS will sample soils down to a depth of 1 foot. The purpose of ICSS sampling within each 25-m^2 area is to obtain a sample that would be more representative of the true average contaminant concentrations for each area than a single sampling location would provide.

Each homogenized ICSS will be split into two equal portions. One half of the ICSS split will be labeled and archived. The other half of the ICSS split will be combined with ICSS splits from seven other 25-m^2 areas to form an 8-sample CSS. The 8 ICSS contributing to the CSS should be from adjacent 25-m^2 areas. The CSS will be thoroughly homogenized. The CSS will be split again after preparation and labeled, with one set of CSS splits sent for off-site analysis by traditional methods and the second set analyzed for PCBs using test kits and metals via XRF on-site (cups, 120-second readings). The purpose of the off-site analysis in this case is to provide verification, comparability and performance information for the real-time analytical techniques.

The analytical results from the real-time analysis will be reviewed for PCB demonstration project hot spot concerns. If one or more CSS results exceeds 12% of the demonstration project hot spot criteria for either U-238 or total PCBs as provided in Table 1, each archived ICSS split from samples contributing to those composites will be analyzed by real-time methods to determine if and which location(s) is (are) above the demonstration project hot spot criteria. Each archived ICSS split will be split once more prior to analysis, with each ICSS split labeled and one set analyzed on-site by XRF and

PCB test kit, and the second set of splits submitted for off-site confirmatory analysis. If one or more of the ICSS split results exceeds the hot spot demonstration project criteria for U-238 and/or PCBs based on on-site analytical results, then the unit "fails". No further action will be taken as part of this field effort. In a "real" deployment of this approach, the 25-m^2 areas exceeding the hot spot demonstration project criteria would require excavation, incorporation into a Class 1 unit, and subsequent re-sampling to verify that demonstration project criteria had been achieved. If none of the split results exceeds the demonstration project level for a COC, then the set of 25-m^2 areas contributing to the original composite are cleared of hot spot concerns.

If none of the original composite results exceeds 12% of the hot spot demonstration project level for a COC, then the exposure unit passes the hot spot evaluation.

The average of the CSS will be calculated. If the average of the CSS is less than the no-action demonstration project criteria, then the conclusion will be that the FSS unit is in compliance with its demonstration project criteria. If the average is above the no-action demonstration project criteria, then the exposure unit fails. No further action will be taken as part of this field effort. In a "real" deployment of this approach, the exposure unit would need to undergo selective excavation of those areas above demonstration project requirements and the affected area re-classified for closure purposes as a Class 1 area. It is expected that with 160 individual sample locations contributing to the composite soil samples, the observed error rates will be much lower than the minimum error rates identified by the DQO process. A statistical evaluation of the data will be used to establish that this, in fact, was the case.

4.7.2.3 Class 3 Unit

As portrayed in Figure 5, the Class 3 unit in the study area is approximately 3,200 yd^2 (2,700 m^2) in size. A GWS with 100% coverage and a data density of approximately 1 measurement per m^2 will have been conducted for this area. The definition of a Class 3 unit is that there are no concerns (prior to sampling) associated with contamination above relevant demonstration project criteria, so the presumption would be that the GWS had not identified any areas of concern within the Class 3 unit (if the GWS had, those areas would have been included in a Class 1 or 2 unit, depending on the demonstration project level of concern). The additional assumption is that Class 3 data collection will take place concurrently with or prior to excavation work, allowing the opportunity to address unexpected contamination that might be encountered during the FSS process.

Eight systematically placed (random start triangular grid) sampling locations will be identified for the Class 3 area. Each location will serve as the center of a 25-m^2 area. An HPGe measurement from a height of 50 cm will be acquired at each location. A 5-sample ICSS will be collected representing each grid node, with the 5 ISS distributed over the 25-m^2 area. Each resulting ICSS will be prepared and then analyzed by XRF and PCB test kit before being sent off-site for laboratory analysis. XRF (cup, 120-second reading) and test kit results will be compared with the hot spot demonstration project criteria. If all are below those criteria, the unit passes from a hot spot perspective.

The average of the ICSS results will be calculated. If the average of the composite samples is less than the no-action demonstration project criteria, then the conclusion will be that the FSS unit is in compliance with its demonstration project criteria. If the average is above the no-action demonstration project criteria, then the exposure unit fails. No further action will be taken as part of this field effort. In a "real" deployment of this approach, the exposure unit would need at minimum further investigation and potentially selective excavation of those areas above demonstration project requirements. The affected areas would be re-classified for closure purposes as Class 1 areas. A statistical evaluation of the data will be used to establish that error goals had been achieved.

Table 3 summarizes the number of direct measurements, samples and sample analyses required by this part of the proposed field effort.

4.7.3 Supporting Soil Excavation

The initial GWS data collection will have identified areas expected to be above demonstration project hot spot and/or demonstration project levels. Real-time data collection will be conducted as part of soil excavation work in these areas to demonstrate the capabilities of real-time measurement systems to support excavation work. Specifically, real-time data collection will be used to determine the lateral extent of excavation work, and to determine for exposed excavated surfaces whether demonstration project criteria have been achieved or not.

The targeted areas will be divided into 25-m^2 areas. Data collection will begin by verifying that contamination in surface soils in each unit is greater than demonstration project hot spot and/or demonstration project levels. Five locations will be selected per unit, with the five systematically distributed across each unit. The number of locations may be adjusted based on the short-scale variability observed in the GWS data sets from this area and/or the results of the biased sampling conducted earlier. The purpose of these locations is to obtain representative average contaminant concentration results for each of the 25-m^2 areas.

From each location a static 30-second FIDLER NaI detector reading will be acquired directly above the location and recorded. The purpose of this data collection is to obtain additional GWS data points that can be compared with other sample/measurement results to flesh-out understanding of GWS performance and appropriate investigation levels. Next, for half (up to 10) of the 25-m^2 areas five *in situ* XRF measurements (30-second readings) will be collected from surface soils for each location, with the five measurement points systematically distributed over a 1-m^2 area centered on each location. For the remaining 25-m^2 areas, a single *in situ* XRF measurement (120-second reading) will be collected from each location. The purpose of the XRF readings is to get an accurate estimate of the average uranium concentrations for each of the 25-m^2 areas, and to determine if there are other heavy metals present that might be potential contaminants of concern.

