Natural and Accelerated Bioremediation Research Program Establishes Field Research Center in Oak Ridge, Tennessee

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Abstract—*The Natural and Accelerated Bioremediation Research Program (NABIR) has established a Field Research Center (FRC) on the Oak Ridge Reservation (ORR) in Oak Ridge, Tennessee. The FRC provides a site for investigators in the NABIR Program to conduct research related to in situ bioremediation of metals and radionuclides. Research at the FRC is integrated with the existing and future NABIR laboratory and field research and provides a means of examining the fundamental biogeochemical processes that influence bioremediation under controlled small-scale field conditions. The FRC includes a contaminated area that can be used for conducting experiments on a plume of contaminated groundwater and sediment, and a background area that provides for comparison studies in an uncontaminated environment (Fig. 1). The contaminated and background areas are located on Department of Energy (DOE) land in Bear Creek Valley (BCV), which lies within the Y-12 Plant area. Contaminants include uranium, Tc-99, strontium, nitrate, barium, cadmium, volatile organic compounds (VOCs) and other inorganics and radionuclides of interest to DOE. NABIR investigators use the FRC as a source of subsurface samples, evaluation of new characterization and monitoring methods, and for conducting multi-disciplinary in situ accelerated bioremediation research projects.*

I. INTRODUCTION

The Natural and Accelerated Bioremediation Research Program (NABIR) has established a Field Research Center (FRC) on the Oak Ridge Reservation (ORR) in Oak Ridge, Tennessee (Fig. 1). Oak Ridge National Laboratory's (ORNL) Environmental Sciences Division (ESD) manages the FRC for the Department of Energy (DOE). The goal of the NABIR Program is to provide the fundamental science that will serve as the basis for development of cost-effective bioremediation and long-term stewardship of radionuclides and metals in the subsurface at DOE sites. The focus of the program is on strategies leading to long-term immobilization of contaminants in place to reduce the risk to humans and the environment. The NABIR program encompasses both intrinsic bioremediation by naturally occurring microbial communities, and accelerated bioremediation through the use of biostimulation (addition of inorganic or organic nutrients). The primary customer for research products from NABIR within the DOE is the Subsurface Contaminant Focus Area. Other customers may include agencies such as the Department of Defense (DOD) and industries dealing with metal contamination.

The primary objective of this paper is to provide potential researchers and problem-holders who may benefit from ongoing research at the FRC, with an overview of the FRC facilities, site setting, and research being conducted at the FRC. The FRC provides a site for investigators in the NABIR Program to conduct research and obtain samples related to in situ bioremediation of metals and radionuclides. Research at the FRC is integrated with the existing and future NABIR laboratory and field research and provides a means of examining the fundamental biogeochemical processes that influence bioremediation under controlled small-scale field conditions.

II. FRC FACILITIES

The FRC includes a contaminated area that can be used for conducting experiments on a plume of contaminated groundwater and sediment, and a background area that provides for comparison studies in an uncontaminated environment (Fig. 1). The contaminated and background areas are located on DOE land in Bear Creek Valley (BCV), which lies within the Y-12 Plant area. Contaminants include uranium, Tc-99, strontium, nitrate, barium, cadmium, volatile organic compounds (VOCs) and other inorganics and radionuclides of interest to DOE. Depth to groundwater is generally less than 5 meters. ORNL's track-mounted combination rotary rig and pneumatic hammer (Fig. 2)

