Natural and Accelerated Bioremediation Research (NABIR) Field Research Center (FRC) Site Characterization Plan-Addendum 1

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Environmental Sciences Division

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1.0 Introduction

To encourage hypothesis-based field research and process-level understanding, the Natural and Accelerated Bioremediation Research (NABIR) program has established a Field Research Center (FRC) for NABIR investigators. The FRC provides a site for investigators to conduct field-scale research and to obtain DOE-relevant subsurface samples for laboratory-based studies of bioremediation. The FRC is located on the U.S. Department of Energy’s Oak Ridge Reservation (ORR) in Oak Ridge, Tennessee. Staff from Oak Ridge National Laboratory’s Environmental Sciences Division have operated the FRC since April 2000. Both contaminated and uncontaminated background (control) areas are located on the ORR’s Y-12 National Security Complex in Bear Creek Valley. The initial focus of research at the FRC has been on in situ biostimulation experiments to promote the immobilization of uranium and technetium.

The FRC is used by NABIR investigators for various purposes including three multi-disciplinary in situ accelerated bioremediation research projects:

- In situ Uranium Reduction Experiments Using Push-Pull Techniques (Oregon State University and Oklahoma University located in Areas 1 and 2)
- Field-scale Bioreduction of Uranium (Stanford and ORNL located in Area 3)
- In situ Immobilization of Uranium in Structured Porous Media via Biomineralization at the Fracture/Matrix Interface (PNNL, ORNL, and University of Alabama located in Area 2)

This document is an addendum to the NABIR FRC Site Characterization Plan (SCP) prepared in April 2001 (Watson et al. 2001). The tasks described in this addendum are a continuation of the site characterization work described in the SCP.

The SCP provided descriptions of:

- Hydrogeologic setting and contaminant distribution,
- Sampling objectives and baseline characterization tasks,
- Procedures for sampling, coring, and well installation,
- Procedures for conducting pumping, tracer, and other hydraulic testing,
- Field and laboratory analytical methods for groundwater and sediment, and
- Quality Assurance (QA), health and safety, and waste management procedures

Unless specified otherwise the same sampling and analysis procedures described in the SCP will be used to conduct the site characterization tasks described in this addendum. Other relevant documents that will be used to implement the SCP addendum tasks are the FRC Management Plan (Watson and Quarles, 2001a), which describes the roles and responsibilities of interested parties and regulatory requirements for working at the site; the FRC Quality Assurance Plan (Brandt, Holladay and Watson, 2001), which outlines Quality Assurance/Quality Control (QA/QC) measures, data management procedures, and the chain of custody, sample handling, labeling, and tracking procedures which are used to maintain sample quality; and the FRC Health and Safety Plan (Watson and Quarles, 2001b), which describes health and safety measures that are adhered to when conducting field work at the site. These documents and additional relevant
information and data can be obtained at the FRC website: (http://www.esd.orl.gov/nabirfrc/). A project specific Research Safety Summary (RSS 824.1) has been completed which provides additional guidance from ORNL subject matter experts on safety procedures that are followed while conducting FRC site characterization tasks.

Based on previous well installation, groundwater and sediment sampling and analyses, hydraulic testing, geophysics, and other site characterization activities, 3 primary areas around the former S-3 Ponds are currently used for conducting FRC research. These research areas (1, 2 and 3) are shown on Figure 1. Within these three areas, small field plots have been established for conducting multi-disciplinary field research. Site-specific information on the three areas has been obtained to support the individual field research team studies (e.g. Oregon State University and Stanford/ORNL). Site-specific information has also been obtained through the ongoing ad hoc coring, well installation, and sampling efforts that are conducted to support requests for FRC samples by NABIR and other researchers.

