Kansas Water Resources Research Institute
Annual Technical Report
FY 2001

Introduction

Roles and Mission The institute plays two important roles: one is to provide and facilitate a communications network among professionals working on water resources research and education; and second is to support research and dissemination of results on high priority topics, as identified by the State Water Plan. The Mission Statement is:

1. Develop and support research on high priority water resources problems and objectives, as identified through the state water planning process; 2. Facilitate effective communication amongst water resources professionals; 3. Foster the dissemination and application of research results.

Research Program

Planned Activities This mission is accomplished by doing the following (but not necessarily limited to only these things):

1. Supporting research through a competitive grants program that encourages: - interdisciplinary approaches - interagency collaboration - scientific innovation - support of students and new young scientists - cost-effectiveness - relevance to present and future water resource issues/problems as identified in the State Water Plan - dissemination and interpretation of results to appropriate audiences 2. Facilitating communication through seminars, conferences, and/or electronic networks 3. Fostering dissemination and application of results through conferences, briefings, white papers, and/or newsletters

In implementing these activities, KWRI desires to: 1. Be proactive rather than reactive in addressing the water resource problems of the state 2. Involve the many water resources stakeholders in identifying research needs and utilize their input to prioritize the water resources research needs of the state 3. Foster collaboration among state agencies, federal agencies, and institutions of higher education in the state on water resources issues 4. Leverage additional financial support from state, private, and other federal sources 5. Be recognized in Kansas as a major institution to go to for water resources research

Competitive Grants Process August 1. The Administrative Council (see Governance below) meets to discuss the output from the Water and the Future of Kansas Conference and to develop the prioritized list of research and technology transfer needs for the Call for Proposals.

September 1. The Call for Proposals is issued.

November 1. Proposal submission due date

December 15. Select successful projects.

January 5. Deliver plan of work to USGS.

March 1. USGS issues contract/K-State issues subcontracts.

In FY01, we funded three projects that all addressed key issues identified by the state. These three projects included:

1. Measuring ssepage losses from waste treatment lagoons: A simplified water balance approach for use by government agencies, consultants, and industry; 2. Real time crop water management and irrigation scheduling website; and 3. A field assessment of direct-push technology for site characterization investigations.

Measuring Seepage Losses from Waste-treatment Lagoons: A Simplified Water balance Approach for Use By Government Agencies, Consultants, and Industry

Basic Information

Title:	Measuring Seepage Losses from Waste-treatment Lagoons: A Simplified Water balance Approach for Use By Government Agencies, Consultants, and Industry
Project Number:	2001KS921B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	
Congressional District:	2
Research Category:	
Focus Category:	Agriculture, Groundwater, Methods
Descriptors:	Animal Waste Lagoon Seepage Groundwater Evaporation
Principal Investigators:	Jay M Ham

Publication

1. Ham, J.M. (1999) Estimating evaporation and seepage from lagoons used to contain animal waste. Trans. ASAE: 42:1303&#64979;1312.
2. Ham, J.M., and DeSutter, T.M. (1999). Seepage losses and nitrogen export from swine waste lagoons: A water balance study. J. Environ. Qual. 28:1090-1099.
3. Ham, J.M. 2002a. Uncertainty analysis of the water balance technique for measuring seepage from animal waste lagoons. J. Environ. Qual. 31:1370&#64979;1379.
4. Ham. J.M. 2002b. Seepage losses from animal waste lagoons: A summary of a four&#64979;year investigation in Kansas. Trans. ASAE. 45:983&#64979;992.

Research Report: Measuring Seepage Losses from Waste-treatment Lagoons

J M Ham, Department of Agronomy, Kansas State University

January 30, 2003

Research Objectives

Anaerobic lagoons are used throughout Kansas to collect, store, and treat waste from concentrated animal feeding operations (e.g., swine, cattle, dairy). Most lagoons are soil-lined, and concerns have been raised that seepage losses from these facilities could pollute local groundwater. This proposal describes a simplified water balance approach for measuring lagoon seepage that could be used by consultants, state agencies, and industry.

