Nebraska Water Resources Center
Annual Technical Report
FY 2001

Introduction

Welcome to the University of Nebraska Water Center's annual report for FY 2001. If you have any questions, please contact J. Michael Jess at (402) 472-7570. Thank you.

Research Program

Listed in this report are six research reports that have received funding through the USGS 104(b) program. Some of these research projects have completed their research and some are still on-going. If you would like to visit with any of the PI's, please contact the Water Center office for their phone number.

The annual report also includes a detailed report from the communications coordinator of the Water Center on Information Transfer for educational purposes.

Determination of Aquifer and Aquitard Hydraulic Properties and Their Role in Streamflow Depletion

Basic Information

Title:	Determination of Aquifer and Aquitard Hydraulic Properties and Their Role in Streamflow Depletion
Project Number:	2000NE1B
Start Date:	9/1/1998
End Date:	8/31/2001
Funding Source:	104B
Congressional District:	1
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Models, Water Use
Descriptors:	Aquifer parameters, conjuntive use, groundwater modeling, surface-groundwater relationships, well hydraulics
Principal Investigators:	Xun-Hong Chen, James Goeke, Robert F. Diffendal

Publication

1. Chen, X. H. 2001. Migration of induced-infiltrated stream water into nearby aquifers due to seasonal groundwater withdrawal, Ground Water (in press).
2. Huang, Huihua, 2000. Evaluation of stream-aquifer interaction considering streambed sediment and stream partial penetration effects, M. S. thesis, University of Nebraska-Lincoln (partially supported).
3. Chen, X. H., 2000. Streamflow depletion due to groundwater irrigation: analysis of reduced baseflow and induced stream infiltration.Proceedings of the International Symposium on Hydrogeology and the Environment, October 17-21, 2000, Wuhan, China.

RESEARCH

Project Number: C-88

Start: 09/01/98
End: 08/31/2001

Title:

Determination of Aquifer and Aquitard Hydraulic Properties and Their Role in Streamflow Depletion

Investigators:

Dr. Xun-Hong Chen, Professor Jim Goeke, and Dr. Robert Diffendal, Jr.
University of Nebraska-Lincoln

Congressional District: NE 1

Focus Category: GW

Descriptors: Aquifer parameters, Conjunctive use, Groundwater modeling, Surface-groundwater Relationships, Well hydraulics

Problem and research objectives:

Problem: Streamflow depletion caused by groundwater withdrawal.
Objectives: 1) to apply new methodologies for collecting high quality pumping and recovery test data and for determination of reliable hydraulic properties of aquifers and aquitards; and 2) to analyze the role of aquifer and aquitard hydraulic conductivity in streamflow depletion due to groundwater pumpage for irrigation.

Methodology:

Design and construction of monitoring wells in alluvial aquifers, which connects to streams; Long-term groundwater level monitoring for determination of recharge and the responses of aquifer to groundwater pumping; Conducting pumping tests in an unconfined aquifer and in a multi-layered aquifer-aquitard system; Determination of aquifer and aquitard hydraulic properties; Analysis of the role of aquifer and aquitard hydraulic properties in streamflow depletion using numerical modeling analysis; Determination of the stream depletion processes: baseflow reduction and induced stream infiltration.

Principal findings and significance:

1. The aquifer test data from the Wood River site have been analyzed, and the results have been used to support our methodology regarding an optimal design of aquifer tests in unconfined aquifers. A manuscript describing this methodology has been submitted to Ground Water for review.
2. The roles of aquifer and aquitard hydraulic properties in stream depletion have been analyzed and we find that baseflow reduction is a major component in the

total stream depletion for many irrigation wells. A manuscript has been submitted to Ground Water for review.

3. In the analysis of the deep-well and shallow-well aquifer tests and long-term groundwater monitoring data at the second test site (Shelton, Nebraska), we found that the alluvial aquifer at this site, which is traditionally considered as unconfined aquifer, shows a hydrologic behavior of a confined aquifer. A manuscript is in preparation for this finding and will be submitted to Ground Water.
4. A numerical model of the stream-aquifer systems (the Platte River, the alluvial aquifer and the Ogallala Group) in the central Nebraska has been designed using MODFLOW. The interactions among the hydrologic processes (recharge, evapotranspiration, groundwater pumpage, stream gaining, stream losing, and boundary flows) for the study area have been analyzed to understand the hydrologic cycle in this area.

Hydraulic Characterization of the Stream-Aquifer Interface: Theory, Field Implementation, and Practical Ramifications - A Multi-State Proposal

Basic Information

Title:	Hydraulic Characterization of the Stream-Aquifer Interface: Theory, Field Implementation, and Practical Ramifications - A Multi-State Proposal
Project Number:	2000NE3B
Start Date:	9/1/1998
End Date:	8/31/2001
Funding Source:	104B
Congressional District:	1
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Methods, Water Quantity
Descriptors:	Surface-Groundwater Relationships, Groundwater Movement, Streams, Groundwater Hydrology
Principal Investigators:	Vitaly A. Zlotnik, Xun-Hong Chen, James Goeke, Carl McElwee

Publication

1. Butler, J.J., Jr., Zlotnik, V.A., and M.-S. Tsou, , 2001, Drawdown and stream depletion produced by pumping in the vicinity of a partially penetrating stream, Ground Water, 39(5), 651-659.
2. Huang, Huihua, 2000, M.S. Evaluation of stream-aquifer interaction considering streambed sediments and stream partial penetration effects. University of Nebraska, Lincoln.
3. Kollet, S., and V.A. Zlotnik, 2000, Field approach to stream-aquifer interactions under pumping and non-pumping conditions: Prarie Creek, Nebraska, GSA Abstracts with Programs, Reno, Nevada, Nov. 9-18, p. A60
4. Cardenas, M.B., and V.A. Zlotnik, 2000, Mapping modern hetrogeneous streambed deposits through hydraulic testing, GSA Abstracts with Programs, Reno, Nevada, Nov. 9-18, p. A360.
5. Tsou, M.-S., and J.J. Butler, Jr., 2000, An analytical solution to assess the influence of anisotropy and stream-channel characteristics on aquifer response to stream-stage fluctuations (abstract), EOS, v. 81, no. 48, p. F422.
6. Butler, J.J., Jr., and M.-S. Tsou, 2000, Mathematical derivation of drawdown and stream depletion produced by pumping in the vicinity of a finite-width stream of shallow penetration, Kansas

Geological Sruvey Open-File Rept. 2000-8.
7. Butler, J.J., Jr., and M.-S. Tsou, 2000, Aquifer response to stream-state fluctuations in a partially penetrating stream (abstract), EOS, v. 81, no. 19, p. S218.
8. Zlotnik, V.A., and Huang, H., 1999, Effect of partial penetration and streambed sediments on aquifer response to stream stage fluctuations, Ground Water, 37(4), 599-605.
9. Kollet, S.J., V.A. , 2002, Zlotnik, and G. Ledder, Discussion of Papers: A stream depletion field experiment by Bruce Hunt, Julian Weir, and Bente Clausen, March-April 2001 issue, v. 39, no. 2: 283-289., Ground Water, 40(4), 448-449.
10. Schulmeister, M.K, Butler, J.J., Jr., Healey, J.M., Zheng, L., Wysocki, D.A., and G.W. McCall, 2003, Direct-push electrical conductivity logging for high-resolution hydrostratigraphic characterization, Ground Water Monitoring and Remediation, in press.
11. Kollet, S. and V.A. Zlotnik, , 2003, Stream depletion predictions using data of pumping tests in heterogeneous stream-aquifer system in the Great Plains, USA, J. Hydrology, in press.
12. Kollet, S.J., Zlotnik, V.A., 2003, Influence of heterogeneity of unconfined alluvial aquifers on pumping test interpretations, J. Hydrology, in review.
13. Cardenas, M.B.R., and V.A. Zlotnik, 2003, Three-dimensional model of modern channel bed deposits, Water Resour. Res., 39, in press.
14. Butler, J.J., Jr., and M.-S. Tsou, 2002, Pumping-induced leakage in a bounded aquifer: An example of a scale-invariant phenomenon, Water Resources Research, in review.
15. Cardenas, Bayani, M.S., 2002, Determination of small-scale spatial variability of hydraulic conductivity of modern streambed deposits through hydraulic testing and grain-size analysis : Prairie Creek, Nebraska
16. Zlotnik, V., Huang, H., and Butler, J.J., Jr., 1999, Evaluation of stream depletion considering finite stream width, shallow penetration, and properties of streambed sediments, in Proceedings of Joint Congress, Water 99,Brisbane, Australia, July 6-8, p. 221-226.
17. Kollet, S.J., V.A. Zlotnik, D. Woodward, 2002, A field and theoretical study on stream-aquifer interactions under pumping conditions in the Great Plains, Nebraska, In Proceedings of AWRA 2002 Summer Specialty Conference Ground Water/Surface Water Interactions, July 1-3, Keystone, Colorado, p. 29-34.
18. Butler, J.J., Jr., Tsou, M.-S., Zlotnik, V.A., and H. Huang, 1999, Drawdown and stream depletion produced by pumping in the vicinity of a finite-width stream of shallow penetration (abstract), Eos, v. 80, no. 17, p. S137.
19. Butler, J.J., Jr., and M.-S. Tsou, 1999, The StrpStrm model for calculation of pumping-induced drawdown and stream depletion (version 1.0), Kansas Geological Survey Computer Series Report 99-1.
20. Butler, J.J., Jr., Healey, J.M., Zheng, L., McCall, W., and M.K. Schulmeister, 1999, Hydrostratigraphic characterization of unconsolidated alluvium with direct-push sensor technology (abstract), GSA Annual Meeting Abstracts with Program, v. 31, no. 7, p. A350.
21. Butler, J.J., Jr., and M.-S. Tsou, 2000, Stream-aquifer interactions: A new model for prediction of pumping-induced drawdown and stream depletion (abstract), Proc. 17th Annual Water and the Future of Kansas Conf., p. 18.
22. Butler, J.J., Jr., and M.-S. Tsou, 2000, Aquifer response to stream-stage fluctuations in a partially penetrating stream (abstract), Eos, v. 81, no. 19, p. S218.
23. Schulmeister, M.K., Zheng, L., Butler, J.J., Jr., Healey, J.M., McCall, W., and D.A. Wysocki, 2000, Detailed hydrostratigraphic characterization with direct-push electrical conductivity profiling (abstract), Eos, v. 81, no. 19, p. S238.

