Report for 2001KS1701B: A field assessment of direct-push technology for site characterization investigations - Year Two

- Conference Proceedings:
  - Sellwood, S.M., Healey, J.M., Birk, S.M., and J.J. Butler, Jr., Direct-push hydraulic profiling in an unconsolidated alluvial aquifer (abstract), 46th Annual Midwest Ground Water Conference, p. 40, 2001.
  - Schulmeister, M.K., Butler, J.J., Jr., Whittemore, D.O., Birk, S.M., Healey, J.M., McCall, G.W., Sellwood, S.M., and M.A. Townsend, A new direct-push based approach for the chemical investigation of stream-aquifer interactions (abstract), GSA 2001 Annual Meeting Abstracts with Program, v. 33, no. 6, p. A426, 2001.
  - Schulmeister, M.K., Birk, S.M., Healey, J.M., Butler, J.J., Jr., Whittemore, D.O., and H. Weiss, Direct-push-installed, gas-driven mini-pumps for discrete-point groundwater sampling: A new in-situ approach to long-term monitoring (abstract), Eos, v. 82, no. 47, p. F402, 2001.
  - Butler, J.J., Jr., Healey, J.M., and S.M. Sellwood, A field assessment of direct-push technology for hydraulic characterization of unconsolidated formations (abstract), Eos, v. 82, no. 47, p. F360, 2001.
  - Butler, J.J.,, Jr., Healey, J.M., and M.K. Schulmeister, A field assessment of direct-push technology for high-resolution hydrostatigraphic characterization (abstract), Proc. 19th Annual Water and the Future of Kansas Conf., p. 25, 2002.
  - McCall, W., Butler, J.J., Jr., and J.M. Healey, Direct push methods for conduction slug tests (abstract), Proc. 10th Annual David S. Snipes/Clemson Hydrogeology Symposium, p. 26, 2002.
- Other Publications:
  - Schulmeister, M.K., Healey, J.M., McCall, G.W., Birk, S., and J.J. Butler, Jr., High-resolution characterization of chemical heterogeneity in an alluvial aquifer, Proc. Of Model Care 2002, Prague, Czech Republic, in press.
- Articles in Refereed Scientific Journals:
  - Butler, J.J., Jr., A simple correction for slug tests in small-diameter wells, Ground Water, v. 40, no. 3, 303-307, 2002.
  - Butler, J.J., Jr., Garnett, E.J., and J.M. Jealey, Analysis of slug tests in formations of high hydraulic conductivity, Ground Water, in review.
  - Butler, J.J., Jr., Garnett, E.J., and J.M. Jealey, Analysis of slug tests in formations of high hydraulic conductivity, Ground Water, in review.
  - Butler, J.J., Jr., Healey, J.M., McCall, W.G., Garnett, E.J., and S.P. Loheide II, Hydraulic tests with direct-push equipment, Ground Water, v. 40, no. 1, 25-37, 2002.
  - McCall, W.G., Butler, J.J., Jr., Healey, J.M., Lanier, A.A., Sellwood, S.M., and E.J. Garnett, A dual-tube direct-push method for vertical profiling of hydraulic conductivity in unconsolidated formations, Environmental and Engineering Geoscience, v.8, no. 3, 75-84, 2002.
  - Schulmeister, M.K., Butler, J.J., Jr., Healey, J.M., Zheng, L., Wysocki, D.A., and G.W. McCall, Direct-push electrical conductivity logging for high-resolution hydrostatigraphic characterization, Ground Water Monitoring and Remediation, in review.
  - Schulmeister, M.K., Healey, J.M., Butler, J.J., Jr., and G.W. McCall, Direct-push geochemical profiling: A new approach for assessment of inorganic chemical heterogeneity in aquifers, Journal of Contaminant Hydrology, in review.