Methods

Previous research has shown that whole-lagoon seepage rates can be determined by measuring changes in depth (ΔD) and evaporation (E) over a 5- to 10-day period (Ham, 1999; Ham and DeSutter, 1999). If waste additions and waste removal is disallowed from a lagoon, then the seepage rate, S, in mm per day, can be calculated as

$$S = \frac{(-\Delta D + P - E)}{t}$$

where P is precipitation (mm) and t is elapsed time (days). Often, P is negligible, so the crucial measurements are ΔD and E. While there are many ways to measure ΔD, the determination of E from lagoons is challenging. Ham (1999) showed that E could be determined very accurately using a bulk transfer approach (see Ham Eq. 3), a method which requires the measurement of lagoon surface temperature, wind speed, and humidity near the middle of the lagoon. In this research project, more simplified methods, namely evaporation pans, were tested as an alternative approach for measuring E.

A portable Class-A-sized evaporation pan was designed and tested (Fig. 1). The pan was made from a 4-ft-diameter stock water tank that had been cut down to a height of 25 cm (10 inches). Liquid levels in the pan were maintained using a remote water level recorder and 55-gal drum filled with waste (Fig. 2). A float-based water level recorder was placed inside the drum to record the change in depth (i.e., evaporation) over time. Deployment of the system consisted of positioning the apparatus on the berm of the lagoon and then filling the pan and drum with waste. During each test of the pan system, E was simultaneously measured using the bulk transfer approach of Ham (1999). The pan coefficient, k_p, was computed as the ratio of the actual E (measured by the Ham method) and evaporation from the pan (E_p).

$$E = k_p E_p$$

For the pan method to be viable, the value of k_p must be known or easily predicted. Pan evaporation is usually larger than actual evaporation; thus, k_p typically ranges between 0.5 and 0.8.

The pan system was tested at locations in eastern, central, and southwestern Kansas. A test also was conducted in central Oklahoma. At the southwest Kansas site, six tests were

performed over a 12-month period. In addition, the pan made from the stock tank was compared to a commercial Class-A pan made from stainless steel.

Results to Date

Data show that the pan apparatus itself worked extremely well. In most cases, it was possible to monitor E_p for 10 to 14 days before the drum reservoir had to be refilled. Evaporation from the stock-tank pan was not significantly different from the commercial Class-A pan during a 30-day test conducted near Manhattan, KS. The pan was easy to deploy, but care had to be taken to avoid any potential leaks in the plumbing. Other possible drawbacks were the accumulation of dust/debris on the pan-water surface and biogas (CH_4, CO_2) bubbles in the hose routing waste from the drum to the pan. The dust problem was worse at cattle feedlots.

Despite the favorable performance of the pan apparatus, the pan coefficients at the different test sites were highly variable. The value of k_p ranged between 0.35 and 0.8, an unaccepted range of uncertainty. Also, it was difficult to predict the value of k_p based on time of year or weather conditions. The variation in k_p was exacerbated by the short duration of the water balance tests (5-10 days) and the large difference in the energy balances of the lagoon and the pan. The problems associated with evaporation pans are well documented in the literature. In the lagoon application, these limitations seem to be even more pronounced. The large temporal and site-to-site variation in k_p would make it very difficult to predict E from lagoons using evaporation pans. The uncertainly in E would cause large errors in the calculation of S , negating any utility in the approach. Data suggest that the bulk transfer approach of Ham (1999, 2002) is the best approach for measuring E from lagoons.