One *in situ* HPGe measurement will be collected from each 25-m^2 area, taken at a height of 50 cm (approximate field of view equal to 25 square meters), centered on each 25-m^2 area. The purpose of the HPGe measurement is to obtain an alternative estimate of U-238 activity concentrations in each 25-m^2 area, and also to determine whether other gamma-emitting radionuclides are present above background levels that might be contributing to observed GWS results.

One 5-point ICSS will be collected from each 25-m^2 area targeting the selected locations. The ISS will be collected from the center of the 1-m^2 locations used for *in situ* XRF readings. The number of increments may be adjusted based on results from work already completed. The resulting ICSS will be homogenized and prepared. This sample will be split again after preparation, with one set of ICSS splits labeled and retained for on-site analysis via XRF (cup, 120-second reading) and PCB test kits, and the second set of ICSS splits labeled and sent off-site for traditional laboratory analysis. The purpose of the on-site analysis is to determine the presence and level of primary contaminants of concern. The purpose of the off-site analyses is to provide a point of comparison with the on-site results.

25-m^2 areas with ICSS results above the hot spot demonstration project criteria will be excavated to a depth of one foot. When excavation is complete, the exposed surfaces will have a GWS conducted with a density of at least one measurement per square meter. The contamination status of the exposed dig bottom will then be evaluated based on the GWS results. If results indicate contamination above hot spot demonstration project levels, an additional one foot will be removed from the exposed dig and GWS data collected. Once excavation is complete, these 25-m^2 areas will be pooled with the balance of the Class 1 unit and FSS data collection conducted as described previously.

Table 3 summarizes the number of sampling locations, samples, measurements, and sample analyses required.

4.7.4 Demonstrating WAC Compliance

The disposal options for excavated soils are determined by the waste acceptance criteria of the potential disposal facilities and the contaminant types and levels present in the soil waste streams. On-site disposal facilities maintained and operated by the Paducah site are subject to waste acceptance criteria as defined in BJC/PAD-11/R4 (DOE 2003). The WAC compliance documentation requirements for particular soil waste streams are determined in part by process and historical knowledge of what potentially is present in the soils. The real-time measurement suite to be demonstrated as part of this field program are capable of partially satisfying those information requirements. In particular, they are applicable to: determining if the 20x rule for TCLP has been violated for select metals (arsenic and lead via the XRF), whether total uranium is present significantly above background levels (XRF), whether Cs-137, U-238, Am-241, and Th-232 are elevated (HPGe), and whether PCBs are present at levels greater than 50 ppm (test kits). Expected detection limits for each of these technologies are provided in Tables 1 and 2. The spatial density of data collection described in excavation support is greater than the data density generally required for WAC compliance. WAC compliance information is typically required for each container of material delivered for disposition. In the case of on-site disposal options, waste soils would likely be delivered by dump truck. Typical dump truck capacities are 20 cubic yards of soil, which corresponds to the hot spot definition proposed for this field effort (i.e., 25 m^2 excavated to a depth of one foot yields approximately 20 yd^3 of soil). The average concentration values observed for 25-m^2 areas will be used for WAC compliance purposes.

4.7.5 Demonstrating Technology Performance

One of the key objectives of the field work is to determine real-time measurement technology performance for soils at Paducah. A significant amount of information will be generated by activities already described that will be pertinent to technology performance evaluation. In addition, technology-specific activities will be undertaken to address other technology-specific performance questions. In some cases these activities will double as quality control checks on measurement system performance. GPS accuracy and location repeatability will be determined through the use of established control points and regular checks. Detector drift and environmental effects (soil moisture, temperature, etc.) will be monitored through established control points. Additional details of these activities for each of the proposed real-time technologies can be found in Section 5 of this plan, and will also be contained in standard operating procedures (SOPs) to be developed for each technology prior to the initiation of field work.

5.0 FIELD ACTIVITIES

This section describes field activities in greater detail. Additional information regarding implementation of the various data collection technologies can be found in their standard operating procedures.

Because of the nature of the study area, at least some clearing and grubbing will be required to allow access for GWS surveys, *in situ* measurements, and soil sampling activities.

Weather will be a potential issue for the proposed work. The actual field work schedule will need to be sensitive to weather and soil conditions. Security and site access will also potentially impact the proposed work. This includes site-specific training requirements for those involved in the field work aside from generic hazardous waste and radiological worker training. There is no expectation that confined space or respiratory training will be required.

5.1 Coordinate Control and Mapping

Acquiring accurate spatial coordinate information is critical to the success of the proposed field work. All spatial data will be reported in Kentucky South State Plane (feet) NAD83 coordinates. It is expected that most, if not all, of the coordinates of spatial data generated will be obtained using a differentially corrected Global Positioning

System (GPS). Sub-meter accuracy is desired for this project; however this level of accuracy is not an absolute pre-requisite.

A survey control point will be established at the start of the project. This control point will preferably be a known benchmark with coordinates already established by civil survey and in the proximity of the AOC-492 area. If such a benchmark does not exist, then a control point will be established using an immobile, readily definable landmark. In this case, the landmark will be surveyed. Daily work involving a GPS will require at least two measurements at the control point, once at initiation of work and once at the end, with the coordinates recorded. These results should be within the known expected accuracy of the system. In addition, GPS performance will be monitored for satellite availability and Position Dilution of Precision (PDOP) during data collection. If conditions are such that GPS accuracy is compromised, work may be delayed until good coordinate control is re-established.

Every location with a sample collected or a measurement (HPGe/XRF) acquired will be staked and labeled so that the location can be recovered as necessary.

An initial walk down of the AOC-492 area will be done with the GPS system. This walk down will focus on delineating spatial features of the proposed work area, including:

- the boundary of the proposed work area;
- the top-of-banks lines for ditches adjacent to and/or bisecting the work area;
- the location of the survey control point to be used for the duration of the project;
- the location of the gamma walkover survey control point to be used for the duration of the project;
- the locations and footprints of any discernible soil mounds that may be of anthropogenic origin;
- other important landmarks clearly visible.

GPS data will be downloaded at least once a day in a format suitable for electronic storage and transmittal (e.g., Excel, or a comma-delimited ASCII file). A method for clearly identifying which site feature(s) coordinate data pertain to will be used (e.g., separating coordinates for different features by files, and/or including a feature field for every location recorded). In addition, electronic GPS data should include data fields such as PDOP to indicate the quality of the data. Post-data collection differential correction processing may be used to improve GPS data quality.

Coordinate data will be mapped and reviewed at least once a day using a suitable Geographical Information System (GIS) along with existing spatial information to identify any obvious location discrepancies requiring corrective action.

