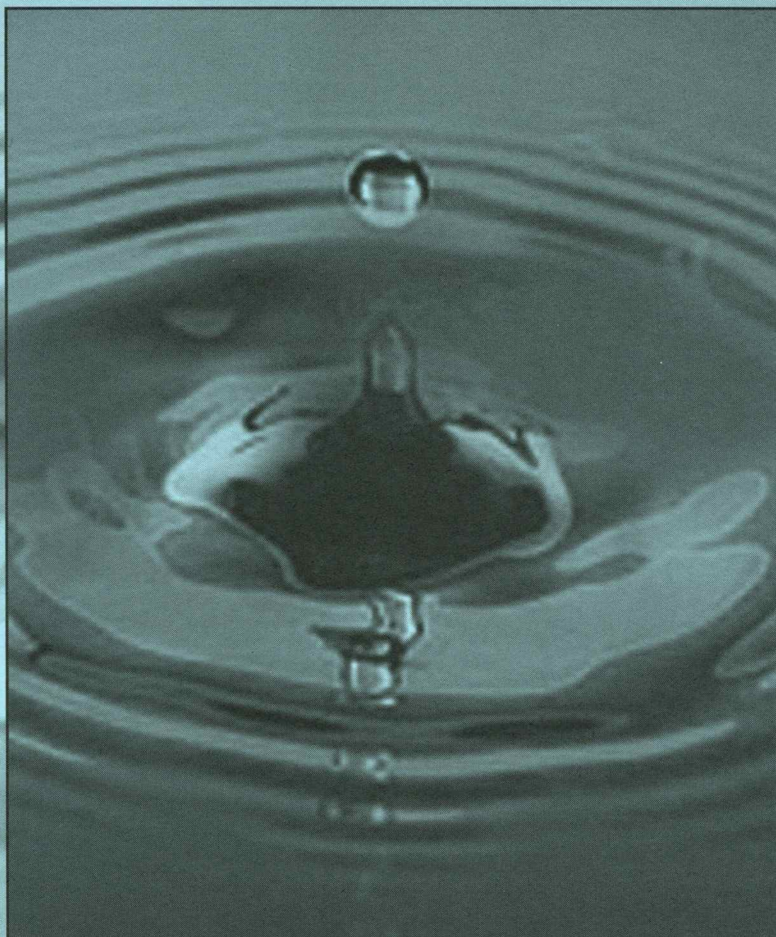
43rd Annual

October 12–14, 1998

Midwest Ground Water Conference



Host Agency: Kansas Geological Survey
Sponsoring Agencies:
Division of Water Resources, Kansas Department of Agriculture, Kansas Ground Water Association,
Kansas Department of Health and Environment, Kansas Water Office

Holiday Inn–Holidome
Lawrence, Kansas

43rd Annual Midwest Ground Water Conference

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Lawrence, Kansas

The Midwest Ground Water Conference began in 1956 in Urbana, Illinois, to promote the exchange of ideas and perspectives between state-supported ground-water professionals working in the midwestern states. Over the years, the meeting has continued to provide an informal setting for discussion and presentation of ground-water issues and research. Typically, a wide range of hydrologists, geologists, engineers, students, and others studying ground-water resources meet and exchange ideas, discuss mutual problems affecting the Midwest, and summarize results of field and laboratory studies. Papers are not published in order to encourage presentation of new ideas and on-going research. The conference is held at the invitation of one of the 14 states that have been the traditional participants: Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin.

The conference was held in Kansas in 1957, 1975, and most recently in Lawrence on October 1–3, 1984. We at the Kansas Geological Survey are happy to host the fourth meeting in Kansas and hope you enjoy your visit.

Planning Committee at the Kansas Geological Survey

Program Planning and Registration

Donald Whittemore, General Coordinator
Margaret Townsend
P. Allen Macfarlane
Melany Miller
Mark Schoneweis
Dana Adkins–Heljeson
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Field Trip

James Butler
David Young
Robert Sawin
Sharon Vaughn

Editing and Publication

Marla Adkins–Heljeson
Melany Miller
Jennifer Sims
Liz Brosius
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Donald Whittemore

In addition, we gratefully acknowledge the staff of the sponsoring agencies—the Kansas Water Office, the Division of Water Resources in the Kansas Department of Agriculture, the Division of Environment in the Kansas Department of Health and Environment, and the Kansas Ground Water Association—for distribution and mailing of the conference call for abstracts and program and registration sheets to selected mailing lists. We also thank the Kansas Ground Water Association for their coordination of the CEU credit program for qualified attendees at the Conference.

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Kansas Water Office

Conference Program

Monday, October 12, 1998

1:30 – 5:00 Field Trip
5:00 – 7:00 Conference Registration, Mixer, Poster Session Setup

Tuesday, October 13, 1998

7:00 – 8:10 Registration, Poster Session Setup (Continental breakfast)
8:10 – 8:30 Plenary Session
Introductions
Welcome: *William Harrison*, Deputy Director, Kansas Geological Survey
Announcements

Session I – Stream-aquifer Interactions / Aquifer Recovery

8:30 – 8:50 Equus Beds Aquifer Storage and Recovery Demonstration Project, South-central Kansas: *Mike Dealy, Jerry Blain,* and *David Stous*
8:50 – 9:10 Characterizing Stream-aquifer Relations in the Tributaries of the Republican River, Southwest Nebraska: *Gregory V. Steele*
9:10 – 9:30 Ground- and Surface-water Quality Interaction in the Lodgepole Creek Valley, Eastern Cheyenne County, Nebraska: *Jeffrey J. Gottula*
9:30 – 9:50 Effective Mitigation of a Rapid Dewatering Event Caused by Quarry Operations in the Dolomite Aquifer in Lannon, Wisconsin: *John Jansen, Wayne P. Fassbender, Patrick Jurcek, Laura L. Barreto,* and *Larry F. Boyer*

9:50 – 10:10 **Break**

Session II – Ground-water Quality Monitoring: Animal Waste Sites to State Networks

10:10 – 10:30 Are Large Hog Facilities a Risk to Ground Water?—Two South Dakota Case Histories: *Mike Meyer*
10:30 – 10:50 Ground-water Monitoring at Earthen Manure-storage Structures in Iowa: *Robert D. Libra, Deborah J. Quade,* and *Lynnette S. Seigley*

10:50 – 11:10	Ambient Ground-water Monitoring at Public Water-supply Springs and Wells in Kentucky: *Bill Yarnell, James Webb,* and *Peter Goodman*
11:10 – 11:30	Land Use and Shallow Ground-water Quality in Eastern Iowa and Southern Minnesota, 1997: *Mark E. Savoca*
11:30 – 11:50	South Dakota's Statewide Ground-water Quality Monitoring Network: *Derric Iles, Stan Pence,* and *Tom Rich*
12:00 –1:00	**Lunch** – provided

Session III A – Concurrent Session—Ground-water Quality: Monitoring and Nitrate Concerns

1:10 – 1:30	Water Quality in the Upper Fifteen Feet of a Shallow Sand Aquifer in a Variable Land-use Setting: *Mike Trojan* and *Minnesota Pollution Control Agency*
1:30 – 1:50	Subsurface Nitrate, Upper Big Blue Natural Resources District, Central Nebraska, 1995–97: *I. M. Verstraeten* and *V. L. McGuire*
1:50 – 2:10	Distribution of Nitrate–Nitrogen in Kansas Ground Water: *Margaret Townsend* and *Dave Young*
2:10 – 2:30	Use of Soil-moisture Nitrate Analysis to Quickly Develop Vertical Nitrate Profile in an Unconfined Sand Aquifer: *Justin L. Blum*

Session III B – Concurrent Session—Ground-water Modeling: Management and Capture Zones

1:10 – 1:30	Decision Support System for Water-resources Management: *Sreepathi R. Ramireddygari, James K. Koelliker, John C. Tracey,* and *Marios Sophocleous*
1:30 – 1:50	Management of Ground-water Resources in the Teays–Mahomet Bedrock Valley in East-central Illinois: *Tiraz Birdie, William Ratekin, John Jansen,* and *Paul McCormick*
1:50 – 2:10	Comparative Study of Five-year Time-of-travel Capture Zones for Community Water-supply Wells in Bethany, Hardin, and Nokomis, Illinois: *Samuel Boateng, Courtney Brooks,* and *Garry Stanley*
2:10 – 2:30	Three-dimensional Analysis of the Capture of a Contaminated Leachate by Wells: *David R. Steward*
2:30 – 2:50	**Break**

Session IV A – Concurrent Session—Ground-water Quality: Pesticides

2:50 – 3:10	Herbicide Transport from River through Aquifer into Municipal Collector Wells: *I. M. Verstraeten, J. D. Carr, G. V. Steele, E. M. Thurman, K. C. Bastian,* and *D. F. Dormedy*
3:10 – 3:30	Pesticides in Shallow Alluvial Aquifers in Agricultural and Urban Areas in Eastern Iowa and Southern Minnesota: *E. M. Sadorf*
3:30 – 3:50	Occurrence of Acetanilide Herbicide Metabolites in Tile Runoff and Ground Water: *E. M. Thurman, D. W. Kolpin, S. J. Kalkhoff,* and *P. J. Phillips*
3:50 – 4:10	An Examination of Pesticide Occurrence in Large-diameter Wells—Are High Detection Rates Related to On-field Applications?: *H. Allen Wehrmann, M. E. Caughey, J. R. Karny, T. R. Holm, E. Mehnert, D. A. Keefer,* and *W. S. Dey*

Session IV B – Concurrent Session—Mapping, GPS, and GIS Applications

2:50 – 3:10	Use of Reported Water-level Values to Map Regional Ground-water Flow Systems in Michigan: *Thomas McClain, Matt Malone,* and *Richard Hill–Rowley*
3:10 – 3:30	Selecting Monitoring-well Locations Using GIS: *Jim Stockinger, Minnesota Pollution Control Agency*

3:30 – 3:50 Incorporating GPS, GIS, and On-site QC into the Kansas Water-level Measurement Program: *John Siceloff, Rick Miller, Brett Bennett,* and *David Laflen*

3:50 – 4:10 GIS Applications in Assessing Waste Disposals and Contaminant Releases for Ground-water Impacts: *Ronald C. Spong*

Session V – Poster Session

4:10 – 5:30 View and discuss posters with authors

Irrigation Reuse Systems Relationship to Ground-water Quality and Crop-nitrogen Budget: *D. D. Adelman*

Changes in Ground-water Levels and Storage in the Wichita Well Field Area, South-central Kansas, 1940–1998: *Walter R. Aucott* and *Nathan C. Meyers*

Kansas Minimum Design Standards for Onsite Wastewater Systems: *Debra Baker, Barbara Dellemand,* and *Morgan Powell*

Application of GIS in Water-quality Risk Assessment in the Battle Creek Watershed, Ida County, Iowa: *G. A. Hadish, J. C. Jennings, C. E. Brockmann,* and *L. Miller*

WIZARD—A Ground-water Information System for Kansas: *Günther Hausberger, Gina Ross,* and *John Davis*

Groundwater Guardian Affiliates: *Robert D. Kuzelka, Susan S. Seacrest, Cindy Kreifels,* and *Rachael Herpel*

A Study of Ground-water Flow and Ground-water/Surface-water Interaction in the Republican River Basin, Southwest Nebraska, Northwest Kansas, and Northeast Colorado: *Matthew K. Landon*

Pilot Testing of Oxygen-release Compound Efficacy in Reducing Aquifer BTEX Contamination: *Peter G. Muckenhaupt*

Boundary-layer Analysis of Aquifer Mineralization by Paleodrainage Channels: *Hillel Rubin* and *Robert Buddemeier*

Multidisciplinary Assessment of Salinity Patterns Along Rattlesnake Creek in South-central Kansas: *R. O. Sleezer, D. P. Young,* and *R. W. Buddemeier*