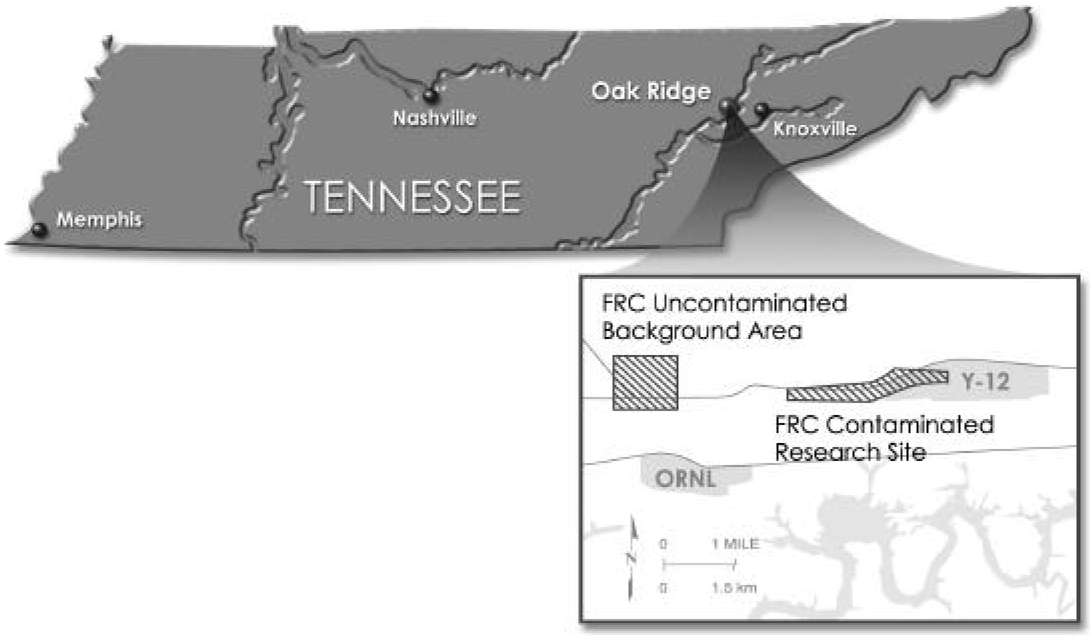

Fig. 1. Location of NABIR FRC in Oak Ridge, Tennessee.

has the capability of installing drive-point wells deep within the unconsolidated zone overlying the shale and limestone bedrock beneath the site and offers an effective alternative to traditional drilling technologies. FRC field trailers and laboratories have been established including a glove-bag for processing up to 1.5 m lengths of core under anaerobic conditions (Fig. 3).

Three areas in the contaminated zone around the former S-3 Ponds (Fig. 4) are currently identified as the primary targets for NABIR field studies. The three areas, plus two subareas that are instrumented for field experiments are shown on Figure 4. An FRC Users Guide, data summaries, figures, several reports, and other site information are available on the FRC web page (http://www.esd.ornl.gov/nabirfrc/). Additional information on the NABIR program is available on the NABIR web page (http://www.lbl.gov/NABIR/).

III. SITE SETTING

The S-3 Ponds consisted of four unlined ponds constructed in 1951 on the west end of the Y-12 Plant (Fig. 5). Liquid wastes, composed primarily of nitric acid plating wastes containing nitrate and various metals and radionuclides (e.g., uranium and technetium) were disposed of in the ponds until 1983. The ponds are now closed and capped. Brooks[1] (2001) provides a more detailed description of the wastes disposed of in the ponds and uranium chemistry. Waste disposal activities at the site have created a mixed waste plume of contamination in the underlying unconsolidated residuum (primarily saprolite and fill) and shale bedrock. Areas 1 and 3 are located adjacent and directly south and west, respectively, of the former S-3 Ponds, where Area 2 is located 200 m to the southwest of the Ponds (Fig. 4).

The Nolichucky shale bedrock underlying the site dips approximately 45 degrees to the southeast and has a strike of N55E (parallel to BCV). Overlying the bedrock is unconsolidated material that consists of weathered bedrock (referred to as residuum or saprolite), man-made fill, alluvium, and colluvium. Silty and clayey residuum comprises a majority of the unconsolidated material in this area.

The residuum overlying the Nolichucky shale is typically between 5 and 10 m (15 and 30 ft) thick. Between the unconsolidated residuum and competent bedrock is a transition zone of weathered fractured bedrock. Remnant fracturing in the residuum and transition zone increases the permeability relative to the silt and clay matrix.