5.2 GWS Surveys

The GWS surveys specified for the site will likely produce thousands of individual measurement records. GWS surveys of areas should be conducted in a manner that produces a data density of at least one measurement per square meter. All GWS data collected will be logged along with accompanying GPS information. The units (e.g., cps or cpm) of measurement results should be clearly identified. GWS data will be downloaded at least once a day for review and incorporation in the GIS. Areas of the site where GWS datasets are incomplete or compromised either because of loss of GPS signal or poor walkover coverage will be re-walked as they are identified.

In the event of heavy rainfall resulting in standing water, walkover surveys will not be conducted over areas containing standing water. Such areas will be delineated by walking their perimeter with the GPS and marked as such on field maps. These areas will be walked as conditions allow.

Mobile GWS data collection will consist of lines walked parallel to each other, separated by approximately one meter. Stakes may be used to ensure properly spaced lines. Walking should be done at an approximate rate of 30 meters per minute (approximately 1 mile per hour), with the detector held approximately six inches above the ground and moved slowly in a serpentine fashion.

At the initiation of work, detector response to a check source placed in a repeatable geometry will be established by ten consecutive check source readings. Based on these readings a control chart will be constructed that shows the mean and two standard deviations above and below the mean. At the start and end of each day, detector response will be check with a known check source placed in a repeatable geometry. Unexpected detector responses (i.e., responses more than two standard deviations from the mean as plotted on a control chart) should be flagged and investigated to ensure the detector is operating correctly. This will be done for each FIDLER NaI detector used to support field work.

At the initiation of GWS work a single control point will be established. Ten consecutive one minute GWS readings will be obtained and logged, with the FIDLER NaI detector held stationary six inches above the control point. This will be repeated for each FIDLER NaI detector used to support the field work. Based on these readings, a control chart will be developed with a two-standard deviation upper and lower control centered on the mean reading. Subsequently, each day a FIDLER NaI detector is used, at least three static one minute readings above this control point will be collected, one at the start of the day, one mid-day, and one at the end of the day. In addition, if environmental conditions change significantly during the course of the day (e.g., a rainfall event takes place), an additional static reading above the control point will be collected (e.g., after rainfall has ceased and before data collection resumes). These data will be plotted on the control chart. Deviations from the original mean result of more than two standard deviations will be noted and investigated (e.g., another static reading taken to confirm first result or check source used) to be sure the detector is working properly and/or that environmental conditions are not adversely affecting detector performance.

Changing surface geometries can also affect FIDLER NaI detector results in ways that complicate data interpretation. Common geometries of concern are soil piles and ditches. Soil piles may be present in the study area and ditches are present.

The initial phase of GWS work includes complete coverage of the study area surface, and then the selection of up to twenty locations for follow-up work, including stationary FIDLER NaI detector readings. All stationary FIDLER NaI detector readings will be taken six inches from above the ground. In the case of the twenty locations for follow-up work, each location will be staked, with the stake clearly identifying the location name. The location name will use the following convention: RT-Loc# where # is a unique three digit number (e.g., 001, 002, etc.).

5.3 XRF Measurements

There are three types of XRF measurements that may be made as part of the proposed field work. The first are *in situ* XRF measurements. With *in situ* measurements, the XRF detector is placed directly against the surface of exposed soil. The second is bagged XRF measurements. With bagged XRF measurements, a soil sample is obtained, placed in a clear plastic bag, and XRF measurements made of the soil through the bag. The final is cup XRF measurements. With cup XRF measurements, a soil sample is prepared following soil preparation protocols (i.e., drying, grinding, homogenization) and a subsample obtained in an XRF cup for analysis. The degree of sample preparation ranges from minimal for *in situ* readings to significant for cup measurements.

In general, XRF measurement times will either be 30 or 120 seconds in duration, depending on data needs. XRF equipment/software will be configured to allow for the reporting and logging of all measurement results, even if those results are below calculated detection limits.

The basic sample preparation process for each of the three types of measurements is described below. Additional detail may be found in the XRF SOP.

- *In Situ* XRF Measurements. For *in situ* XRF measurements the exposed soil surface of interest will have debris and stones removed and will be flattened with a spatula or similar tool. The XRF detector will be placed directly against the exposed soil surface for the duration of the measurement. General soil type and moisture conditions will be recorded in a field notebook.

- Bagged XRF Measurements. For bagged XRF measurements, a soil sample will be retrieved as described in a subsequent section. Debris and stones will be removed prior to bagging the soil. More than one ISS may contribute to a bagged sample if a ICSS is being used. The bagged sample may have minimal sample preparation depending on the state of the sample (e.g., some drying prior to bagging for saturated soil samples, crushing with a rubber mallet or similar device for samples containing aggregates, and hand kneading the bag to obtain basic mixing).

- Cup Measurements. For cup measurements, soil samples will be prepared following standard laboratory protocols. In general these protocols will include sieving the sample to remove debris, organic matter, and stones, thoroughly drying the sample, milling the sample to obtain a uniform soil particle size, and thorough homogenization.

Complete XRF QC procedures are described in the XRF SOP. The following describes basic components that will be included. Soil samples will be obtained prior to the initiation of the field work and provided to the expected XRF vendor for a performance verification check to ensure the XRF used is properly calibrated for uranium in soils characteristic of the study area. If archived samples do exist, three samples will be selected: one with uranium at background levels, one with uranium between 20 and 50 ppm, and one with uranium in the range of 100 to 1,000 ppm. If archived samples do not exist, then three samples will be obtained from the site. Sample selection will be based on a cursory NaI screen of candidate locations. One sample will be obtained from background soils. One will be obtained from soils where the NaI indicates likely elevation above background conditions. One sample will be obtained from a location where the NaI clearly indicates elevated conditions. In each case, the samples will have debris, stones, etc. removed before bagging and shipment. Whether archived or fresh samples are used, the samples will be clearly and uniquely marked in a manner that does not indicate their expected uranium content. The samples will be analyzed by standard laboratory techniques to determine total uranium mass content.

All data generated by the XRF will be logged and recorded for future review. In general, XRF measurements will be made *in situ* or on samples from locations with known coordinate information. If this is not the case, a GPS unit will be used to obtain coordinate information for the XRF measurements.

NIST-traceable standards will be used as calibration checks. At least two standards will be used, one spiked with uranium to levels of 100 ppm, and the second spiked with uranium to levels of 500 ppm. These standards will be used for initial calibration check purposes and daily calibration checks as well. The standards will be characterized by the XRF initially using at least ten repetitive 120-second readings. These readings will be used to develop control charts that will be implemented in support of daily calibration checks. During normal use, 120-second calibration checks will be performed at least three times a day: once at the start of the day, once at midday, and once at the end of the day. Calibration checks falling outside calibration control levels (two standard deviations around the mean) will be repeated to ensure the calibration still holds.