Instrumentation was developed that consisted of a meteorological buoy/raft for measuring evaporation, a high-resolution waste-level recorder, and a data acquisition station (Fig. 3) (Ham, 1999; Ham and DeSutter, 1999). The solar-powered system was portable and could be deployed by a single technician. Variations of this instrumentation were used to measure seepage rates from lagoons at swine and cattle feeding operations in Kansas, Oklahoma, and Texas. Data also were collected from a poultry processing plant in Missouri. A formal uncertainty analysis of the technique was completed (Ham, 2002a). Seepage rates from 21 lagoons averaged 1.1 mm/d and ranged from 0.2 to 2.4 mm/d (Ham, 2002b). The average hydraulic conductivity of the compacted liners, as calculated from the seepage data, was 1.7×10^{-7} cm/s. When evaporation rates were low (e.g., < 4 mm/d), seepage was estimated to within ±0.5 mm/d with 95% confidence. A precision of ±0.25 mm/d was possible during favorable weather conditions. New research will be presented on measuring seepage with a single 24-h test.

Research is underway to streamline the equipment required for this method, and devise a protocol for its use by state agencies and consultants.

References

Ham, J.M. (1999) “Estimating evaporation and seepage from lagoons used to contain animal waste.” *Trans. ASAE*: 42:1303-1312.

Ham, J.M., and DeSutter, T.M. (1999). “Seepage losses and nitrogen export from swine waste lagoons: A water balance study.” *J. Environ. Qual.* 28:1090-1099.

Ham, J.M. 2002a. Uncertainty analysis of the water balance technique for measuring seepage from animal waste lagoons. J. Environ. Qual. 31:1370-1379.

Ham. J.M. 2002b. Seepage losses from animal waste lagoons: A summary of a four-year investigation in Kansas. Trans. ASAE. 45:983-992.

Information Transfer

Technology has been transferred to two engineering firms in Kansas. Both of these private contractors can now measure lagoon seepage using research grade techniques identical to those used by Kansas State University. Information was also transferred by the publication of results in peer reviewed journals.

Students Supported

Several undergraduate students were supported by the project. No M.S. or Ph.D. students were employed.

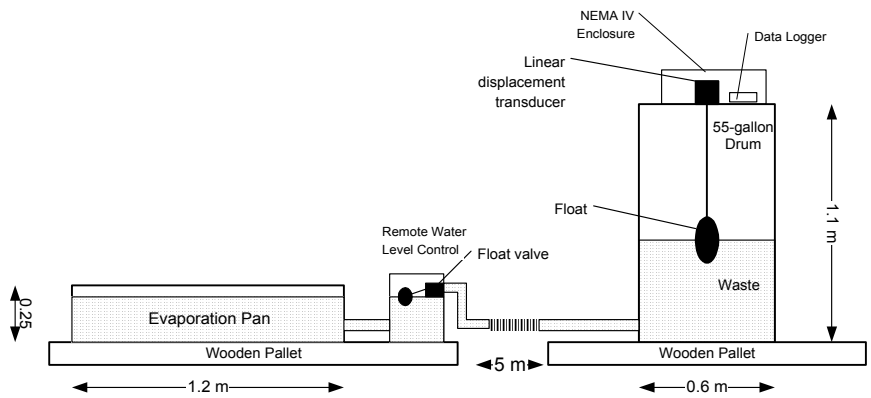

Figure 1. Diagram of the portable Class-A pan system for use at lagoons.

Figure 2. Photograph of the evaporation pan system in the field.

Figure 3. Using the bulk transfer approach of Ham (1999, 2002) to measure seepage from a swine waste lagoon.

REAL TIME CROP WATER MANAGEMENT AND IRRIGATION SCHEDULING WEB SITE

Basic Information

Title:	REAL TIME CROP WATER MANAGEMENT AND IRRIGATION SCHEDULING WEB SITE
Project Number:	2001KS981B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	2nd
Research Category:	Not Applicable
Focus Category:	Irrigation, Agriculture, Water Quantity
Descriptors:	Crop Water Use, Water Management,World Wide Web
Principal Investigators:	Gary Allan Clark, Daniel A. Andresen

Publication

1. Masters Thesis in Computer Science: Mr. Deep Kapadia. Thesis titled: "real Time Crop Management and Irrigation"; May, 2001. A presentation was made at the 2002 Water and the Future of Kansas Conference. Title: Real Time Crop Water Management and Irrigation Scheduling Web Site.
2. Masters Thesis in Computer Science: Mr. Deep Kapadia. Thesis titled: "real Time Crop Management and Irrigation"; May, 2001. A presentation was made at the 2002 Water and the Future of Kansas Conference. Title: Real Time Crop Water Management and Irrigation Scheduling Web Site.