Modeling and Risk Assessing the Impact of Small Kansas Landfills on Underlying Aquifers: *Marios Sophocleous*

Sustainable Development of Water Resources in Kansas: *Marios Sophocleous*

An Interactive System with Automatic Calibration for Ground-water Modeling: *M.-S. Tsou and D. O. Whittemore*

Arkansas River Corridor Study in Southwest Kansas: *D. O. Whittemore, M.-S. Tsou, D. P. Young, and J. Grauer*

Subbasin Water-resources Management Program: *Deborah Zarta Gier, Shannon Rothchild, Chris Gnau, Iona Branscum, Alan Weinbrenner, Jeff Lanterman, and Julie Grauer*

5:30 – 6:30 **Cash bar**

6:30 – 7:30 **Banquet**

7:30 **Invited Speaker – James E. Sherow**
Kansas State University, Department of History

Wednesday, October 14, 1998

7:00 – 8:00 Continental breakfast

Session VI A – Concurrent Session—Aquifer Characterization: Aquifer Test, Tracer, and Seismic Methods

8:00 – 8:20 Slug Tests in Extremely Permeable Aquifers: *Carl D. McElwee*

8:20 – 8:40 Local-scale Aquifer Characterization Using Single-well Tracer Methods: *Stephen H. Hall*

8:40 – 9:00 High-resolution Seismic-reflection Survey to Map Bedrock and Glacial/Fluvial Layers at the U.S. Navy Northern Ordnance Plant (NIROP) in Fridley, Minnesota: *Richard D. Miller* and *Jianghai Xia*

Session VI B – Concurrent Session—Ground-water Quality: Recharge and Contamination Studies

8:00 – 8:20 Equus Beds Ground-water Recharge Demonstration Project, South-central Kansas—Baseline Water Quality and Preliminary Effects of Artificial Recharge on Ground-water Quality: *Andrew C. Ziegler, Victoria G. Christensen,* and *Heather C. Ross*

8:20 – 8:40 Volatile Organic Compounds in Shallow Ground Water and a Stream in the Twin Cities Metropolitan Area, Minnesota, 1996–98: *Alison L. Fong* and *James D. Fallon*

8:40 – 9:00 Sample Collection and Field Determination of Ambient Redox Parameters for Use in Assessing Site Suitability for Natural Attenuation of Contamination by Chlorinated Ethenes: *Timothy Tolle MacDonald*

9:00 – 9:20 **Break**

Session VII A – Concurrent Session—Water Information Systems, Assessment, and Management

9:20 – 9:40 Tear Down the Wall! Developing a Water Information Program: *Mark Bamberger* and *Edward (Ned) Pennock*

9:40 – 10:00 Source-water Assessment as a Result-oriented Activity for Groundwater Guardians: *Robert D. Nuaelka, Susan S. Seacrest, Cindy Kreifels,* and *Rachael Herpel*

10:00 – 10:20 Water-use Permitting and Management of Water Resources in Kansas: *William J. Gilliland*

Session VII B – Concurrent Session—Ground-water Quality: Land Use and Pollution Indices

9:20 – 9:40 Ground-water Quality in Unconfined Glacial Aquifers in Part of the Upper Mississippi River Basin—The Influence of Land Use: *James R. Stark, Alison L. Fong,* and *William J. Andrews*

9:40 – 10:00 The Use of Drastic in the Delineation of Potential Pollution Sites in Lagrange, Indiana: *Solomon Isiorho*

10:00 – 10:20 A Comparison of Ground-water Nitrate Pollution Risk Indices—An Example from the Equus Beds Aquifer in Central Kansas: *R. O. Sleezer* and *R. E. Bassler*

Session VIII – Concurrent Workshops and Discussion

10:25 – 11:55 State Ground-water Monitoring Networks

10:25– 11:55 Effects of Confined Animal-waste Storage and Disposal on Ground Water

11:55 – 12:00 Closing comments (at the end of both workshop sessions)

Post Conference Workshop

1:00 – 5:00 Continuation of State Ground-water Monitoring Networks (at Kansas Geological Survey)

43rd Annual Midwest Ground Water Conference

Abstracts

Equus Beds Aquifer Storage and Recovery Demonstration Project, South-central Kansas

Mike Dealy[1], Jerry Blain, P.E.[2], and David Stous, P.E., P.G.[3]
[1]Equus Beds Groundwater Management District No. 2, 313 Spruce Street, Halstead, Kansas 67056-1925, 316/835-2224, equusbed@ink.org
[2]City of Wichita, 1815 W Pine, Wichita, Kansas 67202, 316/268-4964
[3]Burns and McDonnell Engineering Company, 9400 Ward Parkway, Kansas City, Missouri 64114, 816/822-3088, dstous@burnsmcd.com

The Equus Beds Bank Storage Utilization and Groundwater Recharge Demonstration project is a phased, small-scale $7 million trial project to investigate the feasibility of aquifer storage and recovery (ASR) using a river's bank-storage water, when it is available, as a source of water for ground-water recharge. If testing is successful, a full-scale $106 million recharge, storage, and recovery project is planned to capture 60 million gallons per day (MGD) from bank storage along the Little Arkansas River and recharge it in the Equus Beds aquifer. The full-scale project is a key part of an integrated water-supply plan under consideration by the City of Wichita that will provide additional water supply to the City and nearby communities through the year 2050.

The Little Arkansas River and the Equus Beds aquifer are located in south-central Kansas. The aquifer is the area's principal source of fresh and usable water and is about 1,400 mi^2 (3,630 km^2) in size. The aquifer is part of the High Plains aquifer system and is managed by the Equus Beds Groundwater Management District No. 2 (GMD2) in cooperation with State and Federal agencies. The City is currently pumping approximately 45 MGD from 55 wells completed in the Equus Beds aquifer. The wellfield is located within a 100-mi^2 (260-km^2) area that was overdeveloped, causing water-level declines ranging from 10 to 30 ft (3–9 m). Additionally, the aquifer is threatened by intruding saltwater from natural and human-made sources.

The ASR project includes the capture of bank-storage water and surface water from the Little Arkansas River during "above-base" flow conditions, the transfer to and storage of captured water in the aquifer, and the recovery and use of this captured water to meet City demands. The full-scale project will benefit all users of the Equus Beds aquifer by (1) replenishing up to 104 billion gallons (319,000 acre-feet) of water to aquifer storage for use by the City during times of drought, (2) reducing power costs for pumping because of higher ground-water levels, and (3) creating a hydraulic barrier in the aquifer and preventing water-quality deterioration from saltwater intrusion from natural and human-made sources.

Demonstration facilities will evaluate several methods of recharge including recharge trenches, basins, and a recharge well. Two systems are constructed, one using bank-storage water and the second using surface water diverted from the river and treated to remove turbidity and atrazine. Nearly 300,000,000 gallons of bank storage have been recharged and about 22,000,000 gallons of surface water have been treated and recharged. Through March 1998, over 3,200 water samples have been analyzed to document background conditions and operational impacts. Approximately $2 million has been budgeted for water-quality sampling and analysis. The demonstration facilities will be operated over a 2- to 3-year period to collect operational data, establish design criteria for the full-scale facilities, ultimately confirm the feasibility of the project, and collect sufficient data for GMD2 and State approvals.

The primary demonstration project sponsors are the City of Wichita and the Bureau of Reclamation. Additional participants are the U.S. Geological Survey, the Equus Beds Groundwater Management District No. 2, and the U.S. Environmental Protection Agency. Work is closely coordinated with the Kansas Department of Health and Environment, the Kansas Water Office, and the Kansas Department of Agriculture, Division of Water Resources.

Characterizing Stream-aquifer Relations in the Tributaries of the Republican River, Southwest Nebraska

Gregory V. Steele
U.S. Geological Survey, Room 406 Federal Building, 100 Centennial Mall North, Lincoln, Nebraska 68508, 402/437-5509, gvsteele@usgs.gov

In 1997, the U.S. Geological Survey, in cooperation with the Southwest Nebraska Resource Conservation and Development Area, began a four-year study to quantify the stream-aquifer relations in the Republican River valley. As part of this study, 18 well nests were installed in 1998 at three sites along tributaries of the Republican River in Nebraska (Frenchman Creek near Champion, Frenchman Creek near Palisade, and Sappa Creek near Stamford). These three sites were selected to characterize the ground-water flow in the alluvial valleys of the Republican River tributaries. On Frenchman Creek, the Champion site represents areas downstream of surface-water impoundments, the Palisade site represents rangeland to irrigated farmland, and the Sappa Creek site represents areas of predominately irrigated farmland. At each site there are two transects of wells; each transect consists of three well nests (one near each of the tributary's alluvial valley walls, and a third midway between the other two). Each well nest is composed of one shallow well screened at the water table, one deep well screened at the bottom of the aquifer, and one well screened about midway between the other two.

Review of preliminary data indicates that a strong stream-aquifer relation exists at the Frenchman Creek sites. At the Champion and Palisade sites, ground-water levels rose abruptly in wells adjacent to and nearly 800 ft (240 m) from Frenchman Creek following rapid changes in stream stage. In addition, bank storage, following rises in stream stage, appears to be an important component of streamflow in Frenchman Creek. Preliminary data show that the stream-aquifer relation at the Sappa Creek site is not as strong as at the Frenchman Creek sites. The stream stage of Sappa Creek did not correlate well with large changes in ground-water levels recorded at nearby observation wells.

Ground- and Surface-water Quality Interaction in the Lodgepole Creek Valley, Eastern Cheyenne County, Nebraska

Jeffrey J. Gottula
Nebraska Department of Environmental Quality, P.O. Box 98922, Lincoln, Nebraska 68509-8922, 402/471-0096, deq077@mail.deq.state.ne.us

Ground- and surface-water quality in the Lodgepole Creek valley reflects the source(s) of the water, chemical processes, and contributions from point and nonpoint contamination occurring in the valley. Lodgepole Creek is an interrupted stream that contains perennial reaches with intervening intermittent or ephemeral reaches. Each flowing reach has segments where the stream gains and loses water to ground water. The interaction of the stream with ground water was observed as part of a regional water-quality study in eastern Cheyenne County conducted in 1996 to identify the source of elevated nitrates in ground water.

Attempts to observe the interaction of ground- and surface-water quality were included in order to account for important sources of nitrogen in the valley. Most of the perennial-stream reaches flow due to ground-water discharge, but one reach has surface-water flow primarily as a result of discharge from the City of Sidney's wastewater-treatment facility. Surface-water quality in this reach is distinctly different from that of ground water although the influence of surface-water quality on ground water is evident. Elevated nitrate, chloride, and sodium in ground water were identified in that portion of the valley. Some, if not all, of the chloride and sodium and possibly some of the nitrate contamination of ground water resulted from surface-water losses to ground water in that reach.

Evidence of ground-water contamination from nonpoint sources was also observed in the valley. Elevated nitrates were observed in ground water in two other segments of the valley where irrigated agriculture was the predominant land use. Surface-water quality in those segments was very similar to ground-water quality except for nitrates, which were not elevated in surface water. Attenuation of nitrogen species may be occurring at the stream-sediment interface or in shallow sediments underlying the stream bottom.

Effective Mitigation of a Rapid Dewatering Event Caused by Quarry Operations in the Dolomite Aquifer in Lannon, Wisconsin

John Jansen[1], Wayne P. Fassbender[2], Patrick Jurcek[3], Laura L. Barreto[2], and Larry F. Boyer[2]
[1]Layne GeoSciences, Inc., 1900 Shawnee Mission Parkway, Mission Woods, Kansas 66205, 913/362-9906
[2]Graef, Anhalt, and Schloemer
[3]Layne Northwest

Two quarries are mining stone from the dolomite aquifer in the Village of Lannon, Wisconsin. This aquifer supports almost all the private wells within approximately 20 mi (32 km) of the quarries, including the domestic wells supplying the Village residents. The Village has used local zoning to control the depth of mining and to institute a long-term water-level monitoring program and well-guarantee zone with the quarry owners.