24. Butler, J.J., Jr., and M.-S. Tsou, 2001, New approaches for quantitative assessment of stream-aquifer interactions (abstract), Proc. 18th Annual Water and the Future of Kansas Conf., p. 36.
25. Cardenas,.M. B., and V.A. Zlotnik, 2001, Hydrogeological model of active meander deposits based on three-dimensional hydraulic characterization, 7th International Conference on Fluvial Sedimentology, Program with abstracts, UNL, USA, August 6-10, 2001, p. 71.
26. Cardenas, M.B., and V.A. Zlotnik, 2001, Three-dimensional structure of modern river bend deposits: development and its implications on hydrogeologic models. GSA Abstracts with Program, Boston, Massachusetts, Nov. 1-10, p. A 45.
27. Kollet, S., and V.A. Zlotnik, 2001, Stream-aquifer interactions: pumping tests near a stream with and without stream discharge. GSA Abstracts with Programs, Boston, Massachusetts,, Nov. 1-10, p. A279.
28. Kollet, S. and V.A. Zlotnik, 2001, Interpretation of pumping tests in unconfined aquifers: heterogeneity vs. drainage processes above the declining water table. EOS Transactions, American Geophysical Union, AGU Fall Meeting, San-Francisco, Abstracts, 82(47), F359.
29. Tsou, M.-S., and J.J. Butler, Jr., 2001, A web-based program for computation of pumping-induced drawdown and stream depletion, Kansas Geological Survey Computer Series Report 2001-3 (www.kgs.ukans.edu/StreamAq/input/cgi-html/strpstrm.html).
30. Butler, J.J., Jr., and M.-S. Tsou, 2002, A web-based program for computation of pumping-induced drawdown and stream depletion (abstract), Proc. 19th Annual Water and the Future of Kansas Conf., p. 14.
31. Butler, J.J., Jr., and M.-S. Tsou, 2002, Pumping-induced leakage in a bounded aquifer: An example of a scale-invariant phenomenon (abstract), Eos, v. 83, no. 19, p. S179.
32. Cardenas, B.R., and V.A. Zlotnik, 2002, Assessment of bend topography models via calibration to a ground-penetrating radar profile and permeability data. EOS Transactions, American Geophysical Union, AGU Fall Meeting, San-Francisco, 83(47), F592.
33. Woodward, D., S.J. Kollet, and V.A. Zlotnik, 2002, A field and theoretical study on stream-aquifer interactions under pumping conditions in the Great Plains, Nebraska. In Program of AWRA 2002 Summer Specialty Conference Ground Water/Surface Water Interactions, July 1-3, 2002, Keystone, Colorado, p. 3.
34. Zlotnik, V.A., S.J. Kollet, M.B.R. Cardenas, and D. Woodward, 2002, Study of stream-aquifer interactions in the Platte River watershed using methods of aquifer hydraulics, sedimentology, geophysics, and geostatistics. GSA Abstracts with Program, Denver, Colorado, October 27-31, p. 98.

1. STATEMENT OF THE PROBLEM AND RESEARCH OBJECTIVES

Surface-ground water interactions are often a key component of the hydrologic budgets of aquifers and streams. In Nebraska and Kansas, as well as many other areas in the Great Plains and elsewhere in the United States, these interactions have significant socio-economic and political ramifications. A key element of efforts to quantify stream-aquifer interactions is the estimation of the impact of pumping from alluvial aquifers on stream flows. Although several theoretical methods for estimation of pumping-induced water transfers have been developed over the last 50 years, these methods are based on mathematical models of hypothetical flow systems that often bear little resemblance to stream-aquifer systems in the Great Plains. Recent work has shown that these simplistic models can introduce significant errors into estimates of the impact of groundwater pumping on stream flows as a result of their neglect of critical aspects of the stream-aquifer interface.

The three major objectives of this research are:

(1) develop transient models of stream-aquifer interactions that are suitable for estimation of stream depletion in conditions typically found in the Great Plains, i.e. shallow stream penetration, large stream width-to-depth ratios, and imperfect hydraulic connection between the stream and aquifer;

(2) develop field methods for evaluation of the hydraulic characteristics of the stream-aquifer interface. Particular emphasis will be placed on monitoring approaches that use aquifer head responses to stream-stage fluctuations and pumping, and direct-push methods for hydrostratigraphic characterization;

(3) develop a "tool set" of field and modeling procedures that will allow a more realistic depiction of the stream-aquifer interface to be incorporated into the technical basis of stream-aquifer related administrative decisions.

2. METHODOLOGY

2.1. Theory

We investigated the utility of two-dimensional analytical and semi-analytical models of stream-aquifer systems for representing conditions common to the Great Plains, and the development of easy-to-use web-based implementations of those models. The models explicitly considered conditions of shallow stream penetration, low-permeable streambed sediments, and narrow alluvial valleys common to the Great Plains and many other areas of the U.S.

2.2. Field studies

Field sites were established in the Prairie Creek watershed (Platte River, near Silver Creek, east-central Nebraska) and in the middle reach of the Arkansas River (near Larned, west-central Kansas). Field work in Nebraska included three pumping tests under various stream flow conditions, hydraulic streambed characterization using injection tests, and application of ground penetrating radar. Additional field work for the verification of the direct-push methodology was performed at a research site in the Kansas River floodplain (near Lawrence, northeast Kansas).

3. SUMMARY OF RESULTS

3.1. Theory

Major results include the development and application of two-dimensional analytical and semianalytical solutions that describe the following groundwater flow processes near partially penetrating streams: (1) pumping-induced stream depletion for a stream of infinitely shallow penetration in an aquifer of infinite lateral extent (Zlotnik et al., 1999), (2) pumping-induced drawdown and stream depletion in the vicinity of a stream of infinitely shallow penetration in an aquifer of finite width – BZT model (Butler et al., 2001), and (3) head response to stream stage fluctuations in the vicinity of a stream of any degree of penetration in an anisotropic aquifer (Butler and Tsou, 2000; Tsou and Butler, 2000). These models explicitly consider streambed geometry (width and thickness) and conductive properties and can be used for identification of streambed characteristics. The BZT model was further extended to consider impermeable boundaries (Butler and Tsou, in review, 2002). The BZT model has been implemented in an "Internet calculator" (http://www. kgs.ukans.edu/StreamAq/input/cgi-html/strpstrm.html).

3.2. Field results

Major results are: (1) interpretation of the UNL pumping tests with the homogeneous aquifer model introduced considerable uncertainty into parameter estimates (Kollet and Zlotnik, in review, 2002, Kollet and Zlotnik, in press, 2003); (2) interpretation of the UNL pumping tests with a piece-wise homogeneous form of the BZT model based on sedimentological information improved the results over those obtained assuming a completely homogeneous aquifer (Kollet and Zlotnik, in press, 2003); (3) 3D model of sedimentary structure of the modern streambed deposits (Cardenas and Zlotnik, in press, 2003); (4) direct-push electrical conductivity logging at the KU sites demonstrated that this approach is a powerful tool for the hydrostratigraphic characterization of near-stream portions of the aquifer (Schulmeister et al., in press, 2003).

4. PUBLICATIONS:

PUBLICATIONS IN REFEREED SCIENTIFIC JOURNALS

Zlotnik, V.A., and Huang, H., Effect of partial penetration and streambed sediments on aquifer response to stream stage fluctuations, *Ground Water,* 37(4), 599-605, 1999.

Butler, J.J., Jr., Zlotnik, V.A., and M.-S. Tsou, Drawdown and stream depletion produced by pumping in the vicinity of a partially penetrating stream, *Ground Water*, v. 39, no. 5, pp. 651-659, 2001.

Kollet, S.J., V.A. Zlotnik, and G. Ledder, Discussion of Papers: "A stream depletion field experiment" by Bruce Hunt, Julian Weir, and Bente Clausen, March-April 2001 issue, v. 39, no. 2: 283-289., *Ground Water,* 40(4), 448-449, 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 press, 2003.

Kollet, S. and V.A. Zlotnik, Stream depletion predictions using data of pumping tests in heterogeneous stream-aquifer system in the Great Plains, USA*, J. Hydrology*, in press, 2003.

Kollet, S.J., Zlotnik, V.A., Influence of heterogeneity of unconfined alluvial aquifers on pumping test interpretations, *J. Hydrology*, in review, 2003.

Cardenas, M.B.R., and V.A. Zlotnik, Three-dimensional model of modern channel bed deposits, *Water Resour. Res*., 38, in press, 2003.

IN-REVIEW PUBLICATIONS FOR REFEREED SCIENTIFIC JOURNALS

Kollet, S.J., Zlotnik, V.A., Influence of heterogeneity of unconfined alluvial aquifers on pumping test interpretations, *J. Hydrology*, in review, 2002.

Butler, J.J., Jr., and M.-S. Tsou, Pumping-induced leakage in a bounded aquifer: An example of a scale-invariant phenomenon, *Water Resources Research*, in review, 2002.

DISSERTATIONS

Huang, Huihua, 2000, M.S. Evaluation of stream-aquifer interaction considering streambed sediments and stream partial penetration effects. University of Nebraska, Lincoln.

Cardenas, Bayani, M.S., 2002, Determination of small-scale spatial variability of hydraulic conductivity of modern streambed deposits through hydraulic testing and grain-size analysis : Prairie Creek, Nebraska

NON-REVIEWED PAPERS

Zlotnik, V., Huang, H., and Butler, J.J., Jr., Evaluation of stream depletion considering finite stream width, shallow penetration, and properties of streambed sediments, in "*Proceedings of Joint Congress, Water 99,Brisbane, Australia, July 6-8",* p. 221-226, 1999.