Studies to date indicate that the primary pathway for the migration of groundwater contaminated with nitrate, U, Tc, and other contaminants is located in the southern portion of Area 3 (Figure 1) and follows the geologic strike of bedding planes in the Nolichucky shale saprolite and bedrock (Figure 2). The Stanford/ORNL field plot in Area 3 is located within this flowpath.
Figure 1 - Proposed location of new exploratory boreholes and wells
Figure 2. Conceptual rendering of hydrogeologic setting and typical depths of pushprobe and auger refusal. The direction of groundwater flow is into the page along bedding fractures.
2.0 Rationale and Objectives

The FRC Strategic Plan (U.S. DOE, 2003) describes the mission and goals of the FRC along with the short, mid, and long-term activities needed to accomplish these goals. Two of the characterization related activities described in the Strategic Plan include 1) obtaining site characterization data on the existing field plots (Area 1, 2, and 3 and Background Area) so researchers can better design and implement their research and 2) characterization of new areas to determine if there are additional sites that have hydrogeochemical characteristics of interest to NABIR researchers. New areas in the vicinity of the former S-3 Ponds will be used for two primary purposes:

- Providing a source of groundwater and core material from a range of geochemical conditions that could be used for NABIR (and potentially other programs) laboratory studies
- Establishing several new small field research plots
- Providing information to enhance the current site-wide numerical and conceptual model

New areas (Areas 4 and 5) targeted for characterization are located along the strike of the bedding planes to the east and west of the former S-3 Ponds (Figure 1). These areas are located within the FRC boundary and were selected because the contaminants of interest are likely to be found here along the strike active flowpath. To the west, between the S-3 Ponds Parking Lot and Bear Creek North Tributary 1 (NT-1), there is known to be a geochemical gradient (e.g., increase in pH, decrease in nitrate) in the groundwater and sediment as the plume moves away from the source area (U.S. DOE, 1997). NABIR and other researchers (e.g., Genomes To Life) are likely to be interested in studying changes in microbial populations and geochemical conditions along this gradient. Another consideration in selecting the locations of Areas 4 and 5 is that they are relatively free of underground and overhead utilities. Coring and well installation will be conducted with the Geoprobe drilling rig and limited to the unconsolidated saprolite zone (i.e., there will not be any sampling of bedrock).

The objectives of the site characterization work are as follows:

- Obtain data necessary to determine if Areas 4 and 5 have geochemical characteristics suitable for NABIR research.
- Assess the geochemical and mineralogic changes in groundwater and saprolite along the flowpath shown on Figure 1 west of the S-3 Ponds.
- Establish the basic hydraulic characteristics of existing and proposed new sites.
- Provide potential NABIR and other investigators with the data needed to design experiments and determine whether existing or new sites are suitable for their proposed project and for input to numerical models.

The activities described in this plan are not intended to be all-inclusive, and it is expected that NABIR investigators will conduct their own detailed characterization where additional data are required.
3.0 Scope of Work

The site characterization activities that will be conducted in the new and existing study areas are described in this section. Tasks described for the new areas are a continuation of similar tasks that have been conducted in the Areas 1, 2, and 3 and the Background Area. Therefore, there is overlap between the tasks that will be completed for the existing and new areas. Microbial characterization of groundwater and sediments is conducted as needed by the field research teams, and therefore, will not be conducted as part of this FRC characterization effort.

3.1 Sampling Approach

The characterization tasks will be phased, with the findings of each phase used to help determine the specific scope of subsequent phases (e.g., boring locations and sampling intervals). First, the sites will be preprobed using the Geoprobe electrical conductivity probe to help determine sampling intervals and the depths of well installations. Surface geophysics may also be conducted. Based on the results of the preprobing, continuous core samples will be collected and single or multi-level wells installed. Analyses will be conducted on the core material and groundwater samples collected from the wells. Pumping and flowmeter testing will be conducted to determine hydraulic aquifer parameters. The well elevations will be surveyed and water levels collected and tracer tests and/or point dilution tests conducted to determine the rates and direction of groundwater and contaminant transport. Additional phases of preprobing, coring, well installation, and sample analysis will be conducted to fill remaining data gaps as needed.

3.2 Areas 4 and 5 and Primary Transport Pathway

The flowing tasks will be completed as part of the assessment of the new areas.

Task 1 – Preprobing/Geophysics

The Geoprobe will be used to conduct electrical conductivity logging at the approximate locations shown on Figure 1 in an effort to provide an indication of the depth to bedrock (i.e., depth of penetration), and stratigraphic and groundwater quality changes with depth. The Wenner or dipole-dipole array will be used to collect the conductivity data. Conductivity profiles will also be obtained near the existing Area 3 field plot wells (e.g., FW106 and FW024) to obtain equivalent information on conductivity response in an area that has previously been cored and is well characterized. Preprobing information will be used to select the zones that will be cored and wells installed. If the preprobed borehole stays open, a small ¾” interior diameter (ID) piezometer may be installed in the hole; otherwise the hole will be backfilled and sealed with bentonite.