This monitoring network has been in effect for over 10 years. During this time, water levels have dropped in a regular and largely predictable manner as the quarries were deepened. However, in November 1996, in at least 24 residential wells surrounding the quarries, water levels dropped several feet up to 40 ft (12 m) over a period of a few hours to about three days. The background data provided by the monitoring-well data allowed the Village to identify the complaints of homeowners without water as one significant correlated event as opposed to an unrelated series of unreliable complaints by disgruntled homeowners. The data also provided a time line for the event and a mechanism to obtain more detailed information during the event.

After consultation with the quarries, we concluded that the rapid decline in head was caused by a single boring drilled to a depth of 75 ft (23 m) below the floor of one quarry. The borehole penetrated a localized fracture zone under confined artesian head. The borehole was pressure-grouted under supervision by the Village, and water levels recovered to previous static levels within nine days after grouting the borehole.

The rapid drawdown event demonstrates the potential impact that mining in fractured aquifers can have on surrounding wells. Encountering small fracture zones or voids can cause sudden in-flow and a rapid drop in head. The apparent complete recovery of the aquifer demonstrates that quick response can sometimes restore an aquifer. However, had the quarry blasted or mined into this zone, the loss in head would probably have been irreversible unless the quarry was abandoned.

The potential for blasting into a similar zone illustrates the need for a properly designed aquifer-monitoring program and emergency-response plan. All parties have agreed that vertical expansion of the quarries is unwise. They are currently discussing improved monitoring strategies to allow the quarries to expand laterally without significant risk to the aquifer. In addition, the issues of quarry abandonment and restoration, with particular concern for protecting water quality, are being linked to the continued operation of the quarries to provide for the long-term interest of all parties. The experience of the Village is a good example of the problems of managing conflicting uses of a finite resource and the importance of collecting baseline data needed to make informed decisions.

Are Large Hog Facilities a Risk to Ground Water?—Two South Dakota Case Histories

Mike Meyer, PG
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Plans to construct numerous, large-scale, concentrated swine operations in South Dakota have created public concern as to environmental risks, including contamination of ground water.

The main ground-water risk from hog wastes is nitrates. Although hog manure has large concentrations of nitrogen, it is mostly ammonia and organic N with virtually no nitrates. These wastes have a very high oxygen demand (BOD). Where oxygen is lacking, conversion of organic N to nitrate (nitrification) is difficult.

Two case histories are reviewed. One hog facility includes a clay-lined lagoon and concrete confinement buildings. This facility was built over a former barnyard. Elevated nitrates and sulfates in the farm well and monitoring wells reflect past contamination from barnyard wastes and not seepage from the lagoon or buildings. By contrast, high ammonia, low sulfates, and low nitrates indicate manure effluent.

At the second facility, the State expressed concern as to nitrates in monitoring wells near the concrete lagoon and buildings. This case showed elevated nitrates are widespread in the aquifer near the facility, mainly from commercial fertilizer use. Based on low chlorides, low TDS (at background concentrations), and nitrogen isotopes, the facility does not appear to be leaking.

It is concluded that large-scale confined hog operations are not likely to be a major source of ground-water contamination in the state. These sites must be over a shallow aquifer to be a potential ground-water risk. Even over shallow aquifers, only very localized plumes appear likely and nitrate risks appear minimal. The main ground-water risk appears to be excessive land application. Surface spills and odors appear to be the main concerns with large hog-feeding operations.

These case histories emphasize the importance of collecting ground-water-quality data from nearby private and site wells before constructing the facilities. Elevated nitrate concentrations are common in many aquifers and typically do not indicate manure effluent seepage.

Ground-water Monitoring at Earthen Manure-storage Structures in Iowa

Robert D. Libra, Deborah J. Quade, and Lynnette S. Seigley
Iowa Department of Natural Resources, Geological Survey Bureau, 109 Trowbridge Hall, Iowa City, Iowa 52242

Ground water has been monitored monthly since 1994 at three earthen manure-storage (EMS) structures. Seepage of waste liquid has been detected at all downgradient wells at the DML (basin) and IES (two-cell lagoon) sites. Indications of seepage are similar and include the decline or loss of nitrate-N and sulfate, and an increase in concentrations of chloride and total organic carbon. Chloride concentrations in the closest well at the DML site are 40% of those measured in the liquid waste; at the IES site, concentrations at the closest well equal those in the waste. Fecal coliform bacteria have been sporadically detected in the closest well at one site. Concentrations of nutrients, such as ammonia-N, initially did not increase, indicating these species were being retained by cation exchange. However, ammonia-N concentrations have recently shown increases, suggesting the exchange capacity is being depleted. Organic-N concentrations have increased and are typically higher than ammonia-N concentrations. Exchange reactions that limit ammonia-N transport result in a build-up of ammonia-N beneath an EMS. At the allowable seepage rate of 1/16th inch/day, a basin such as used at the DML site (4,500-head hog-finishing operation) would add 5,300 pounds of ammonia-N to the glacial materials beneath the 1/2-acre (0.2 ha) basin annually.

Ambient Ground-water Monitoring at Public Water-supply Springs and Wells in Kentucky

Bill Yarnell, James Webb, and Peter Goodmann
Kentucky Division of Water, Groundwater Branch, 14 Reilly Road, Frankfort, Kentucky 40601, 502/564-3410

Since 1995, the Groundwater Branch of the Kentucky Division of Water has sampled source water at more than 50 public water-supply springs and wells throughout the state as part of its statewide ambient ground-water-monitoring program. Most sites are sampled quarterly, and 14 quarters of data have been collected to date. Among the parameters monitored are nutrients, major inorganic ions, metals, and pesticides, including atrazine, alachlor, metalachlor, simazine, and cyanazine.

The purposes of this monitoring are to assess ambient ground-water quality, nonpoint-source pollution impacts, and ground-water-quality trends; to identify existing or potential source quality problems; to provide an early warning system to public water supplies of possible source problems; to evaluate surface/ground-water interactions; and to provide monitoring support for various State and Federal regulatory programs. Several sites have active Well Head Protection programs that benefit from ambient ground-water monitoring.

Sites are located throughout the state and are representative of six of Kentucky's physiographic provinces: the Mississippian embayment of the Gulf Coastal Plain (or Jackson Purchase), the Western Kentucky coal field, the Mississippian Plateau, the Inner Bluegrass, the Eastern Kentucky coal field, and the Ohio River alluvium. Flow regimes vary from predominantly fracture flow in the coal fields, to solution cavity/conduit flow in the karst areas of the Bluegrass and the Mississippian Plateau, and granular flow in the Jackson Purchase and the Ohio River alluvium.

Nitrate and pesticide levels were generally highest in the karst areas, where flow through solution cavities and conduits is dominant. In addition, these karst areas, especially the Mississippian Plateau, are areas of high row-crop production and fertilizer/pesticide use. Nitrate and pesticide levels were below detection limits in the Eastern Kentucky coal field. In areas of granular flow, primarily the Jackson Purchase and Ohio River alluvium, nitrate levels varied from below detection limits to above the MCL. Pesticides were rarely detected in these areas. Throughout the study area, no correlation was seen between the occurrence of pesticides and nitrates. Land use and flow regime appear to be the primary factors controlling the occurrence of nitrates and pesticides.

Land Use and Shallow Ground-water Quality in Eastern Iowa and Southern Minnesota, 1997

Mark E. Savoca
U.S. Geological Survey, 400 South Clinton Street, Iowa City, Iowa 52240

The relation between land use and shallow ground-water quality in alluvial aquifers was investigated in the Eastern Iowa Basins study area as part of the U.S. Geological Survey's National Water Quality Assessment Program. The program is designed to assess the status and trends in the quality of the nation's water resources and to better understand the natural and human factors affecting water quality. The study area includes the Wapsipinicon, Cedar, Iowa, and Skunk River basins, and extends over an area of 19,500 mi^2 (50,500 km^2) in eastern Iowa and southern Minnesota. Alluvial aquifers cover about 22% of the study area. About 85% of the area covered by alluvial aquifers is used for agricultural activities, and about 3% is used for urban activities. Ground-water samples were collected from shallow monitoring wells completed in saturated alluvial deposits during the summer of 1997. Thirty-one wells were located within agricultural land-use areas, and 30 wells were located in urban areas. Well depths ranged from 10 to 32.5 ft (3–9.9 m).

Nitrate ($NO_2^- + NO_3^-$), major ion, and volatile organic compound (VOC) concentrations in shallow ground water reflect differences in land use. Nitrate concentrations were greater in agricultural land-use areas, while sodium, chloride, and sulfate concentrations were found to be greater in urban areas. Four

VOC compounds were detected in samples from agricultural areas, but 34 compounds were detected in samples from urban areas.

Median nitrate concentrations were significantly greater in samples from agricultural areas (5.13 milligrams per liter or mg/L) than in urban areas (1.83 mg/L). Nitrate concentrations exceeded the U.S. Environmental Protection Agency's Maximum Contaminant Level for drinking water of 10 mg/L in 39% of samples from agricultural areas and in none of the urban samples. Median sodium, chloride, and sulfate concentrations were significantly greater in samples from urban areas (23 mg/L, 41.5 mg/L, and 45 mg/L) than in agricultural areas (5.6 mg/L, 12 mg/L, and 22 mg/L). VOC's were detected in 19% of agricultural and 37% of urban land-use wells. Toluene was the most commonly detected (16%) VOC in samples from agricultural areas and methyl tert-butyl ether (MTBE), a fuel oxygenate, was the most commonly detected (23%) VOC in urban areas.

South Dakota's Statewide Ground-water Quality Monitoring Network

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South Dakota has designed and implemented a statewide network that is unlike any other in the region for the assessment of shallow ground-water quality, including nonpoint-source pollution. The goal of this monitoring effort is to systematically examine the water quality and determine if any changes are occurring. While designing this monitoring network, it was necessary to anticipate the state's needs and to make the resulting monitoring network and information as usable as possible for the greatest number of people.

Two key reasons why this proactive monitoring was needed are (1) to help formulate sensible and workable regulations for South Dakota, based on information from South Dakota's aquifers, rather than information from some other part of the country, and (2) to facilitate early recognition of water-quality problems and to allow preventative measures to be taken.

The initial four-year phase of well installation has been completed and has resulted in 146 water-quality monitoring wells at 80 sites in 24 shallow aquifers. The aquifers being monitored cover much of South Dakota and are among the most likely to be impacted by human activities because of their near-surface occurrence combined with overlying land use. Each water-quality monitoring well in the network will contain dedicated sampling equipment, drastically reducing manpower needs and ensuring representative samples. Ground-water samples from the network are being tested for items important in drinking-water considerations such as major ions, trace metals, radionuclides, volatile organic compounds, and pesticides.

Results of this comprehensive monitoring have shown areas of elevated nitrate concentrations in shallow aquifers. Also, the results of nearly 1,000 water-sample analyses have shown limited pesticide detections. Future work will include an examination of pesticide metabolites to ensure the water is safe for drinking.

Water Quality in the Upper Fifteen Feet of a Shallow Sand Aquifer in a Variable Land-use Setting

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In 1996 the Minnesota Pollution Control Agency began a study to investigate effects of land use on ground-water quality of a shallow, surficial sand and gravel aquifer. The 30 mi^2 (78 km^2) study area is located near St. Cloud, a rapidly expanding metropolitan area of 60,000 people located in central Minnesota. Results for 1997 from a monitoring network of 44 shallow and deep wells revealed impacts from all land uses and a three-dimensional distribution of many chemicals in the aquifer. To enhance information collected from the monitoring network and determine if the network is adequate to achieve the study goals, 35 sites were selected for geoprobe analysis. Samples for major cations and anions, volatile organic compounds (VOC's), pesticides, and some trace inorganics were collected between March and June 1998. Field measurements were made to assess geochemical conditions within the upper portion of the aquifer. Samples were collected at the water table at all 35 sites and at depths of 7.5 and 15 ft (2.3 and 4.6 m) below the water table at 17 sites. Concentrations of most chemicals were greater under all land uses compared to undeveloped land-use settings. Nitrate was the chemical of greatest concern, with concentrations near or above the drinking-water criteria under irrigated agriculture, nonirrigated corn or soybeans, and unsewered developments. VOC's, primarily gasoline-related compounds, were detected at 80% of the urban sites.