Total dissolved solids (TDS) content of the groundwater plume is > 40,000 mg/L in some areas near the ponds. The S-3 Ponds plume also contains elevated levels of nitrate (40,000 mg/L), bicarbonate, and other ions, metals, uranium (50 mg/L), technetium-99 (40,000 pCi/L), and tetrachloroethylene (4 mg/L). The plume is stratified, with the distribution of contaminants dependent on geochemical characteristics of the contaminants and groundwater. For example nitrate and technetium, which are not highly particle reactive, have the most extensive distribution in groundwater. Uranium and metals that are more reactive are not as deep and have not migrated as extensively away from the ponds.

Flow in the shallow interval is oriented predominantly along geological strike, but is influenced by local topography with discharge occurring at Bear Creek and tributaries to Bear Creek. Geochemistry

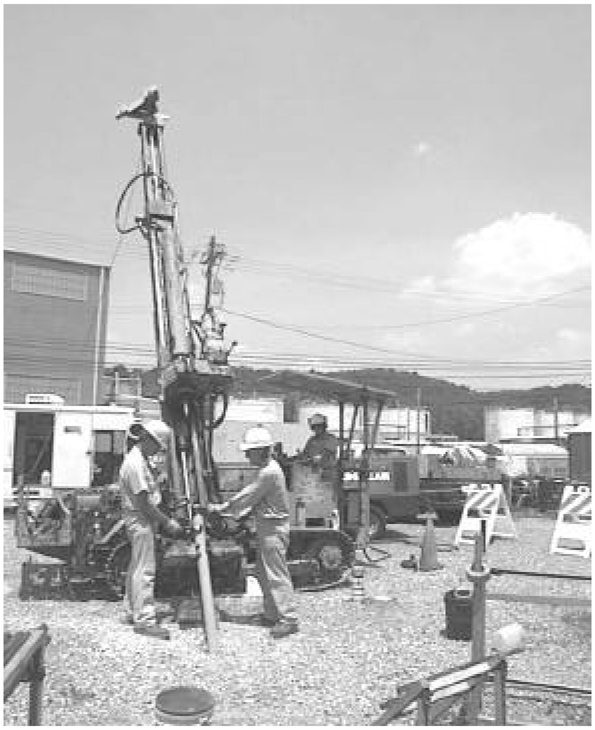

Fig. 2. Dedicated Holegator drill rig.

indicates that greater groundwater residence times and, thus slower flow, generally occur below 30 m in the intermediate interval. However, the distribution of contaminant plumes in BCV indicates that more rapid flow than predicted by major ion geochemistry may occur in an along-strike direction in preferential pathways in the intermediate interval and some flow may occur up to 61 m in depth (nitrate from the S-3 Site has migrated approximately 1 km or more in the Nolichucky Shales since 1950). One of these preferential pathways appears to be located in the southern portion of Area 3. A block diagram showing a conceptual rendering of contaminant transport near the formerS-3 Ponds is provided in Figure 6.

A number of tracer tests have been conducted within the background and contaminated areas to evaluate transport behavior and to identify key processes affecting transport. Two processes contribute significantly to retardation of solute transport and the storage of solute mass in the matrix: sorption and matrix diffusion. High clay content within the weathered matrix coupled with high porosity and small pore size impart a large surface area for sorption of reactive solutes within the matrix, and, secondarily, on fracture surfaces. In addition, these same characteristics result in a large, relatively immobile volume of porewater that acts as a reservoir for storage of solutes that diffuse into the matrix through the fracture walls. The result is a significant slowing of the transport rates and the creation of secondary sources within the matrix that can and do release solutes over long periods of time. Because fracture flow rates are high, mass can be transported rapidly through preferred fracture flow pathways. This is particularly true of colloids and bacteria that reside only in the fractures due to size exclusion from the matrix. However, the overall mass flux may be low because of the low overall fracture porosity and, in the case of solutes, because of mass transfer into the matrix pores and onto solid surfaces.