Project Title: Real Time Crop Water Management and Irrigation Scheduling Web Site
Project Number:
Start Date: March 1, 2001
End Date: February 28, 2002
Investigators and Affiliations:

Gary A. Clark, Department of Biological and Agricultural Engineering
Daniel A. Andresen, Department of Computing and Information Sciences
Danny H. Rogers, Department of Biological and Agricultural Engineering

Research Category: Statewide Competitive Grant
Focus Categories:
Descriptors: Irrigation, Water Management, Irrigation Scheduling, World Wide Web

Problem and Research Objectives:

Irrigation accounts for over 90% of the water use in Kansas. With increasing concern over current water usage and supplies, substantial emphasis has been focused on improved irrigation management practices. To help with irrigation management, water balance, evapotranspiration-based (ET-based) irrigation scheduling approaches have been promoted for over 30 years. However, the process requires frequent (often daily) maintenance of weather and system data records and can be rather tedious without the use of computer software. Accurate and reliable ET data are a key component of the scheduling process, and within recent years have become readily available from automated weather stations. However, some of those weather stations in Kansas only provide data for the current (or previous) day and the user must call or access the weather station on a daily basis. Recently, data from some Kansas weather stations is available on a Kansas State University web-site that contains historic data for the current year. With the availability of such data, a web-based water management account could be used to access and utilize those data on an automatic basis so that the user is not required to obtain and enter those data.

Because access to and interest in the use of the World Wide Web has been growing at a fast pace, this project was designed to improve the transfer of production-based agricultural irrigation water management knowledge and technology for resource conservation through the use of a Water Management Web Site. The goal of this project was to develop, test, and display a user friendly water management and irrigation scheduling web-based program that provides a personal crop water management account that utilizes web-based, real-time evapotranspiration data. This computer assisted decision tool can be used to improve water use efficiency and utilization, crop management and planning, and economic returns.

Methodology:

A water budget, account-based irrigation scheduling program (KanSched) was developed to help incorporate real-time evapotranspiration data into a farm-level irrigation scheduling procedure. The KanSched program was originally written in 1998 as a Microsoft Excel spreadsheet. During 1999 – 2001, that spreadsheet program was tested and calibrated using farm-based data and feedback from selected farmers in south-central Kansas. This project was designed to create a version of KanSched that would be as a web-based, personal accounting program. During the last phase of this project a stand-alone Visual Basic (VB) executable file version was simultaneously created and tested as a shared activity with another project (this is discussed below).

During 2000 and 2001, the spreadsheet program design was written in Java computer language and designed as a web-based decision aid for farmers to assist in the task of water management

and irrigation scheduling. The Java-based irrigation scheduling website program is located at http://kwrri.cis.ksu.edu/servlet/login and the basic architecture of the entire application is shown in Figure 1. Weather data is downloaded daily from different weather stations all over Kansas and is available as a text file, which can then be downloaded for processing or into a client's system. A small Java program converts the available data into a format where it can be inserted into the database. One of the goals is to provide for server side scalability by restricting most of the computation to the client end. The central figure in the system is the web server, which acts as the interface between the client and the database. Most of the middle tier is comprised of servlets running on the web server.