In the case of cup measurements, for the first sample with elevated uranium present (i.e., above XRF detection limits), the process of obtaining an XRF cup and completing a measurement will be repeated five times. The purpose is to determine the effectiveness of sample preparation procedures in producing a representative cup subsample. If the variability observed in five measurements is greater than 1.5 times the average reported error for the five measurements, the sample preparation process will be revisited to improve sample homogenization. After the "improvements", the effectiveness of the homogenization process will again be checked for the next elevated U prepared sample by five replicate subsample cup analyses on a prepared sample.

In the case of bagged measurements, within bag uranium variability will be assessed via multiple XRF measurements. This information will be used to assess the number of measurements per bagged sample required to obtain an accurate assessment of average uranium concentrations within bagged samples when samples have not been thoroughly prepared.

In some cases, multiple XRF readings may be required for either *in situ* or bagged sample data collection. In these cases a minimum of four measurements will be made systematically across the exposed soil or bagged surface. In the case of bagged samples, two measurements would be taken from each side of the bag. The identifier for each measurement should be the location/bag identifier with a "-#" at the end, where the # is a unique sequential integer starting with 1 and ranging up to the number of individual measurements taken for that location/bag.

At least twenty samples with XRF data indicating elevated uranium will be submitted for off-site laboratory confirmatory analysis. Based on the current CSM for the site, elevated metal contamination other than uranium may be present. The XRF is calibrated for a range of metals and will report a suite of metal concentrations with each measurement. These metal results will be monitored. If there is evidence of elevated metal contamination that is potentially above demonstration project levels for metals other than uranium, additional sampling locations may be selected and samples sent for confirmatory laboratory analysis.

5.4 In Situ HPGe Measurements

In situ HPGe measurements will be made of surface soils at selected locations across the study area. In general, *in situ* HPGe measurements will be uncollimated and taken at an instrument height of one half meter. Measurement times will be selected to obtain U-238 detection limits below the demonstration project level, if possible, but will not exceed 20 minutes. Details for the deployment and operation of the HPGe can be found in the HPGe SOP.

Each HPGe measurement will be uniquely identified with a location identification, measurement height, and acquisition duration. In general, HPGe measurements should coincide with data collection locations that have existing coordinate information. If this is not the case, a GPS will be used to determine coordinate information for the HPGe measurement. *In situ* HPGe measurements will be accompanied by an estimate of the surface soil moisture present.

In situ HPGe measurement quality can be affected by geometry and shine. Shine is not expected to be a problem for the proposed study area. Geometry effects are most likely along steep slopes associated with either mounds or ditch banks. In these cases the height of the HPGe may be reduced to 15 cm and/or a collimated HPGe used to minimize geometry effects. In any case, if collimation or a height adjustment is used, these adjustments must be recorded in a field notebook and the instrument re-calibrated for the altered source geometry.

HPGe energy calibrations and quality control checks will include at minimum calibration source checks twice a day, once at the start of field data collection and once at the end of the day. NIST-traceable radioactive standards should be used. Ideally three different standards representing three different characteristic energy levels will be used (e.g., Am-241 @ 59.5 keV, Cs-137 @ 661.6 keV, and Co-60 @ 1332.5 keV). The purpose of the checks is to verify proper energy calibration for the detector. Resolution and net counts for each peak should be recorded and tracked to document the detector is operating as expected.

Based on the current CSM for the site, uranium is the only gamma-emitting radionuclide expected to be present in study area soils above background conditions. However, the HPGe will report activity concentrations for a range of radionuclides. Specifically, results for Cs-137, K-40, Ra-226, Ra-228, Th-230, and Am-241 results will be recorded and monitored. Results for K-40, Ra-226 and Ra-228 will be recorded but not reported because these isotopes are not representative of plant process history. If there is evidence of other plant process related isotopes present above background conditions, a representative multi-increment sample will be collected and submitted for laboratory gamma spectroscopy analysis.

5.5 Soil Test Kit Analyses

PCB soil test kit analyses will be demonstrated by field activities in the study area. Kit use will conform to manufacturer recommendations and follow the kit-specific SOP.

Test kit QC will, at a minimum, include at least two calibration checks each day, once at the start of the day and once at the end, using prepared known samples.

5.6 Photographs

Digital photography will be used to document field activities associated with this field sampling plan. Field photographs will be clearly identified and recorded in a field notebook, including the time, location, bearing, and purpose of the photograph. Digital field photographs will be downloaded and archived at the end of each day.

5.7 Sample Collection and Control

See the Quality Assurance Project Plan (QAPP) for sample type and sample identification/labeling details.

Samples intended for off-site laboratory analysis will conform to chain-of-custody control tracking. The shipment of samples for off-site laboratory analysis will conform to applicable DOT packing and labeling requirements.

5.8 Laboratory Analyses

Samples submitted for off-site laboratory analysis will have the following analyses performed:

- RCRA metals
- Tc-99 (beta scintillation)
- Isotopic Uranium, Isotopic Thorium, Isotopic Plutonium (alpha spectroscopy)
- SVOC analysis (including aroclor-specific PCB analysis and total PCBs)
- Cs-137, Am-241 (gamma spectroscopy)

It is expected that the laboratory will temporarily archive the samples until notified that samples can be disposed of or returned for archiving by the site. It is expected that notification will be provided within 90 days of delivery of final data packages by the laboratory.

5.9 DECONTAMINATION

A work zone will be defined and enforced for the duration of the field effort. Equipment and personnel entering and exiting the work zone will be screened for possible radionuclide contamination.

The potential for cross-contamination and the volume of investigation-derived wastes (IDW) will be minimized to the extent possible. Disposable sampling equipment will be used whenever possible. Sampling equipment (e.g., scoops, pans, mixing tools) will be scrubbed with a brush or equivalent after use to remove loose contamination, and then segregated and sealed in bags. Disposal of IDW will conform to existing site protocols. For non-disposable equipment (e.g., HPGe, GPS, XRF, soil augers, etc.), contact with potentially-contaminated soil will be minimized. If the potential for contamination has occurred, the equipment will be dry-decontaminated using brushes to remove loose soils, and then rinsed with rinsate captured for disposal, dried, and screened for the presence of surface radionuclide contamination prior to continued use.