Kollet, S.J., V.A. Zlotnik, D. Woodward, A field and theoretical study on stream-aquifer interactions under pumping conditions in the Great Plains, Nebraska, In *Proceedings of AWRA 2002 Summer Specialty Conference "Ground Water/Surface Water Interactions",* July 1-3, Keystone, Colorado, p.-29-34, 2002.

OTHER PUBLICATIONS

Zlotnik V.A., Huang, H., and J.J. Butler, Jr., Evaluation of stream depletion considering finite stream width, shallow penetration, and properties of streambed sediments, in *Proc. of Water 99 Joint Congress*, Brisbane, Aust., pp. 221-226, 1999.

Butler, J.J., Jr., Tsou, M.-S., Zlotnik, V.A., and H. Huang, Drawdown and stream depletion produced by pumping in the vicinity of a finite-width stream of shallow penetration (abstract), *Eos*, v. 80, no. 17, p. S137, 1999.

Butler, J.J., Jr., and M.-S. Tsou, The StrpStrm model for calculation of pumping-induced drawdown and stream depletion (version 1.0), *Kansas Geological Survey Computer Series Report 99-1*, 1999.

Butler, J.J., Jr., Healey, J.M., Zheng, L., McCall, W., and M.K. Schulmeister, Hydrostratigraphic characterization of unconsolidated alluvium with direct-push sensor technology (abstract), *GSA 1999 Annual Meeting Abstracts with Program*, v. 31, no. 7, p. A350, 1999.

Butler, J.J., Jr., and M.-S. Tsou, Stream-aquifer interactions: A new model for prediction of pumping-induced drawdown and stream depletion (abstract), *Proc. 17th Annual Water and the Future of Kansas Conf.*, p. 18, 2000.

Butler, J.J., Jr., and M.-S. Tsou, Aquifer response to stream-stage fluctuations in a partially penetrating stream (abstract), *Eos*, v. 81, no. 19, p. S218, 2000.

Schulmeister, M.K., Zheng, L., Butler, J.J., Jr., Healey, J.M., McCall, W., and D.A. Wysocki, Detailed hydrostratigraphic characterization with direct-push electrical conductivity profiling (abstract), *Eos*, v. 81, no. 19, p. S238, 2000.

Kollet, S., and V.A. Zlotnik, Field approach to stream-aquifer interactions under pumping and non-pumping conditions: Prairie Creek, Nebraska, *GSA Abstracts with Programs,* Reno, Nevada, Nov. 9-18, p. A60, 2000.

Cardenas, M.B., and V.A. Zlotnik, Mapping modern heterogeneous streambed deposits through hydraulic testing, *GSA Abstracts with Programs,* Reno, Nevada, Nov. 9-18, p. A360, 2000.

Tsou, M.-S., and J.J. Butler, Jr., An analytical solution to assess the influence of anisotropy and stream-channel characteristics on aquifer response to stream-stage fluctuations (abstract), *Eos*, v. 81, no. 48, p. F422, 2000.

Butler, J.J., Jr., and M.-S. Tsou, Mathematical derivation of drawdown and stream depletion produced by pumping in the vicinity of a finite-width stream of shallow penetration, *Kansas Geological Survey Open-File Rept. 2000-8*, 2000.

Butler, J.J., Jr., and M.-S. Tsou, New approaches for quantitative assessment of stream-aquifer interactions (abstract), *Proc. 18th Annual Water and the Future of Kansas Conf.*, p. 36, 2001.

Cardenas,.M. B., and V.A. Zlotnik, Hydrogeological model of active meander deposits based on three-dimensional hydraulic characterization, 7th International Conference on Fluvial Sedimentology, Program with abstracts, UNL, USA, August 6-10, 2001, p. 71, 2001.

Cardenas, M.B., and V.A. Zlotnik, Three-dimensional structure of modern river bend deposits: development and its implications on hydrogeologic models. *GSA Abstracts with Program*, Boston, Massachusetts, Nov. 1-10, p. A 45, 2001.

Kollet, S., and V.A. Zlotnik, Stream-aquifer interactions: pumping tests near a stream with and without stream discharge. *GSA Abstracts with Programs*, Boston, Massachusetts,, Nov. 1-10, p. A279, 2001.

Kollet, S. and V.A. Zlotnik, Interpretation of pumping tests in unconfined aquifers: heterogeneity vs. drainage processes above the declining water table. *EOS Transactions, American Geophysical Union,* AGU Fall Meeting, San-Francisco, Abstracts, 82(47), F359, 2001.

Tsou, M.-S., and J.J. Butler, Jr., A web-based program for computation of pumping-induced drawdown and stream depletion, *Kansas Geological Survey Computer Series Report 2001-3*, 2001 (www.kgs.ukans.edu/StreamAq/input/cgi-html/strpstrm.html).

Butler, J.J., Jr., and M.-S. Tsou, A web-based program for computation of pumping-induced drawdown and stream depletion (abstract), *Proc. 19th Annual Water and the Future of Kansas Conf.*, p. 14, 2002.

Butler, J.J., Jr., and M.-S. Tsou, Pumping-induced leakage in a bounded aquifer: An example of a scale-invariant phenomenon (abstract), *Eos*, v. 83, no. 19, p. S179, 2002.

Cardenas, B.R., and V.A. Zlotnik, Assessment of bend topography models via calibration to a ground-penetrating radar profile and permeability data. *EOS Transactions, American Geophysical Union,* AGU Fall Meeting, San-Francisco, 83(47), F592, 2002.

Woodward, D., S.J. Kollet, and V.A. Zlotnik, A field and theoretical study on stream-aquifer interactions under pumping conditions in the Great Plains, Nebraska. In *Program of AWRA 2002 Summer Specialty Conference "Ground Water/Surface Water Interactions",* July 1-3, 2002, Keystone, Colorado, p. 3, 2002.

Zlotnik, V.A., S.J. Kollet, M.B.R. Cardenas, and D. Woodward, Study of stream-aquifer interactions in the Platte River watershed using methods of aquifer hydraulics, sedimentology, geophysics, and geostatistics. *GSA Abstracts with Program*, Denver, Colorado, October 27-31, p. 98, 2002

5. INFORMATION TRANSFER

Results were presented at several national meetings (American Geophysical Union, Spring 1999-2000 and 2002, Fall 2000, 2001; Geological Society of America, 1999, 2000, 2001, 2002).

Results were also presented to users in Kansas and Nebraska: Central Platte Natural Resources District, Nebraska in 2000, 17th-19th Annual Water and the Future of Kansas Conferences, 2000-2002; 10th Annual Kansas Hydrology Seminar of the American Institute of Hydrology in 2001, 2002 Annual Convention of the Kansas Ground Water Association, and meeting of the Middle Arkansas Subbasin (Kansas) Water Resources Management Program in 2002, American Water Resources Association Summer Specialty Conference "Ground Water/Surface Water Interactions", Keystone, Colorado, 2002.

A web site was set up at the Kansas Geological Survey, KU - www.kgs.ukans.edu/StreamAq - for rapid dissemination of project information. An Internet-calculator implementation of the BZT model is available on the site and reports can be downloaded.

Results were also presented in the seminar "Modern Problems of Hydrogeology", Spring 2001, University of Nebraska-Lincoln; in an invited presentation given by Butler at Texas A&M University entitled "Quantitative assessment of stream-aquifer interactions: New models and field methods" Nov. 2001, and in a short course that included a lengthy discussion of the BZT model entitled "The Design and Analysis of Pumping Tests for Aquifer Evaluation" given by Butler to the Division of Water Resources of the Kansas Department of Agriculture, Oct. 2001. Butler also presented a lecture that included a discussion of the BZT model entitled "Review of aquifer tests" to personnel of the Division of Water Resources of the Kansas Department of Agriculture, July 2000. Two-day course "Groundwater – Surface Water Interactions and Stream Depletion Evaluation" was taught by V. Zlotnik at 13th Natl. Taiwan Conference on Hydraulics, Natl. Yunlin Univ., R.O.C., 2002, and invited talks were presented in Geological Survey, Taipei, R.O.C., 2002

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6. STUDENT SUPPORT. One undergraduate, two M.S., and one Ph.D. students were partially supported from the grant in the Geosciences Department, UNL. One undergraduate student and

one postdoctoral fellow were partially supported from the grant at the Kansas Geological Survey, KU. Total number - 5 students.

Director’s Budget

Basic Information

Title:	Director’s Budget
Project Number:	2001NE2421B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	1
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	Operating Expenses
Principal Investigators:	Michael Jess, Kyle D. Hoagland

Publication

Project Number: D01

Title: Directors Budget

Investigators J. Michael Jess, Acting Director
Kyle D. Hoagland

Congressional District: NE 1

Focus Category: not applicable

Objectives:

Several vacancies at the University resulted in Water Center Director Kyle Hoagland being asked to serve as Acting Director of the School of Natural Resources Sciences. While away on that assignment, I have served as the ?Acting Director? of the Water Center. Both Kyle and I communicate regularly, and in August 2002 a reorganization of the Water Center?s affiliated Water Sciences Laboratory was put into place.

The Lab employs a half dozen full time chemists and is a recognized training facility for part-time undergraduate and graduate students enrolled in engineering and the sciences. The Lab?s primary function is to provide analytical support for research activities of faculty members located on the University?s four campuses. As such faculty members are afforded needed matching assistance when seeking research grants and proposals.

Besides underwriting financial support with Sec. 104b funds, the Water Center supported additional research and equipment acquisitions by using a variety of other federal, State and philanthropic funding sources.

Input from a nine-person advisory board is used to assist the Water Center in setting direction and establishing priorities. A separate five member panel team was asked to review Sec. 104b proposals in late 2002.

