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General
Intermediate
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Abstract

This report is a compilation of five Kentucky Senate Bill 271 Education and Research Program contract reports summarizing work completed between 1995 and 2000. Original reports were submitted to the University of Kentucky College of Agriculture.

In project year 1995-96, efforts began to assess the impact of current agricultural practices for growing corn, soybean, alfalfa, and pasture on groundwater quality in a Western Kentucky Coal Field upland bedrock setting. A farm in Henderson County was selected as the project site at which nitrate-nitrogen (nitrate-N) concentrations in the domestic well water were consistently four times greater than the maximum contaminant level of 10 mg/L. Four existing domestic wells and one stream were sampled for field measurements (pH, electrical conductivity, temperature, and Eh), chloride, sulfate, nitrate-N, and herbicides.

In project year 1996-97, soil cores were collected in each of the agricultural fields (row crop, alfalfa, and pasture), the farmstead area, and an abandoned dairy feedlot. Also, monitoring wells were installed in the corn (eight wells), pasture (eight wells), and alfalfa (three wells) fields. Monitoring wells were sampled for field measurements, anions, metals, nutrients, herbicides, and nitrogen and oxygen isotopes.

In project year 1997-98, 20 wells and four seeps were sampled for field measurements, anions, metals, nutrients, herbicides, and isotopes. Soil cores collected during the 1996-97 project year were analyzed for texture, Mehlich 3 extractable nutrients (phosphorus, potassium, calcium, magnesium, and zinc), pH in water, organic matter and total nitrogen by dry combustion, and potassium chloride extractable ammonium-nitrogen (ammonium-N) and nitrate-N.

In project year 1998-99, sampling of all wells and seeps continued. Three additional wells were installed near an abandoned dairy feedlot. Each well was sampled for field measurements, anions, metals, nutrients, herbicides, and isotopes. Forty-six soil cores
were collected in and around the abandoned feedlot area and 14 soil cores were collected in and around an abandoned homestead site. Soil samples were analyzed for texture, Mehlich 3 extractable nutrients (phosphorus, potassium, calcium, magnesium, and zinc), pH in water, organic matter and total nitrogen by dry combustion, and potassium chloride extractable ammonium-N and nitrate-N.

In project year 1999-2000, sampling of all wells and seeps continued. One monitoring well was installed in an alfalfa field. Forty-nine soil cores were collected in and around an abandoned dairy feedlot to a depth of 8 ft. An additional 14 continuous soil cores were collected to depths ranging from 17 to 28 ft in and around the abandoned feedlot area. Soil samples were analyzed for texture, Mehlich 3 extractable nutrients (phosphorus, potassium, calcium, magnesium, and zinc), pH in water, organic matter and total nitrogen by dry combustion, and potassium chloride extractable ammonium-N and nitrate-N.

Introduction

This report is a compilation of five Kentucky Senate Bill 271 Education and Research Program contract reports submitted to the University of Kentucky College of Agriculture. The reports summarize work completed during project years 1995-96, 1996-97, 1997-98, 1998-99, and 1999-2000. The purpose of this report is to formally document and present preliminary research findings to the public. Only minor revisions have been made to each report, and the reports are presented chronologically as submitted to the University of Kentucky College of Agriculture. Specific details related to well-construction design, water- and soil-sampling methods, and analytical methods used during this project are described in Beck and others (2010a, b). Groundwater-quality data collected during this project have been assimilated into the Kentucky Groundwater Data Repository. Vadose-water- and surface-water-quality data and soil-quality data are tabulated in Beck and others (2010a, b). Funding for this research was provided in part by the Kentucky Senate Bill 271 Education and Research Program administered by the University of Kentucky College of Agriculture.
Chapter 1: Project Year 1995-96

Brief Project Summary

The goal of the proposed study is to evaluate the impact of agricultural land use and the fate of agricultural contaminants on groundwater resources in an upland setting of the Western Kentucky Coal Field physiographic region. Upland settings in this region are typically rolling hills covered by loess-derived soils and underlain by interbedded Pennsylvanian sandstone, siltstone, limestone, and coal (Converse and Cox, 1967; Johnson, 1973). Bedrock-derived groundwater has always been and continues to be an important domestic water source in this region. Well over half of the domestic wells of the region are located on broad uplands, hilltops, or hillslopes and derive water from bedrock as opposed to unconsolidated deposits (Harvey, 1956).

Proposed counties for the project field site were Henderson, Webster, or Union. This three-county area was targeted for study because of intensive use of groundwater as a domestic water supply and the presence of a relatively shallow sandstone aquifer in the area. The results of this project will provide a working conceptual model for groundwater flow in western Kentucky bedrock aquifers and relate it to potential mechanisms and fate of nitrate-nitrogen (nitrate-N) and pesticides so that impacts to groundwater can be understood at this site and predicted in similar agricultural settings in the region. General objectives of this study are to:

1. Evaluate movement and fate of nitrate-N and pesticides in a farmed, upland bedrock setting. The selected site will utilize farming practices typical of the region. The long-term fate of agricultural chemicals in this setting will be predicted.

2. Define the local (shallow) and regional (deeper) groundwater flow system in the upland bedrock setting, which is typical of heavily farmed areas in the Western Kentucky Coal Field, in order to evaluate the occurrence and movement of agricultural chemicals in groundwater. Preliminary predictions will be field verified and a conceptual model of the flow system will be developed.

3. Identify future research needs concerning the fate and transport of agricultural chemicals in this hydrogeologic setting.

The progress of the project over the first funding year conformed closely with the proposed work schedule. Below is a list of first-year accomplishments:

1. A farm site was selected in Henderson County southwest of the city of Henderson (Fig. 1.1).
2. A substantial library of scientific publications on topics relating to all aspects of the project is being compiled and studied.
3. Water samples were collected from domestic wells and other groundwater sources on the farm and its vicinity. Pesticide and nitrate-N contamination in the groundwater of the farm area was identified.
4. A soil coring and monitoring well installation program was developed for the farm site.
A contract to core and install monitoring wells has been awarded to a contractor. At the request of the landowner, drilling will commence when field conditions are dry, but no earlier than March 1996.

**Specific Project Objectives**
Tasks pertinent to achieving the objectives of this study will be completed in such an order as to systematically build upon existing information.

**Objective 1–Task 1: Site Selection.** A suitable site will be chosen on the basis of the following:
- Cooperative landowner
- Crop type and intensity of production
- The use of atrazine for weed control
- An upland geologic setting with a shallow, bedrock water source
- Groundwater is used as drinking water in the vicinity.

**Objective 2–Task 2: Characterization of Soils and Geology.** A site assessment will be completed utilizing existing information and data collected from the site. Characterization will include:
- Preparation of geologic maps and cross sections
- Assembly of information available for representative soil profiles
- Collection of representative soil samples from cores for horizon analysis of texture, structure, color, pH, carbon, and nitrogen.

**Objective 2–Task 3: Hydrogeologic Analysis.** A preliminary hydrogeologic assessment will be completed from available data and will consist of:
- Locations of springs
- Development of potentiometric-surface maps
- Prediction of approximate boundaries for the shallow and deep flow systems in order to develop an appropriate monitoring plan
- Evaluation of water quality from existing well data (KGS database, USGS Hydrologic Atlases, and other sources)
- Inventory and sampling of domestic wells in the vicinity.

**Objective 2–Task 4: Monitoring-Well Installation.** Monitoring wells will be installed to collect data on nitrate-N and pesticide movement and fate, and to delineate groundwater flow systems. The following is proposed:
- Install approximately four well nests (four to five wells per nest) generally along a downslope cross section
- Monitor intervals that encompass any genetic soil horizon that impedes water flow movement (fragipan), the soil zone below the water table, the soil/bedrock interface, shallow bedrock, and deeper bedrock
- Select intervals on the basis of the preliminary geologic and hydrologic evaluation, approximate domestic-well depths, and possible interception of contaminants.

**Objective 2–Task 5: Monitoring Program.** Water levels and water-quality data will be collected on various schedules. Monitoring will encompass the following:
- Sample nitrate-N and pesticides on a schedule consistent with agricultural practices at the site (bimonthly sampling during the planting and growing season and monthly in fall and winter)
- Perform general water-quality analysis to adequately characterize groundwater quality and differentiate groundwater flow systems (quarterly in year 1, biannually thereafter)
- Collect groundwater levels utilizing strategically placed data loggers to define the potentiometric field and flow directions.

**Objective 2–Task 6: Data Analysis and Report.** Analysis of groundwater- and surface-water-quality data will be an ongoing process in order to monitor the progress of achieving overall objectives. Reports describing conceptual flow in the upland Western Kentucky Coal Field setting as well as assessment of the potential mechanisms and fate of nitrate-N and pesticides in this system will be prepared.

**Project Progress**
**Objective 1–Task 1: Site Selection (completed).** Suitable project site prospects were initially identified by searching available groundwater databases for number, density, elevation, and depth of wells and springs and by studying topographic, geolog-
Objective 2–Task 2: Characterization of Soils and Geology (ongoing, but in final stages). After a suitable farm was identified, more detailed geologic and soil information on the site and its surrounding area was obtained. Information for the study area from groundwater records and database searches was looked at in greater detail. In addition to groundwater data, numerous oil-well drillers’ lithologic logs were obtained from the KGS western Kentucky office, and locations and data from core, oil, gas, and water-injection wells on the farm property and surrounding area were obtained from the KGS database and well records. An overlay map of all compiled well locations and data has been created for the study area. These well records have also allowed for better stratigraphic control in the area in order to know the targeted depths for monitoring-well installation. These data are being used to construct stratigraphic, depth-to-bedrock, and depth-to-water maps of the farm site. Information gained from coring and drilling for this project will be added for better resolution on these maps. Information on existing soil maps of the farm and proposed monitoring-well sites was confirmed by field inspection with handheld soil probes.