Concentrations of nitrate decreased rapidly with depth, in response to decreasing oxidation-reduction potential and increased organic carbon. Standard deviations in geoprobe samples differed from those in monitoring wells by 11%. The monitoring network appears to be representative of water quality under different land-use settings, and sampling from the existing network will continue for several years.

Subsurface Nitrate, Upper Big Blue Natural Resources District, Central Nebraska, 1995–97

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Following the ground-water Special Protection Area designation in 1993 by the Nebraska Department of Environmental Quality, a ground-water-quality monitoring network of 197 domestic and registered wells, eight nested monitoring wells, and associated unsaturated-zone subsites was established for the Upper Big Blue Natural Resources District (UBBNRD) by the U.S. Geological Survey. The principal aquifers are the High Plains and Dakota aquifers. The ground-water samples had a median nitrate concentration of 4.6 mg/L, with median nitrate concentrations in the unconfined and the confined part of the High Plains aquifer of 6.2 and 2.9 mg/L, respectively. Water samples from the Dakota aquifer had a median nitrate concentration of 0.11 mg/L. Twenty-one percent of the samples exceeded the U.S. Environmental Protection Agency Maximum Contaminant Level of 10 mg/L for nitrate as nitrogen. Among the 12 UBBNRD management zones established to manage water quantity and quality, the median nitrate concentrations varied from 0.97 mg/L in zone 12 to 10 mg/L in zone 5, the latter exceeding the UBBNRD's Phase II trigger of 9 mg/L. Tritium data for ground water suggest that the shallow part of the High Plains aquifer likely was recharged during the last 10 to 20 years, while the deeper, confined part of the High Plains aquifer likely was recharged more than 50 years ago. The median nitrate concentration of 245 unsaturated-zone samples was 3.7 mg/kg. Nitrate concentrations in the unsaturated zone below grassland generally were smaller than below cropland and those below irrigated land were smaller than below nonirrigated land, potentially caused by increased flushing under irrigated land.

Distribution of Nitrate-Nitrogen in Kansas Ground Water

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Nitrate in ground water is a potential problem in many parts of Kansas. From 1990 to 1998, 780 water samples were collected from domestic, irrigation, monitoring, and public water-supply wells for numerous studies conducted by the Kansas Geological Survey. Of all the samples, 30% of the wells have nitrate-N concentrations <3 mg/L; 50% of the wells have concentrations between 3 and 10 mg/L; and 20% of the wells have concentrations >10 mg/L. Nitrogen-15 isotope values were used in a number of studies to determine sources for the observed nitrate-N in the ground water. A total of 111 samples were analyzed for nitrogen-15. Of those samples, 28% were in the δN-15 range of +2 to +8 ‰ which is indicative of fertilizer sources; 23% were in the δN-15 range of +8 to +10 ‰, which is indicative of mixed sources; and 49% were in the δN-15 range ≥ +10 ‰, which is indicative of animal waste sources (including feedlots and septic tanks). Factors that show a relationship to the nitrate in ground water in smaller-scale studies in Kansas include depth to water, depth of well, soil type, land use, fertilizer use, crop grown, irrigation-well density, well construction, and age of well. These factors, as well as geographic region, are evaluated in this statewide assessment.

Use of Soil-moisture Nitrate Analysis to Quickly Develop Vertical Nitrate Profile in an Unconfined Sand Aquifer

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The public water-supply wells in Perham, Minnesota, are affected by nitrate contamination very close to the drinking-water criteria of 10 mg/L. Ground-water flow modeling has been performed as a part of wellhead protection-plan development. The model is assisting the City in its search for additional supplies of clean drinking water. Nine deep borings were drilled to obtain soil samples in the area of existing contamination and in the area designated for water-system expansion. Pore moisture in the soil samples was analyzed for nitrate to develop a vertical profile of nitrate concentrations. Monitoring wells were installed subsequently and sampled to verify the pore-water analyses. This information was used to characterize the source of nitrate contamination, to optimize pumping of existing wells to maintain concentrations of nitrate below the drinking-water critera, and to quickly verify the cleanliness of water in the area of the prospective new well(s). Information from the monitoring wells will also be used to improve the ground-water flow model and wellhead-protection plan.

Decision Support System for Water-resources Management

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The Rattlesnake Creek basin in the Great Bend Prairie of south-central Kansas has experienced various water problems in recent years. These problems include surface-water depletions, ground-water declines, and deterioration of the quality of water. A comprehensive, integrated numerical model for simulating surface-water flow, ground-water flow, and stream-aquifer interactions on a continuous basis has been developed. This model provides a tool for evaluating long-term management strategies. The well-established surface-water flow model SWAT and the ground-water flow model MODFLOW were utilized for constructing the comprehensive combined model SWATMOD. In order to construct a representative and reliable simulator of the Rattlesnake Creek basin, the model was calibrated and validated using the historical data (streamflows and ground-water-level observations).

The SWATMOD model is complex and data-intensive. Therefore, a graphics-based, user-friendly pre- and post-processor program, named Decision Support System (DSS), was developed. The DSS enables the user to conveniently modify model conditions and water-withdrawal patterns, perform simulations, and view the hydrologic impact of such modifications on streamflows and ground-water levels. The DSS is useful in examining various long-term management scenarios, and effective management strategies can be developed for more efficient management of water resources in the basin. A brief overview of the model and important features of the DSS will be presented.

Management of Ground-water Resources in the Teays–Mahomet Bedrock Valley in East-central Illinois

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The Teays–Mahomet bedrock valley, extending from West Virginia to Illinois, is a primary source of ground water in east-central Illinois. Being a deep buried aquifer, it is not as extensively studied as the less productive glacial deposits above it. No firm estimates of ground-water flow within the valley in east-central Illinois exist. The City of Urbana–Champaign is the major user of ground water from the buried valley withdrawing approximately 17 MGD on an average daily basis. The city of Decatur, Illinois, recently constructed a 25-MGD wellfield in the Mahomet Valley for municipal and industrial purposes. However, the capability of the aquifer to support the wellfield withdrawals at full capacity has never been verified.

A computer-modeling study of the buried valley will be completed by the end of this summer to determine the "safe yield" of the Mahomet aquifer and to develop a technical tool for optimal management of ground-water resources in the valley. The model area is fairly extensive, spanning approximately 130 mi (208 km) from east to west. A salient feature of the study is a 30-day pump test with wellfield pumpage of 15 MGD. To the authors' knowledge, this is one of the largest and most extensive pump tests conducted in the Midwest. Due to low recharge to the aquifer, the contributing area is extensive and therefore draw-downs are currently being recorded up to 20 mi (32 km) from the wellfield. At several observation sites, drawdowns are being recorded in the Mahomet aquifer, as well as in the confining and the alluvial units above it. The spatial estimates of hydrogeologic properties and recharge will be estimated by the model using the pump-test data as control points. The calibrated model will then be utilized to determine the "safe yield" of the aquifer. Various management scenarios will be conducted with the calibrated model to develop optimal management strategies. The model was also to be utilized to assess the impact of Decatur wellfield withdrawals on domestic and agricultural users in the area. The study exemplifies the productive results to be expected from cooperation between municipalities, water-management authorities, and private consultants to address complex water-management issues.

Comparative Study of Five-year Time-of-travel Capture Zones for Community Water Supply Wells in Bethany, Hardin, and Nokomis, Illinois

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Three-dimensional ground-water flow and particle-tracking models have been developed for the cities of Bethany, Hardin, and Nokomis, Illinois. The purpose of this study is to compare the five-year time-of-travel capture zones for the communities' water-supply wells and to determine the controlling hydrogeologic factor(s). The community water-supply facilities are composed of four wells in Bethany, four in Hardin, and six in Nokomis. Each community has two wellfields. The USGS Modflow and Modpath packages incorporated in the Groundwater Modeling System (GMS) software are used. All the aquifers are considered as unconfined during the modeling. Even though the aquifer materials are predominantly sand and gravel, there are variations in depositional environments from one area to another. Sand and gravel deposits in Nokomis are found in alluvial fans with less-permeable zones in-between. The Bethany wellfields are placed in glacial-outwash deposits of the Glasford formation. In Hardin, the wells are drilled into alluvial sand and gravel deposits in the bedrock valley along the Illinois River. The data used in modeling ground-water flow are obtained from earlier studies by the Illinois State Geologic Survey and the Illinois State Water Survey.

The capture zones of the two well fields in Nokomis are significantly influenced by the less-permeable zones between the alluvial fans. Thus the capture zones are independent and separate from each other. An apparent disconnection occurs between the two wellfields in Bethany caused by a bedrock topographic high that trends northwest-southeast beneath the central part of the study area. Finally, the capture zones within both wellfields of the City of Hardin are greatly influenced by the Illinois River. The two wellfields are approximately 4,000 ft (1,200 m) apart in a north-south alignment, thus the capture zones do not interfere with each other.

Three-dimensional Analysis of the Capture of a Contaminated Leachate by Wells

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Remediation of an aquifer is often performed using pump-and-treat wells. Wells that partially penetrate an aquifer and wells that are placed horizontally in an aquifer will generate a three-dimensional flow. Using a three-dimensional model to design these wells requires a greater effort than using a two-dimensional model. The question that must be addressed is, "under what circumstances may a three-dimensional flow be simulated using a two-dimensional model?" To help answer this question, the capture of a contaminated leachate is examined using a conceptually simple three-dimensional model. Design charts are presented that depict the location and minimum pumping rate of wells over a range of aquifer parameters. These charts are interpreted to obtain guidelines for when a three-dimensional model is required for well design.

Herbicide Transport from River through Aquifer into Municipal Collector Wells

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During high-flow events, herbicides in the Platte River are transported through the alluvial aquifer into collector wells operated by the City of Lincoln in about 6 to 7 days. During two high-flow events in 1995 and 1996, atrazine concentrations in water from these wells reached approximately 7 mg/L, 70 times more than the background concentration in ground water. Concentrations of the herbicides and metabolites atrazine, deethylatrazine, deisopropylatrazine, alachlor, alachlor ethane-sulfonic acid, metolachlor, cyanazine, and acetochlor in the collector wells generally were about one-half to one-fifth their concentrations in the river, suggesting that at least 20 to 50% of the water pumped by the collector wells is river water. The effect of the river on the quality of water from the collector wells can be reduced through management of the laterals of the collector wells. The quality of water from the collector wells is depen-

dent upon the (1) selection of the collector well used, (2) number and selection of laterals used, (3) chemical characteristics of the contaminant, (4) location of the contaminant in the surface-water system, and (5) location relative to the Platte River and a major upstream tributary.

Pesticides in Shallow Alluvial Aquifers in Agricultural and Urban Areas in Eastern Iowa and Southern Minnesota

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Ground water is an important source for domestic and municipal urban water supplies in the Cedar, Iowa, Skunk, and Wapsipinicon watersheds in eastern Iowa and southern Minnesota. About 190 million gallons (720 million liters) per day are pumped from aquifers in these watersheds and about 44%, or 83 million gallons (314 million liters) per day, are pumped from the alluvial aquifers. Alluvial aquifers generally consist of variable thicknesses of sand and gravel deposits in the valleys of most streams and rivers. The shallow depth to ground water and permeable materials result in these aquifers being potentially vulnerable to contamination by pesticides used to control vegetation and insects in agricultural and urban areas.