Evaluation of Conductive Properties of the Surficial Aquifer in the Nebraska Sand Hills

Basic Information

Title:	Evaluation of Conductive Properties of the Surficial Aquifer in the Nebraska Sand Hills
Project Number:	2001NE2461B
Start Date:	4/1/2001
End Date:	8/31/2002
Funding Source:	104B
Congressional District:	1
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Methods, Geomorphological Processes
Descriptors:	hydraulic, conductivity, air, permeameter, eolian, sediments,Dunes
Principal Investigators:	Vitaly A. Zlotnik, David B. Loope, Joseph A. Mason

Publication

Statement of the Problem

Hydraulic properties of the aquifer underlying the Nebraska Sand Hills control water availability and quality in an area of 50,000 km^2 (Figure 1). The Sand Hills is one of the largest grass-stabilized dune fields in the world (Ahlbrandt et al., 1980, Loope and Swinehart, 2000). Deposited by eolian processes, this dune field serves as a water buffer that preserves precipitation and conveys a part of it to the underlying alluvial sand, gravel, and silt, and further to the High Plains aquifer (Ogallala formation). In absence of this buffer, water would be consumed by the evapotranspiration in the area where potential evapotranspiration exceeds the average annual precipitation by at least 70 cm (Winter, 1986). Hydraulic conductivity is the major property of this buffer that controls groundwater recharge.

However, surprisingly little is known about the hydraulic conductivity of this area (Keen, 1992, Gosselin et al., 1999) in spite of the importance for water resources of Nebraska, the High Plains aquifer, and wetlands protection. Therefore, it is important to develop methodology and to initiate studies of hydraulic conductivity in the Sand Hills that will provide the field data needed for evaluation of water resources and water quality of the region. The developed methodology will also have broader scientific ramifications by providing a tool for field investigations of conductive properties in unconsolidated aquifers in unsaturated conditions.

Related research

Analysis of permeability for assessment of hydraulic conductivity was used for older consolidated sediments of eolian origin (Goggin et al., 1988a) or alluvial sands (Dreyer et al., 1990). We propose to take advantage of this approach for unconsolidated sand of the modern sand dunes and surficial aquifers in the Nebraska Sand Hills.

Hunter's (1977) work on coastal dunes has shown that wind-blown sand can be deposited by three distinct processes: 1) grainflow (sand avalanches down the lee face); 2) grainfall (sand is shot over the dune crest and lands on upper lee face), and 3) wind ripple migration (traction deposits mainly found on the stoss slope and the apron or plinth at the base of the slip face. Sand deposited by migrating wind ripples should have the lowest porosity (and k) and grainflows should have the highest. These processes develop a structured (layered) heterogeneity in k.

In the Sand Hills another anticipated source of heterogeneity relates to post-depositional processes. Fine-grained material, chiefly silt and clay can move downward through the sand with infiltrating water, thereby creating soil lamellae. These features are well developed at many Sand Hills localities and probably increase the moisture retention of soil (Sweeney, 1999, Sweeney and Loope, 2001).

Another critical related development in studies of permeability of porous materials is use of air injection that eliminates difficulties of operating with large volumes of water in difficult terrain conditions. This new approach requires development of several components: instruments, field methodology, and data interpretation. Use of air received significant attention recently in laboratory (Sharp et al., 1994, Tidwell and Wilson, 1997) and field investigations (Davis et al., 1994). However, new instruments were designed for use in outcrops of the aquifers with different degrees of consolidation or with laboratory rock slabs only that limited spatial analysis of k heterogeneity.

These methods of permeability estimating by air injection avoided the drilling or use of subsurface probes at depths from the surface. In contrast, recent developments in remediation

methodology address the subsurface testing (when measurements are performed at depth from the surface), but the methodology requires installation of permanent wells (Baer and Hult, 1991). The direct push method for delivery of the screen to different depths became common in aquifer hydraulic testing (Butler et al., 2001), however its applications for air testing has not been reported yet.

Nature and scope of the project

The project combined theoretical, laboratory, and field studies for development of methodology and *in situ* assessment of permeability of eolian sediments forming the surficial aquifer in typical dune areas of the Nebraska Sand Hills.

Measurements of hydraulic conductivity K in unconsolidated sediments for aquifer characterization are based commonly on a range of methods (Zlotnik et al., 2000). The most common group of methods - hydraulic testing – involves water injection into or withdrawal from the aquifers below the water table. Difficulty of this approach in the dune environment of the Nebraska Sand Hills lies in several factors: large depth to the water table, high variability of this depth due to the dune relief, significant quantities of water required for injection in a relatively highly permeable formation, and inaccessibility of the area for standard drilling and testing equipment.

To overcome these difficulties, we took advantage of an important sedimentary feature of eolian dunes, i.e. relative vertical consistency of the dune lithology. The grain size characteristics of dune sediments vary only slightly over large thickness (Schlee et al., 1964). After investigation of the hydraulic properties of sand dunes one can extrapolate data collected in the unsaturated zone (above the water table) to the larger depth (including saturated conditions). In this approach, one measures permeability k of formation, which is in a relatively simple relationship to the hydraulic conductivity K.

The scope of this work is three-fold:

1. Development of new methodology for estimation of permeability by air injection (equipment, procedures, and data interpretation)
2. Evaluation of hydraulic conductivity in characteristic dune areas and analysis of spatial patterns of eolian sediments (shallow aquifer) of the Nebraska Sand Hills
3. Validation of the methodology by comparing data with previously collected data in the area.

Methods and procedures

The laboratory studies lead to a development of the air permeameter that could be applied at depths ranging from few cm to 1.5 m. All previously proposed air permeameters are based on developing a steady-state air mass flow rates and pressure head. Use of previously published design (Davis et al., 1994, Sharp et al., 1994) was not robust enough in field conditions due to a significant size needed to store and supply the steady air flow and necessity of relatively prolonged injection. To provide sufficient air supply and accurate interpretation of relationship between the air mass flux relationship, a new design was proposed. Schematic diagram of the air permeameter is shown in Figure 2. This permeameter includes the subsurface and the ground components. The subsurface component consists of a steel pipe of 2.8 cm diameter fitted with a short screen (8.8 cm long). This pipe can be driven to the tested depth. The ground component

involves the air mass flowmeter for measurements of the mass flow rate Q, pressure transducer for measurements of the injected air pressure P, and thermometer. Together with the screen depth, these characteristics can be used for estimation of permeability of the formation zone that is adjacent to the screen.

Theoretical studies will include derivation of the formula for permeability estimates. In steady-state regime, the permeability k can be estimated from a simple equation

$$k = f\,Q / P,$$

where f is a shape factor for the particular configuration of the device (Goss and Zlotnik, 2000). Shape factor for this instrument was derived by generalization of previous studies of the air permeameter (Tartakovsky et al., 2000, Goggin et al., 1988 b, Zlotnik, 1994). Analysis of the quasi-linear airflow in the system was reduced to a solution of the boundary value problem for the Laplace equation in uniform media. Hydraulic conductivity K is related to the formation permeability by relationship $K = k\rho g / \mu$, where ρ is water density, μ is dynamic viscosity, and g=9.81 m/s^2 (Freeze and Cherry, 1979). The parameter μ is temperature dependent; and this was taken into account in the process of field data collection (see Ronan et al., 1998). This was included in the calculation of the factor f above. The viscosity of water in the conversion of k to K was taken to have the value characteristic of the mean annual temperature (20 °C) of the ground at the latitude of the site. The pressure sensor was calibrated in the laboratory by direct comparison with water manometer.

At the stage of field studies, the characteristic site locations for air permeameter applications were identified. Considering limited resources, these studies emphasized the collection of permeability data at morphologically different locations at one representative dune (Figure 3).

Summary

Devices – air permeameters - were designed and constructed to supply air at known pressure and mass flow rate to a subsurface probe. Subsurface probes were designed and constructed for use in the near subsurface (at depths up to 1.5 m from ground surface) for use in with poorly consolidated sediment.

After selecting the optimal system, the guidelines for instrument operation and data interpretation for evaluation of the permeability in the vicinity of the probe were developed. Geometric effects were incorporated by calculation of a shape factor f.

The permeability k was estimated by measuring the flow rate Q and the applied pressure P for a given geometric configuration. In each test, this pressure was measured using linear relationship V' between voltage across a pressure sensor and P for a given geometric configuration. The correlation coefficient r for each site and depth location had a range r=0.915-1.00, with the most values greater than 0.99.

Systematic measurements were made upon a selected dune location (Gudmundsen Sandhills Lab, approximately N42°4.9'and W101°28.3')with a history of episodic vegetative covering in characteristic locations. Measurements of the permeability were performed at five depths between 0.1 m and 1.3 m at 34 distinct locations.

The depth-averaged permeability values of k and hydraulic conductivity K may be sorted into distinct ranges according to the dune features at different site locations. The five highest values of k= (61.9-72.4)10^{-12} m^2 or K=(60.3-70.6) 10^{-5} m/s, were associated with a step in the dune profile; the 22 lowest values of k= (3.3-11.9)10^{-12} m^2 or K=(3.2-11.6) 10^{-5} m/s were

associated primarily with the stoss slope and the compacted steep face of the dune; most of the seven intermediate values of k= (12.7-25.5)10^{-12} m^2 or K=(12.4-24.9) 10^{-5} m/s were associated with alluvial fans.

For modern unvegetated dunes, the permeability followed qualitative expectations of being greatest for grainflow and grainfall regions, and smaller for stoss slope ripple strata. For vegetated dunes, there were two sets of permeability found that differed by an order of magnitude; these were located at different identifiable locations and may be related to the form of the dune while it was investigated. The implication is that the lee slope grain flow deposits correspond to the high permeability cases, and the stoss slope ripples correspond to the lower permeability. Permeability and hydraulic conductivity values obtained were consistent with a few earlier hydraulic conductivity measurements by Sweeney (1999). The later were performed using steady-state water injection in unsaturated zone. More direct investigations of hydraulic conductivity were unavailable due to inaccessibility of wells.

The permeability of the vegetated dunes is strongly influenced by the existence of vegetation and herbivores. For example, the intermediate to low permeability values on the steep face appear to be the result of compaction of soil in the process of formation of climbing cow trails (catwalks). Low spots on the dune surface are seasonally covered with lose sand ejected from ground squirrel burrows; this fluffy material seems to have a higher permeability than the surroundings.