Objective 2–Task 3: Hydrogeologic Analysis (ongoing). Available groundwater data and topographic, geologic, and soil maps of the region, as well as field investigations, have allowed us to develop a crude potentiometric-surface map, identify springs, seeps, wetlands, and streams, estimate depths and extent of shallow and deeper flow systems, and evaluate historic and current groundwater quality in the study area. Historic groundwater-quality data indicate that pesticides, principally atrazine, have been detected in the groundwater of the farm area. Furthermore, nitrate-N has also proved to be a problem in selected domestic groundwater supplies. On Oct. 26, 1995, a Telog continuous-recording tipping-bucket rain gage was installed. Rain-gage data were downloaded to a spreadsheet on a monthly schedule. All domestic wells on the farm property have been located and sampled. Domestic wells and springs on surrounding farms are being located. Spring, seep, and stream sampling sites on the farm property have also been identified. Two domestic wells on the farm property had old, broken hand pumps in them. The pumps were removed in preparation for sampling and pump tests. In total, seven domestic-well samples and one stream sample have been collected from the farm (Fig. 1.2). Triazines were detected in the stream and the landowner’s domestic well (DW03), although levels did not exceed the MCL of 3 µg/L. Nitrate-N was above the MCL of 10 mg/L in two domestic wells (DW02 and DW03) on the farm (Fig. 1.2). The landowner’s domestic well (DW03) was consistently found to have severe nitrate-N contamination. Sample results are being entered into a spreadsheet in preparation for statistical and graphical manipulation. The first-year results are tabulated in Table 1.1.

Objective 2–Task 4: Monitoring-Well Installation (bidding complete, wells to be installed in March 1996). Compilation of local geologic data, confirmation of soil types, identification of seeps, and documentation of historical and future crop rotations have allowed for the identification of potential monitoring-well sites. Coring and monitoring well contract bids have been written and approved. Coring and the installation of monitoring
Figure 1.2. Locations of the stream sampling site and the four domestic wells located on the Henderson County farm site.

Table 1.1. Water-quality data collected from one stream site and four domestic wells located on the Henderson County farm. “ND” indicates that the analyte was not detected. Blank fields indicate that a measurement was not taken.

<table>
<thead>
<tr>
<th>Sample Site</th>
<th>Sample Date</th>
<th>Temperature (°C)</th>
<th>pH</th>
<th>Eh (mV)</th>
<th>E.C. (μS/cm)</th>
<th>Cl– (mg/L)</th>
<th>SO₄²⁻ (mg/L)</th>
<th>Nitrate-N (mg/L)</th>
<th>Triazines (μg/L)</th>
<th>2,4-D (μg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>St01</td>
<td>09/22/95</td>
<td>18.6</td>
<td>8.30</td>
<td></td>
<td>457</td>
<td>19.1</td>
<td>29.4</td>
<td>0.07</td>
<td>ND</td>
<td>ND</td>
</tr>
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<td>6.95</td>
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<td>52.6</td>
<td>40.0</td>
<td>0.12</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
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<td>6.81</td>
<td>257</td>
<td>396</td>
<td>5.2</td>
<td>18.9</td>
<td>0.29</td>
<td>ND</td>
<td>ND</td>
</tr>
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<td>7.14</td>
<td>341</td>
<td>639</td>
<td>14.5</td>
<td>42.3</td>
<td>10.3</td>
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<td>ND</td>
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<td>6.77</td>
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<td>50.4</td>
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</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>52.5</td>
<td>43.8</td>
<td>59.7</td>
<td>0.18</td>
<td>ND</td>
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<tr>
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<td>6.99</td>
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<td>117.2</td>
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<td></td>
<td>53.8</td>
<td>40.3</td>
<td>41.1</td>
<td>0.16</td>
<td>ND</td>
</tr>
</tbody>
</table>

wells is scheduled for March 1996, weather and landowner permitting. One bedrock core will be drilled to 100 ft below land surface and five monitoring-well nests will be installed. A continuous soil core will be recovered from land surface to the top of bedrock at each of the proposed monitoring-well nests. Each well nest will contain four monitoring wells: one to sample deep (70 to 100 ft) bedrock groundwater, one to sample groundwater in the vicinity of the bedrock surface, another to sample soil water midway in the soil column at any impermeable zones (fragipans, paleosols, etc.) that may be encountered, and the shallowest one to sample soil water at the root base or at the first fragipan encountered. Two nests will be installed in a pasture setting and two in a row-crop setting. One nest in each setting will be installed in a Loring (fragipan) soil and the other in a Memphis (nonfragipan) soil. The fifth well nest will be installed in an alfalfa field to test the influence of alfalfa on nitrate-N occurrence in the groundwater. In addition to field-setting wells, one monitoring well will be drilled near the landowner’s domestic well (DW03). This well will be installed properly, and packer tests will be performed on it in order to determine the reason for the nitrate-N problem in the landowner’s current well.
Objective 2–Task 5: Monitoring Program (to be initiated in March 1996). Following installation of monitoring wells, intensive sampling of all sites will commence in March 1996.

**Summary**

The progress of this project is on schedule and with no unforeseen delays will begin producing large amounts of data by late March 1996. The planned sampling schedule calls for all sites to be sampled once every 2 weeks from March to July (during application time) and once a month the rest of the year. Sampling for this project should continue uninterrupted for a period of 3 years in order to yield statistically valuable data. Data gathered from this project will be invaluable for the ongoing understanding of the hydrogeology, geochemistry, and occurrence of agricultural contaminants in the groundwater of the Western Kentucky Coal Field.
Chapter 2: Project Year 1996-97

Brief Project Summary

The goal of this project is to evaluate the impact of agricultural land use and the fate of agricultural contaminants on groundwater resources in a Western Kentucky Coal Field upland setting. This physiography consists of rolling hills covered by loess-derived soils and underlain by interbedded Pennsylvanian sandstone, siltstone, limestone, and coal. Bedrock-derived groundwater continues to be an important domestic water source in this region. More than half of the domestic wells are located on broad uplands, hilltops, or hillslopes and derive water from bedrock as opposed to unconsolidated deposits. The study site was selected because of the intensive use of groundwater as a domestic water supply and the presence of a shallow sandstone aquifer. Routine sampling was initiated in July 1996. Ongoing sampling will aid the interpretation of a working conceptual model for groundwater flow in western Kentucky upland aquifers and the relationship of nitrate-nitrogen (nitrate-N) and pesticide mechanisms for this hydroagronomic setting. The following is a list of the first- and second-year accomplishments:

(1) A farm site was selected in Henderson County southwest of the city of Henderson (Fig. 1.1).

(2) Scientific publications on topics relating to various aspects of the project are being reviewed.

(3) Drilling and well installation took place in the spring of 1996. Wells were then developed prior to sampling. Five well nests and one potential domestic well monitor various subsurface horizons beneath pasture, crop, and farmstead locations.

(4) A groundwater sampling program has been ongoing since July 1996. Since that time, four sampling runs have been completed and are scheduled to continue when field conditions are favorable.

Specific Program Objectives

(1) Evaluate movement and fate of nitrate-N and pesticides in a farmed, upland bedrock setting. The selected site utilizes farming practices typical of the region. The fate of agricultural chemicals in the saturated zone of this setting will be defined.

(2) Define the local (shallow) and regional (deeper) groundwater-flow systems in order to evaluate the occurrence and movement of agricultural chemicals in groundwater. Preliminary predictions will be field verified and a conceptual model of the flow system will be developed.

(3) Identify future research needs concerning the fate and transport of agricultural chemicals in this hydrogeologic setting. Results will be developed with input from agricultural specialists at the University of Kentucky College of Agriculture.

Work Plan

Tasks pertinent to achieving the objectives of this study will be completed in such an order as to systematically build upon existing information.

Objective 1–Task 1: Site Selection. A suitable site has been chosen on the basis of the following:

• Cooperative landowner
• Crop type and intensity of production
• The use of atrazine for weed control
• An upland geologic setting with a shallow sandstone aquifer
• Groundwater at the site is used for domestic water supply.

Objective 2–Task 1: Characterization of Soils and Geology. A site assessment is being completed utilizing existing information and data collected from the site. Characterization consists of:

• Preparation of geologic maps and cross sections
• Assembly of available information for representative soil profiles
• Collection of representative soil/unconsolidated material samples from cores for horizon analysis of texture, structure, color, pH, carbon, and nitrogen.

Objective 2–Task 2: Hydrogeologic Analysis. A preliminary hydrogeologic assessment is being completed from available data and will consist of:

• Development of potentiometric-surface maps
• Locations of springs
• Prediction of approximate boundaries for the shallow and deeper groundwater flow
systems in order to develop an appropriate monitoring plan:

- Evaluation of existing water-quality data from wells in the region (Kentucky Groundwater Data Repository, USGS Hydrologic Atlases, etc.)
- Inventory and sampling of domestic wells in the vicinity.