In the case of multi-increment sampling, sampling equipment (soil coring tool, etc.) will be wiped clean to remove loose soil between increments. More thorough decontamination of re-usable equipment is required after all increments contributing to a sample have been collected and before re-use of the equipment.

6.0 DOCUMENTATION AND REPORTING

Field notes will be recorded in a weather-proof format. At the end of the field work, all field notes will be electronically scanned for archiving and dissemination.

All results from real-time measurement technologies will be electronically logged if possible. In those cases where electronic logging is not possible, results will be recorded as field notes. Whether electronically recorded or hand-written, real-time results will include at minimum the location where the measurement was taken/sample obtained, a unique measurement or sample identifier, the measurement/analysis type (e.g., QC or actual), the media measured, the date and time of the sample, the result, the associated error or an equivalent data quality qualifier, the operator, the purpose of the measurement or analysis, and any notes pertinent to data interpretation (e.g., moisture content, etc.). Electronically logged results will be down-loaded and transferred at least once a day to a centralized data repository. Daily backups of the data repository to non-re-recordable (i.e., write once CD or DVD) media will be done, and these backups kept physically separate from project work.

In the case of composite samples, sample notes will clearly indicate the original samples, referenced by i.d., that were used to form the composite.

Off-site laboratory deliverables will consist of a complete data package that includes at minimum chain-of-custody records, analytical results, QC information, and raw spectra/instrument output as appropriate delivered in an appropriate electronic format (e.g., PDF and as spreadsheets for laboratory results).

7.0 REFERENCES

Department of Energy. December 2000. Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky Volume I. Human Health. DOE/OR/07-1506&D2.

Department of Energy. August 2000. Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), Revision 1. DOE/EH-0624, Rev. 1.

Department of Energy. January 2003. Waste Acceptance Criteria for the Department of Energy Treatment, Storage, and Disposal Units at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Department of Energy. February 2003. Sampling Plan for the Remedial Action for Sections 1 and 2 of the North-South Diversion Ditch to Address Near-Surface Soil Contamination at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky. BJC/PAD-400-FINAL.

Department of Energy. December 2004. Sampling and Analysis Plan for Site Investigation and Risk Assessment of the Surface Water Operable Unit (On-Site) at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky. DOE/OR/07-2137&D2.

Table 1. Primary Contaminants of Concern for AOC-492, No Action and Hot Spot Levels, and Detection Limits

	Demonstration Project Level	Demonstration Project Hot Spot Level	Detection Limits[4]				
			GWS	*in situ* HPGe	XRF[5]	Test Kit[3]	Standard Laboratory[2]
PCB (low risk)	3.64 ppm	33 ppm	NA[1]	NA	NA	0.5 ppm	0.1 ppm
U-238	3.64 pCi/g	33 pCi/g	30 pCi/g	3 pCi/g	6 pCi/g	NA	2 pCi/g

[1]Not applicable
[2]As reported in Sampling and Analysis Plan for SWOU, December, 2004
[3]There are a variety of test kits available, ranging from qualitative to quantitative, with actual detection limits and dynamic ranges varying depending on the type of kit used. The numbers quoted are for "screening" kits.
[4]For many systems, detection limits are a direct function of sampling and measurement protocols, including counting times in the case of spectroscopy (e.g., HPGe and XRF). The numbers quoted are for standard protocols, which may differ significantly from technique to technique (e.g., standard count times for an in situ HPGe measurement are 15 minutes, while for an XRF they are 2 minutes).
[5]Individual XRF measurements provide concentration information for a variety of metals. Table 2 summarizes detection limits as reported by EPA Method 6200. This information is dated; actual detection limits can be expected to be significantly better than these for some elements. In the case of U-238, total U is measured by the XRF. Detection limits provided assume natural U.

Table 2. EPA Method 6200 XRF Detection Limits[1]

Analyte	Chemical Abstract Series Number	Detection Limit in Quartz Sand (milligrams per kilogram)
Antimony (Sb)	7440-36-0	40
Arsenic (As)	7440-38-0	40
Barium (Ba)	7440-39-3	20
Cadmium (Cd)	7440-43-9	100
Calcium (Ca)	7440-70-2	70
Chromium (Cr)	7440-47-3	150
Cobalt (Co)	7440-48-4	60
Copper (Cu)	7440-50-8	50
Iron (Fe)	7439-89-6	60
Lead (Pb)	7439-92-1	20
Manganese (Mn)	7439-96-5	70
Mercury (Hg)	7439-97-6	30
Molybdenum (Mo)	7439-93-7	10
Nickel (Ni)	7440-02-0	50
Potassium (K)	7440-09-7	200
Rubidium (Rb)	7440-17-7	10
Selenium (Se)	7782-49-2	40
Silver (Ag)	7440-22-4	70
Strontium (Sr)	7440-24-6	10
Thallium (Tl)	7440-28-0	20
Thorium (Th)	7440-29-1	10
Tin (Sn)	7440-31-5	60
Titanium (Ti)	7440-32-6	50
Vanadium (V)	7440-62-2	50
Zinc (Zn)	7440-66-6	50
Zirconium (Zr)	7440-67-7	10

[1]EPA Method 6200 detection limits were reported in 1998. Subsequent XRF technology improvements have for some elements significantly reduced detection limits. For example, arsenic detection limits are now routinely around 10 ppm with an XRF.

Table 3. Summary of Proposed Data Collection for AOC-492 (Minimum Number/Maximum Number)

	GWS Data Points	XRF Measurements[1]	In Situ HPGe Measurement	Sample Increments	Test Kit PCB Analysis	Laboratory Analysis
Initial Walkover Biased Sampling	~5,000	320	20	100	20	20
Closure Data Collection	0	20/30	0	400	20/30	20/30
Soil Removal Support Data Collection	0/1,000	0/320	0/20	0/100	0/20	0/20
QA/QC[2] Requirements	20	120	0	0	20	0[3]
Total:	~6,000	460/790	20/40	500/600	60/90	40/70

[1]The majority of XRF readings will be 30-second acquisitions, with a much smaller number of 120-second acquisitions
[2]The preponderance of QC requirements listed here refer to calibration checks
[3]Laboratory QC requirements are assumed to conform to laboratory protocols