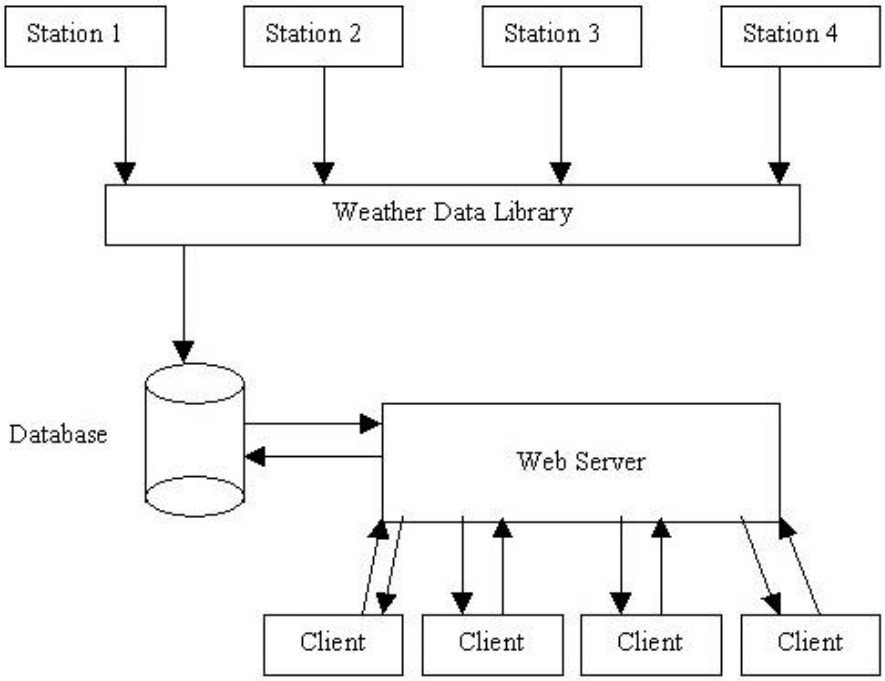

Figure 1. General structure of the system with a basic three-tier architecture associated with most Internet applications.

The scheduling program opens with a general login page (Fig. 2) with inputs for a username and password. A data input page (Fig. 3) is then used to input general information on the planting date, hybrid maturity, soil characteristics, and crop growth characteristics. The client's system then runs a Java applet that computes the soil water content based on the inputs provided by the user at the beginning of the growing season and the accumulated values of crop water use, rainfall and irrigation. Whenever the client accesses the program, their water budget is automatically updated with the current weather data. That data is used to calculate estimated crop water use from reference evapotranspiration data and a generated crop coefficient function. The web site will provide automatic links and electronic access to a Kansas weather database maintained by the Kansas State University Research and Extension State Climatologist (http://www.oznet.ksu.edu/wdl/bbw_et.htm).

