Project 86870, Annual Report
June 2003 (after 9 months of a 24 month contract)
Differential Group-Velocity Detection of Fluid Paths
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Research Objective: The objective of differential surface-wave interpretation is to identify and locate temporal perturbations in the shear-wave velocity. Perturbations in phase velocity are created when the stress and/or fluid content of soils changes, such as in pumping to remove or flush out contaminants. Differential surface wave analysis is a potential method to track the movement of fluids during remediation programs. This proposal is to develop and test this new technology to aid in the selection and design of remediation options in shallow aquifers.

The key to differential surface-wave interpretation is recognizing that there exists a measurable sensitivity of shear-wave velocity to changes in stress and water content. The theory of the technique can be viewed at http://quake.eas.gatech.edu In conceptual terms, we propose to detect and examine slight perturbations in the phase velocity of surface waves. The sensitivity of the technique is based on analysis techniques which detect differences in tests repeated at different times. For surface waves, the phase shift at each position in a refraction line is measured using a frequency domain technique and then differentiated over the length of a refraction line to identify zones of anomalous velocity. The perturbations in phase velocity are then related directly to perturbations in velocity structure. Because the technique looks for perturbations, the structure does not need to be known exactly and details of a perturbation can be processed without solving each time for the velocity structure.

Research Progress and Implications: This report summarizes work after 9 months of a 2-year contract. Work completed to date has focused on refining and developing the tools for acquisition and preliminary analysis. First, we have rewritten the data acquisition program. In a previous project, we built a bank of seismic amplifiers and a seismic cable with the flexibility to easily implement variations in array geometry. To record the data, we have developed a data acquisition program for a portable PC equipped with a 16 channel (expandable) analog to digital conversion board. This program was updated in this project year to provide more flexibility in displaying the data and in converting the data to SEGY and SU formats for subsequent analysis. The system represents an inexpensive seismic acquisition system that operates under Microsoft XP.

A signal differential analysis program was developed for this project so that data sets can be compared in real time in the field. This computer program inputs two different sets of data and displays their difference. The program allows interactive variation of the relative amplitude of the traces used to compute the difference and a correction for first break variations. This will allow examination of the differences between successive traces in an experiment in the field. Our first test showed that increased stress, as induced by a load on the

surface, could be detected. An example of this test can be found at http://www.pnl.gov/emsp/fy2003/presentations/long_tim_86870.pdf.

The primary result of this initial test was to illustrate the need for quality control in the source function. Consequently, a new design for the coupling plate has been implemented and is ready for testing. The initial field tests also showed the advantage of multiple cable systems to provide rapid setup of the field system for test implementation.

Planned Activities: The primary objective for the next three months is to obtain test data in a variety of settings. We have tentatively identified over 20 appropriate test sites, through communications with the Atlanta Geological Society, who's members are directly involved in waste monitoring and pollution remediation projects. These sites are concerned with water-level monitoring in waste sites, pumping in shallow aquifers and related shallow tests.

Specific objectives for the next year include:

1) Additional tests of stress perturbations by varying the surface load along a refraction line.

2) Using tomography to detect changes in position of surface loads by the differential technique.

3) Continuous improvement of the weight-drop source and impact plate to provide more consistency in the source function. It is most important to avoid bounces and variations in coupling between excitations. The differential technique is very sensitive to variations in the source.

4) Use a water pump to vary the fluid content at different depths at a point along a refraction line. This analysis is planned at the Cobb County Field Test Site maintained by the Georgia Tech Research Institute.

5) Establish a working relation with regional geological consulting companies to gain access to sites for additional field tests.

6) Examine using both theoretical and observational techniques the perturbations expected as a function of depth.

7) Program the inversion technique for differential dispersion data. The inversion technique will be examined for resolution as a function of depth and sensitivity to changes in structure. By examining data from a variety of sites, we hope to evaluate the influence of the properties of soils and unconsolidated rocks on the effectiveness of the differential dispersion technique.

8) Construct multiple cable system for more rapid deployment under a variety of geophone separation distances.

Information Access: The theory was presented annual meeting of the Society of Exploration Geophysicists in Salt Lake City. The expanded abstract for that presentation will be available on http://quake.eas.gatech.edu.

Long, L. T. and T. Toteva, 2002. Differential surface-wave interpretation of temporal changes in velocity, Expanded Abstract, Society of Exploration Geophysicists International Exposition and 72nd Annual Meeting, Salt Lake City, Utah, October 6-11, 2002.

Examples to the differential analysis technique and a discussion of possible applications were presented at the EMSP project directors meeting and can be found at: http://www.pnl.gov/emsp/fy2003/presentations/long_tim_86870.pdf.