Objective 2–Task 3: Monitoring-Well Installation. Monitoring wells have been installed to collect data on nitrate-N and pesticide movement and to delineate groundwater flow systems. The following have been initiated:

- Two well nests (four wells per nest) have been installed on hilltops in a Memphis soil and three well nests (three to four wells per nest) along a downslope in a Loring soil
- The monitored intervals encompass genetic soil horizons (fragipans) that impede downward vertical leakage of water within the root zone, the unconsolidated material below the water table, the top of bedrock–bedrock interface, and bedrock
- Monitored intervals were selected by evaluating geologic and hydrologic characteristics, approximate domestic well depths, and potential interception of contaminants.

Objective 2–Task 4: Monitoring Program. Water levels and water-quality data will be collected on various schedules. Monitoring will encompass the following:

- Nitrate-N and pesticides analysis on a schedule consistent with agricultural practices at the site (monthly sampling during the planting and growing season and once every 2 months in fall and winter)
- Standard water-quality analysis to adequately characterize groundwater quality and differentiate groundwater flow systems
- Groundwater levels utilizing strategically placed data loggers to define the potentiometric field and flow directions.

Objective 2–Task 5: Data Analysis and Report. Data analysis will continue in order to assess progress of overall objectives. Reports will define groundwater flow systems of the upland Western Kentucky Coal Field setting as well as assess the potential mechanisms and fate of nitrate-N and pesticides in this system.

Project Progress

Objective 1–Task 1: Site Selection (completed). Suitable project site prospects were initially identified by searching available groundwater databases for number, density, elevation, and depth of wells and springs and by studying topographic, geologic, and soil maps of the region. After a number of potential areas in the Western Kentucky Coal Field were identified, a meeting with county Extension agents representing those areas was held to discuss the project. Extension agents then talked with cooperative landowners about the project. Prospective farms were visited, the scope of the project was outlined for each farmer, and cropping history on their land was discussed. A farm located southwest of Henderson in Henderson County was then chosen as the field site for the project. This farm fits well with all aspects of the project, including the presence of an existing nitrate-N problem in the landowner’s domestic groundwater supply. In addition to a project site search, a search for literature on the Western Kentucky Coal Field was begun to obtain information on stratigraphy, sediment deposition, hydrogeology, loess deposition and occurrence, groundwater geochemistry, pollution potential, and pesticides and nitrogen-related species in groundwater.

Objective 2–Task 1: Characterization of Soils and Geology (near completion). After a study site was identified, more detailed geologic and soil information for the site and its surrounding area were assessed. Information from groundwater records and database searches was further evaluated. In addition to groundwater data, numerous drillers’ lithologic logs, locations, and data from core and oil, gas, and water-injection wells on the farm property and surrounding area were obtained from the KGS Western Kentucky Office and the Kentucky Groundwater Data Repository. An overlay map showing all compiled well locations and data points has been created for the study area. These well records have been used for stratigraphic control in the area in order to target depths for
well installation. These data were used to construct maps of stratigraphy, depth to bedrock, and depth to water. Information gained from coring and drilling during 1996 will be added for improved resolution on these maps. Information on existing soil maps of the farm and proposed monitoring-well sites was confirmed by field inspection with handheld soil probes. Equipment failures have impeded some soil analyses for nitrogen and carbon content. In addition, grain sizes of fertile soil and underlying sediment are to be measured.

**Objective 2–Task 2: Hydrogeologic Analysis (ongoing).** Available groundwater data and maps of topography, geology, and soils, as well as field investigations were used to develop an initial groundwater potentiometric-surface map, identify springs, seeps, wetlands, and streams, estimate depths and extent of shallow and deeper groundwater flow systems, and evaluate historic and current groundwater quality in the study area.

Historic groundwater-quality data indicate that pesticides, principally atrazine, have been detected in groundwater of the farm area. Furthermore, nitrate-N has also proved to be a problem in some domestic groundwater supplies throughout the Western Kentucky Coal Field (Harvey, 1956).

In October 1995, a Telog continuously recording tipping-bucket rain gage was installed. Data were downloaded to a spreadsheet on a monthly schedule. All preexisting domestic wells on the farm property have been sampled. One potential domestic well (DW05) has been installed. Several domestic wells and springs on surrounding farms have been located, and this survey continues. Spring, seep, and stream sampling sites on the farm property have also been identified and sampled. Two domestic wells on the farm property contained broken hand pumps. These were removed in preparation for sampling and pump tests. In total, seven domestic wells and one stream location on the farm have been sampled.

Triazines were detected in the stream and the operating domestic well, and the new potential domestic well, although levels did not exceed the MCL (3 mg/L). Nitrate-N was above the MCL (10 mg/L) in two domestic wells (DW02 and DW03) on the farm. Sample results have been entered into a spreadsheet in preparation for statistical and graphical analysis.

**Objective 2–Task 3: Monitoring-Well Installation (bidding and installation complete).** Coring and monitoring-well installation contracts were approved in late winter of 1996. Initial coring and well installation were scheduled for completion in March 1996. However, wet weather conditions in late winter and early spring that kept the farmer out of the field delayed installation of several wells until May 1996. One bedrock core was drilled to a depth of 100 ft. Eight soil cores were collected from land surface to the top of bedrock (Fig. 2.1). Three different agricultural land uses are commonly present at this research site (corn, pasture, alfalfa), and each of these land uses was instrumented with monitoring wells (Fig. 2.2). The sandstone aquifer is part of the regional flow system, and is used as a domestic water supply.

Evaluation of geologic data; confirmation of soil types; identification of seeps, springs, streams, and wetlands; history of land use; initial sampling of domestic wells; and construction of hydrogeologic maps were used to identify sampling and monitoring-well sites. Two well nests were installed in a pasture setting and two in a row-crop (corn) setting. One nest in each setting was installed in a Loring (fragipan) soil and the other in a Memphis (nonfragipan) soil. The fifth well nest was installed in an alfalfa field to measure any influence of alfalfa on nitrate-N occurrence in the groundwater.

The nests contain shallow to moderately deep wells that represent movement through different horizons in the unconsolidated and bedrock profile (Table 2.1). With the exception of the alfalfa nest, which does not contain a bedrock-aquifer well, these nests each contain four wells of varying depths significant to vadose and groundwater movement. Shallowest are the root-zone wells, at the base of the root zone or the first low-permeability zone (fragipan, paleosol, etc.). These wells are screened from 4 to 5 ft from the land surface and have a total depth of approximately 10 ft. The paleosol wells represent soil water midway in the soil column at a low-permeability zone. They have a 3-ft screen at depths between 9 and 20 ft from ground surface. Total depths range from 20 to 25 ft.
The bedrock-surface wells have an 11-ft screen at the bedrock-soil interface at 12 to 39 ft and total depths from 30 to 40 ft from ground surface. The bedrock wells have a 21-ft screen within the sandstone aquifer. Their screen base and total depths range between 62 and 88 ft from ground surface.
Table 2.1. Wells used for groundwater sampling. The last four letters of the well ID are derived from information contained in the location, soil, and sample interval columns.

<table>
<thead>
<tr>
<th>Well ID</th>
<th>Location</th>
<th>Soil</th>
<th>Sample Interval</th>
<th>Total Depth (ft)</th>
<th>Installation Date</th>
</tr>
</thead>
<tbody>
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<td>corn (C)</td>
<td>Memphis (M)</td>
<td>root zone (RZ)</td>
<td>9.80</td>
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</tr>
<tr>
<td>SKCMPS</td>
<td>corn</td>
<td>Memphis paleosol (PS)</td>
<td>bedrock surface (BS)</td>
<td>19.92</td>
<td>04/16/96</td>
</tr>
<tr>
<td>SKCMBS</td>
<td>corn</td>
<td>Memphis bedrock aquifer (BA)</td>
<td>35.14</td>
<td>05/18/96</td>
<td></td>
</tr>
<tr>
<td>SKCMBA</td>
<td>corn</td>
<td>Memphis bedrock surface</td>
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<td>04/21/96</td>
<td></td>
</tr>
<tr>
<td>SKCLRZ</td>
<td>corn</td>
<td>Loring (L)</td>
<td>root zone</td>
<td>9.96</td>
<td>03/18/96</td>
</tr>
<tr>
<td>SKCLPS</td>
<td>corn</td>
<td>Loring paleosol</td>
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</tr>
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<td>SKCLBS</td>
<td>corn</td>
<td>Loring bedrock surface</td>
<td>29.93</td>
<td>04/24/96</td>
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<td>Loring bedrock aquifer</td>
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<td>05/22/96</td>
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</tr>
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<td>Loring root zone</td>
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<td>04/18/96</td>
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</tr>
<tr>
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</tr>
<tr>
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<td></td>
</tr>
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<td>Memphis bedrock aquifer</td>
<td>75.00</td>
<td>03/20/96</td>
<td></td>
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</tbody>
</table>

One additional potential domestic well was installed near the landowner’s currently operating domestic well with a 29-ft screen and a total depth of 79 ft. Packer tests will be performed at this site in order to determine the reason for the nitrate-N conditions in the landowner’s domestic well. This was postponed because of equipment failures. Table 2.2 contains additional measurements of the monitored wells.

Objectives 2–Task 4: Monitoring Program (initiated July 1996). Following installation of monitoring wells, intensive sampling of all sites commenced in July 1996 as weather conditions allowed. Because of wet weather, the farmer was unable to plant corn where intended. Soybeans were instead planted in this field in 1996. Corn will likely be grown in this field in the next few years, weather permitting. Because of the crop change, the agricultural chemicals used in 1996 were not those typically used in this field. Practices in the alfalfa and pasture sites were more typical of what was expected.