Project Title: A field assessment of direct-push technology for site characterization investigations
Project Number:
Start Date: March 1, 2001
End Date: February 28, 2002
Investigators and Affiliations: James J. Butler, Jr. (PI), Li Zheng (Co-PI), John M. Healey, Marcia K. Schulmeister, and Donald O. Whittemore; all investigators at the Kansas Geological Survey of the University of Kansas
Research Category: Statewide Competitive Grant
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Descriptors: direct-push technology, site characterization, stream-aquifer interactions, hydraulic-conductivity profiling, electrical-conductivity logging, geochemical profiling

PROBLEM AND RESEARCH OBJECTIVES

Currently, groundwater resources provide more than 85% of the water used in Kansas. Many of the important aquifers for drinking water supplies consist of unconsolidated sediments lying in past or present river valleys. Protection of these resources is a matter of highest public concern. The quality of the water in alluvial aquifers can be threatened by contamination via a number of mechanisms, including point-source contamination from sites on the overlying flood plain (e.g., landfills, animal waste lagoons, hazardous waste storage areas, and accidental chemical releases) and intrusion of saline river water (e.g., Arkansas River). Effective management of these important groundwater resources depends on our ability to reliably assess the threat posed by existing and potential contamination. This assessment, however, is only as good as the data on which it is based. Using conventional field methods, large amounts of time and money can be expended without necessarily improving our knowledge of conditions in the subsurface. There is a critical need for efficient and scientifically sound field methods that will enable us to acquire the information necessary to reliably evaluate the severity of contamination threats in a practically feasible manner. The development of such a "tool set" for regulators and practicing water-resources professionals in Kansas is the primary goal of this project.

This research is directed at the development and evaluation of a set of practical site-characterization techniques designed to significantly reduce the uncertainty associated with hydrogeologic investigations. This set of techniques will be based on direct-push methods, an innovative alternative to conventional drilling approaches that has been developed since the mid-1980s for obtaining soil-gas, water, and core samples at sites of groundwater contamination. The major focus of this research will be the development and evaluation of direct-push techniques for the detailed hydraulic, geochemical, and stratigraphic characterization of unconsolidated alluvial deposits. The information that can be obtained from such a detailed characterization is essential for siting waste storage and disposal facilities, designing effective remediation schemes, and evaluating the risks to human health and the environment posed by existing contamination. Although direct-push technology is currently limited to environmental site investigations, it has

the potential for much broader application. As a secondary focus of this project, we will attempt to extend the use of direct-push technology to include characterization of stream-aquifer interactions, a key component of the hydrologic budget of many aquifers in Kansas. In the second year of this project, we had the following five objectives:

1) Development and field assessment of a method for obtaining profiles of hydraulic conductivity using direct-push equipment;

2) Development and field assessment of a small-diameter correction for slug tests in direct-push installations;

3) Complete calibration and verification of direct-push electrical conductivity logging;

4) Development and field assessment of a method for obtaining profiles of geochemistry using direct-push equipment;

5) Demonstration of the potential of direct-push technology for characterization of stream-aquifer interactions.

METHODOLOGY

The majority of the work in the second year of this project was performed at the Geohydrologic Experimental and Monitoring Site (GEMS), a Kansas Geological Survey (KGS) research site located just north of Lawrence, Kansas. GEMS has been the site of a great deal of previous work on groundwater flow and transport, and spatial/temporal geochemical variability. This previous work enabled the tasks of this project to be performed in a very controlled field setting.

In the second year of this project, an additional research site was established along the Arkansas River in central Kansas just east of Larned. A number of wells were emplaced on either side of the river in the vicinity of a USGS stream-gage station, and direct-push electrical conductivity logging and geochemical profiling were performed. By chance, the research team was on site during a peak flow event and was therefore able to demonstrate the potential of direct-push methodology for detailed characterization of stream-aquifer interactions during high-flow events.

A modified dual-tube method was developed for obtaining profiles of both hydraulic conductivity and electrical conductivity. The method involved electrical-conductivity logging as the direct-push rods are advanced and slug testing selected intervals as the rods are retracted. The method was evaluated by comparing results to those from multilevel slug tests and dipole flow tests performed in nearby conventional wells, and with results obtained using the original dual-tube system developed in the first year. The slug tests were analyzed using a spreadsheet approach developed in the first year of this research.

Results of previous slug tests performed at GEMS using direct-push equipment revealed that the K estimates from direct-push slug tests were lower than those from tests in conventional wells. This discrepancy was found to be a product of frictional losses in the well casing. These frictional losses were incorporated into existing models for slug tests in high-K aquifers and previous tests were reanalyzed using these modified models.

The calibration and verification of direct-push electrical conductivity (ec) logging was accomplished by comparing ec logging responses to results of grain-size analyses of cores collected over the same intervals. Additional traverses were performed at GEMS and the Larned site to better assess the potential of ec logging for stratigraphic characterization.