Sand features due to erosion, transport, and deposition by running water showed systematic variations in permeability according to features. Clay bands (lamellae) decrease the permeability locally and cause it to be anisotropic and moisture dependent. This was verified by coring a sand location where the permeability was unreasonably low, and finding lamellae at the depth where the permeability was unmeasurable.

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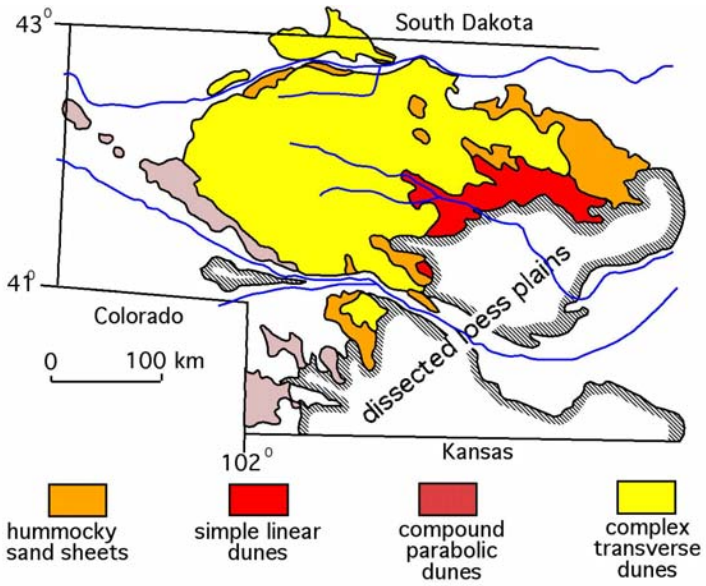

Figure 1. Distribution of wind-blown sediment and dune types in the Nebraska Sand Hills.

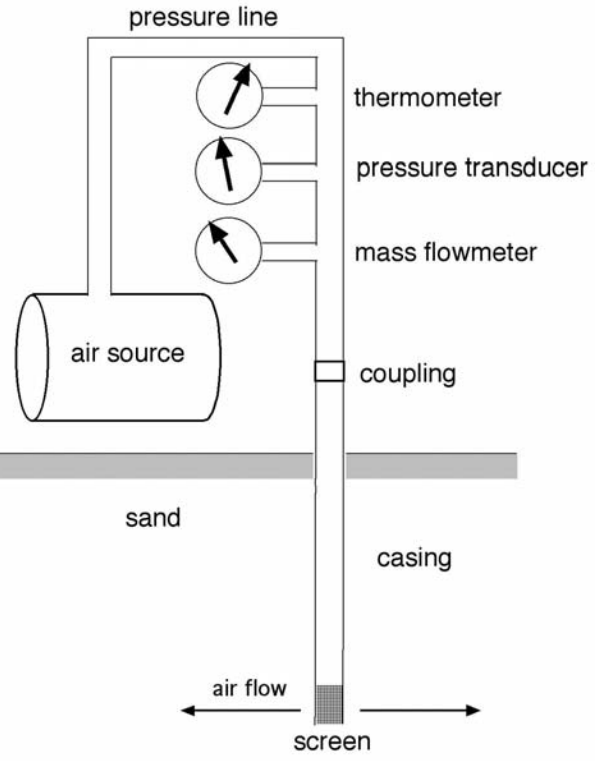

Figure 2. Air permeameter for use in sandyaquifer materials.

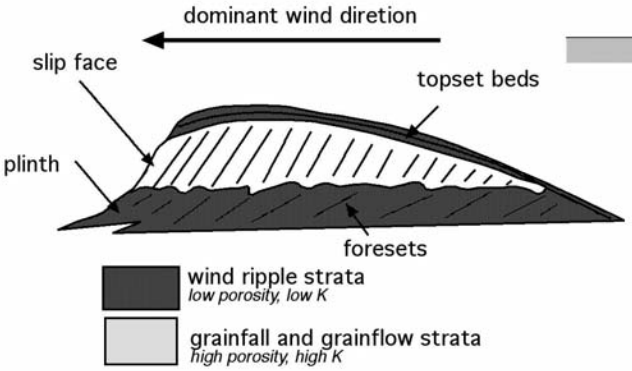

Figure 3. Cross-section of wind-blown sand dune showing distribution of different stratification types

Investigation of Microbially-Influenced Copper Corrosion in Nebraska Drinking Water Systems

Basic Information

Title:	Investigation of Microbially-Influenced Copper Corrosion in Nebraska Drinking Water Systems
Project Number:	2001NE23B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	NE1
Research Category:	Engineering
Focus Category:	Treatment, Water Supply, Groundwater
Descriptors:	drinking water, water quality standards, groundwater, copper corrosion
Principal Investigators:	Matthew C Morley, Bruce I Dvorak

Publication

1. El-deek, Sherif. (2002) Investigation of Microbially Influenced Copper Corrosion in Representative Nebraska Drinking Waters. M.S. Thesis (Environmental Engineering) presented to the University of Nebraska Lincoln, Department of Civil Engineering, 124 pages (completed December, 2002).

Project #: D25
RESEARCH

Project Number: D25

Start Date: March 1, 2001

End Date: August 31, 2002

Title: Investigation of Microbially-Influenced Copper Corrosion in Nebraska Drinking Water Systems

Investigators: Matthew C. Morley, Ph.D. and Bruce I. Dvorak, Ph.D.

Congressional District: NE1

Focus Category: TRT, WS, GW

Descriptors: drinking water, water quality standards, groundwater, copper corrosion

Problem and Research Objectives: Copper is extensively used for water distribution piping and in plumbing fixtures. Although copper is fairly resistant to corrosion, it may corrode under some conditions. In response to the potential for adverse health effects at high concentrations, the U.S. Environmental Protection Agency (USEPA) has established an action level of 1.3 mg/L for copper in drinking water, and as of August 1999, a total of 58 drinking water systems in Nebraska exceeded the U.S. EPA's action level for copper in drinking water. Microbially influenced corrosion (MIC) is one of the processes that may induce corrosion, but it is a poorly understood process. The current research evolved from the need to study MIC and understand the conditions under which MIC occurs. This research was undertaken to simulate as closely as possible distribution system conditions, including source water, water chemistry, stagnation time, bacterial contamination and microbial byproducts.

Methodology: A bench-scale apparatus was constructed in the environmental engineering laboratory at the University of Nebraska – Lincoln using four sections of new copper pipe. Water from the city of Waverly was used in this experiment and a mixed bacterial culture was obtained from previous research. Batch tests were performed along with bench-scale study to help in correlating and verifying the results.

Findings: Results of the bench scale experiment showed three main conclusions. First, the copper concentrations in the new pipes with sulfate-reducing bacteria (SRB) showed a substantial increase after the addition of total organic carbon (TOC) compared to the pipes receiving the same water with no TOC addition and the pipes with no bacteria addition. This means that the presence and availability of substrate in addition to the presence of SRB can lead to an increase in the dissolution of copper in drinking water systems. Second, there is an obvious relationship between SRB and copper corrosion. Under conditions that promote SRB growth, copper dissolution increases from pipes. This dissolution may be due to the H_2S formed by the SRB that are present as a biofilm or as suspended growth. Third, hydrogen sulfide production not

only contributes to the corrosion process but according to this research, it may also be used as a way of identifying the presence or absence of SRB in water distribution systems.

The batch tests yielded some important results that can be summarized as follows. Low sulfide concentrations resulted in low copper concentrations, possibly due to the build up of a protective scale layer. A high sulfide concentration resulted in elevated copper concentrations in water. Finally, increase of chloride concentrations in the water may lead to a reduction in the corrosion of copper.

A. Publications

El-deek, Sherif. (2002) Investigation of Microbially Influenced Copper Corrosion in Representative Nebraska Drinking Waters. M.S. Thesis (Environmental Engineering) presented to the University of Nebraska Lincoln, Department of Civil Engineering, 124 pages (completed December, 2002).

B. Student Support

El-deek, Sherif. M.S. Student, Environmental Engineering (partial support)

Investigation of directional hydraulic conductivities of streambeds and evaluation of their roles in stream-aquifer interactions

Basic Information

Title:	Investigation of directional hydraulic conductivities of streambeds and evaluation of their roles in stream-aquifer interactions
Project Number:	2001NE24B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	NE 1
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Sediments, Hydrology
Descriptors:	Stream sediment, Hydraulic conductivity, Surface-groundwater Relationships
Principal Investigators:	Xun-Hong Chen, James W. Goeke

Publication

1. Chen, X.H., and L.C. Shu, 2002. Stream-aquifer interactions: evaluation of depletion volume and residual effects from ground water pumping. Ground Water, v. 40, no. 3, p. 284-290. Shu, L. C., and X. H. Chen, 2002. Measurement of streambed hydraulic conductivity from the Platte River, central Nebraska. Advances in Water Sciences (Chinese with English Abstract), v. 13, no. 5, p. 629-633.
2. Chen, X.H., 2002. Determination of streambed hydraulic conductivity using extended permeameter methods. American Water Resources Association Annual Summer Conference Ground Water/Surface Water Interactions, July 1-3, 2002, Keystone, Colorado, p. 529-534.

RESEARCH

Project Number: D-26

Start: 03/01/2001
End: 02/28/2002

Title:
Investigation of directional hydraulic conductivities of streambeds and evaluation of their roles in stream-aquifer interactions

Investigators:
Dr. Xun-Hong Chen, and Professor Jim Goeke, University of Nebraska-Lincoln

Congressional District: NE 1

Focus Category: GW

Descriptors: Stream sediment, Hydraulic conductivity, Surface-groundwater Relationships.