The U.S. Geological Survey, National Water-Quality Assessment Program, conducted a water-quality study in the summer of 1997 to determine the occurrence of selected pesticides in alluvial aquifers in the Eastern Iowa Basins study unit. Thirty-one sites in agricultural areas and 30 sites in urban areas with underlying alluvial aquifers were randomly selected for installation of monitoring wells. The monitoring wells were sampled during June through August 1997.

The sum of the concentrations of all detected pesticides was significantly greater in agricultural samples (average of 1.3 μg/l) than in urban samples (average of 0.17 μg/l). Although urban ground-water samples generally had lower pesticide concentrations, a larger number of pesticides were detected. Twenty of 88 pesticide compounds analyzed were detected in water samples. Atrazine was the most commonly detected pesticide in both agricultural and urban samples. Metolachlor was the next most commonly detected compound in agricultural samples and prometon in urban samples. Seventeen of the 20 pesticides detected were herbicides, and three were insecticides.

Degradation products comprised a substantial part of the pesticide occurrence in both agricultural and urban samples. Concentrations of selected degradation products were 7.9 times greater in agricultural samples and 7.5 times greater in urban samples than the sum of all the parent compound concentrations. Metolachlor ethanesulfonic acid was the most commonly detected metabolite in both agricultural and urban samples. Deethylatrazine was the next most commonly detected metabolite in agriculture samples and alachlor ethanesulfonic acid in urban samples.

Occurrence of Acetanilide Herbicide Metabolites in Tile Runoff and Ground Water

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The parent acetanilide herbicides, acetochlor, alachlor, and metolachlor, are detected much less frequently in ground water of the Midwest than their metabolites. The acetanilide herbicides form both oxanilic acid (OA) and ethane sulfonic acid (ESA) metabolites in shallow soil. These metabolites are much more water soluble than the present compounds. Apparently, the ESA metabolite is more stable or is more rapidly formed than the OA metabolite because the concentrations of ESA in ground water are about three times greater than the concentrations of the OA metabolite. In addition, both metabolites are commonly 10 to 100 times more concentrated in ground water than the parent compounds. Tile-drain and lysimeter studies in the midwestern United States show that both OA and ESA metabolites form in the shallow soil and reach ground water.

An Examination of Pesticide Occurrence in Large-diameter Wells: Are High Detection Rates Related to On-field Applications?

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The Illinois State Water and Geological Surveys have shown that the occurrence of agricultural chemicals in shallow, large-diameter ($\geq$3 ft [1 m]), dug or bored wells is much greater than for drilled wells of similar depth. It has been surmised that the construction of these types of wells is at fault because these wells often are not properly sealed against surface leakage. At present, the source of agricultural chemicals found in these wells is not known. The objective of this project was to conduct a field study to determine whether the source of agricultural chemicals found in large-diameter wells is related to current and past on-field applications of agricultural chemicals. Investigations at one farm site in particular will be discussed.

At this farm, 13 monitoring wells were nested at six locations around the farmyard. Atrazine was routinely detected in one monitoring well (0.15–15.1 µg/L) and in the large-diameter well (n.d.– 0.69 µg/L) but not in other monitoring wells situated closer to surrounding fields. This same monitoring well was also found to contain the atrazine degradates desethylatrazine and desisopropylatrazine. Nitrate concentrations in the large-diameter well were always 10–15 mg N/L. Another monitoring well, installed near the edge of a neighboring field, contained similar nitrate concentrations, but other monitoring wells, also located near field edges, contained much less, sometimes nondetectable, nitrate concentrations.

Water samples from selected monitoring wells, the farm well, neighboring farm wells, and surface water were also analyzed for tritium and nitrogen and oxygen isotope ratios. We also conducted electrical earth-resistivity surveys to map the areal extent of shallow sands at the site and a short pumping test to evaluate the hydraulic properties of two sand bodies.

Results of these investigations and the implications for protection of large-diameter wells from agricultural chemical contamination will be discussed.

Use of Reported Water-level Values to Map Regional Ground-water Flow Systems in Michigan

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The State of Michigan does not have a network of ground-water monitoring wells to provide high-quality data for regional ground-water elevation mapping in the glacial deposits. Therefore, reconnaissance mapping at the township level (36 mi^2 [93.2 km^2]) has commonly been accomplished using reported data from water-well completion reports, although the choice of which points and how many has led to erroneous interpretations of water-table elevations. In order to carry out township-scale mapping studies, the Regional Groundwater Center at the University of Michigan–Flint developed a methodology to measure static water levels in two wells per square mile in the glacial deposits. Additional control was achieved using local lakes and streams as ground-water points. This spacing of wells and surface-water points is adequate to accurately define the ground-water surface. The methodology is based on the concept that the glacial deposits are homogeneous in their heterogeneity.

A further development of the mapping methodology was to randomly select two points per square mile from the reported data to evaluate whether contouring these data would yield a result similar to measured values. These reported data points were added to the surface-water points, plotted, and contoured. Erroneous data caused anomalous highs and lows on the surface and were corrected or discarded. The resulting ground-water surface compared well with the measured one. The reported data were further sorted by driller, year, and season. Results indicate the most important factor was the choice of two points per square mile. The methodology has been tested at scales ranging from about four points per square mile to about 900 points per square mile in varying glacial terrain. Field checks of maps compiled with reported data showed differences ranging from about 2 to 6 ft (0.6–1.8 m) between measured and reported ground-water elevation values.

Selecting Monitoring-well Locations Using GIS

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The Ground Water Monitoring and Assessment Program (GWMAP) of the Minnesota Pollution Control Agency (MPCA) conducts a variety of studies to assess land-use impacts to ground-water quality. In designing these studies, GWMAP has used Geographic Information Systems (GIS) to identify monitoring locations that are representative of the various land uses. By using GIS, GWMAP staff have delineated land-use areas, expedited field verification, selected monitoring locations, identified street addresses, and determined property owners, without leaving the office.

One of the coverages used in this process is the Digital Orthophoto Quadrangle (DOQ) produced by the U.S. Geological Survey (USGS). DOQ's are computer-generated images of aerial photographs covering 3.75 minutes of longitude and 3.75 minutes of latitude. The images have been rectified to remove displacements caused by topography and camera angle. DOQ's have proven to be a useful tool in determining land use and locating monitoring points.

Using DOQ's, GWMAP staff can zoom into a particular region to select potential sampling locations that represent a certain land use. A detailed photograph of the area is printed and taken into the field to verify land use, thereby increasing our efficiency. During the field verification process, potential well locations are identified and located using Global Positioning System (GPS) technology. Once a potential well site is located, it is entered into the computer as a point coverage. Additional coverages for plate maps, roads, and utilities are overlaid with the DOQ's and GPS coverages to identify property owners and addresses. At this point, property owners are contacted to obtain permission to install the monitoring points.

Prior to well installation, additional hydrogeologic coverages can be overlaid. Coverages such as ground-water flow, soil types, surficial geology, and depth to bedrock assist with the logistics for well-installation purposes.

Incorporating GPS, GIS, and On-site QC into the Kansas Water-level Measurement Program

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The statewide cooperative annual water-level measurement program is designed and maintained as a means of monitoring changes in Kansas aquifers and establishing trends associated with their use. Water-level measurements are scheduled annually for about 1,380 wells spread across 47 central and western Kansas counties. These annual measurements are nominally made during the month of January in wells used for livestock, irrigation, household, municipal, industrial, and monitoring (abandoned agricultural or domestic wells). The principal product of this program is a regional view of water levels in the High Plains, Dakota, and alluvial aquifers of central and western Kansas. Ultimately this program provides accurate regional depths to ground water to various monitoring and regulating boards and agencies. Water levels in over half the network wells are at depths of less than 100 ft (30 m), with slightly more than 1% at depths greater than 300 ft (90 m). Each year replicated water-level measurements on about 6% of the network wells are used to estimate the reproducibility of water-level measurements. A computerized data-acquisition system (WaterWitch), incorporating Global Positioning System (GPS) devices with vehicle-mounted computers, provides navigational assistance, data logging, and on-site quality control. WaterWitch interfaces GPS technology with an extensive digital-map system. Continuous feeds of real-time location coordinates by GPS devices to vehicle-based computer systems drives the digital-map display each measurer uses to navigate the optimum route to each well. All the current year's data and historical records are archived and maintained at the KGS in a large, statewide data base. This centralized data base of Kansas water-level information (WIZARD) provides a quick and accurate means to analyze or evaluate ground-water resources for areas as small as a township or as large as the entire state.

GIS Applications in Assessing Waste Disposals and Contaminant Releases for Ground-water Impacts

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Utilizing the Dakota County GIS (Geographic Information System), over 1,700 solid and hazardous waste-disposal and contaminant-release sites were inventoried. Additional themes, features, and data were added or accessed to permit initial classification and evaluation of the sites. Approximately 450 high-priority sites were further examined for ground-water susceptibility to contamination and other critical factors. Clusters of identified high-priority sites were found near urbanized settings and transportation corridors. The areas were further prioritized, and preliminary investigations and assessments (Phase I) are being conducted in the first dozen clusters.

In assessing relative risk, ground-water consumers were often the most significantly impacted. Traditional ground-water receptor surveys missed older, shallower, and more poorly constructed wells because most pre-1980 wells (about 50% of all wells) were not recorded by the State. Using GIS to evaluate portions of communities without water utilities but with building occupancies where no wells were recorded, locations of more contamination-prone wells were located and eventually tested.

Environmental media-test data are collected and entered from the sites, area monitoring points, and receptors. GIS multi-thematic mapping and relational data-base queries provide clues from which statistical analysis, hydrogeologic modeling, and other interpretational tools can facilitate a more comprehensive understanding of the problems and develop strategies for appropriate response actions.

After problematic sites are identified, the owners and responsible parties are requested to voluntarily conduct detailed investigations (Phase II) and clean-ups (Phase III). If they do not respond or if the properties are government-owned and/or are tax-forfeited, the county may initiate a Phase II and eventually a Phase III.

The GIS is a permanent repository, along with indexed hard files and keyed data bases, for the actions, status, conditions, monitoring results, clean-up residuals, appropriate land-use compatibilities, and future planning for the property to protect the environment, public health, and safety.

Slug Tests in Extremely Permeable Aquifers

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One of the most popular techniques for measuring hydraulic conductivity is the slug test, due to the simplicity and cost effectiveness. We have a field site called GEMS (Geohydrologic Experimental and Monitoring Site), with about 70 wells, that is located in the Kansas River alluvium. The site consists of about 70 ft (21 m) of alluvium; 35 ft (10.7 m) of silt and clay overlying 35 ft (10.7 m) of a generally fining-upward sequence of sand and gravel. While doing slug tests in some of the coarser material, we have observed that conventional linear theories do not explain the field data well, because they have a systematic lack of fit and indicate that hydraulic conductivity varies with the initial slug displacement.

We have developed a general nonlinear model based on the Navier–Stokes equation, nonlinear frictional loss, non-Darcian flow, acceleration effects, radius changes in the wellbore, and a Hvorslev model for the aquifer, which produces a very good fit to the field data. We find that the proposed nonlinear model explains the field data quite well, while reducing to traditional linear models (linear oscillatory, Hvorslev, etc.) when appropriate. The nonlinear model has three parameters: β which is related to radius changes in the water column, A which is related to the nonlinear head losses, and K the hydraulic conductivity.

This paper will focus on the problems of doing slug tests in extremely permeable aquifers. We will show details of the field techniques that we use and provide examples of what to look for in the field data to indicate that conventional theories are inappropriate for analysis. The ultimate objective of this research is to develop and improve field and analysis techniques for better definition of the spatial distribution of hydraulic conductivity in high-permeability environments.

Local-scale Aquifer Characterization Using Single-well Tracer Methods

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The practical success of ground-water remediation using pump-and-treat, in situ bioremediation, reactive barriers, or the like, depends heavily on knowledge of local flow patterns and velocities. Conventional methods such as pumping tests and gradient measurement, while adequate for most water-supply investigations, do not yield sufficient information to accurately model local ground-water transport. However, by combining conventional hydraulic stress tests and water-level measurements with single-well tracer tests using an innocuous flow tracer such as potassium bromide, it is possible to determine ground-water velocity, effective porosity, and vertical profiles of hydraulic conductivity directly from field data. New field techniques, instruments, and methods of interpretation developed under the U.S. Department of Energy's thermal-energy storage program render the single-well methods both time and cost effective.