Nitrate-N concentrations over time are shown in Figures 2.3 through 2.8. Each of the graphs show nitrate-N concentrations for one well nest, with the exception of Figure 2.8, which shows the data for the monitored domestic wells. Results of January 1997 sampling have not yet been received from the laboratory.

Summary

Farming practices and well installation were significantly delayed in late winter and early spring of 1996, because of wet weather. Sampling of monitoring wells began in July 1996. The 1996 spring cropping sequence was not monitored; therefore, the first year of complete sampling through an annual crop cycle will occur in 1997. The current
Table 2.2. Detailed measurements for each monitoring and domestic well.

<table>
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<tr>
<th>Well Name</th>
<th>Well Total Depth (ft)</th>
<th>Borehole Total Depth (ft)</th>
<th>Screen Length (ft)</th>
<th>Storage Cup Length (ft)</th>
<th>Borehole Diameter (in.)</th>
<th>Well Diameter (in.)</th>
<th>Screen Base Depth (ft)</th>
<th>Funnel Top Depth (ft)</th>
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<td>SKDWO3</td>
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<td>8</td>
<td>79.00</td>
</tr>
</tbody>
</table>

The sampling schedule calls for all sites to be sampled monthly during planting and growing seasons and every other month during the fall and winter. Sampling should continue uninterrupted for a period of 3 years (through the 1999 cropping sequence) in order to obtain representative data. As expected, the Memphis soil does not retain water as well as the Loring soil. Response to storms shows that groundwater movement is less impeded by this soil type. The work completed to date indicates that the chosen site is an excellent study area. Data gathered from this project will be invaluable for the ongoing understanding of interrelationships between hydrogeology, geochemistry, and potential occurrence of contaminants related to agricultural practices in the groundwater of the Western Kentucky Coal Field.
Figure 2.3. Nitrate-N concentrations for the pasture-Memphis wells.

Figure 2.4. Nitrate-N concentrations for the pasture-Loring wells.
Figure 2.5. Nitrate-N concentrations for the corn-Memphis wells.

Figure 2.6. Nitrate-N concentrations for the corn-Loring wells.
Figure 2.7. Nitrate-N concentrations for the alfalfa-Loring wells.

Figure 2.8. Nitrate-N concentrations for the domestic water wells.
Chapter 3: Project Year 1997-98

Brief Project Summary

The goal of this project is to evaluate the impact of agricultural land use and the fate of agricultural contaminants on groundwater resources in a Western Kentucky Coal Field upland setting. This physiography consists of rolling hills covered by loess-derived soils (Memphis and Loring) and underlain by interbedded Pennsylvanian sandstone, siltstone, limestone, and coal. Bedrock-derived groundwater continues to be an important domestic water source in this region. Over half of the domestic wells are located on broad uplands, hilltops, or hillslopes and derive water from bedrock as opposed to unconsolidated deposits (alluvium). The study site was selected because of the intensive use of groundwater as a domestic water supply derived from a shallow sandstone aquifer. Initial agricultural settings selected for monitoring at the site were different fields used for corn/soybean rotation, alfalfa, and pasture.

Twenty monitoring wells were installed, between March and June 1996, at varying depths that are significant to water movement. Well placement was based on data collected from soil cores, soil maps, geologic maps, and land-use history. Four distinct geologic media (soil, paleosol, loess, and sandstone aquifer) and corresponding hydrogeologic zones (vadose zone, seasonally perched water table zone, and saturated zone) were identified at the study site.

Routine sampling was to begin in early spring 1996, but because of wet weather conditions, sampling did not begin until July 1996. Because of the delay, only one full growing season (1997) of data have been collected. During the 1997 growing season, water samples were collected biweekly, whereas fall and winter samples were collected monthly.

Soil-core data indicate that organic matter, total nitrogen, nitrate-nitrogen (nitrate-N), and ammonium-nitrogen (ammonium-N) values are much higher in the abandoned feedlot core than in the corn, alfalfa, and pasture cores. These higher values are believed to be coming from organic material derived from dairy cows. The cores also indicate that the farmer is not overapplying nutrients to his fields.

The highest nitrate-N concentrations in groundwater (40 to 65 mg/L) have been in samples collected from a domestic well (DW03), which until recently had been used as a water supply for a farmer’s home. The maximum contaminant level for nitrate-N is 10 mg/L. A possible source for the high nitrate-N is a nearby abandoned feedlot that was part of a dairy operation at the farm until it was discontinued approximately 20 years ago.

Samples collected from wells in the corn/soybean field indicate that nitrate-N and chloride concentrations are highest (both greater than 20 mg/L) in the soil and paleosol water, immediately after application of agricultural chemicals. Nitrate-N and chloride concentrations were higher than expected (both greater than 7 mg/L) in the sandstone aquifer at the corn-Loring site. Following application, atrazine concentrations were highest in the soil water (greater than 700 \( \text{mg/L} \)), but concentrations decreased shortly thereafter. Atrazine concentrations in the paleosol, loess, and sandstone aquifer water were below the MCL of 3 \( \mu \text{g/L} \).

Research to date indicates that additional data are needed to substantiate the movement of pesticides and nutrients in the corn/soybean, pasture, and alfalfa settings. Additional monitoring wells and chemical analysis of soil cores are needed to define the movement of potential groundwater contaminants from the abandoned feedlot to the shallow bedrock aquifer, and to suggest potential best management practices to minimize the effects of this agricultural practice on the groundwater system.

Objective

The goal of this project is to evaluate the impact of agricultural land use on groundwater in an upland bedrock setting. The objectives are to:

1. Define groundwater conditions in this upland bedrock setting. Definition of the groundwater flow system is necessary so that the movement and fate of agriculturally related chemicals and nutrients may be studied.
2. Evaluate the origin, movement, and fate of nitrate-N and pesticides in a farmed, upland bedrock setting. The selected site utilizes farming practices typical of the region. The long-term
movement and fate of agricultural chemicals in this setting is being measured.
(3) Identify future research needs concerning the fate and transport of agricultural chemicals in this hydrogeologic setting.
(4) Evaluate best management practices that may mitigate the problem, if present or past agricultural practices are determined to contribute to elevated nitrate-N concentrations in groundwater.

Methods
In late summer 1995, prospective project sites were initially identified by searching available groundwater databases for number, density, elevation, and depth of wells and springs, and by studying topographic, geologic, and soil maps of the Western Kentucky Coal Field. After a number of potential areas in the region were identified, a meeting was held to discuss the project with UK Cooperative Extension Service agents representing those areas. Extension agents then talked with cooperative landowners about the project. Prospective farms were visited, cropping histories were discussed, and the scope of the project was outlined for each farmer. A farm located southwest of Henderson in Henderson County (Fig. 3.1) was then chosen as the field site because
(1) It represents the last major hydrogeologic setting (an upland setting in the Western Kentucky Coal Field) to be intensively studied under the SB-271 program
(2) It contains a bedrock aquifer used for domestic and livestock water supply that has nitrate-N concentrations above drinking water MCL’s
(3) There are a variety of soil conditions, including the presence of a fragipan that may have significant controls on nutrient and pesticide behavior
(4) Cultivated crops, including alfalfa, represent the norm for much of western Kentucky for which environmental studies are not available in Kentucky
(5) There is an abandoned feedlot area within the site and continued livestock operations, which may have significant impact on shallow groundwater quality.

Figure 3.1. Monitoring locations at the Henderson County farm site.
A Telog continuously recording tipping-bucket rain gage was installed in October 1995. Data were downloaded to a spreadsheet on a monthly schedule. Soil and rock coring began in March 1996. One rock core (Fig. 3.1) was drilled to a depth of 100 ft below land surface and described for lithology and features, such as weathered sandstone, that may be indicative of water-producing zones. Eight soil cores were collected, ranging in depth from 25 to 35 ft below land surface. Two soil cores were collected from each of the corn/soybean, pasture, and alfalfa settings. One soil core was collected within the abandoned feedlot area and one outside of the abandoned feedlot (Fig. 3.1). Each soil core was subdivided into 1-ft increments and subjected to several physical and chemical analyses. Texture (sand, silt, and clay) was determined by suspension sedimentation and pipette extraction analysis (Gee and Bauder, 1986). The pH was determined in a 1:1 (m/v) material:distilled water mixture. Bioavailable phosphorus, potassium, calcium, magnesium, and zinc were determined by Mehlich 3 extraction (Mehlich, 1984). Organic matter and total nitrogen were determined by dry combustion (Bradstreet, 1965; Nelson and Sommers, 1996). Inorganic nitrogen (both ammonium and nitrate) were determined by colorimetry after molar potassium chloride extraction (Technicon Corp., 1965; Keeney and Nelson, 1982).