Problem and research objectives:
Problem: Lack of the data of streambed hydraulic conductivities in the analysis of stream-aquifer interactions.
Objectives: 1) development of an instrument to determine in-situ streambed hydraulic conductivities; 2) investigation of directional hydraulic conductivities and the anisotropy of streambed at selected study sites along a number of rivers in Nebraska; and 3) development of stream-aquifer model to evaluate the role of streambed hydraulic conductivity in streamflow depletion.

Methodology:
Permeameters were developed for measurement of streambed hydraulic conductivity from river channels. Tests were conducted at 11 sites in the Platte, Republican, and Little Blue rivers in Nebraska. The hydraulic conductivities of streambed sediments were determined across the channels at most of the test sites.

Principal findings and significance:
1) Streambed hydraulic conductivity shows a significant spatial variation across the river channels and in up- and down-stream reaches;
2) The vertical hydraulic conductivity is one key variable in the determination of streamflow depletion;
3) The hydraulic gradient between the stream water and groundwater varies very much in different reaches of a river, and this is the other key variable in the analysis of stream depletion.

PUBLICATIONS

1. Articles in Refereed Scientific Journals

Chen, X.H., and L.C. Shu, 2002. Stream-aquifer interactions: evaluation of depletion volume and residual effects from ground water pumping. Ground Water, v. 40, no. 3, p. 284-290.

Shu, L. C., and X. H. Chen, 2002. Measurement of streambed hydraulic conductivity from the Platte River, central Nebraska. Advances in Water Sciences (Chinese with English Abstract), v. 13, no. 5, p. 629-633.

2. Conference Proceeding

Chen, X.H., 2002. Determination of streambed hydraulic conductivity using extended permeameter methods. American Water Resources Association Annual Summer Conference – Ground Water/Surface Water Interactions, July 1-3, 2002, Keystone, Colorado, p. 529-534.

STUDENT SUPPORT

The grant has partially supported two post-doctoral researchers.

AN ASSESSMENT OF FACTORS INDICATING WELL VULNERABILITY IN NEBRASKA

Basic Information

Title:	AN ASSESSMENT OF FACTORS INDICATING WELL VULNERABILITY IN NEBRASKA
Project Number:	2001NE25B
Start Date:	3/1/1999
End Date:	8/30/2001
Funding Source:	104B
Congressional District:	1
Research Category:	Water Quality
Focus Category:	Water Supply, Water Quality, Groundwater
Descriptors:	virus
Principal Investigators:	Bruce I Dvorak, Wayne E. Woldt

Publication

1. Fisher, J.L, and Dvorak, B.I. (2001) Assessment Of Viral Contamination In Nebraskas Small Community Wells, Proceedings of the 2001 American Water Works Annual Conference, Washington, DC. June.
2. Fisher, J.L. (2001) An Assessment of Well Vulnerability to Viruses in Nebraska, MS Dissertation, University of Nebraska, Lincoln, NE, 175 pages.

Synopsis

Project Number NE1581 Information Transfer Plan

Title: Production of Educational Newsletter "Water Current" and Other Materials identified as Important for the General Public to Understand

Focus Categories: EDU

Keywords: Newsletter, Irrigation, Water Quality, Herbicides, Bioremediation, Groundwater

Duration: Start: March 1, 2003
End: February 28, 2004

FY 2003 Federal Funds: $19,000
FY 2003 Non-Federal Funds: $33,750
Total $52,750

Principal Investigator: Steven W. Ress, Communications Coordinator
J. Michael Jess, Acting Director

Congressional District: 1

Abstract:
As research results supported by USGS and other state and federal agencies become available, it is critically important to inform the public, policy decision-makers, and water resource managers. In addition, federal, state, and private organizations, as well as industry and the general public need readily available information regarding contacts for water resource related questions and additional information, new federal and state policies, educational opportunities through the university, and other water-related issues. Thus, the primary aim of this Information Transfer Plan is to better inform citizens and agency personnel concerning water resource quality and quantity issues of health, economic, and esthetic importance. The specific objectives are to publish a newsletter (*Water Current*) six times during the year, including an estimated distribution of 3,000 copies, and to produce and publish special educational and informational materials dealing with timely and important water issues throughout the year using high quality graphics and print-quality materials.

Statement of Critical Need:
As research results become available, it is important to inform the public as to how these results might impact water supplies to Nebraska's in both quantity and quality. Also, Federal, state, and private organizations as well as the general public need a constant flow of information regarding contact personnel, new Federal and state policies and how these policies might effect citizens, and opportunities within the University to learn more concerning the water issues relating to Nebraska.

Statement of Result or Benefits:
The primary result is a better informed citizens and state and Federal agency personnel concerning water issues directly impacting them health- wise or economically.

Nature, Scope, and Objectives of the Research:
While this project cannot be directly called research, it identifies those projects that have direct application to Nebraska's and how those applications can directly affect them. It also identifies areas of research need through constant feedback.
The objectives are:

1. Produce and publish the Water Current six times a year. Distribution of the publication is made through an extensive mailing list containing approximately 3,500 names.

2. Produce and publish other special educational materials dealing with timely and important issues that need immediate public input or attention.

Methods, Procedures, and Facilities:
The Water Center/Environmental Programs unit either writes or invites guest editorials for publication. Contact is determined by solicitations to faculty and staff. The unit maintains control over all materials printed to insure quality and uniformity. Word processed documents and graphics are supplied to the University print shop where printing and mailing occurs.

Related Research:
Many Water Resources Institutes publish similar materials in the form of newsletter and have found this to be inexpensive an useful method to inform the public of water related issues directly impacting their state.

Investigator's Qualifications: Should be on file from previous years.

Training Potential:
Only those students that have training in Journalism would be able to assist in this effort.

AN ASSESSMENT OF FACTORS INDICATING WELL VULNERABILITY IN NEBRASKA

Basic Information

Title:	AN ASSESSMENT OF FACTORS INDICATING WELL VULNERABILITY IN NEBRASKA
Project Number:	2001NE27B
Start Date:	2/28/1999
End Date:	8/30/2001
Funding Source:	104B
Congressional District:	1
Research Category:	Water Quality
Focus Category:	Water Quality, Water Supply, Groundwater
Descriptors:	viruses
Principal Investigators:	Bruce I Dvorak, Wayne E. Woldt

Publication

1. Fisher, J.L., 2001, An Assessment of Well Vulnerability to Viruses in Nebraska, Environmental Engineering, M.S. Dissertation, University of Nebraska, Lincoln, NE, 175 pages.
2. Fisher, J.L, and Dvorak, B.I., 2001, Assessment Of Viral Contamination In Nebraskas Small Community Wells, in Proceedings of the 2001 American Water Works Annual Conference, American Water Works Association, Washington, DC. June.

RESEARCH

Problem and Research Objectives:

Most Nebraska communities rely on groundwater as a source of drinking water. Nebraska's groundwater aquifers typically have a non-Karstic hydrology: they are more or less typical aquifers in unconsolidated sands and gravels that do not initially appear to be at particular risk for microbial contamination. It has often been assumed that Nebraska's municipal groundwater supplies are free of pathogens due to natural filtration provided by the soil. Although there are few published studies on virus occurrence in groundwater, limited data available from some states seem to indicate that groundwaters may be vulnerable to contamination and may contain pathogens (e.g., Abbaszadegan et al.; 1998). The presence of human pathogens such as viruses in well waters has not been studied sufficiently, and no general consensus on the presence of viruses for regions like Nebraska.

To assess the vulnerability of Nebraska's drinking water wells from pathogen contamination, a study of well integrity factors or 'well vulnerability' was performed. In this study, only small (<10,000 population) Nebraska communities that do not currently disinfect or treat their drinking water were studied. There are 608 small community water systems in Nebraska. In addition there are 719 non-community water systems. Although few Nebraska community wells are in "vulnerable" (karst, fractured bedrock and gravel) formations, some wells are close to (or in violation) of setback distances to potential microbial contamination and/or have other water quality issues (e.g., high nitrates, total coliform detects in the distribution). Thus, the overall goal of this study was to assess the general frequency of pathogen (bacterial and viral) contamination in community water systems in Nebraska by monitoring wells that are among the most likely according to theory to be contaminated. In this project, a total of seven small community wells were studied intensively; the wells selected for study were believed to be among the most vulnerable to microbial contamination in Nebraska.

Methodology:

The general methodology of this study was to select seven community wells (located in the eastern half of Nebraska) that were perceived to be most vulnerable to being infected with viruses. Each of those seven wells was tested six times for viruses (using two methods, PCR and Cell Culture) as well as for bacteria and other water quality parameters. Six of the seven community wells were tested at least once before August 28, 2000. The seventh community well was not tested until September 11, 2000 because there was a severe drought during the summer and early falls of 2000. This drought has caused higher than normal pumping rates and possibly lower water table levels.

Selection of Community Wells

The only wells considered for this study were those serving small community water systems in Nebraska that rely on untreated groundwater (including no regular disinfection) for their public water supply. All communities considered had wells that were not under the influence of a surface water. An initial list of possible community wells were selected by placing a 200-mile radius around Lincoln, Nebraska. There were 32 candidates wells within Butler, Colfax, Dodge, Greeley, Lancaster, Merrick, Nance, Pawnee, Platte, Polk, Saunders, Seward, and York counties in Nebraska. The project team ranked the most vulnerable communities from the list of 32 in an extensive table listing important well characteristics related to the below criteria.

The first criteria concerned the well depth. All the selected community wells were shallow; for Nebraska communities. A relatively shallow well is one less than 250 feet. The depths of the selected

wells are listed in Table 1. The seven community wells tested are listed in Table 1. The letters A-G in this paper refers to the wells. Each well is located in a different community.

Table 1. Community Wells Sampled.