The transport behavior described above has been demonstrated in laboratory tests in undisturbed cores (Sanford[2] et al. 1996; Jardine[3] et al. 1988, Jardine[4] et al. 1993a; Jardine[5] et al. 1993b; Reedy[6] et al. 1996; Moline[7] et al. 1997) as well as field-scale tracer tests conducted at the background area (Lee[8] et al. 1992; Moline[9] et al. 1998; Sanford and Solomon[10] 1998) and similar sites on the Oak Ridge Reservation (Wilson[11] et al. 1993; Jardine[12] et al. 1999). Cook[13] et al. (1996) discuss the implications of the matrix diffusion process on the use of environmental tracers for dating the age of groundwater and interpretation of the data for inferring such parameters as recharge rates and vertical groundwater velocities.

Fig.3. Controlled atmosphere chamber with 5-foot air lock for core processing.

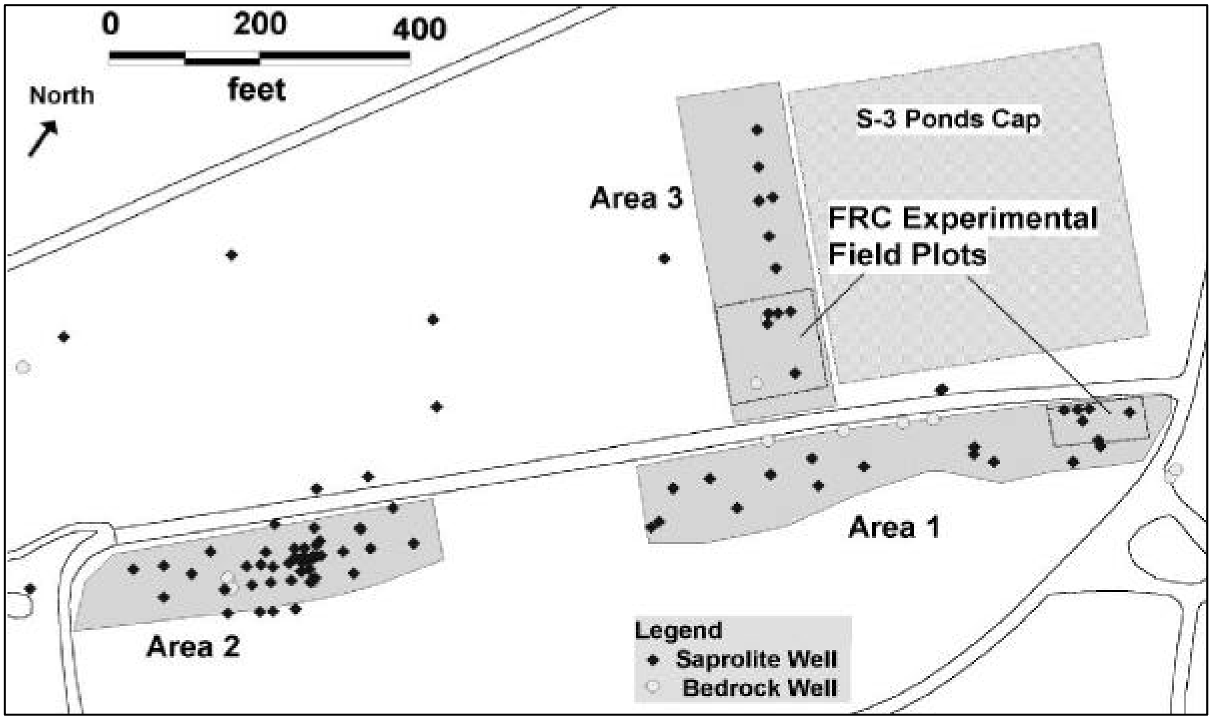

Fig. 4. FRC research areas and monitoring wells.