The exposed screen profiling tool used in the first year of this project was modified by replacing steel components with stainless-steel and heat-treated parts, and adding an adapter that prevents mixing with water stored in the direct-push rods. Geochemical field parameters and water samples were obtained from direct-push installations and compared to those from adjacent multilevel sampling wells at the same levels. Use of recently developed pneumatic-driven mini-pumps for water sampling at depths greater than the suction lift were also assessed as part of an ongoing cooperative research project with the University of Tuebingen in Germany.

PRINCIPAL FINDINGS AND SIGNIFICANCE

The principal findings and their significance will be discussed in the context of the five objectives of the project:

Objective 1: Development and field assessment of a method for obtaining profiles of hydraulic conductivity using direct-push equipment – The initial method for hydraulic profiling developed and demonstrated in the first year of the project was significantly modified for more efficient operation. Hydraulic and electrical-conductivity profiling were combined for greater subsurface control and the combined approach was assessed in a controlled field setting. This new method is described in two presentations (Midwest Ground Water Conf. and Fall AGU Mtg.), a MS thesis in the Dept. of Geology at the University of Kansas (Steven Sellwood – thesis awarded honors), and a paper under preparation. The results of work on the initial profiling method were recently published in *Environmental and Engineering Geoscience*. Both the original and modified methods allow information about vertical and lateral variations in hydraulic conductivity to be obtained at a level of detail that was not previously possible with direct-push equipment or any other approach in a practically feasible manner;

Objective 2: Development and field assessment of a small-diameter correction for slug tests in direct-push installations – slug tests in small-diameter direct-push installations can be affected by pipe diameter in highly permeable systems. A simple linear correction was developed to account for the effect of pipe diameter. This correction was verified through a comparison with slug tests in nearby large-diameter wells. The results of this work were recently published in *Ground Water*. This correction should be of considerable practical value because of the significant logistical and budgetary advantages of small-diameter installations;

Objective 3: Complete calibration and verification of direct-push electrical conductivity logging – The assessment of the potential of direct-push electrical conductivity (ec) logging for hydrostratigraphic delineation was completed. This assessment demonstrated that direct-push ec logging has great potential for rapid delineation of site hydrostratigraphy. The power of direct-push ec logging was further demonstrated in the hydraulic profiling work described in objective 1 and the stream-aquifer study described in objective 5. The ec logging assessment is the topic of a paper currently under review at *Ground Water Monitoring and Remediation*;

Objective 4: Development and field assessment of a method for obtaining profiles of geochemistry using direct-push equipment – a modified direct-push profiler was developed in the second year of this project. Samples from adjacent multilevel sampling wells compared favorably with those obtained with the modified sampler for all constituents and parameters monitored (temperature, pH, specific conductance, dissolved oxygen, ORP, NO_3, Cl, Mn, and Fe). A paper on the geochemical profiling is currently in review at the *Journal of Contaminant Hydrology*. This modified direct-push profiler should be of considerable practical value for the

detailed characterization of the inorganic chemistry of unconsolidated aquifers. The assessment of the pneumatic-driven mini-pumps is still ongoing;

Objective 5: Demonstration of the potential of direct-push technology for characterization of stream-aquifer interactions –direct-push technology was used in a study of the impact of a high-flow event on the shallow aquifer adjacent to the Arkansas River. Electrical-conductivity logging was utilized to identify the zone in which low-conductance river water moved into the shallow aquifer. The interpretation obtained from the ec logging was confirmed by geochemical profiling at locations adjacent to those at which the direct-push profiles were obtained. The interpretation was also consistent with water-level data. Presentations and papers on this work are currently in preparation. The results of this work demonstrated that direct-push techniques have great potential for use in investigations of stream-aquifer interactions.

PUBLICATIONS IN REFEREED SCIENTIFIC JOURNALS

Butler, J.J., Jr., A simple correction for slug tests in small-diameter wells, Ground Water, v. 40, no. 3, 303-307, 2002.

Butler, J.J., Jr., Garnett, E.J., and J.M. Healey, Analysis of slug tests in formations of high hydraulic conductivity, Ground Water, in review.

Butler, J.J., Jr., Healey, J.M., McCall, W.G., Garnett, E.J., and S.P. Loheide II, Hydraulic tests with direct-push equipment, Ground Water, v. 40, no. 1, 25-36, 2002.