Well:	A	B	C	D	E	F	G
Year Well Drilled[1]	1991	1987	1984	1937	1982	1985	1972
Well Depth[1]	205'	230'	214'	101'	116'	178'	276'
Nitrate/Nitrite[2] (mg/L)	6.2	N/A	1.3	5.1	5	7.2	7.4
Total Coliform Detections[2]	Yes	Yes	No	Yes	No	No	Yes
Sanitary Sewer Lines	>1500'	75'	50'	30'	200'	160'	30'
Sewer Lines Service Connection	>1500'	85'	50'	80'	245'	160'	78'
Wastewater Lagoon	>1500'	>3000'	700'	4500'	N/A	N/A	N/A
Sewer Manholes	>1500'	125'	150'	50'	545'	170'	156'
Septic Tanks	858'	N/A	N/A	300'	>1500'	>1500'	N/A

Violation of Nebraska's setback distance guideline

1 - From sources such as well logs (Nebraska Conservation and Survey), NDHHS files, and NDEQ files

2 – Reported on Community's 1999 Customer Confidence Reports

The second criteria used for selecting the communities was Nitrate/Nitrite concentrations reported to the Nebraska Department of Health and Human Services (NDHHS) during 1998 and 1999. High Nitrate/Nitrite concentrations were considered to be a possible indication of a connection to the surface.

The third criteria was total coliform bacteria (TBC) detections in the distribution system reported to the Nebraska Department of Health and Human Services (NDHHS) during 1998 and 1999. Frequent TCB violations were considered to show the potential for microbial contamination of the well; although it is also possible that the TCB could have come from regrowth within the distribution system, backflow or intrusion into the distribution system, or poor maintenance.

The fourth type of criteria concerned the proximity of viral sources to the wells. The communities' setback distances from possible sources of contamination were used as a criterion (as listed in Table 1). If the community had a violation of Nebraska's current guidelines or was close to the setback distance considered a high probability for virus contamination. Nearly all wells selected were within each community's boundaries, and these would have a higher possibility of (human) virus contamination from leaky sewers, sewer connections or septic systems.

The last criterion was the willingness of each community to participate in this study. A total of eleven communities were approached in order to obtain seven that agreed to participate in the study. Overall, the communities selected were considered to be among the most vulnerable wells to microbial contamination within Nebraska. The selected data for the selected communities is listed in Table 1.

Information on the candidate communities was obtained from several sources. The Nebraska Natural Resources Commission Data Bank for registered groundwater well data were used to determine the well depth, pump depth, pump column diameter, pumping level, static level and pumping rate. The Nebraska Department of Environmental Quality (NDEQ) obtained data concerning the Well Head Protection Area. This data included current pumped water level, current non-pumped water level, average annual pumpage, storage facilities for the water, screen length, screen diameter, screen material, wastewater

disposal, distance to the nearest water, and what is near the well. Nitrate-Nitrite and Total Coliform Bacteria data were obtained from the Nebraska Department of Health and Human Services (NDHHS). Aerial photos were gathered for each of the candidate communities from a USGS website. These aerial photos allowed a birds-eye view of what is near the wells in each of the communities to check for obvious sources of contamination. The Nebraska Department of Health and Human Services field staff assisted in confirming information related to the setback distances, pump rates and frequencies, and in obtaining community agreement to participate in the study.

Water Sampling

For each community, the water was sampled at a sample tap from the well of interest. Approximately 528 gallons (2000L) of water was filtered as part of the virus testing procedure. Samples were collected for the bacteriological parameters and other water quality parameters after virus testing filtration was completed.

A virus sampling apparatus was assembled. Then the groundwater was pumped from the well to the apparatus. Water flowed through the 25 micron pre-filter and the Virosorb filter at a flow rate between 1.5 and 1.0 gallons per minute for approximately 528 gallons (2000L). After completion of the filtration run, the virus filter was removed and then placed into a Ziploc bag along with the remaining water in the cartridge housing. The Ziploc was then placed into an insulated container and transferred to the University of Nebraska Medical Center Virology Laboratory for the virus testing within 18 hours after completion of the sampling.

The University of Nebraska Medical Center Virology Laboratory conducted the virus analyses. The Polymerase Chain Reaction PCR) and cell culture methods were both used for detecting enterovirus presence. The groundwater samples analyzed by the PCR method consist of a filter-adsorption and elution method. This method stereotypes all positives and sequences all polio positive as well as the lab controls. The cell culture method used inoculated the sample into MRC, PMK, and A-549 cell lines, which detects infectious enteriviruses in the environment.

The sampling and analysis method used for enterovirus was verified by a four QA/QC field studies. This study consisted of running approximately 300-gallons of dechlorinated water spiked with 6.5 mL of CVB3 virus. The filter was analyzed by the PCR and the cell culture method. The results of all four studies were positive for enterovirus presence.

Other water quality parameters that were evaluated include: alkalinity, pH, dissolved oxygen, UV-254, E. Coli, and total coliform. These parameters were measured in samples taken at the point of collection for the virus samples. The samples for these parameters were collected immediately after collecting the virus samples. These water sampling and analysis techniques follow procedures in Standard Methods for the Examination of Water and Wastewater.

Groundwater Modeling

Ground water modeling was conducted with the computer program CANVAS (Version 2.1), which is a composite analytical-numerical model for viral transport simulations, distributed by International Ground Water Modeling Center in Golden Colorado (Park et al., 1995). This model is designed to predict the following: 1) Viral concentration at the water table from a viral source in the subsurface (unsaturated zone modeling). 2) The viral concentration at the wellhead from a source at the water table (saturated zone modeling). 3) The viral concentration at the wellhead from a source in the subsurface (both unsaturated and saturated zone modeling). The program simulates the transport and fate of virus particles with consideration for source strength, hydrogeologic conditions, advection, dispersion, adsorption/desorption, colloidal filtration, inactivation, and well operation.

Flow and transport through the unsaturated zone assumes a one-dimensional, vertical downward direction, under steady-state conditions (semi-analytical). Virus transport through the porous media was assumed to be based on a two-site kinetic modeling approach, which assumed the sorption was controlled by a rapid reaction with instantaneous equilibrium, or a reaction with a kinetic expression for a slower adsorption rate. It was assumed that the sorption is controlled by a rapid reaction with instantaneous equilibrium or a reaction with a kinetic expression for a slower adsorption rate. Virus flow and transport through saturated porous media was simulated using an areal two-dimensional, finite element-based steady-state modeling approach.

Site specific hydrogeologic and well construction information were gathered for all seven communities in this study. Only one site was selected for further exploration through computer-based modeling due to the established research timetable and associated time constraints. Well G was selected for the site application because it had the most available information for model development. In this case, the model was developed according to site conditions to assess the potential for viral contamination of the community well from a potential source (sewer line) near the well.

The modeling effort also explored the use of CANVAS for interpretive and generic modeling applications. Interpretive models provide a framework to gain an understanding of physical settings and the associated interrelationship with available data sets for the given physical setting. Generic modeling applications provide insights into highly complex, connected systems, under hypothetical conditions, which may be useful for establishing a baseline for policy review and formulation. The CANVAS model was used for two different modeling scenarios within the context of interpretive and generic applications. The first scenario looked at what soil types would allow virus to pass through the unsaturated zone and enter in the water table. This scenario involved a leakage source 15 feet below the subsurface and an unsaturated zone thickness of 75 feet. This configuration provides a geometry that is similar, on average, to the sites that were sampled. The second scenario explored the transport of virus from the water table to a given well under differing conditions. In this case, the model was run with variable strength sources located at three different spatial locations and distances from the well; which were 50 feet, 150 feet and outside the well capture zone.

Principle Findings and Significance

Out of the 47 samples tested, only one sample tested positive for enterovirus contamination using PCR; however no positives were detected for cell culture, as listed in Table 1. The sample that tested positive for viral contamination was Community B, which was positive on 8/7/00. Note the PCR method detects viral DNA and cell culture analysis only detects viable viruses.

Table 1. Virus Data.

	PCR		Cell Culture	
Well	**Positive**	**Negative**	**Positive**	**Negative**
A	0 (0%)	7 (100%)	0 (0%)	7 (100%)
B	1 (16.6%)	5 (83.4%)	0 (0%)	6 (100%)
C	0 (0%)	6 (100%)	0 (0%)	6 (100%)
D	0 (0%)	6 (100%)	0 (0%)	6 (100%)
E	0 (0%)	6 (100%)	0 (0%)	6 (100%)
F	0 (0%)	6 (100%)	0 (0%)	6 (100%)
G	0 (0%)	7 (100%)	0 (0%)	7 (100%)
Total	1 (2.3%)	44 (97.7%)	0 (0%)	44 (100%)

Throughout this study, no E. Coli samples (0 of 47 samples) were detected in any well. However two different sites tested positive for total coliform listed in Table 2. Note the Nebraska Health Department Total Coliform History data results from each community's distribution system is also provided in Table 2. The wells that were positive for total coliform did not have detects in the distribution systems. In addition, the two wells that tested positive for total coliform did not test positive for viral contamination using PCR or cell culture. The water quality for the water samples collected for this study was consistent throughout sampling and showed no direct relationship with the microbial data.

Table 2. Total Coliform Results.

	Collected Samples for Study *July of 2000 to Jan of 2001*			**NHHS Total Coliform History Data** *July of 2000 to Jan of 2001*		
Well	Number of Positive	Total Number Sampled	% Positive	Number of Positive	Total Number Sampled	% Positive
A	1	4	25%	0	7	0%
B	0	6	0%	11	59	19%
C	0	6	0%	0	8	0%
D	1	6	11%	0	16	0%
E	0	6	0%	0	8	0%
F	0	6	0%	0	15	0%
G	0	6	0%	11	62	18%

The results of this study have been compared to the Abbaszadegan et al. (1998) study mentioned previously. Abbaszadegan et al. (1998) sampled 174 sites that have sewage sources within 150 feet; for these wells, Abbaszadegan et al. showed that 17% were positive using PCR, 6% were positive for cell culture and 9% were positive for total coliform bacteria. Note that all of the Nebraska wells sampled in this study have similar geology; whereas in the Abbaszadegan study the geology was different at the 174 sites. The wells tested in this study were also within 200 feet of sewage sources but had lower positives for the PCR method (2.1%), cell culture (0%), E.Coli (0%), and total coliform (5%) than the Abbaszadegan study.