High-resolution Seismic-reflection Survey to Map Bedrock and Glacial/Fluvial Layers at the U.S. Navy Northern Ordnance Plant (NIROP) in Fridley, Minnesota

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Shallow seismic-reflection, in conjunction with uphole velocity profiles and local borehole data, allowed delineation of discrete layering within the glacial drift overlying the St. Peters Sandstone and/or the Prairie du Chien dolomites at an average depth of around 120 ft (36 m) along the western perimeter of the Northern Ordnance Plant, currently the Naval Industrial Reserve Ordnance Plant (NIROP) in Fridley, Minnesota. Identifying pathways for contaminants to move away from this industrial facility was essential for appropriate remediation techniques to be employed. Transport and fate models of this site incorporated borehole studies and surface geophysical data. The primary goals of this study were to determine the feasibility and limitations of the technique and to develop a continuous subsurface image of all geologic/hydrologic contrasts represented by changes in acoustic impedance. Establishing feasibility includes determining the horizontal and vertical resolution potential, optimum acquisition geometries and parameters, best-suited equipment for surface and subsurface conditions, and level of effort necessary to delineate the geologic/hydrologic features of interest, as well as establishing a reasonable set of expectations for the technique across the entire facility. Shallow seismic-reflection profiles allowed delineation of potentially discontinuous confining units within the glacial drift at this site.

Equus Beds Ground-water Recharge Demonstration Project, South-central Kansas: Baseline Water Quality and Preliminary Effects of Artificial Recharge on Ground-water Quality

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The Equus Beds Ground-Water Recharge Demonstration Project began in 1995 to help the City of Wichita meet future water needs and is sponsored by the City of Wichita and the Bureau of Reclamation, U.S. Department of Interior. During the project, high flows from the Little Arkansas River are captured and recharged into the aquifer through infiltration basins, a trench, or an injection well. The U.S. Geological Survey collected data from February 1995 through September 1997 to document baseline concentrations of inorganic, pesticide, volatile organic, acid-base neutral organic, and bacterial constituents in ground and surface water and to document the preliminary effects of artificial recharge. Baseline sampling indicated that the primary constituents of concern were chloride and atrazine. The U.S. Environmental Protection Agency drinking-water standard for chloride is 250 mg/L (milligrams per liter) and for atrazine is 3 μg/L (micrograms per liter) as an annual average. Concentrations of chloride ranged from 5.8 to 290 mg/L and concentrations of atrazine ranged from <0.05 to 1.6 μg/L in water samples collected from the 24 ground-water wells. The concentrations of chloride and atrazine, as well as other constituents, were monitored in ground-water wells at two artificial recharge sites—Halstead and Sedgwick.

From May 1997 through May 1998, about 250 million gallons of water were recharged at the Halstead site. During high flows, water from the Little Arkansas River is induced into the alluvium and diverted for recharge by a pumping well immediately adjacent to the river. Chloride concentrations in the diverted water ranged from 52 to 80 mg/L, and atrazine concentrations ranged from 0.025 to 0.13 μg/L. As of May 1998, chloride concentrations in the monitoring wells at the Halstead site are similar to that of the diverted water. The maximum atrazine concentration detected in the wells was 0.09 μg/L. From October 1997 through June 1998, about 12 million gallons of water have been recharged at the Sedgwick site. During high flows, water is diverted from the Little Arkansas River, treated to remove sediment and atrazine, and recharged at the Sedgwick site. Chloride concentrations in the diverted water ranged from 38 to 180 mg/L, and atrazine concentrations ranged from <0.10 to 6.8 μg/L. Chloride concentrations in shallow wells (40–60 ft [12–18 m] deep) ranged from 4.5 to 78 mg/L. As of June 1998, water from one of two deep wells sampled (190 ft [58 m] deep) has shown a decrease in chloride concentrations, whereas concentrations in the other deep well remain unchanged. The maximum atrazine concentration detected in the shallow wells was 0.3 μg/L. Atrazine was not detected in the deep wells.

Preliminary effects of recharge at both the Halstead and Sedgwick recharge sites indicate that concentrations of chloride and atrazine have increased in some of the wells, although concentrations remain within the range of baseline values in the Equus Beds aquifer and are considerably less than drinking-water standards. However, enough water has not been recharged at the Sedgwick site to date to determine the overall effects.

Volatile Organic Compounds in Shallow Ground Water and a Stream in the Twin Cities Metropolitan Area, Minnesota, 1996–98

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Forty-five volatile organic compounds (VOC's) were detected in ground- and surface-water samples collected from 30 monitoring and six multiport wells, and from Shingle Creek in the northwestern part of the Twin Cities metropolitan area, Minnesota. More VOC's (36) were detected in water samples from Shingle Creek than in samples (27) from wells completed in a surficial aquifer composed of sandy river-terrace deposits. In Shingle Creek, more VOC's (34) were detected during normal or low-flow conditions than during high-flow conditions (28); however, some VOC's had higher concentrations during high flow. Eighteen VOC's were unique to streamwater, whereas nine VOC's were unique to ground water. In ground water, more VOC's were detected in 15 samples from multiport wells (22) than in 30 samples from monitoring wells (19) installed at the water table. These data suggest that some VOC's are contributed to streams by relatively constant sources, such as partitioning from the atmosphere, ground water, lakes, and wetlands, whereas others are contributed by point and nonpoint sources during runoff. The greater detection frequencies of VOC's from multiport wells suggest that more VOC's exist deeper in the aquifer or that the multiport wells were closer to VOC sources.

Surface-water samples were collected from Shingle Creek in August 1996, and on a biweekly or monthly schedule from January 1997 to March 1998. Ground-water samples were collected once in June or July 1996 from 30 monitoring wells to investigate the effects of urban land use on the quality of shallow ground water and from 15 sampling ports installed to investigate processes affecting the water quality in the entire thickness of the surficial aquifer. Wells were located in the Shingle Creek drainage basin or in a neighboring basin with similar hydrogeologic and land-use characteristics. These water samples were taken as part of the U.S. Geological Survey National Water-Quality Assessment Program.

Sample Collection and Field Determination of Ambient Redox Parameters for Use in Assessing Site Suitability for Natural Attenuation of Contamination by Chlorinated Ethenes

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Over the last several years, natural attenuation (intrinsic bioremediation) has been an emerging technology in the remediation of chlorinated ethenes in a ground-water system. Clearly, however, not all ground-water systems necessarily favor the natural attenuation of chlorinated ethenes, and an accurate delineation of redox conditions is required to assess the suitability of a ground-water system for natural attenuation.

The accurate determination of ambient redox conditions is a skill-intensive procedure. My presentation will provide practical insight into the collection and field determination of the following parameters:

Dissolved Oxygen (DO)	Nitrate (NO_3)
Dissolved ferrous iron (Fe^{2+})	Nitrite (NO_2)
Sulfate (SO_4)	Hydrogen Sulfide (H_2S)
Dissolved Methane (CH_4)	Dissolved Ethene (C_2H_4)
Dissolved Ethane (C_2H_6)	

TEAR DOWN THE WALL! Developing a Water Information Program

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Developing an internet-based water-information system involves far more than mere data collection and presentation. The overall intent of Groundwater 2000 is to provide a "one-stop" access point to anyone interested in ground-water data or supporting information about the Great Miami basin and affiliated aquifer system of southwestern Ohio—one of the most prolific saturated zones in the United States. This has involved tackling the significant issues of data ownership, reliability, use, and interpretations made therefrom. Given the value of the aquifer in the region as a resource, a myriad of scientific and political interests overseeing data bases of important water data exist. The Miami Conservancy District has endeavored to inventory and provide access to these data in an organized manner. These data may be useful in and of themselves, or useful in models and other scientific evaluations of the region.

A large component of the work in this project has involved developing good working relations with shareholders around the basin, accomplished through an organized game plan of workshops, information meetings, and open modes of communication. Program administrators organized initial workshops throughout the basin to measure the interests, issues, and concerns of potential shareholders. These workshops were followed by structured liaison and technical advisory meetings to collect on-going input and update shareholders of progress made. These meetings continue to be supplemented with pro-active and consistent interaction with interested parties, especially those expressing concern in program goals and objectives, or those expressing strong opinions as to what the information program should, or should not be.

Source-water Assessment as a Result-oriented Activity for Groundwater Guardians

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In 1993, The Groundwater Foundation began the development of a program to promote community-level ground-water protection solutions on a nationwide basis. Known as Groundwater Guardian (GG), it provides support, recognition, and connection to communities protecting their ground-water source.

The GG process begins with citizens forming a team composed of diverse representation from community groups, local government, educational institutions, and local business, industry, and agriculture. The team identifies existing ground-water protection issues and then develops, adopts, and implements result-oriented activities (ROA) to address these issues effectively through time. Substantive progress toward implementation of ROA's will mean GG designation for the community.

Source-water assessment is a process that can involve citizens in the protection of their own drinking water by helping them to understand where their water supply comes from and what conditions and practices pose threats to its quality. A source-water assessment would be a logical ROA for a community that has entered the annual Groundwater Guardian program. In early 1998, The Groundwater Foundation held workshops on source-water assessments for Nebraska Groundwater Guardian communities. The goal was to have at least 50% of those communities adopt source-water assessment as an ROA in 1998.

This presentation will discuss those workshops, the reaction of the communities to the workshops and source-water assessments and "a progress made towards the foundation's 1998 goal." Plans to hold future similar workshops in other states with Groundwater Guardians will also be discussed in this presentation.

Water-use Permitting and Management of Water Resources in Kansas

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Since June 28, 1945, all the water within the state of Kansas has been dedicated to the use of the people of the state and subject to control and regulation by the State, via the Water Appropriation Act. To facilitate that control and regulation, water use is authorized by way of a permit system. Water use established prior to the Act is covered by Vested Water Rights. Water use that commenced after the Act requires approval of an application to appropriate water and development of a Water Right by use of the water in accordance with the terms and conditions of the permit. Once established, a water right becomes a real property right, for the use of that water and can be bought, sold, and changed. However, permission for the use of water can be lost if it is not put to beneficial use for a period of three or more successive years, during which time good cause for non-use of water is not demonstrated. Special limited-time users of water are covered by Term and Temporary Permits which do not develop a water right.

The Kansas Legislature passed a Groundwater Management Act in 1968 and modified it in 1972, resulting in the establishment of five (5) Groundwater Management Districts which provide local input into their specific aquifer or portion of an aquifer. Ground water outside the districts is managed on the basis of sustainable yield related to annual recharge, well spacing, and protection of prior water rights.

In an effort to conserve water use, a Water Rights Conservation Program was established in 1992. This program allows an irrigator to contract to stop pumping water for a period of three to ten years, without forfeiture of their water right.

Ground-water Quality in Unconfined Glacial Aquifers in Part of the Upper Mississippi River Basin—The Influence of Land Use

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Water-quality studies of unconfined glacial aquifers in urban, agricultural, and forested areas of Minnesota indicate that land use has affected the quality of ground water. The studies, completed as part of the U.S. Geological Survey's National Water Quality Assessment Program in the Upper Mississippi River basin, show that these aquifers are susceptible to leaching of fertilizers, pesticides, and other substances related to land use.

Calcium, magnesium, sodium, bicarbonate, chloride, and sulfate were the most prevalent dissolved constituents in ground-water samples, and the relative proportions of these constituents varied among geographical areas having different predominant land uses. Sodium and chloride concentrations, for example, were greater than normal in ground water from urban areas, probably due to leaching of sodium chloride used to de-ice roadways.