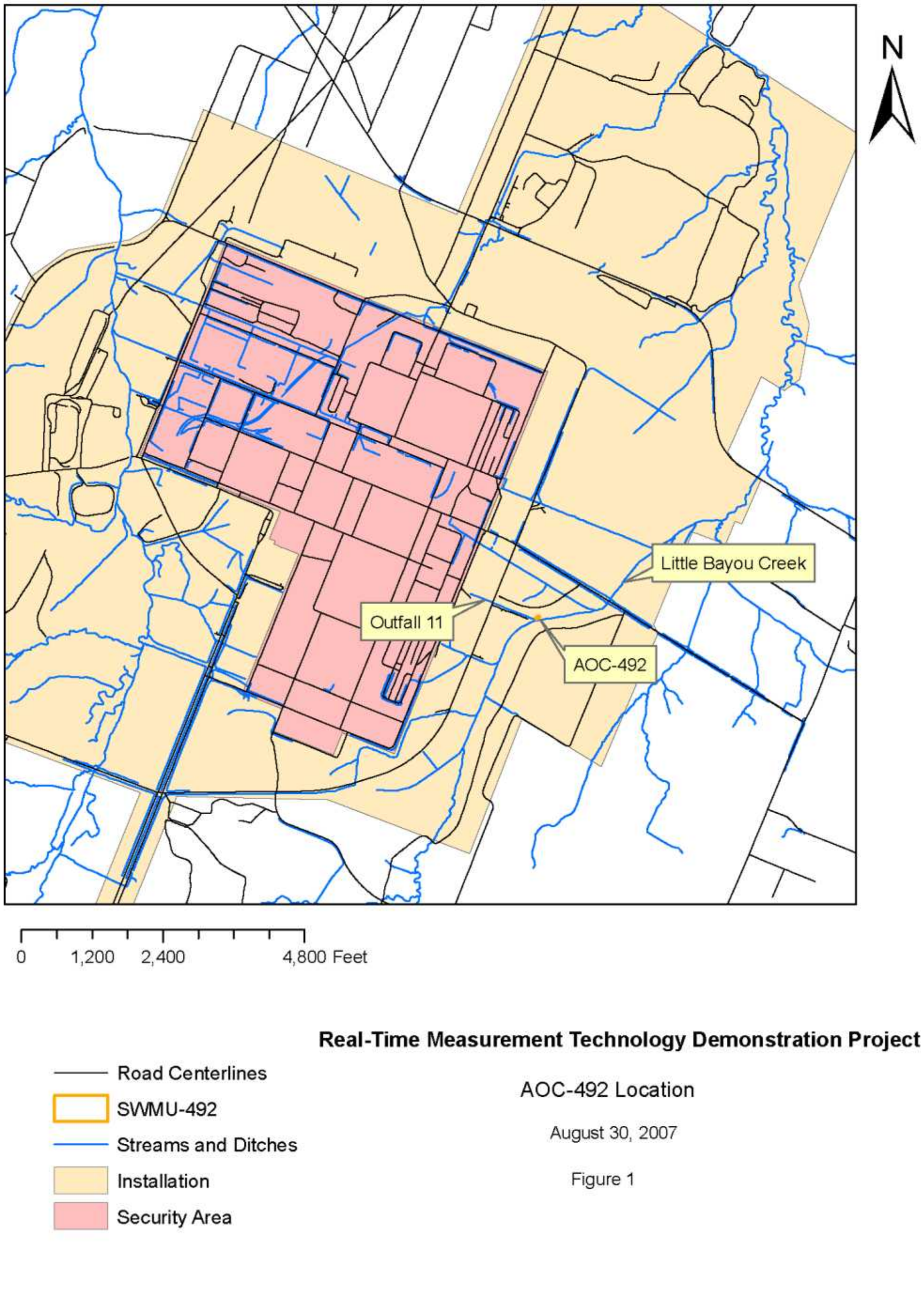

Figure 1. Paducah Gaseous Diffusion Plant with Location of AOC-492

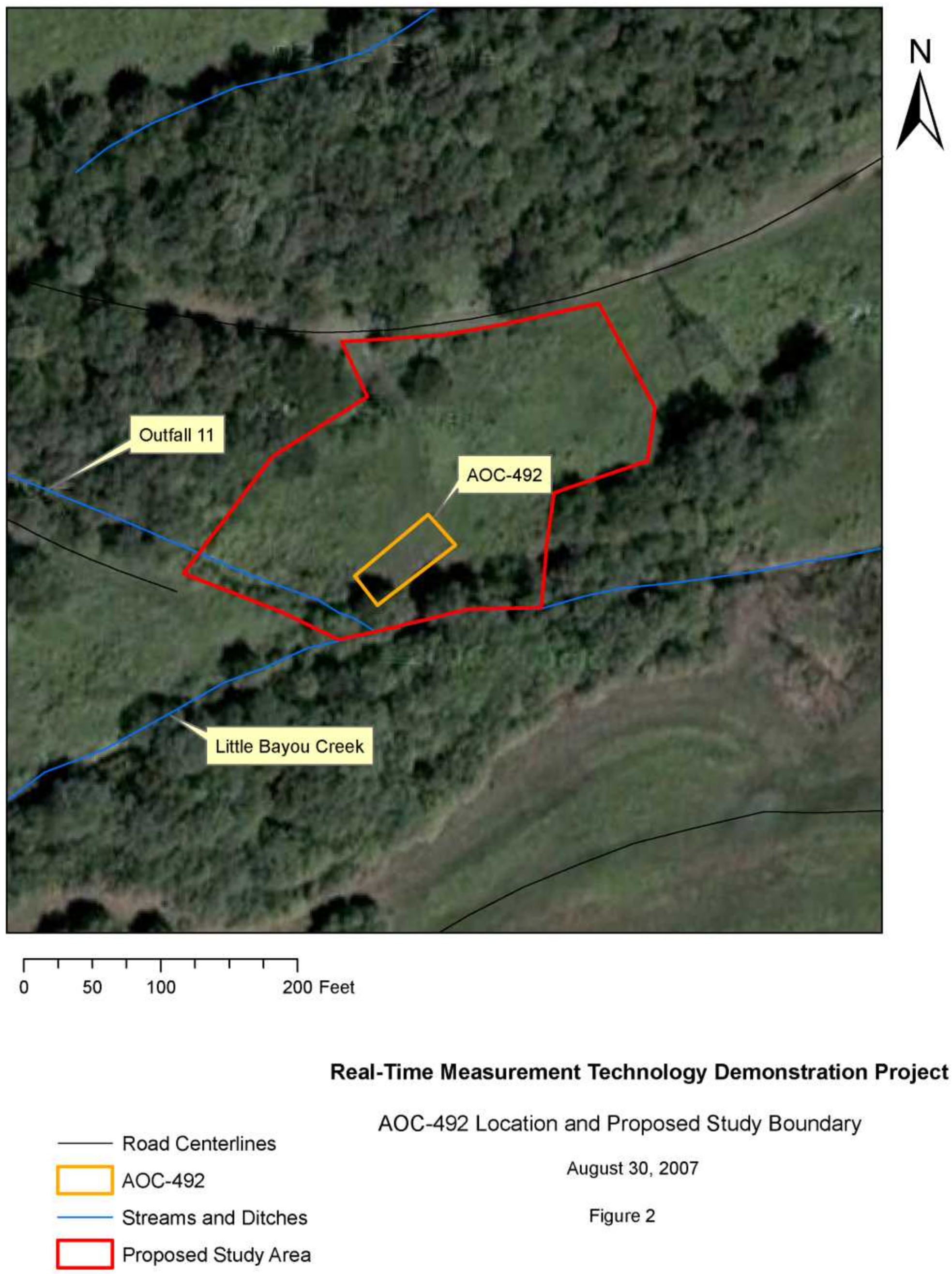