Placement and depth of monitoring wells were based on geologic data; confirmation of soil types; identification of seeps, streams and wetlands; history of land use; preliminary sampling of domestic wells (DW01, DW02, DW03, and DW04); and construction of hydrogeologic maps. Monitoring-well installation began in March 1996, but because of wet weather was not completed until June 1996. Table 2.2 shows the construction details of each monitoring well. Twenty monitoring wells have been installed at the study site, ranging in depth from 5 to 88 ft below land surface. Monitoring wells were installed as follows: two well nests (eight wells) in a row-crop (corn/soybean) setting, two nests (eight wells) in a pasture setting, one nest (three wells) in an alfalfa setting, and one monitoring well (DW05) was installed near the abandoned feedlot area (Fig. 3.1). One well nest in each of the crop (C) and pasture (P) settings was installed in a Loring (L) (fragipan) soil and the other in a Memphis (M) (nonfragipan) soil. The alfalfa (A) well nest was installed in a Loring soil. Each well nest contains four wells of varying depths (root zone (RZ), paleosol (PS), bedrock surface (BS), and bedrock aquifer (BA)), except for the alfalfa well nest, which does not contain a bedrock-aquifer well. Each well was installed in a different geologic media (soil, paleosol, loess-bedrock interface, and sandstone aquifer) (Fig. 3.2). The root-zone and paleosol wells were installed and screened at the bottom of the soil profile (4 to 5 ft below land surface) and at the bottom of the paleosol horizon (11 to 21 ft below land surface), respectively. Bedrock-surface wells were installed and screened just below the loess-bedrock interface (12 to 40 ft) to monitor vadose water entering the sandstone aquifer. The sandstone aquifer was monitored by the bedrock-aquifer wells, which ranged in depth from 62 to 88 ft below land surface.

Vadose-water and groundwater sampling began in July 1996. From July 1996 to March 1997, 20 monitoring wells, three domestic wells, and four seeps were sampled monthly. During the 1997 planting and growing season (April to August), the corn/soybean wells were sampled biweekly for nutrients and pesticides; all other sites during this period were sampled monthly for nutrients. All sites were sampled on a monthly schedule during the fall and winter.

To adequately characterize water quality and define recharge to the water-flow system through the soil, paleosol, and loess, 17 water samples were collected and analyzed for total metals and total dissolved metals. Eighteen water samples and one rain sample were analyzed for tritium.

Between July 1996 and August 1997, water levels were measured during each sampling event. From August 1997 to March 1998, water levels were measured daily in three corn-Memphis wells and three corn-Loring wells, using six Telog continuously recording water-level gages.

**Results and Discussion**

Initial sampling of all wells and seeps was to begin in early spring 1996. However, heavy rainfall during this time delayed installation of monitoring wells, and subsequent water sampling did not begin until July 1996. Therefore, water monitoring during the spring application of nutrients and
pesticides was missed for the 1996 growing season. The 1997 growing season is the only season for which the project has adequate water-quality data. Experience from the other six research sites studied under the SB-271 program in the early 1990’s indicates that at least 3 years of data are needed to effectively evaluate the role of cropping systems, soil, and geology with respect to generation of nitrate-N and its movement.

Water-level data indicate that there are three hydrogeologic zones present at the study site: (1) Vadose zone (2) Seasonally perched water table zone (3) Saturated zone (shallow sandstone aquifer) (Fig. 3.2).

(4) The vadose zone corresponds to the soil, paleosol, and parts of the loess media (0 to 28 ft) during the dry season when a perched water table is not present. Perched water tables form on fragipans and paleosols during the wet season, which causes parts of the vadose zone to become saturated for short periods.

Soil Core Findings

Texture. Across the entire core set, the predominant size fraction is silt. The Loring sites (Fig. 3.3) are dominated by sand below a depth of 15 ft, except for the corn-Loring site, which is dominated by silt (Fig. 3c). At the Memphis sites (Fig. 3.4), sand begins to rise drastically below 20 to 25 ft in depth, reaching a value of 80 percent between 25 and 35 ft below land surface. The abandoned feedlot core (Fig. 3.5a) was similar to the pasture-Loring site (Fig. 3.3b) in its textural pattern with depth. The sand content first increases (from 10 to 40 percent) at 20 ft, and then between 25 and 30 ft the silt returns to high levels (70 to 80 percent), with the clay remaining between 5 and 30 percent throughout these changes. With regard to silt and sand, the domestic well (DW05) core (Fig. 3.5b) exhibited a pattern similar to that of the Memphis sites in which the sand fraction increased from 6 to 80 percent at a depth of around 25 ft.

Clay peaks caused by soil profile development between the 0- to 5-ft interval were observed at all locations (Figs. 3.3–3.5). Deeper clay peaks (clay fraction more than 40 percent of the total), indicative of either paleosol development or parent material stratification, were observed in the pasture-Loring (Fig. 3.3b), pasture-Memphis (Fig. 3.4a), alfalfa-Memphis (Fig. 3.4b), and corn-Memphis (Fig. 3.4c) cores.

Bioavailable Phosphorus. Except for the corn-Loring core (Fig. 3.6), all the cores tend to exhibit a similar pattern in extractable phosphorus with
Figure 3.3. Soil-texture data for the alfalfa-Loring (a), pasture-Loring (b), and corn-Loring (c) soil cores.
Figure 3.4. Soil-texture data for the pasture-Memphis (a), alfalfa-Memphis (b), and corn-Memphis (c) soil cores.
Figure 3.5. Soil-texture data for the feedlot (a) and domestic well (DW05) (b) soil cores.
depth (Figs. 3.6–3.8). Concentrations initially decrease with depth, then increase to a peak somewhere between 7 and 10 ft beneath land surface, and then generally decrease with further depth to values typical of the loess parent material (2 to 10 ppm). Below the 7- to 10-ft interval peak, the phosphorus concentrations in the pasture-Memphis, abandoned feedlot, and DW05 cores (Figs. 3.7 and 3.8, respectively) oscillate between 5 and 20 ppm. The reasons for these oscillations with depth are unknown at present, but may be caused by stratification of mineral composition in the parent material.

The highest surface-soil value for phosphorus was observed at the top of the abandoned feedlot core (14,400 ppm; not shown in Figure 3.8), followed by the DW05 core (49 ppm) (Fig. 3.8).

**Organic Matter.** All cores (Figs. 3.9–3.11) exhibited greater values for organic matter at the soil surface, and six of the eight cores exhibited another similarity: a large peak in value(s) between 5 and 20 ft below land surface. This peak tends to be associated with pH values near 8.3 and much higher extractable calcium values (4,000 to 5,000 ppm). This strongly suggests that these peaks are not due to carbon associated with organic matter, but to carbon associated with calcium-carbonate deposits formed at these depths.

Among Loring cores (Fig. 3.9), the forage pasture and alfalfa cores have greater surficial organic matter (approximately 2.5 percent) than the row-cropped corn core (1.75 percent). This is not the case among the Memphis cores (Fig. 3.10): surficial organic matter is about 1.5 percent in all Memphis cores. The abandoned feedlot core (Fig. 3.11) has the highest value for organic matter in the 0- to 1-ft interval (18.7 percent), decreasing to a value near that of all the other cores (0.55 percent) in the 1- to 2-ft interval.

**Total Nitrogen.** All sites (Figs. 3.12–3.14) exhibited a similar pattern in total nitrogen values with depth. There is a peak in the 0- to 1-ft interval, followed by a decline in values with depth. The highest concentration at the surface is exhibited by the abandoned feedlot core (19,200 ppm; not shown in Figure 3.14).

Loring cores (Fig. 3.12) exhibited little change in total nitrogen concentrations with depth, whereas the Memphis (Fig. 3.13) and farmstead cores (Fig. 3.14) show greater fluctuations in total nitro-
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Figure 3.8. Soil bioavailable phosphorus concentrations for the feedlot and domestic well (DW05) soil cores.

Figure 3.9. Organic matter values for the pasture-Loring, corn-Loring, and alfalfa-Loring soil cores.

deeper organic matter peaks are in fact carbonate carbon rather than organic carbon.

**Nitrate-Nitrogen.** In the Loring cores (Fig. 3.15), nitrate-N concentrations range between 0.1 and 3.4 ppm in the 0- to 5-ft interval, and between 0.1 and 0.5 ppm in the deeper sampling increments. The lowest nitrate-N concentrations across the several sampling depths are found in the alfalfa-Loring core (0–2 ppm; Fig. 3.15) and the highest concentrations are found in the corn-Loring core (0–3.4 ppm; Fig. 3.15).

Nitrate-N concentrations among the Memphis cores (Fig. 3.16) are highest (10–12.6 ppm) in the 0- to 5-ft interval of the pasture core (Fig. 3.16), and decrease until a value close to 0.5 ppm is reached at a depth of 5 ft. In the corn-Memphis core (Fig. 3.16), the nitrate-N concentration increases from 2 to 9.4 ppm between 0 and 4 ft below land surface and then decreases to 0.2 ppm below the 8-ft depth. Among all Memphis cores, the corn-Memphis core had the highest nitrate-N values. The corn-Memphis core pattern suggests nitrate-N possibly moved because of the increase in nitrate-N (2–9.4 ppm) within the first 4 ft below land surface.

The abandoned feedlot core (Fig. 3.17) has the highest nitrate-N concentration at the surface (36 ppm) and then decreases to 15 ppm between the 0- and 3-ft interval. Surface nitrate-N concentration for the DW05 core (Fig. 3.17) is 5 ppm. At the 5-ft depth of both farmstead soils, the nitrate-N concentration declines to values between 1 and 5 ppm. These values are much greater than those observed at the other sites.