Ground water in agricultural land-use areas generally had the greatest concentration of nutrients. Concentrations of nitrate and nitrite nitrogen, a nutrient of primary concern in ground water, were greater than the U.S. Environmental Protection Agency's Maximum Contaminant Level of 10 milligrams per liter (10 mg/L) in about 10% of the samples.

Pesticides were detected in ground water in each of the land-use areas, but in small concentrations, and generally were less than 1 microgram per liter (1μ/L). Prometon, a herbicide commonly used on highway right-of-ways, was the most frequently detected pesticide in urban areas. Atrazine and its metabolites were the most frequently detected pesticide compounds in ground water in agricultural areas. Few pesticides were detected in ground water in forested areas. Ground water in urban areas contained volatile organic compounds in the greatest number and at the greatest concentrations (generally less than 1 microgram per liter) of the urban, agricultural and forested areas.

The Use of Drastic in the Delineation of Potential Pollution Sites in LaGrange, Indiana

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Drastic is one of the tools used in creating the vulnerability map for LaGrange County, Indiana. Drastic was also used to create a vulnerability map for the state of Indiana. The use of Drastic assumes uniform conditions within the subsurface environment and should be used with caution because it was not designed to replace site-specific investigations; erroneous or inaccurate data could affect the reliability of results. The consideration of the regional hydrology is important in the delineation of potential pollution sites.

Well logs in several northeast Indiana counties were found to be inaccurate. However, certain practices such as well construction, septic systems, and the abandonment of wells led to errors in the vulnerability maps made using Drastic. Lima and Milford Townships that were rated as low- to medium-potential risk for pollution according to a Drastic map, were examined in greater detail and found to be high-risk areas based on their water samples. Fifty four percent and 50% of well waters in these townships have nitrate above background (2 mg/L) levels. The regional geology, well construction, and other anthropogenic activities led to high nitrate levels in the well waters.

A Comparison of Ground-water Nitrate Pollution Risk Indices: An Example from the Equus Beds Aquifer in Central Kansas

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A number of methods have been devised to predict or assess the vulnerability of ground water to pollution from nonpoint sources. Some of these methods are standardized for application to a wide range of hydrogeologic settings. Others have been devised to assess risk in specific geographic areas and must be used with caution outside of the area in which they were originally developed. Regardless of their general applicability, all such models must rely on large volumes of spatial data regarding agronomic, topographic, pedologic, geologic, and hydrologic parameters for model input. Unfortunately, the immense potential capabilities of geographic information systems are diminished greatly by the amount and quality of input data that are readily available for this type of application. In most cases, the input parameters for the models are not readily derivable from existing digital maps and data bases. The original maps and the digital maps and data bases derived from them were not compiled with this type of application in mind. Also, the creators of pollution-risk models are generally not familiar with the terminology of the other disciplines from which they must incorporate data. In this paper, a number of the problems associated with compiling spatial data for ground-water pollution-risk assessment are discussed for the Equus Beds aquifer in south-central Kansas. The relative importance of a variety of factors that influence pollution potential are analyzed. Three risk indices are compared in terms of their ease of use, general agreement or disagreement in terms of pollution risk, and their ability to predict actual ground-water pollution when compared to spatial patterns of nitrate concentration in the aquifer.

Poster Session Abstracts

Irrigation-reuse Systems Relationship to Ground-water Quality and Crop-nitrogen Budget

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Large portions of the country where intensive row-crop farming is practiced are experiencing nitrate contamination of ground water. As farmers have become aware of increasing nitrate concentrations in the ground water they use for irrigation, they have started in some areas to test their ground water for nitrate concentrations and quantify this nitrate so they can include it in their crop-nitrogen budget. By including this ground-water nitrate, they can reduce the amount of fertilizer they need to apply and still expect to maintain their yield goals for corn and other irrigated crops.

If an irrigator has a reuse system that is unlined, it is reasonable to assume that he/she is losing some nitrate out of the reuse pit and may underestimate how much nitrogen fertilizer is required to achieve the yield goal. The objective of this research was to compute how much nitrate is lost from the pit during an irrigation season that extends from July 1 to August 31, or a 62-day period.

A computer program was written that was based on equations where the seepage rate was a function of the stage in the pit. The volume of seepage at the end of the irrigation season was multiplied by the steady-state nitrate concentration of the pit inflow to give the total mass of nitrate leached from the pits. Total-irrigation-season pit-sidewall and bottom-nitrate leaching for three starting stages and three combinations of pit-bottom dimensions were plotted, with each plot being for one set of pit-bottom dimensions. Each plot had three curves for three nitrate concentrations. The greatest magnitude of leaching from the reuse pit was 30 kg (66 lbs) for one irrigation season. If the pit was used to collect water from a 32.4-hectare (80-acre) field, the nitrate loss for the field would be 0.93 kg/hectare (0.83 lbs/acre).

Changes in Ground-water Levels and Storage in the Wichita Wellfield Area, South-central Kansas, 1940–1998

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The Wichita wellfield was developed in the Equus Beds aquifer northwest of Wichita, Kansas, to supply water to the city. On September 1, 1940, pumping began from 25 wells in the well field. City pumpage increased from then until the early 1950's and between the late 1970's and early 1990's. Since then, city withdrawals from the wellfield have decreased as withdrawals increased from Cheney Reservoir, the other major water-supply source for the city. Nearby agricultural withdrawals increased substantially in the 1970's and 1980's and, in the 1990's, were similar in magnitude to city withdrawals in the study area although more seasonal and variable in response to changing climatic conditions.

Ground-water withdrawals in the vicinity of the wellfield caused a large area of water-level declines to develop in the Equus Beds aquifer. Water levels declined from 1940 through the 1950's drought, stabilized in the 1960's and 1970's, continued to decline between the late 1970's and the 1988–1992 drought, and reached their maximum to date of as much as 40 ft (12 m) or more during 1991–93. Loss of ground water in storage since August 1940 followed a pattern similar to water-level declines, with a maximum loss of storage of 255,000 acre-feet reached in January 1993. Water-level declines encompassed an area of about 190 mi^2 (492 km^2) at their maximum in January 1993 and extended from the Arkansas River to the Little Arkansas River in the vicinity of Halstead and Sedgwick. Ground-water levels have since recovered more than 10 ft (3 m) in some areas and aquifer storage replenished by 79,000 acre-feet between 1993 and 1998, primarily as a result of decreased city withdrawals.

Kansas Minimum Design Standards for Onsite Wastewater Systems

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Research on ground water often focuses on identifying nonpoint-source pollution impacts. Recently the State of Kansas took action to reduce one potential nonpoint source by issuing a set of minimum design standards for onsite wastewater systems.

Failing and inadequate onsite-wastewater systems can be contributors to both ground-water and surface-water pollution. However, properly designed, constructed, and maintained onsite wastewater systems, when installed in adequate soils, can perform wastewater treatment and water dispersal without water contamination. (Most systems' reduction of the total level of nitrogen compounds is limited.)

In 1996–97, the Kansas Department of Health and Environment, with the cooperation of the K-State Research and Extension at Kansas State University, developed a comprehensive document to incorporate the latest research and information on onsite systems. *Bulletin 4–2: Minimum Standards for Design and Construction of Onsite Wastewater Systems* summarizes good practices for the installation of conventional onsite wastewater systems.

Although Kansas encourages the use of soil profiles for estimating the capability of the soil to treat and disperse septic tank effluent, *Bulletin 4–2* provides loading-rate data for both soil morphology and percolation tests. Acceptable loading rates range from 0.25 gpd/ft^2 for some clay loams through 1.1 gpd/ft^2 for coarse sands. *Bulletin 4–2* emphasizes standard septic tank/lateral field systems, but includes information on wastewater-stabilization ponds and limiting conditions that indicate use of alternative systems such as mounds, aeration systems, or sand filters.

Other key provisions of the design standards include construction parameters for septic tanks and absorption fields, calculations for sizing absorption fields, minimum and recommended sizes for septic tanks, and minimum and recommended separation distances between wastewater systems and water systems or structures.

Application of GIS in Water-quality Risk Assessment in the Battle Creek Watershed, Ida County, Iowa

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Ground-water protection continues to be of vital interest to the public as water quality is impacted by both intensive and non-intensive agricultural systems. The Battle Creek Watershed Groundwater Protection Project is intended to help protect and improve shallow ground water and well-water resources impacted by agricultural nonpoint-source pollutants in the 33,500-acre (13,600-ha) watershed area. Primary risk concerns are due to excess nutrients related to crop and livestock production. The 1988–89 Statewide Rural Well Water Survey of active private wells found that in the hydrogeographic region that includes Ida County, over 50% of the wells were less than 50 ft (15 m) deep; Ida County also had the highest percentage (38.2%) of wells with nitrate-N concentrations in excess of the health advisory level (10 mg/L). A geographic information system (GIS) is being employed to assess priority water-quality risks with the use of a resource-management data base developed specifically for the watershed. The data base includes spatial and attribute data related to soil properties, geology, land use, well locations and well test records, livestock-operation locations, hydrographic, and other landscape features. A global positioning system (GPS) is being used in the collection of field data. The GIS is being used in the process to target locations for best management practices such as nutrient and pest management, filter and buffer strips, manure management, grazing management, and well closing. Example GIS data and analysis procedures will be presented.

WIZARD—A Ground-water Information System for Kansas

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WIZARD is a large ORACLE data base and software for manipulating data on water levels measured in wells in Kansas. WIZARD is maintained by the Kansas Geological Survey and contains information on more than 51,000 water wells, including approximately 2,000 "observation wells" that are measured annually.

WIZARD consists of several interrelated tables containing information on the location of each well, ownership, construction information, water-depth measurements, and so forth. Most original data were derived from preexisting sources, supplemented by annual measurements made by the Kansas Geological Survey and other agencies. Because of the relational design of the data base, information can quickly be retrieved based on any combination of selection criteria. Most importantly, information on a well can be added or changed easily without affecting other parts of the data base. There are interfaces into SAS for statistical analyses, into ARC/INFO for mapping, and into EXCEL spreadsheets. Data can be accessed by anyone, anywhere, through the World Wide Web at

HTTP://magellan.kgs.ukans.edu/WaterLevels/

WIZARD includes automated quality control and strict checks. Water depths are recorded using laptop computers with attached Global Positioning Systems (GPS) containing navigational maps to insure that wells are located correctly. The computers compare measured depths to historical values and nearby wells, warning if a depth seems unreasonable. Information is computer-checked for syntax, completeness, and reasonableness at the wellsite, and statistical and logical checks are performed when the portable computers are downloaded into WIZARD. Changes in data are automatically noted and preserved; if an erroneous location is detected and corrected, the person making the change, the date, and the erroneous prior location are recorded. Thus, a complete history of the data base can be reconstructed, from the origin of data to the present time.

Groundwater Guardian Affiliates

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In 1993, the Groundwater Foundation began the development of a program to promote community-level ground-water protection solutions on a nationwide basis. Known as Groundwater Guardian (GG), it provides support, recognition, and connection to communities protecting their ground-water source.

For the first three years of the program, 1994, 1995, and 1996, only communities could enter the program. Although the definition of community is quite broad—an entity having a territorial and legal interest in a ground-water resource—there were still groups wishing to participate in the program who were not communities.

After careful study by the national advisory council for the GG program, a category called "Groundwater Guardian Affiliates" was created. An affiliate is an entity at the state, regional, or other level that works to promote shared responsibility for ground-water protection by assisting communities with their local ground-water protection activities. They do this by developing, adopting, and implementing Result Oriented Services (ROS). The candidates for designation as GG Affiliates go through an annual process similar to the communities.

In 1997, twenty-three entities entered the affiliates program and 21 were designated. In 1998, thirty-five entities have entered this program including all 21 of the 1997 Groundwater Guardian Affiliates.

This presentation will discuss the program, the entities that have been designated and/or entered in the program, and the types of ROS's they have undertaken. We will also discuss early evaluations of this part of the GG program and its impact on the entire program.