McCall, W.G., Butler, J.J., Jr., Healey, J.M., Lanier, A.A., Sellwood, S.M., and E.J. Garnett, A dual-tube direct-push method for vertical profiling of hydraulic conductivity in unconsolidated formations, Environmental and Engineering Geoscience, v. 8, no. 2, 75-84, 2002.

Schulmeister, M.K., Butler, J.J., Jr., Healey, J.M., Zheng, L., Wysocki, D.A., and G.W. McCall, Direct-push electrical conductivity logging for high-resolution hydrostratigraphic characterization, Ground Water Monitoring and Remediation, in review.

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ABSTRACTS

Sellwood, S.M., Healey, J.M., Birk, S.M., and J.J. Butler, Jr., Direct-push hydraulic profiling in an unconsolidated alluvial aquifer (abstract), 46th Annual Midwest Ground Water Conference, p. 40, 2001.

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Schulmeister, M.K., Birk, S.M., Healey, J.M., Butler, J.J., Jr., Whittemore, D.O., and H. Weiss, Direct-push-installed, gas-driven mini-pumps for discrete-point groundwater sampling: A new in-situ approach to long-term monitoring (abstract), Eos, v. 82, no. 47, p. F402, 2001.

Butler, J.J., Jr., Healey, J.M., and S. M. Sellwood, A field assessment of direct-push technology for hydraulic characterization of unconsolidated formations (abstract), Eos, v. 82, no. 47, p. F360, 2001.

Butler, J.J., Jr., Healey, J.M., and M.K. Schulmeister, A field assessment of direct-push technology for high-resolution hydrostratigraphic characterization (abstract), Proc. 19th Annual Water and the Future of Kansas Conf., p. 25, 2002.

McCall, W., Butler, J.J., Jr., and J.M. Healey, Direct push methods for conducting slug tests (abstract), Proc. 10th Annual David S. Snipes/Clemson Hydrogeology Symposium, p. 26, 2002.

OTHER REPORTS

Schulmeister, M.K., Healey, J.M., McCall, G.W., Birk, S., and J.J. Butler, Jr., High-resolution characterization of chemical heterogeneity in an alluvial aquifer, Proc. of Model Care 2002 , Prague, Czech Republic, in press.

OTHER PRESENTATIONS (NO ABSTRACTS)

Butler, J.J., Jr., and J.M. Healey, Advances in Pumping and Slug Testing for Improved Site Characterization: New Concepts, Field Methods, and Data Analysis Techniques, two-day workshop sponsored by the Midwest Geosciences Group and Fermi National Accelerator Laboratory, Fermi National Accelerator Laboratory, Batavia, Il., Sept. 11-12, 2001.

Butler, J.J., Jr., Tsou, M.-S., and J.M. Healey, Quantitative assessment of stream-aquifer interactions, 10th Annual Kansas Hydrology Seminar, American Inst. of Hydrology, Topeka, Ks., Nov. 16, 2001.

Butler, J.J., Jr., Quantitative assessment of stream-aquifer interactions: New models and field methods, invited presentation given as part of the Department of Geology & Geophysics Seminar Series, Texas A&M University, College Station, Tx., Nov. 29, 2001.

Butler, J.J., Jr., Healey, J.M., and M.K. Schulmeister, Direct-push technology for hydrogeologic investigations, invited presentation given at the 2002 Annual Convention of the Kansas Ground Water Association, Great Bend, Ks., January 16, 2002.

INFORMATION TRANSFER

Three peer-reviewed articles were published and three more are currently in review. Results were also presented at two national meetings (American Geophysical Union, Dec. 2001, San Francisco; Geological Society of America, Nov. 2001, Boston), one workshop (Midwest Geosciences Group workshop at Fermi National Accelerator Laboratory, Sept. 2001), two regional meetings (Midwest Ground Water Conf., Oct. 2001, Madison; Snipes/Clemson Hydrogeology Seminar, April 2002, Clemson, SC), and one invited talk at a university (Texas A&M Univ., Nov. 2001). In addition, a presentation will be given in June 2002 at an international meeting in Prague (Model Care 2002). Results were also presented to the Kansas water resources community at the 10th Annual Kansas Hydrology Seminar in Topeka (Nov.

2001), the Annual Convention of the Kansas Ground Water Association in Great Bend (Jan. 2002), and the 19th Annual Water and the Future of Kansas Conference in Lawrence (March 2002).

STUDENT SUPPORT

One graduate student (Steven M. Sellwood) was supported from this grant during the summer of 2001.