**Ammonium-Nitrogen.** Ammonium-N values for the Loring cores (Fig. 3.18) are low (less than 4 ppm) at all depths greater than 5 ft. The pasture-Loring core (Fig. 3.18) has the highest ammonium-N content at the surface (12.6 ppm), whereas in the alfalfa-Loring core (Fig. 3.18), ammonium-N increases from 1.4 to 11.2 ppm between 0 and 2 ft below land surface.
Among ammonium-N values in the Memphis cores (Fig. 3.19), the pasture-Memphis core exhibits the highest concentration at the surface (13.2 ppm). Similar to the corn-Loring core (Fig. 3.18), the corn-Memphis core (Fig. 3.19) has an ammonium-N concentration of 9 ppm at the surface. The alfalfa-Memphis core (Fig. 3.19) has the lowest ammonium-N value at the surface (6 ppm). Ammonium-N concentrations are slightly higher with depth in the Memphis cores (4–7 ppm) than in the Loring cores (less than 4 ppm).

Compared to core from the other sites, the abandoned feedlot core (Fig. 3.20) has the highest ammonium-N concentration at the surface (20 ppm), but quickly declines to 3 ppm between 0 and 3 ft. The DW05 core (Fig. 3.20) has an ammonium-N concentration of 6 ppm at the surface, but also declines to around 3 ppm at greater depths. Ammonium-N concentrations seem to oscillate more with depth at the feedlot and in DW05 cores than in the Loring and Memphis cores.

**Soil Core Conclusions.** The most apparent conclusion that can be drawn from the soil-core data is that there is a major nutrient chemical difference between the corn, alfalfa, and pasture cores compared to the abandoned feedlot core. For example, the organic matter percentage and total nitrogen concentrations at the abandoned feedlot site are 18.7 percent and 19,200 ppm, respectively, compared to the highest organic matter and total nitrogen values of the other sites (3.5 percent and 3,700 ppm, respectively). The high nutrient values in the abandoned feedlot core are suspected to be produced from organic material derived from dairy cows. The dairy was in existence for about 40 years, but has not been in operation for the last 20 years. For further needs and concerns, see “Abandoned Feedlot Findings.”

Soil cores, along with water-quality data, from the corn/soybean, alfalfa and pasture settings indicate that the farmer is not overapplying nutrients to his fields. For further needs and concerns, see “Corn/Soybean, Alfalfa, and Pasture Fields Findings.”

**Abandoned Feedlot Findings**

Throughout the study area, nitrate-N concentrations within the shallow bedrock aquifer range from 2 to 65 mg/L. The U.S. Environmental Protection Agency MCL for nitrate-N is 10 mg/L. The highest nitrate-N concentrations (45–65 mg/L)
have been in samples collected from monitoring well DW05 and domestic well DW03, which the farmer was using as a water supply for his home. Chloride concentrations have also been high (60 mg/L). A possible source for the high nitrate-N and chloride is a nearby feedlot, which was part of a dairy farm operation that was discontinued approximately 20 years ago. The following steps need to be taken to better understand the impact of the abandoned feedlot on the local, shallow groundwater system:

1. Install additional monitoring wells in and around the abandoned feedlot area to determine the extent of nitrate-N contamination within the shallow aquifer system. Water-level data collected from these wells will also help to determine the potentiometric gradient, which will help to define groundwater flow direction.

2. Collect soil cores within and outside the now-obscured feedlot boundary. Soil cores will reveal the presence and distribution of any organic matter that may be associated with the abandoned feedlot and help to determine if nitrate-N is moving vertically downward through the soil, paleosol, and loess column to the shallow sandstone aquifer.

Corn/Soybean Field Findings

Vadose water and groundwater from eight wells in a corn/soybean setting have been monitored for nutrients and pesticides. Four wells are in a Memphis soil site (corn-Memphis) and four are in a Loring soil site (corn-Loring). Nitrate-N concentrations in the corn-Memphis wells and corn-Loring wells range from 0.07 to 23.1 mg/L and 1.8 to 41.7 mg/L, respectively. The highest nitrate-N concentrations (greater than 20 mg/L) have been in the root-zone and paleosol wells following application of nitrogen fertilizers.

Chloride concentrations in the corn-Memphis wells and corn-Loring wells range from 4.4 to 41.8 mg/L and 8.8 to 50.7 mg/L, respectively. Chloride is applied to the fields as potash (KCl). The highest concentrations of chloride (greater than 20 mg/L) have also been in wells monitoring the vadose zone.
Nitrate-N and chloride seem to follow two distinct patterns in the corn-Memphis and corn-Loring sites as they move through the vadose zone to the saturated zone. Nitrate-N and chloride concentrations decrease with depth at the corn-Memphis site (Figs. 3.21a, b) and increase with depth at the corn-Loring site (Figs. 3.21c, d). Preliminary groundwater levels at each site tend to indicate that during the wet season a higher perched water table is present at the corn-Loring site than at the corn-Memphis site. The perched water table is probably caused by the presence of a fragipan (low permeability zone) at the corn-Loring site. As the water level rises and falls in response to precipitation at the corn-Loring site, nitrate-N and chloride may be flushed from the vadose zone, which may allow for higher nitrate-N and chloride concentrations to reach the shallow aquifer. To understand why nitrate-N increases with depth at the corn-Loring site, the following data are needed:

1. Nitrate-N concentrations for two additional growing seasons, which may help to determine any patterns associated with crop rotations, fertilizer applications, or climatic events.
2. Water-level measurements collected on a daily basis for 1 year at selected wells. These measurements may reveal the seasonal changes in water-table elevations that could be playing a major role in increasing nitrate-N and chloride concentrations with depth.

Atrazine was applied in the corn/soybean field during the 1997 planting and growing season. Concentrations in the vadose zone range from greater than 0.06 to 751 µg/L, the highest concentrations occurring in wells immediately after application. Atrazine decreased with depth and was always below the MCL (3 µg/L) in the sandstone aquifer.

**Pasture Field Findings**

Nitrogen fertilizer has only been applied one time (1997) in the pasture field since water sampling began in July 1996. Nitrate-N concentrations at the pasture site range from 0.02 to 5 mg/L. With depth, nitrate-N concentrations generally follow the same pattern with regard to Memphis versus Loring soils as seen at the cropped site. The highest nitrate-N concentrations are in the sandstone aquifer at the pasture-Loring site (3-5 mg/L).
Alfalfa Field Findings

Because of wet weather, the farmer has not been able to plant alfalfa as initially planned. Therefore, no data have been collected related to how alfalfa affects the movement and fate of nitrate-N.

Summary

At this location, groundwater is a viable water supply being used for domestic and agricultural purposes. The aquifer supplying the groundwater is a sandstone unit approximately 30 ft beneath the land surface and approximately 25 ft thick. In this upland setting, the overlying material is loess, which has two major soil types: Memphis and Loring. The Memphis soil is a silt loam, occurs on hilltops, and is very well drained. The Loring soils occur along the sides of the hills and in the local swales of the landscape. It is moderately drained because of the presence of a fragipan, which somewhat inhibits downward recharge of water to the groundwater system.

Initially, three agricultural land-use activities were selected to be monitored at the site: corn/soybean field, alfalfa field, and pasture. Using 20 monitoring wells, four domestic wells, four seeps, and four distinct geologic media were monitored (soil, paleosol, loess, and sandstone aquifer) and three corresponding hydrogeologic zones (vadose zone, seasonally perched water tables, and saturated zone) were monitored for nutrient and pesticide movement.

Soil core data indicate that organic matter, total nitrogen, nitrate-N, and ammonium-N values are much higher in the abandoned feedlot core than in the corn, alfalfa, and pasture cores. These higher values are believed to be coming from organic material derived from dairy cows. The cores also indicate that the farmer is not overapplying nutrients to his fields.

Throughout the study area, nitrate-N concentrations within the shallow bedrock aquifer range from 2 to 65 mg/L. The MCL for nitrate-N is 10 mg/L. The highest nitrate-N concentrations (45–65 mg/L) are in samples collected from monitoring well DW05 and the farmer’s domestic supply well, DW03. Chloride concentrations have also been high (60 mg/L). A possible source for the high nitrate-N and chloride is a near-
by feedlot, which was part of a dairy-farm operation that was discontinued approximately 20 years ago.

Because of wet weather, only one full growing season (1997) of data has been collected for the corn/soybean field. Concerning the corn/soybean field, nitrate-N concentrations tend to be highest in the root-zone wells (greater than 20 mg/L) immediately after application, but decrease shortly thereafter. At the Memphis-soil site, nitrate-N concentrations decrease with depth, but increase with depth at the Loring-soil site where the fragipan is present. Atrazine concentrations are highest in the vadose zone wells immediately after application (greater than 700 µg/L).

Nitrate-N concentrations at the pasture site range from 0.02 to 5 mg/L. With depth, nitrate-N concentrations generally follow the same pattern with regard to Memphis versus Loring soils as seen at the cropped site. The highest nitrate-N concentrations are in the sandstone aquifer at the pasture-Loring site (3–5 mg/L). At present, because of wet weather, no water-quality data have been collected at the alfalfa site.

Research to date indicates that additional data are needed to substantiate the movement of pesticides and nutrients in the corn/soybean, pasture, and alfalfa settings. Additional monitoring wells and chemical analysis of soil cores are needed to define the movement of potential groundwater contaminants from the abandoned feedlot to the shallow bedrock aquifer, and to suggest potential best management practices to minimize the effects of this agricultural practice on the groundwater system.
Figure 3.20. Ammonium-nitrogen concentrations for the feedlot and domestic well (DW05) soil cores.