Surface geophysics, seismic and/or resistivity tomography, may also be conducted if there is enough open space, and if electrical interference from power sources is not too great.
Task 2 – Coring and Well Installation

Continuous core will be taken adjacent to the preprobe locations (Figure 1) from the watertable (@ 12 ft. below surface) to refusal using the Geoprobe dual tube method. Refusal is expected to be encountered around 30 to 45 feet below ground surface. Generally, the core tubes will be capped and sealed with duct tape for future analysis. However, some representative sections of core will be split and half of the core will be preserved, archived and stored for future microbial and/or redox sensitive mineralogical and geochemical analysis. Some of the archived cores will be placed under argon and refrigerated at 4° C and other sections of core will be frozen in the -80° C freezer. A notification will be sent to NABIR researchers to determine if there is interest in obtaining the archived core.

Multi-level wells will be installed in most of the coreholes. However, one or two coreholes in Areas 4 and 5 will be screened across the entire saturated interval with a 2 in. diameter well for subsequent flowmeter testing (Task 5). Wells of a large enough diameter will be logged with a NaI detector that has a 1in. diameter for gamma activity, which will provide an initial indication of contaminant distribution as a function of depth.

Task 3 – Core Analyses

The following physiochemical and mineralogical analyses will be conducted on selected cores from Areas 4 and 5. Some analyses will only be conducted if zones of interest (e.g., zones with concentrated levels of U, Fe, or Mn) are observed.

Core Sample Description Including Lithology, Soil Color, and Radioactivity: Core material will be described according to Soil Survey Staff (1992). The core samples will be divided into ~6 in. increments, except where there are changes in the morphology of the material which will be sampled separately. The saprolite samples collected from the core will be air-dried and ground to pass though an 80-mesh sieve. Undisturbed samples will also be collected for XRD diffraction and microscopic study.

Soil/Saprolite pH: Saprolite pH will be determined in 1:1 soil/water (wt/wt basis) slurry and in 1:1 soil/0.01M CaCl₂ solution to approximate normal soil solution ionic strength (McLean, 1982).

Cation Exchange Capacity: Cation exchange capacity (CEC) and exchangeable bases will be determined using 1M NH₄OAc at pH 7 and NaCl by automatic extractor (Soil Survey Laboratory Staff, 1992). A Perkin Elmer 6100 inductively coupled plasma/mass spectrometer (ICP/MS) will be used to conduct the analysis.

Ammonium oxalate extractable Fe, Mn, Al, Si, and other cations: Poorly crystalline Fe, Al, Mn, Si and other oxides will be extracted by shaking in the dark a solution of ~0.2 gram of core material in 25 ml ammonium oxalate solution buffered to pH 3.0 for 4 hours (Jackson, 1969). After centrifuging at 2000 rpm for 15 min, these oxides will be analyzed using the ICP/MS.
Sodium-citrate-bicarbonate extractable Fe, Mn, Al, Si, and other cations: Fe, Mn, Al, Si and other cations will be extracted with a 0.3 M sodium-citrate-bicarbonate solution until the samples change to a gray color (at least 2-4 extractions) (Soil Survey Laboratory Staff, 1972). After centrifuging at 2000 rpm for 15 min, these oxides will be analyzed using the ICP/MS. This method provides a measure of total Mn and Fe-oxides and an indication of co-precipitated Al in the Fe-oxide structure.

Uranium and other metals/oxides by acid extraction and total rock fusion: Uranium and other metals will be extracted by shaking ~0.5 gram of core material in 10 ml 2 M HNO\textsubscript{3} (3 extractions) overnight, then centrifuging at 2000 rpm at 15 min and analyzed using the ICP/MS. For select samples total phosphorous and other oxides will be analyzed by the whole rock fusion method where selected core samples will be fused using lithium metaborate-pentaborate, then dissolved in 5% nitric acid and analyzed using ICP/MS. Total sulfur will be analyzed with a Leco C, N, S analyzer.

