I. INTRODUCTION

To advance solutions needed for remediation of DOE contaminated sites, approaches are needed that can elucidate and predict reactions associated with coupled biological, geochemical, and hydrological processes over a variety of spatial scales and in heterogeneous environments. Our laboratory experimental, which were conducted under controlled conditions, suggest that geophysical methods have the potential to elucidate system transformations that often occur during remediation, such as the generation of gases and precipitates. In this new ERSP project, we will integrate hydrological, geochemical, and geophysical expertise and approaches to:

- Explore the potential of geophysical methods for detecting changes in physical, chemical, and biological properties at the field scale.
- Explore the joint use of reactive transport modeling and geophysical monitoring for improvements in both methods.

A brief review of our previously-conducted laboratory results are given in Section II. Section III describes the approach for our new project, which will have both laboratory and field-scale components. The field scale component will be conducted at the Rifle, CO, site, which is described in Section IV.

II. PREVIOUS EXPERIMENTAL RESULTS

With EMSP support, we have recently investigated the utility of the following different geophysical techniques for detecting various system transformations at the column scale:

- Seismic measurements to detect onset of gas evolution during denitrification (Hubbard and Williams, 2004).
- Ground Potential (SP) measurements for characterization of redox conditions. The experimental results helped to confirm the ability of SP measurements to distinguish between regions of sulfate-reducing and methanogenic conditions (Williams et al., 2005).
- Seismic Amplitude and Induced Polarization (IP) methods to track the formation and aggregation of precipitates associated with sulfate reduction.
- Magnetotelluric and electrical methods to track changes in abundance of microbial FeS oxidation products.

Examples of a few of these results are briefly described below.

III. NEW STUDY: RESEARCH DESIGN AND METHODS

Our proposed research includes theoretical, numerical, and experimental investigations performed at the laboratory and the field scale, which involve the remote monitoring and prediction of geochemical processes using geophysical methods and reactive transport modeling, respectively. Linkage between the laboratory-scale and field-scale investigations will be ensured by using the same (native) sediments (and in some cases, groundwater), and by using the same geophysical measurement techniques and reactive transport code at both scales. By investigating the geophysical response to coupled processes and by performing calibrated and validated reactive transport modeling at both scales under the same environmental conditions, we can begin to investigate how novel monitoring and modeling approaches scale with time and space.

IV. RECENT RESULTS: FIELD AND LABORATORY INVESTIGATIONS ASSOCIATED WITH THE RIFLE SITE

Ongoing work within the aquifer at Rifle, CO, is focused on investigating the utility of electron-donor amendments for facilitating microbial reduction of U(VI) to U(IV) (Long et al., 2005; Vonk et al., 2005) through a series of experiments in different flow cells conducted from 2002-2005. Early results of this work showed that U(VI) bioreduction occurred synchronously with growth of Geobacter after electron acceptor amendment, and illustrated the importance of maintaining iron-reducing conditions for optimal U(VI) removal. Since the interplay between iron and sulfate reduction is a critical factor in the effectiveness of these amendments, we have used the SP technique to measure the changes in spatiotemporal location of sulfate-reduction during bioremediation (Williams et al., 2005).

Monitoring Gas Evolution during Denitrification

Laboratory-scale biostimulation experiments were performed to assess the seismic and radar responses to gas generation using instrumented columns such as those shown in Figure 5. Using a three-phase mixing model (gas, water, solids) model with radar velocity measurements, the volume of pore space filled with evolved N2 gas was estimated to be within 1% of that obtained using gravimetric measurements (Figure 2; Hubbard and Williams, 2004). Seismic methods indicated that the presence of gas in the pore space corresponded to the signal (Figure 3; Williams et al., 2005).

To address some of these questions, recent LABORATORY EXPERIMENTS have examined the changes in the complex resistivity response of a model diodes (Electrochemical Engineering). In some cases, such as the estimated aggregation of precipitates over space and time (Williams et al., 2005a; Natrallah et al., 2005).

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