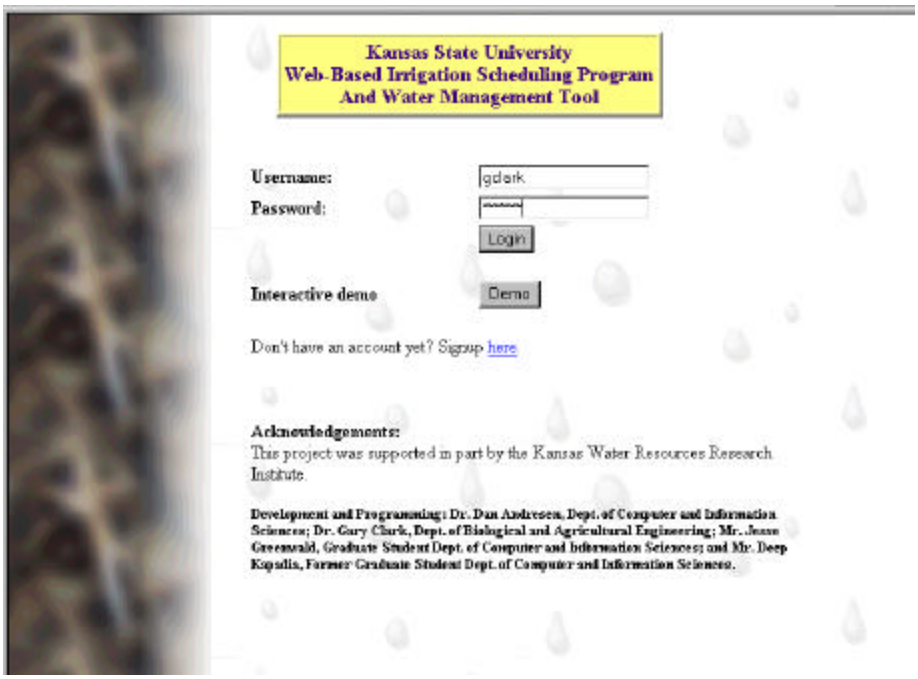

Figure 2. Logon screen.

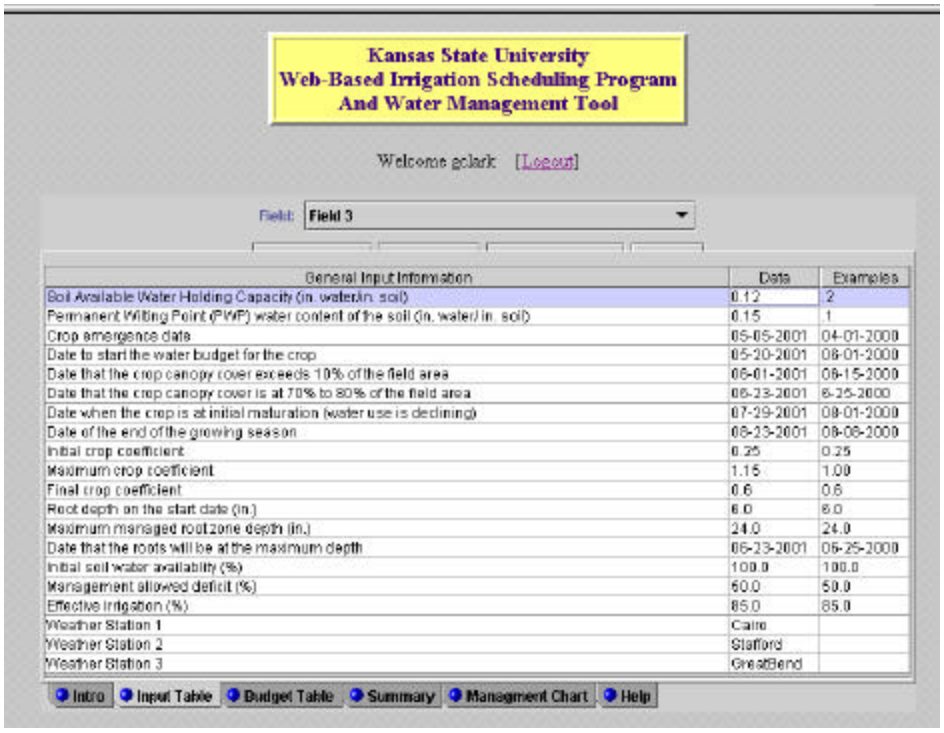

Figure 3. General field and crop data input page.

The website program creates crop water management accounts for individual users and multiple field sites based upon inputs of their crop, soil, and geographic location. The user can identify up to three weather stations per field so that if the primary station has data problems, the second or third station data can be used as needed. In addition, the user can also enter their own field-based data if they so desire. The individual will input rainfall and irrigation amounts that are associated with their production field to complete the water budget. Crop water use, irrigation and rainfall data are displayed on a budget page (much like a spreadsheet) and the resultant field water status data are displayed on a Management Chart (Fig. 4).