Figure 3.21. Nitrate-N ($\text{NO}_3^-$N) and chloride concentrations with depth for the corn-Memphis (a and b) and corn-Loring (c and d) well nests. Samples were collected in May 1997, 1 week after application of nitrogen fertilizer and potash.
Chapter 4: Project Year 1998-99

Brief Project Summary

The continued goal of this project is to evaluate the impact of past and present agricultural land use and the fate of agricultural contaminants on groundwater resources in a Western Kentucky Coal Field upland setting. This physiography consists of rolling hills covered by loess-derived soils and underlain by interbedded Pennsylvanian sandstone, siltstone, limestone, and coal. Bedrock-derived groundwater continues to be an important domestic water source in this region. More than half of the domestic wells are located on broad uplands, hilltops, or hillslopes and derive water from bedrock as opposed to unconsolidated deposits. The study site was initially chosen for an SB-271 Phase II project (1995–97) because of the intensive use of groundwater as a domestic water supply and the presence of a shallow sandstone aquifer. During this initial investigation, it was discovered that the local groundwater system being used for drinking water contained nitrate-nitrogen (nitrate-N) levels in the range of 60 mg/L (the U.S. Environmental Protection Agency MCL is 10 mg/L). Groundwater with the highest nitrate-N concentrations is suspected to be affected by an abandoned dairy feedlot. The present investigation is focused on:

1. Determining the impact of the abandoned feedlot on the local groundwater system
2. Creating a working conceptual model for groundwater flow in western Kentucky upland aquifers that can be applied to similar areas in the region
3. Interpreting the relationship of nitrate-N and pesticide mechanisms for this hydroagronomic setting.

Project Objectives

The goal of this project is to continue the evaluation of the impact of past and present agricultural land use on groundwater in an upland bedrock setting that was begun in phase II of the SB-271 program. The objectives are to:

1. Determine groundwater conditions in this upland bedrock setting. Definition of the groundwater flow system is necessary so that the movement and fate of agriculturally related chemicals and nutrients may be studied.
2. Evaluate the origin, movement, and fate of nitrate-N and pesticides in a farmed, upland bedrock setting. The selected site utilizes farming practices typical of the region. The long-term movement and fate of agricultural chemicals in this setting is being measured.
3. Identify future research needs concerning the fate and transport of agricultural chemicals in this hydrogeologic setting.
4. Evaluate best management practices that would mitigate present or past agricultural practices, if they are determined to contribute to elevated nitrate-N concentrations in groundwater.

Methods

The present study site is a 560-acre farm located southwest of Henderson in Henderson County (Fig. 3.1) and was initially used during an SB-271 Phase II project. The reasons for the continued use of this site are:

1. It represents the only major hydrogeologic setting that has not been intensively studied under the SB-271 program (an upland setting in the Western Kentucky Coal Field)
2. It contains a bedrock aquifer used for domestic and livestock water supply that has nitrate-N concentrations above drinking-water maximum contaminant levels
3. There are a variety of soil conditions, including the presence of a fragipan that may have significant controls on nutrient and pesticide behavior
4. Cultivated crops represent the norm for much of western Kentucky, including alfalfa, for which environmental studies are not available in Kentucky
5. There is an abandoned dairy area within the site, and continued livestock operations, which may have significant impact on groundwater quality.

All existing monitoring wells (20), domestic wells (three), seeps (four), and hydrogeologic data will be used during the present SB-271 project to continue the evaluation of the movement and fate of nitrate-N and pesticides in four agricultural set-
tings: corn/soybean, pasture, alfalfa, and an abandoned dairy feedlot.

Sampling of groundwater in existing wells and seeps was initiated in April 1998. Eight monitoring wells and one seep in a corn/soybean setting and eight monitoring wells and one seep in a pasture setting were sampled once a month for field parameters (pH, Eh, electrical conductivity, dissolved oxygen, temperature, turbidity, and salinity), nitrate-N, and chloride. The corn/soybean wells and seep were sampled for total metals, nutrients, triazines, and tritium throughout the year. Because of wet weather in 1996, only two growing seasons (1997 and 1998) of data have been collected for the corn/soybean setting. Experience from the other six sites studied under the SB-271 program indicates that at least 3 years of data are needed to effectively evaluate the role of cropping systems, soil, and geology with respect to generation of nitrate-N and its movement.

From April to August, groundwater levels at six of the row-crop wells were measured using Telog continuously recording water-level gages. The data from the gages were downloaded to a spreadsheet on a monthly schedule. After the water-level gages were removed, water levels were measured monthly. One free-drainage lysimeter was installed in a well-drained soil (Memphis) at the corn/soybean and pasture settings to help delineate nitrate-N and pesticide movement and fate to the shallow groundwater system. The lysimeters have only been sampled twice because of dry weather.

Three monitoring wells and one seep in an alfalfa setting were sampled monthly for field parameters, nitrate-N, and chloride, except between August and November 1998, when they were sampled biweekly. This is the first year that alfalfa has been planted, because of wet climatic conditions, since the previous SB-271 project began in 1995. Only 8 months of data have been collected at the alfalfa site. Therefore, additional sampling at the alfalfa site is needed to determine the role alfalfa may have in the movement and fate of nitrate-N.

Three domestic wells and one monitoring well were sampled monthly for field parameters, nitrate-N, and chloride. Total metals, triazines, and tritium were sampled throughout the year. During the SB-271 Phase II study (1995–97), groundwater at one of the domestic wells (DW03), which the farmer was using as a water supply for his home, was found to have a nitrate-N concentration of 45 mg/L. A potential source for the high nitrate-N is a nearby abandoned feedlot, which was associated with a discontinued dairy farm. The dairy farm has not been in operation for approximately 20 years. In 1996, monitoring well DW05 was installed near the abandoned feedlot. Nitrate-N levels in the groundwater at the monitoring well have ranged from 45 to 60 mg/L. Chloride levels have also been high (60 mg/L).

To elucidate how existing surface soil characteristics may obscure the relationship between past land use and subsurface transport of a contaminant, soil cores were collected within an area thought to contain an abandoned feedlot, because the feedlot is suspected of being a source of nitrate-N contamination to the shallow groundwater system. In May 1998, the area was grid-sampled at 46 locations on approximately 15-m intervals to a depth of 105 cm (Figs. 3.1 and 4.1). An old homestead at a nearby location (Figs. 3.1 and 4.2) was also sampled along crossed transects for comparison with the abandoned feedlot and to determine any chemical remnants of human influence. Cores were subdivided into 0- to 30-, 30- to 60-, 60- to 90-, and 90- to 105-cm depth increments. All samples were analyzed for Mehlich 3 extractable nutrients (phosphorus, potassium, calcium, magnesium, and zinc) (Mehlich, 1984), pH in water, and organic matter and total nitrogen by dry combustion (Bradstreet, 1965; Nelson and Sommers, 1996). In addition, potassium chloride extractable ammonium-nitrogen and nitrate-N were determined for every sample (Technicon Corp., 1965; Keeney and Nelson, 1982).

A correlation analysis, among depths for the same variate, and across depths for different variates, was performed on the samples taken across the abandoned feedlot area. Selected variates were subjected to a further spatial analysis. The spatial structure of the variance was determined for each of the selected variates. Then, kriging was used to generate maps of each selected variate’s distribution in space.

In October 1998, three additional water wells (DW06, DW07, and DW08) were installed in and around the abandoned feedlot (Fig. 4.1) to deter-
concentrations are also the highest in the root-zone and paleosol wells following application of potash. Nitrate-N and chloride follow two distinct patterns in the corn-Memphis and corn-Loring sites as they move through the vadose zone to the saturated zone (shallow aquifer). Nitrate-N and chloride concentrations decrease with depth at the corn-Memphis site (Figures 4.3a and 4.3b) and increase with depth at the corn-Loring site (Figures 4.3c and 4.3d). Groundwater levels at each site indicate that during the wet season a perched water table is present at the corn-Loring site which is not present at the corn-Memphis site. The perched water table is probably caused by
mine the extent of nitrate-N contamination to the shallow groundwater system and to delineate the direction of groundwater movement. Each well has been sampled five times for field parameters, nitrate-N, and chloride. Groundwater from two wells (DW07 and DW08) has been sampled and analyzed for total metals and triazines.

**Results and Discussion**

**Crop Fields Findings.** Vadose water and groundwater from eight wells in a corn/soybean setting have been monitored for nutrients and triazines (Fig. 3.1). Four wells are in a Memphis soil site (corn-Memphis) and four are in a Loring soil site (corn-Loring). Nitrate-N concentrations in the corn-Memphis and corn-Loring wells range from 3 to 25 mg/L and 2 to 21 mg/L, respectively. The highest nitrate-N concentrations have been in the root-zone and paleosol wells (vadose zone) following application of nitrogen fertilizers. Chloride concentrations in the corn-Memphis and corn-Loring wells range from 3 to 17 mg/L and 7 to 39 mg/L, respectively. Chloride concentrations are also the highest in the root-zone and paleosol wells following application of potash. Nitrate-N and chloride follow two distinct patterns in the corn-Memphis and corn-Loring sites as they move through the vadose zone to the saturated zone (shallow aquifer). Nitrate-N and chloride concentrations decrease with depth at the corn-Memphis site (Figs. 4.3a, b) and increase with depth at the corn-Loring site (Figs. 4.3c, d). Groundwater levels at each site indicate that during the wet season a perched water table is present at the corn-Loring site, which is not present at the corn-Memphis site. The perched water table is probably caused by the presence of a fragipan (low-permeability zone) at the corn-Loring site. As the water level rises and falls at the corn-Loring site, nitrate-N and chloride may be flushed from the vadose zone, which may allow for higher nitrate-N and chloride concentrations to reach the shallow aquifer.