A Study of Ground-water Flow and Ground-water/Surface-water Interaction in the Republican River Basin, Southwest Nebraska, Northwest Kansas, and Northeast Colorado

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Development of ground-water supplies in the High Plains aquifer for irrigation in the Republican River basin has led to concerns about diminishing streamflow in the basin. A cooperative study between the U.S. Geological Survey and the Southwest Nebraska Resource Conservation and Development Area is being conducted to evaluate ground-water flow and ground-water/surface-water interaction using a digital, finite-difference, ground-water flow model (MODFLOW) of the entire basin upstream of the gaging station on the Republican River near Hardy, Nebraska, at the Kansas–Nebraska border. The objectives of the modeling component of the study are to: (1) quantify ground-water/surface-water interaction throughout the basin, and (2) simulate the effects of future pumpage scenarios on streamflow. Digital spatial-data coverages of aquifer geometry, properties, and stresses are being constructed using available information to generate model-input data for the study area of about 30,000 mi^2 (78,000 km^2). The model boundaries are the Platte River on the north, the Little Blue River on the northeast, and the edge of the High Plains aquifer in northeast Colorado and northwest Kansas on the west and south, respectively. The model will be calibrated under both steady-state (pre-1950) and transient (1950–1997) conditions. The study will provide a ground-water model capable of quantifying the effects of ground-water pumping on streamflow in the basin, enabling better management of limited ground- and surface-water resources.

Pilot Testing of Oxygen-release Compound Efficacy in Reducing Aquifer BTEX Contamination

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A pilot test of Oxygen Release Compound Efficacy on the reduction of BTEX compounds in ground water was implemented at a site in early 1998. BTEX concentrations were measured from a maximum of 14,520 ppb in February 1998 to 9,480 ppb in May 1998, for a reduction of 34.7%. The aquifer is characterized by a medium-grained sand with some silty clay. Prevention of migration of the contaminant plume is controlled by a Pump and Treat System with an Air Stripper Unit. The oxygen release compound consists

of a solid-phase magnesium peroxide enclosed in a polyester sock. Upon hydration the magnesium peroxide releases oxygen into the aquifer, resulting in an inert magnesium hydroxide during the process. Oxygen concentration in a downgradient well has increased from 3.1% to 7.8%. Ground-water hydraulic conductivity is critical, as are pH concentrations within the aquifer. The pH affects the capacity of the microorganisms to degrade the contaminants of concern. The microorganisms use the hydrocarbons for cell reproduction and maintenance. The chemical byproducts of these reactions are carbon dioxide and water. The long-term effects of the oxygen-release compounds will continue to be studied. Additional oxygen will be applied to the contaminant plume as oxygen levels approach 3% in the monitoring wells.

Boundary-layer Analysis of Aquifer Mineralization by Paleodrainage Channels

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This study concerns mineralization of ground-water resources in some regions of south-central Kansas. The mineralization occurs in those regions due to the penetration of saline water originating from deep bedrock formations, into small-size formations of high permeability. The formations of high permeability are located in places occupied by streams and rivers in past geological eras. These geological formations are termed "Paleodrainage channels." The comparatively fast migration of saline water through these channels of high permeability is associated with the transfer of salinity into the overlying freshwater aquifer. The permeability of the overlying aquifer is significantly smaller than that of the "channel formation." In the framework of this study, a set of boundary-layer (BL) approaches are developed to quantify the process of salinity transfer from the channels into the aquifer. The methods used in the present study provide quick estimate and evaluation of the dilution of the channel flow, as well as of the possible salinity profile changes in the mineralized zone, which is created in the overlying aquifer.

The application of the method is exemplified by the performance of a complete set of calculations referring to the possible mineralization process at a particular channel located in a specific place of south-central Kansas. In the framework of this example, some sensitivity analyses were performed and provided information about the importance of the various field parameters that affect the mineralization process. Some possible scenarios of the aquifer-mineralization phenomena are described and evaluated. It is shown that the channel mineralization may create either several stream tubes of the aquifer with high salinity, or many stream tubes mineralized to a low extent. Characteristics of these two patterns of aquifer mineralization are quantified and discussed.

Multidisciplinary Assessment of Salinity Patterns Along Rattlesnake Creek in South-central Kansas—Considerations of Ground Water, Surface Water, Soils, and Vegetation

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During the past 15 years, the Kansas Geological Survey has conducted hydrogeologic research in the vicinity of the Rattlesnake Creek drainage basin in south-central Kansas. The recent Mineral Intrusion Project and other studies have focused on issues of ground-water quality and quantity, and stream/aquifer interactions. This presentation is an attempt to synthesize data of various types to assess spatial and temporal patterns of salinity in Rattlesnake Creek and the ground water in close proximity to it. It is a

multidisciplinary summary that includes a description of temporal variations of salinity in the surface water, ground water, and soils. Information from surface and downhole geophysical measurements, soil data bases, analysis of vegetative cover, and seasonal variations in precipitation were used to help explain spatial and temporal patterns of salinity. Remote-sensing techniques appear to have potential for detection and characterization of salt-affected areas. Variations in the salinity of the surface water as a function of ground-water discharge to the stream, soil-salinity patterns along the stream, and precipitation patterns are illustrated. Vegetation patterns as a function of soil salinity and potential causes of seasonal variability in soil salinity along the stream are discussed. Implications of the temporal patterns of surface-water, soil, and ground-water salinity for interpretation of surface geophysical data are also discussed. The importance and advantages of a multidisciplinary approach to salinity issues are outlined.

Modeling and Risk Assessing the Impact of Small Kansas Landfills on Underlying Aquifers

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Small landfills are exempt from compliance with Resource Conservation and Recovery Act Subtitle D standards for liners and leachate-collection systems. We investigate the ramifications of this exemption under western Kansas semiarid environments and explore the conditions under which naturally occurring geologic settings provide sufficient protection against ground-water contamination. The methodology we employed was to run water-budget simulations using the Hydrologic Evaluation of Landfill Performance (HELP) model, and fate and transport simulations using the Multimedia Exposure Assessment Model (MULTIMED) for several western Kansas small landfill scenarios in combination with extensive sensitivity analysis. We also employed a Probabilistic Risk Assessment (PRA) methodology to quantitatively evaluate risks of municipal landfill-related contamination. For this purpose we performed a Monte Carlo type of uncertainty analysis using carbon tetrachloride as a risk agent.

We demonstrate that requiring landfill cover, leachate-collection system (LCS), and compacted soil liner will reduce leachate production by ~56%, whereas requiring only a cover without LCS and liner will reduce leachate by half as much. The most vulnerable small landfills are shown to be the ones with no vegetative cover underlain by both a relatively thin vadose zone and aquifer and which overlie an aquifer characterized by cool temperatures and low hydraulic gradients. The aquifer-related physical and chemical parameters proved to be more important than vadose zone and biodegradation parameters in controlling leachate concentrations at the point of compliance (POC), which is 150 m (500 ft) downgradient from the landfill boundary. We also found that the probability of compliance to specified standards can increase or decrease depending on the number of uncertain variables and the nature of the impact each uncertain variable has on the resulting concentrations at the POC.

Sustainable Development of Water Resources in Kansas

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Sustainable development of water resources refers to a holistic approach to development, conservation, and management of water resources, which requires that, in the long term, a balance must exist between the amount of water entering and the amount leaving the system. In this presentation, we show that neither the surface-water nor the ground-water system can be properly understood or managed by itself, and thus the combined stream-aquifer system must be considered. We then trace the progressive evolution of water-resources management in Kansas towards sustainable development.

This progressive evolution of Kansas water management incorporates the establishment of local Groundwater Management Districts (GMD's), minimum streamflow standards, the conjunctive stream-aquifer management embodied in the sustainable-yield policies of some GMD's, and the DWR's sub-basin water-management program. Additional measures toward public education and water conservation, and vigorous monitoring and research will further insure the goal of sustainable water development in Kansas.

An Interactive System with Automatic Calibration for Ground-water Modeling

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An interactive integrated system for modeling ground-water flow and contaminant transport was developed in the GIS environment. The graphical user interface (GUI) is customized within ARCVIEW as the command control to integrate ARC/INFO, ground-water models (MODFLOW and MT3D), and automatic model calibration using PEST and a geological structure method. The automatic calibration is based on an inverse solution method using nonlinear least-squares regression. The advantages of this system are:

1. The system is interactive and user-friendly.
2. Laborious and time-consuming tasks in data handling are avoided.
3. Results can be displayed for visual inspection and comparisons.
4. Optimal parameter values and confidence limits on parameter estimates can be obtained through the inverse procedure.
5. Additional numerical models can be easily incorporated into the system.
6. Integration using ARCVIEW and ARC/INFO allows use of these GIS programs and their extensions for further analysis and display of input and output data.

The integrated system was applied to evaluate saline-water intrusion into ground water in southwest Kansas. A special feature of this case is the incorporation of available lithologic data in the inverse solution procedure for estimating model parameters. The results obtained in this study helped determine the impact of different contaminant mechanisms and the effects of the uncertainties of parameter values on the contaminant spreading and consequently, its effect on the quality of water supplies. The integrated system proved to be very effective in the application and could be further developed for use in water-resources management.

Arkansas River Corridor Study in Southwest Kansas

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The Upper Arkansas River Corridor Study is a Kansas Water Plan project conducted in cooperation with other State and local agencies. The study is documenting the fate and effects of saline Arkansas River flows on the High Plains aquifer in southwest Kansas for use by State and local agencies in water-resources management and protection.

The Arkansas River in southwestern Kansas is one of the most saline rivers in the United States. The flow across the Kansas border is saline during both high- and low-flow periods. The main dissolved constituents are sodium, calcium, and sulfate; sulfate concentration can reach 2,400 mg/L. The main process causing the salinity is consumption of Arkansas River water in Colorado (by evapotranspiration related to agriculture and water storage) and concomitant increase in the concentration of dissolved salts remaining in the residual water. Water levels have declined in the High Plains aquifer in southwest Kansas from consumptive pumping from the alluvial and High Plains aquifers and from decreased river flows available for recharge. Currently, most of the Arkansas River flow entering Kansas seeps into the subsurface in the river channel or in areas of ditch irrigation in southwest Kansas; some water is also lost by evapotranspiration, particularly during ditch irrigation. During the 1970's, the rate of water-level declines in the High Plains aquifer increased. Water levels dropped below the shallow aquifer and allowed the saline water to move down into the main aquifer. Lower-permeability silt and clay layers in the High Plains aquifer retard the rate of downward movement of the saline water. However, their occurrence, thickness, and lateral extent are highly variable. This study has discovered that flow down unsealed gravel packs in the annular space of wells (mainly irrigation wells) appears to be an additional avenue for movement of saline water into the lower aquifer.

Subbasin Water-resources Management Program

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The Division of Water Resources initiated the Subbasin Water Resources Management Program in 1993, to address water-resources issues and problems identified in the State Water Plan. The Program utilizes a hydrologic-basin approach to deal with ground-water declines, streamflow depletions, and water-quality concerns. The Program is designed to be holistic in nature so that the best available technical information and expertise are combined with a cooperative effort by local, State, and Federal government agencies and input from interested parties and citizens affected by the program. Community involvement is a crucial component in the philosophy of this program.

The methodology consists of five phases:

- Phase I Compile and review all existing data and information about a subbasin
- Phase II Collect and compile additional data
- Phase III Develop an appropriate hydrologic computer model to be used as a tool, if necessary
- Phase IV Develop new, comprehensive, long-term management strategies which address the water-resources problems in the basin
- Phase V Implement the new management strategies

The Subbasin Program is currently active in the following areas of the state:

1) Rattlesnake Creek Subbasin	Current Status: Phase IV
2) Middle Arkansas River	Current Status: Phase II
3) Pawnee/Buckner	Current Status: Phase II and III
4) Upper Arkansas River IGUCA	Current Status: Phase III