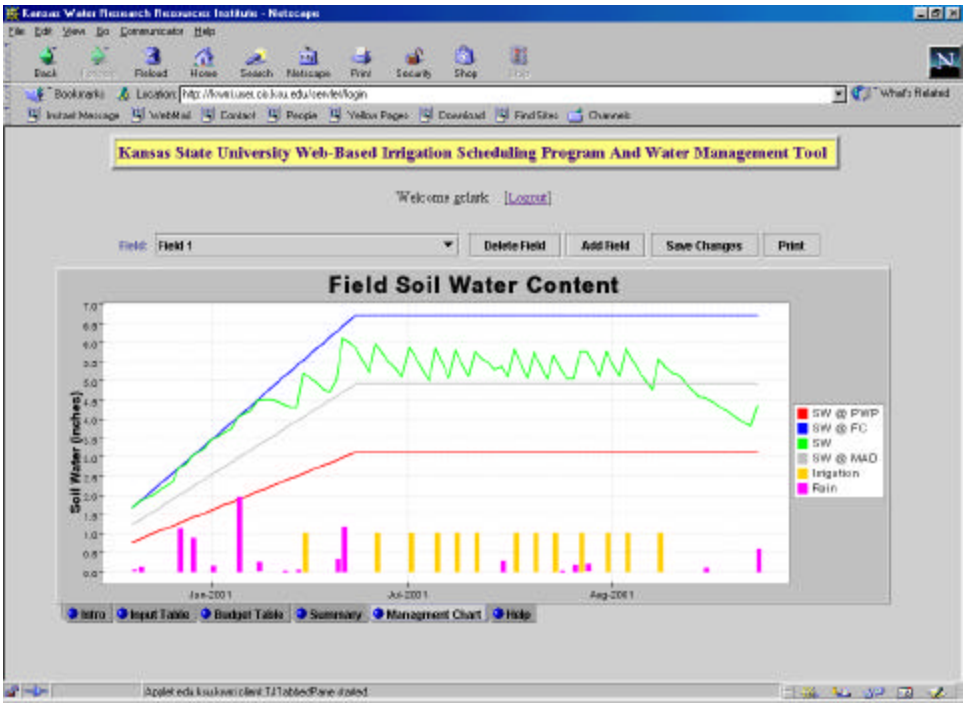

Figure 4. Field Water Management Chart Page.

Principal Findings and Significance

The website program has been tested with production site field data from the year 2000. The website has been deployed on Sun Solaris, Redhat Linux 6.0 and Microsoft Windows NT platforms and has been easy to configure on all of them. The client side applet has been tested on Microsoft Internet Explorer 5.0 and 5.5, Netscape Navigator 4.7 and 6.0 and Mozilla 0.7 browsers on Windows 98/NT and on Netscape Navigator 4.7 on Sun Solaris and Redhat Linux 6.0. All browsers require the user to download the Java plug-in except for Netscape 6.0 and Mozilla, which come bundled with the plug-in. The applet download process sometimes requires several steps when using some versions of Netscape Navigator which can be confusing to some computer novices, but is automatic with Internet Explorer. Because of the size and the requirement of several steps with the download process, the entire procedure can take a long time on some modem-based connections. Thus, as discussed below, another version of KanSched was created.

The application also worked through a firewall because all the communication is being done over HTTP. One drawback was identified when the user operated the applet on a Windows NT machine. Under such conditions, they need to have administrative rights to that machine and should be logged on as an administrator. A permanent server host is being located for the Java-based irrigation scheduling website. That server requires the loading of a Java servlet program and details are being discussed with a KSU-based website server administrator.

During the website development process it was also observed that the web-based weather station database (administered by another group) was not always up-to-date. This is a situation that could not be influenced by this project team. Therefore, due to this concern and the applet download requirements as previously discussed, it was decided to develop a stand-alone, Visual Basic (VB) coded version of KanSched that farmers could use for multiple field sites while not having to rely on a web-based connection. That program and other water management based items are available on a Mobile Irrigation Lab (MIL) website (http://www.oznet.ksu.edu/mil/) that was developed as a shared activity with another related project (K-State, Mobile Irrigation Lab, MIL; supported in part by Kansas Water Plan Funds through the Kansas Water Office). The MIL web site was designed to provide relevant photos, PDF files of publications, and electronic tools that would be useful for agricultural system irrigation system operators/managers and related industry/agency personnel. While the VB coded version of KanSched is also large (~6 Mb), it is being distributed on a CD as part of a MIL electronic toolkit. Hands-on workshops on using the VB version of KanSched have been conducted with farmers and agricultural industry representatives. After completing the workshop (about 1-1/2 hours long), participants are provided with a copy of the MIL toolkit CD. The MIL toolkit CD has been coded to automatically load the KanSched program and associated files onto the users computer. To date, approximately 75 copies of the MIL toolkit CD have been distributed and tested.