The first ground water modeling approach, simulation of well G, using the CANVAS program for both the unsaturated and saturated zone, predicted that the concentration of viruses reaching the water table directly below the viral source was below the detection limit. The concentration at the water table from a viral source of 10^7 PFU/liter was reduced to 0.11×10^{-6} PFU/Liter.

The first interpretive/generic modeling scenario involved modeling viral transport through the unsaturated zone using parameter specifications for four different soil types (approximately 75 feet). Table 3 shows the concentration at the water table given two source strengths of 10^3 PFU/liter to 10^7 PFU/liter.

Table 3. Concentration (PFU/liter) at the Water Table Given Different Soil Types.

Depth	Clay	Silty Loam	Silty Clay Loam	Sand
75'	0.50×10^{-22} to 0.45×10^{-18}	0.48×10^{-21} to 0.48×10^{-17}	0.11×10^{-21} to 0.11×10^{-17}	10^3 to 10^7

The second scenario modeled three different upgradient locations; 50 feet, 150 feet and outside

the capture zone. It was assumed that the viral contamination had reached the water table. This modeling predicted that a source 50 feet from a well would present a risk if no die off and no retardation factors were considered. However if die-off and retardation were considered, the likelihood of viral contamination at the well was significantly reduced. Modeling results predict that a well located further downgradient from a source (i.e., 150 ft.) will have less risk of exposure, assuming no die-off and no retardation. Here again, if die-off and retardation were considered, the likelihood of viral contamination at the well was reduced significantly from a source located at 50 feet. The last location to be evaluated, outside the capture zone, showed that no viral contamination, regardless of the concentration source strength, would present a risk to the well.

The main conclusions from this study are:

- Only 2% of the public water supply samples were positive to viral contamination using the PCR method and, none of the samples were positive using the cell culture method.
- No obvious relationship exists between viral contamination in the supply wells and Total Coliform Bacteria contamination detected in the distribution system.
- The availability of well information and aquifer data was quite limited for older wells, which leads to a lack of understanding about the hydrogeologic conditions, and numerous assumptions about how the aquifer behaves.
- The CANVAS model predicted no viral contamination at well G, which is consistent with the sampling results.
- Modeling of viral transport through the unsaturated and saturated zones, for the site specific case and interpretive/generic cases, tends to indicate that the greatest risk to wells similar to the case study sites may be human induced types of factors, such as abandoned wells and improperly constructed wells that enhance the transport of virus to water supply aquifers.

Information Transfer Program

Basic Information

Title:	Information Transfer
Start Date:	3/1/2001
End Date:	2/28/2002
Descriptors:	Groundwater, Bioremediation, Herbicides, Water Quality, Irrigation,Newsletter
Principal Investigators:	Steven W. Ress, Michael Jess

Publication

2001 USGS ANNUAL REPORT
UNL WATER CENTER

INFORMATION TRANSFER PROGRAM:

NEWSLETTER:

The *Water Current* newsletter is in its 35th year of continuous publication. Published six times per year (February, April, June, August, October and December). An annual reader survey is published in the April issue. The newsletter was completely redesigned for general appearance and certain content directions in October 2000. Fine-tuning of this redesign continues. University of Nebraska water-related research and cooperative extension faculty are featured on a regular basis. Guest columns are published from area water-related professionals in each issue. Individual issues are 8 or 12 pages, usually 12 pages as our coverage and focus expands. A 16-page commemorative issue celebrating the centennial of U.S. Bureau of Reclamation projects in Nebraska and Wyoming was published in October 2002. Research briefs, research progress reports and RFPs are frequently published. Subscriptions are available at no charge to the public and there are approximately 2,700 subscribers. The Water Current is printed in full color, including all photographs and graphics.

Virtual copies (PDF-format) of the newsletter are on-line at http://watercenter.unl.edu.

OTHER PRINT RESOURCES:

Water Center informational brochures. Updated as needed to provide overviews of the mission and programming of the UNL Water Center. Distributed free. Published in 2002 were full-color informational brochures on the Cooperative Ecosystems Studies (CESU) and Ecology and Evolutionary Biology Program (EEAI). A complete redesign of the Water Center's informational brochure is in the works.

Water Center Pocket Directory. Published in 2002. It is a pocketsize brochure listing key NU, federal, state and local water resource agencies and points of contact. A quick guide to water professionals and assistance for the public. Distributed through the local Natural Resource District (NRD) and state offices.

Sixteen-page newspaper tabloids on wetlands and drinking water issues, respectively published in 1997 and 1999 continue to be used by a variety of university programs, 4-H, FFA, state agencies and the public schools in natural science curriculums and educational programs on these issues. Distributed free (in quantity).

Calendar. For the first time, the Water Center cooperatively funded and developed a promotional wall calendar with the University of Nebraska's Conservation and Survey Division. NU archival photographs have been used and the calendar celebrates the history

and successes of both the Water Center and Conservation and Survey Division. These will be distributed at conferences, tours and open houses.

A range of water-related publications produced outside the UNL Water Center are also made available in print and/or electronic versions, most at no charge, through the Water Center's web site.

NEWS RELEASES:

The Water Center writes and publishes about 25 press releases annually based on research, cooperative extension, teaching and public outreach programming sponsored or co-sponsored by the Water Center. They are used to announce conferences, seminars, summer festivals, tours, waste pesticide collections and other activities as well as to publicize recent research results. These are widely published in state newspapers, as well as in organizational, trade and professional journals. The releases support a wide variety of UNL water-related research and programming that crosses department lines and is interdisciplinary in nature.

ELECTRONIC RESOURCES:

Electronic versions of newsletters and other print materials, RFPs, information about the Water Center and its research faculty, information about the Water Sciences Laboratory and course information for graduate and undergraduate students in water-related fields of study are available at http://watercenter.unl.edu. The Water Center co-sponsors four additional sites: the UNL Water Sciences Laboratory, the Platte Watershed Program, the UNL Department of Agronomy and Horticulture's Festival of Color and the UNL-based Cooperative Eco-Systems Study Unit (CESU). Each of these is program specific. Many free water-related publications and other resources are available through these sites. They can be found at:

***UNL Water Sciences Laboratory*:** http://www.ianr.unl.edu/waterscience/wsl.html

Cooperative Eco-Systems Studies Unit (CESU): This site went on-line earlier this year at

Ecology and Evolutionary Biology: This site also went on-line earlier this year at http://ecology.evolution.unl.edu/

UNL Groundwater Chemistry Laboratory: http://csd.unl.edu/csd/staff/harvey/lab.html

The Water Center's web site was extensively redesigned in late 2000. It is actively maintained and frequently updated. Faculty members now have their own web page and there are links to current research, academic programs for undergraduate and graduate students, extension and outreach programming, water-related links, and much more.

Vastly increased use of color and graphics was part of the site redesign. A PDF-format, virtual copy of the *Water Current* newsletter was added.

CONFERENCES, SEMINARS AND TOURS:

Nebraska Water Conference normally conducted in March and co-sponsored by the Water Center, Nebraska Water Conference Council and other academic, commercial and non-profit organizations. The conference attracts about 200 speakers and participants. News releases, brochures and a program are produced for this event.

Water Resources Seminar Series is a series of 12 to 14 public lectures held from January to April each year and co-sponsored by the Water Center and other NU departments and concerns. The series may be taken for graduate or undergraduate student credit or as a free public series. News releases, mailings and brochures are produced in conjunction with this event. This year's seminar was held in conjunction with the NU Conservation and Survey Division and other UNL departments.

Summer Water and Natural Resources Tour: Co-sponsored by the Water Center, Nebraska Water Conference Council and other NU, public, private and commercial entities. The annual three-day tour is conducted in June and is used to educate on current water and natural resource issues effecting Nebraskans. About 100 water users, legislators, ag producers and members of the public attend. News releases, mailings and a brochure are produced in conjunction with this event. This year's tour, held in late July, attracted a five-year high in attendance.

Annual Water Faculty Forum: Held for the first time in nearly three years in April 2002. The forum was revitalized as a means for gathering NU water-related faculty to spur discussion of interdisciplinary research, sharing of research results and progress and to showcase cooperative extension and outreach programs. Assisting research faculty to work cooperatively in attracting large, interdisciplinary research grants and funding was a prime goal of the forum. The event was attended by more than 40 NU water-related faculty, support staff and graduate students.

School of Natural Resource Sciences Research Colloquium: Held for the first time in 2002. A one-day symposium designed to give researchers, extension program leaders and graduate students the opportunity to present their work in front of their UNL colleagues, as well as for planning future research and programming collaborations. Co-sponsored and co-planed by the Water Center.

EDUCATIONAL DISPLAYS:

The Water Center makes frequent public displays in association with conferences, symposiums, water-related trade shows, educational open houses and water and environmental festivals. These average 8-10 per year.

Water Center staff participate as presenters in such educational festivals as The Groundwater Foundation's "Children's Groundwater Festival," NU's "Earth Wellness Festival," "Husker Harvest Days" and others.

PROMOTIONAL ITEMS:

Inexpensive promotional items such as coffee mugs, key chains, lanyards, etc. imprinted with the Water Center's new bi-color logo and web address and telephone numbers are produced for distribution in conjunction with educational programs/displays, student recruitment seminars, conferences and tours as funds are available.

PESTICIDE EDUCATION OFFICE:

The Water Center helps with publicity, promotion and press relations for programs conducted by the UNL Pesticide Education Office, which is part of the UNL Department of Agronomy and Horticulture. These efforts include press releases supporting statewide programs supporting pesticide container recycling and waste pesticide collections. The UNL Pest. Ed. office was formerly part of the Water Center until an administrative reorganization split the two.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	3	0	0	0	3
Masters	8	0	0	0	8
Ph.D.	2	0	0	0	2
Post-Doc.	3	0	0	0	3
Total	16	0	0	0	16

Notable Awards and Achievements

A poster titled "Assessment of Viral Contamination in Nebraska’s Small Community Wells," won second place in the poster competition at the 2001 American Water Works Annual Conference, Washington, DC. June, 2001. the poster was presented by Julie Fisher.

Publications from Prior Projects