Figure 2. AOC-492

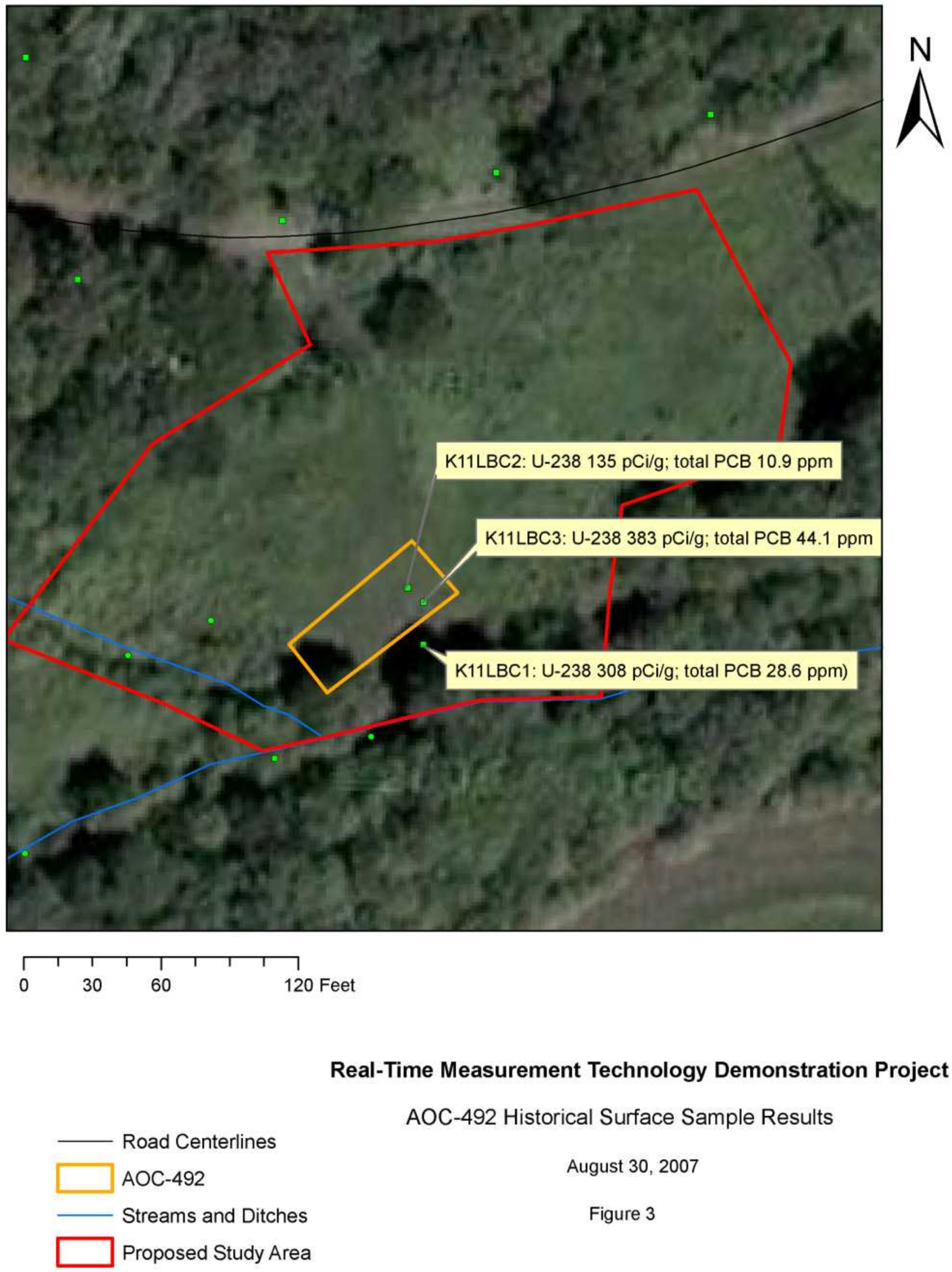

Figure 3. Surface Soil Samples Associated with AOC-492

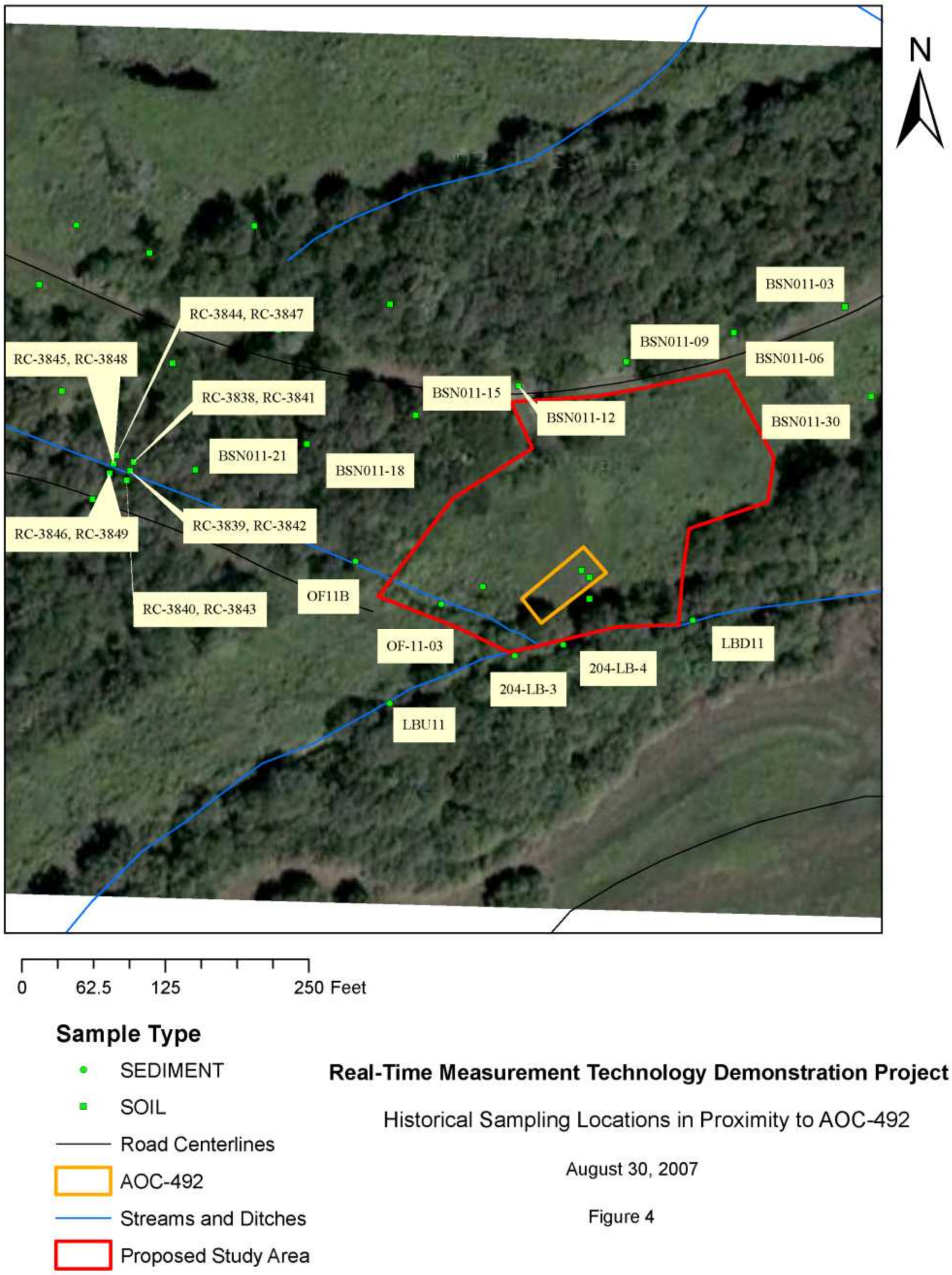