Current and future efforts are focusing on the enhancement and continued development of the MIL irrigation and water management website, loading and displaying the website-based Java coded version of KanSched, and enhancing the VB version of KanSched. That effort is currently being supported in-part by State Water Plan Funds through the Kansas Water Office and by the Kansas Corn Commission.

Articles in Refereed Scientific Journals None at this time.

Book Chapters None at this time.

Dissertations Masters Thesis in Computer Science: Mr. Deep Kapadia. Thesis titled: "Real Time Crop Management and Irrigation"; May, 2001.

Outreach

A presentation was made at the 2002 Water and the Future of Kansas Conference. Title: Real Time Crop Water Management and Irrigation Scheduling Web Site.

A field assessment of direct-push technology for site characterization investigations - Year Two

Basic Information

Title:	A field assessment of direct-push technology for site characterization investigations - Year Two
Project Number:	2001KS1701B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	
Congressional District:	3
Research Category:	
Focus Category:	Groundwater, Methods, Water Quality
Descriptors:	Direct Push, Site Characterization, Hydraulic Tests, Water Sampling, Hydrostratigraphy
Principal Investigators:	James J. Butler, Li Zheng

Publication

1. Butler, J.J., Jr., A simple correction for slug tests in small-diameter wells, Ground Water, v. 40, no. 3, 303-307, 2002.
2. 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.
3. 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.
4. 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.
5. 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.
6. 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.
7. 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.
8. 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.
9. 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.
10. 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.
11. 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.
12. 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.
13. 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.
14. 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.

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
Focus Categories:
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.

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.

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.

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 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.

Information Transfer Program

One of the goals of KWRRI is to communicate information on water resources in Kansas. Our targeted audiences include the scientific community, other state and federal agencies, the agricultural community, and the general public. Our primary information transfer activities include the following:

1) Water and the Future of Kansas Conference - The annual Water and the Future of Kansas Conference is an event sponsored by KWRI that brings together scientists, agency personnel, agricultural interests, and other water resources professionals. The conference: 1) is an important venue for disseminating results of research sponsored by KWRI; 2) serves as a Water Resources Town Meeting to discuss general research needs, specific agency needs, and technology transfer needs in the area of water resources; and 3) provides a forum for stakeholders to make input that would serve as a basis for the competitive grants program Call for Proposals.

The annual conference is usually held in March; the venue rotates between Kansas State University and the University of Kansas. Attendance is usually about 200-250 people.

2) Monthly electronic newsletter - KCARE produces a quarterly newsletter with information from KWRRI.

3) Special Seminars - We sponsor special seminars on water topics

4) Special Reports - We produce special reports from time to time. Last year we produced a report on the effectiveness of lagoons in containing animal waste.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	3	0	0	0	0
Masters	2	0	0	0	0
Ph.D.	0	0	0	0	0
Post-Doc.	0	0	0	0	0
Total	5	0	0	0	0

Notable Awards and Achievements

Publications from Prior Projects

1. Pan, S., S.J. Randtke, F. deNoyelles, Jr., and D.W. Graham, "Occurrence, Biodegradation, and Control of Geosmin and MIB in Midwestern Water Supplies," Proceedings fo the Annual Conference of the American Water Works Association, New Orleans, LA, June 16-20, 2002.
2. Pan, S., and s.J. Randtke, "Alternative Methods for Monitoring Geosmin and MIB," Proceedings of the Water Quality Technology Conference, American Water Works Association, Nashville, TN, November 11-14, 2001.