IV. RESEARCH ACTIVITIES

NABIR investigators use the FRC for various purposes including:

- A source of subsurface samples
  - Groundwater and core samples are collected under controlled atmosphere conditions
  - Over 400 groundwater and sediment samples (cores and composites) have been collected and shipped from the background and contaminated sites for use by 7 National Labs and 15 Universities
  - Characterization and source of humic material
- Evaluation of new characterization and monitoring methods
  - Deployment of coupons (or bug traps) for rapid assessment of in situ microbial activity (University of Tennessee, ORNL, INEEL, and others)
  - Microcosm studies, microbial enrichments, and analyses of DNA, RNA, and PLFA's
  - Development of microarray technology for assessment of community dynamics
  - Improvement of mathematical models for prediction of community structure and dynamics
  - Field-Portable immunoassay instruments and reagents to measure chelators and mobile forms of uranium (Tulane University)
  - Characterization of the subsurface with surface and crosswell geophysics (ORNL and LBNL)
  - In situ uranium assay with downhole NaI detector (ORNL)
- Multi-disciplinary in situ accelerated bioremediation field research projects
  - In-situ uranium reduction experiments using push-pull techniques (Oregon State University and Oklahoma University located in Area 1)
  - Field-scale bioreduction of uranium (Stanford and ORNL located in Area 3)
  - Solicitation for a third project that will probably be located in Area 1 or 2

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Fig. 5. The former S-3 Ponds during denitrification.

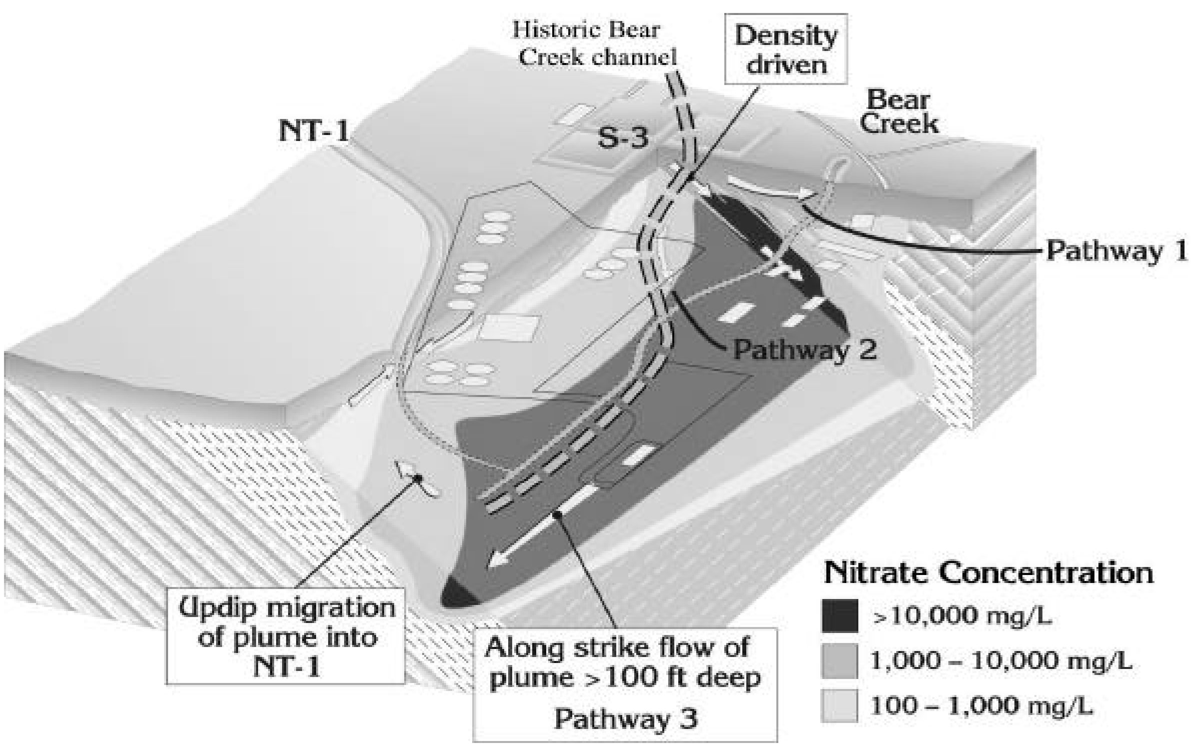

Fig. 6. Contaminant migration pathways at the S-3 ponds.

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