Figure 4. Surface Soil Samples in the Vicinity of AOC-492

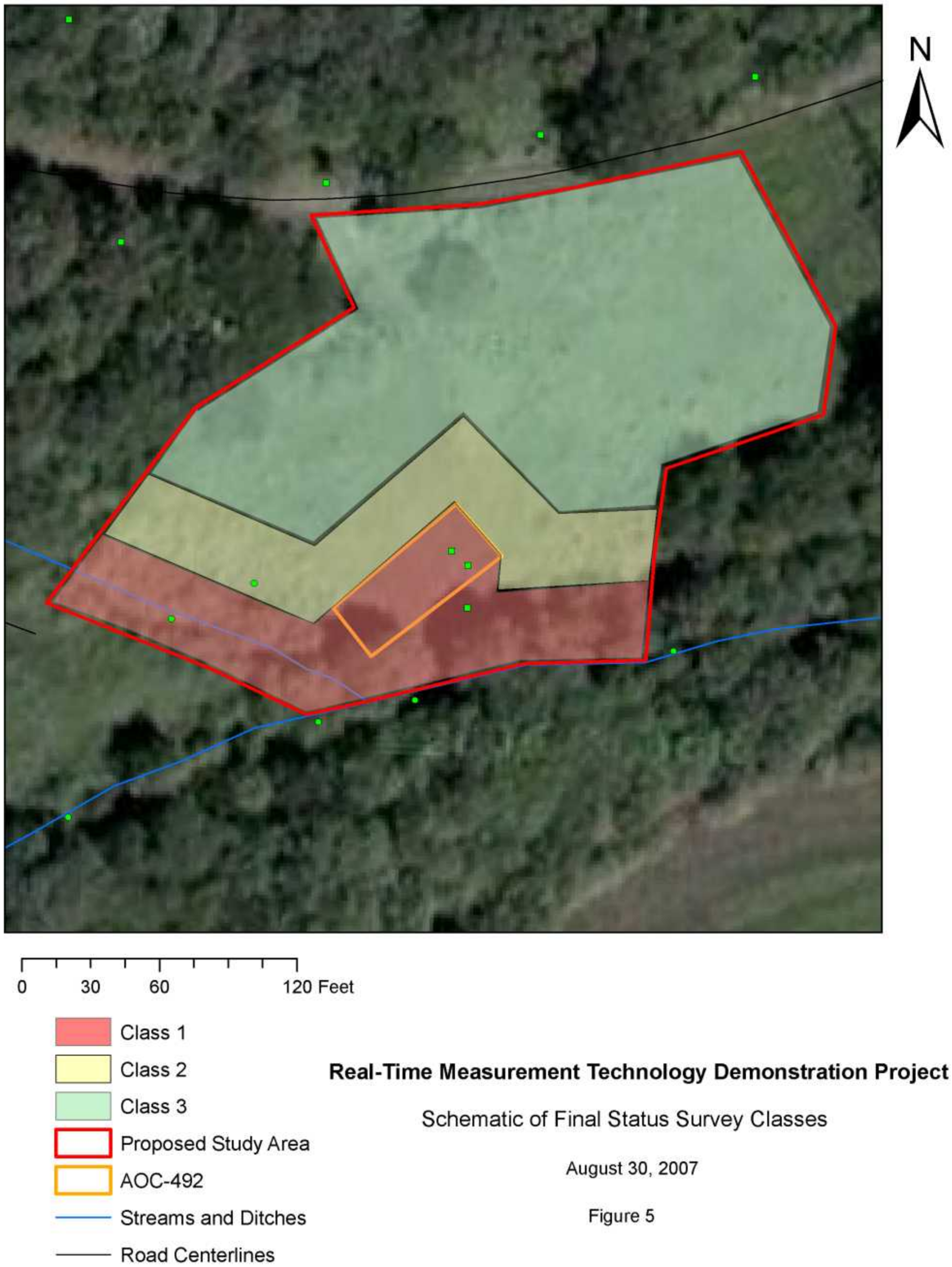

Figure 5. Schematic Layout of Final Status Survey Unit Classes