Manganese Mineralogy (XRD, SEM-EDX): Cores enriched in manganese iron oxides will be separated by hand picking and then dried at room temperature. The dried manganese oxide will be characterized by scanning electron microscopy (SEM), combined energy dispersive X-ray (EDX) analyzer, and X-ray diffractometer (XRD). Manganese mineralogy of the manganese oxide in the contaminated core sample will be compared with the manganese mineralogy of a manganese oxide sample obtained from the Background Area.

Mineralogical characterization of clay and bulk mineralogy by XRD plus SEM-EDX-BSE analysis: Untreated samples of the clay size fraction (< 2 µm) from selected clay coatings and clay-rich highly weathered saprolite will be obtained by wet sedimentation. Iron and manganese oxides will be removed from the clay fraction of selected samples using 0.3 M sodium citrate bicarbonate dithionite (CBD) solution followed by saturation of split samples with 1 M KCl and 0.5 M MgCl\textsubscript{2} (Jackson, 1969). The untreated and treated samples will be oriented onto glass slides using the filter-membrane peel technique (Drever, 1973) for XRD analysis. Air-dried Mg saturated clay samples will be analyzed by XRD and after a 10% glycerol treatment at room temperature overnight. Air-dried K saturated clay samples will be analyzed at 25°C and after heat treatments of 105°C, 350°C and 550°C. Thin sections of selected undisturbed areas of the core material cut from samples impregnated with epoxy resin will be examined with a microscope. Selected areas of the thin sections and undisturbed fragments of the core material will be carbon coated and examined with SEM-EDX and backscatter electron (BSE) analysis. Elemental distribution maps may be made of U, Fe, Mn, Al, Si, P and S by exposing the samples for up to 24 hours.

XANES-EXAFS for characterizing Fe mineralogy and U Speciation/valence: Pending funding of an unsolicited proposal by ANL, undisturbed bulk solid phase material will be anaerobically sent to the APS for analysis. Fe and U x-ray absorption near edge structure (XANES) will provide information on metal valence state and extended x-ray absorption fine structure (EXAFS) will provide a quantitative measure of the Fe and U chemical environment; essentially a snapshot of metal speciation of chemical association.
Task 4 – Groundwater Analyses

New wells and selected existing wells along the primary groundwater flowpath will be purged, sampled, and analyzed for a mass balance including U and other metals by ICP/MS, and nitrate and other anions (inorganic and organic) by ion chromatography (IC). Field parameters (e.g., pH, electrical conductivity, temperature, dissolved oxygen) will be measured in the field as the groundwater is pumped through a sealed flow-through cell.

Task 5 – Hydraulic Testing

Wells will be surveyed and water levels obtained to help determine the direction of groundwater flow. Flowmeter testing will be conducted on selected 2 in. diameter wells to determine hydraulic conductivity profiles with depth, and to determine if the high flow zones can be correlated with the high flow zones observed at the Area 3 Field Plot. Pumping tests or slug tests will be conducted in Area 4 and 5 to determine hydraulic parameters and the interconnection with the Area 3 Field Plot. Point dilution tests with distilled water and/or bromide tracer tests may also be conducted to assess flow regimes. Dye trace permits will be obtained prior to conducting tracer tests.

3.3 Areas 1, 2, and 3 and Background Area

Archived core samples collected from Areas 1, 2, and 3 and the Background Area will be analyzed for CEC. Manganese Mineralogy (XRD, SEM-EDX) will also be conducted on selected cores from these areas. More complete analyses as described in Section 3.2 (Task 3) are currently being conducted on cores collected from Area 2. Pumping tests and other hydraulic testing in Area 4 will likely include monitoring of the Area 3 field plot wells. Area 4 monitoring will be used to assess the downgradient transport/cleanup related to operation of the Area 3 treatment system.

Water level monitoring and a pumping test will be conducted at the Site A Background field plot.

4.0 Schedule

The preprobing work will begin around the end of February or early March 2004 and be completed by April 2004. The rest of the work will start after the completion of the preprobing work and continue intermittently through FY2004 and into FY2005. The site characterization will have to be scheduled around work that is being conducted for the field research teams and NABIR PIs. If there are subsequent phases of drilling and well installation, this may extend into FY2005 and FY2006.
5.0 References