In 1998, atrazine, a triazine herbicide, was not applied because soybeans were planted instead of corn. All waters analyzed for atrazine from the corn-Memphis and corn-Loring wells for this year are below the method detection limit of 0.06 µg/L. Since only one growing season (1997) of data has been collected for atrazine, further

![Figure 4.3. Nitrate-N (NO₃-N) and chloride concentrations with depth for the corn-Memphis (a and b) and corn-Loring (c and d) well nests. Samples were collected in January 1999.](image-url)
investigation is needed to determine its pattern of movement within a western Kentucky upland bedrock setting.

Nitrate-N concentrations at the pasture site mimic those of the cropped site, in that nitrate-N concentrations are high in the vadose zone immediately after nitrogen application but concentrations decrease shortly thereafter. With depth, nitrate-N concentrations generally follow the same pattern with regard to Memphis versus Loring soils as seen at the cropped site.

**Abandoned Feedlot–Old Homestead Findings.**

Soil core analysis revealed that in the 0- to 30-cm-depth interval of soil, extractable nutrient levels are much higher in the area of the abandoned feedlot (Table 4.1) than in the area of the old homestead (Table 4.2, Fig. 3.1). Phosphorus and potassium, nutrients associated with buildup of animal manure, are seven to nearly 10 times higher in the abandoned feedlot area than at the old homestead area. Calcium, magnesium, and zinc are two to nearly four times higher. Sample-to-sample variation, as measured by one standard deviation value, is quite high at both sampled locations, nearly equaling the mean for many variates.

With greater sampling depth, phosphorus concentrations decrease dramatically at both sampled locations (Tables 4.1–4.2). There is evidence of considerable phosphorus movement vertically downward in the feedlot area, where phosphate concentrations at all depths exceed expected background levels. Potassium exhibits even greater mobility at the abandoned feedlot site, where concentrations are greatly elevated throughout the sampled depth (Table 4.1) relative to those observed at the old homestead site (Table 4.2). Both locations give evidence of downward potassium movement. In comparing the two locations, calcium and magnesium do not vary greatly at depth intervals deeper than 30 cm (Tables 4.1–4.2). Zinc exhibits a decreasing concentration within the upper 60 to 90 cm of depth at both locations.

Soil pH, organic matter, total nitrogen, and extractable nitrate-N and ammonium-N are generally elevated at the abandoned feedlot location, as compared to the old homestead, and especially so

### Table 4.1. Mehlich 3 extractable nutrients for grid-sample cores taken at the abandoned feedlot location (concentration means and one standard deviation values).

<table>
<thead>
<tr>
<th>Depth Interval (cm)</th>
<th>Phosphorus (pp2m)</th>
<th>Potassium (pp2m)</th>
<th>Calcium (pp2m)</th>
<th>Magnesium (pp2m)</th>
<th>Zinc (pp2m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–30</td>
<td>525.2 ± 368.8</td>
<td>1,699.9 ± 918.6</td>
<td>4,775.3 ± 2,057.3</td>
<td>762.9 ± 337.7</td>
<td>41.1 ± 33.5</td>
</tr>
<tr>
<td>30–60</td>
<td>93.0 ± 128.1</td>
<td>1,635.5 ± 902.3</td>
<td>2,709.2 ± 783.3</td>
<td>786.1 ± 252.4</td>
<td>7.4 ± 33.4</td>
</tr>
<tr>
<td>60–90</td>
<td>21.5 ± 26.3</td>
<td>1,340.0 ± 923.4</td>
<td>2,189.0 ± 732.5</td>
<td>835.6 ± 228.1</td>
<td>1.0 ± 2.0</td>
</tr>
<tr>
<td>90–105</td>
<td>17.7 ± 10.7</td>
<td>904.2 ± 784.6</td>
<td>1,791.8 ± 737.5</td>
<td>774.9 ± 220.6</td>
<td>1.0 ± 1.3</td>
</tr>
</tbody>
</table>

### Table 4.2. Mehlich 3 extractable nutrients for transect cores taken at the old homestead location (concentration means and one standard deviation values).

<table>
<thead>
<tr>
<th>Depth Interval (cm)</th>
<th>Phosphorus (pp2m)</th>
<th>Potassium (pp2m)</th>
<th>Calcium (pp2m)</th>
<th>Magnesium (pp2m)</th>
<th>Zinc (pp2m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–30</td>
<td>57.3 ± 79.7</td>
<td>228.7 ± 177.4</td>
<td>1,646.6 ± 321.7</td>
<td>264.3 ± 78.6</td>
<td>19.9 ± 24.0</td>
</tr>
<tr>
<td>30–60</td>
<td>6.3 ± 4.4</td>
<td>349.4 ± 275.5</td>
<td>2,191.2 ± 545.9</td>
<td>707.3 ± 257.2</td>
<td>3.6 ± 10.7</td>
</tr>
<tr>
<td>60–90</td>
<td>2.5 ± 1.2</td>
<td>306.1 ± 200.2</td>
<td>1,537.4 ± 439.4</td>
<td>876.3 ± 171.9</td>
<td>2.8 ± 8.5</td>
</tr>
<tr>
<td>90–105</td>
<td>5.3 ± 2.1</td>
<td>204.4 ± 107.2</td>
<td>1,164.9 ± 369.5</td>
<td>905.2 ± 195.1</td>
<td>2.3 ± 4.3</td>
</tr>
</tbody>
</table>
in the 0- to 30-cm interval of soil (Tables 4.3–4.4). Organic matter and total nitrogen concentrations in the 0- to 30-cm interval at the homestead location are about half of those at the feedlot location (Table 4.4), whereas extractable nitrate-N is only one-seventh as high as at the feedlot. Soil pH is about one unit higher at the feedlot site (Tables 4.3–4.4). Extractable ammonium-N exhibited the least response, being only modestly elevated at the feedlot location (Tables 4.3–4.4). Accumulations of animal waste, from the time of the feedlot’s operation, are believed to account for the much higher quantities of organic matter and total nitrogen. The organic matter is believed to be the source, via mineralization, of the nitrate-N that moves through soil and loess to the aquifer supporting the domestic well, contaminated with nitrate-N.

At the deeper soil depth intervals, soil pH and concentrations of organic matter, total nitrogen, and extractable ammonium-N decline at both locations, whereas extractable nitrate-N concentrations rise considerably only at the abandoned feedlot site (Tables 4.3–4.4). This suggests considerably greater nitrate-N leaching at the feedlot site than at the old homestead site.

Correlation analysis was performed to help delineate any potential genetic relationships with a particular variate and depth of sample, and between several of the variates with depth of sample (Table 4.5). Nitrate-N is well correlated (autocorrelated) with itself (R > 0.5) among the different sampled depths. Extractable ammonium-N and organic matter are autocorrelated among the deeper increments (30- to 105-cm intervals; R > 0.59), but concentrations in the 0- to 30-cm interval are not well related to those for the same variate at deeper intervals (30- to 105-cm intervals; R < 0.32) (Table 4.5). However, organic matter and total nitrogen in the 0- to 30-cm-interval are better related to the extractable nitrate-N found at the two deepest sampling intervals (60- to 90-cm and 90- to 105-cm; R > 0.34) (Table 4.5). This strongly suggests that the surface organic nitrogen fraction is the source of the nitrate-N found in highest concentrations at the two deepest intervals.

### Table 4.3. Soil pH, organic matter, total nitrogen, extractable nitrate-N, and ammonium-N for transect cores taken at the abandoned feedlot location (concentration means and one standard deviation values).

<table>
<thead>
<tr>
<th>Depth Interval (cm)</th>
<th>pH</th>
<th>Organic Matter (percent)</th>
<th>Total Nitrogen (ppm)</th>
<th>Nitrate-N (ppm)</th>
<th>Ammonium-N (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–30</td>
<td>6.9</td>
<td>2.36</td>
<td>3,659</td>
<td>7.48</td>
<td>1.84</td>
</tr>
<tr>
<td></td>
<td>± 0.5</td>
<td>± 0.1</td>
<td>± 156</td>
<td>± 0.54</td>
<td>± 0.13</td>
</tr>
<tr>
<td>30–60</td>
<td>6.6</td>
<td>0.67</td>
<td>2,842</td>
<td>7.48</td>
<td>1.84</td>
</tr>
<tr>
<td></td>
<td>± 0.9</td>
<td>± 0.1</td>
<td>± 156</td>
<td>± 0.54</td>
<td>± 0.13</td>
</tr>
<tr>
<td>60–90</td>
<td>5.9</td>
<td>0.40</td>
<td>1,970</td>
<td>7.48</td>
<td>1.84</td>
</tr>
<tr>
<td></td>
<td>± 1.1</td>
<td>± 0.2</td>
<td>± 156</td>
<td>± 0.54</td>
<td>± 0.13</td>
</tr>
<tr>
<td>90–105</td>
<td>5.5</td>
<td>0.32</td>
<td>1,000</td>
<td>7.48</td>
<td>1.84</td>
</tr>
<tr>
<td></td>
<td>± 1.0</td>
<td>± 0.2</td>
<td>± 156</td>
<td>± 0.54</td>
<td>± 0.13</td>
</tr>
</tbody>
</table>

### Table 4.4. Soil pH, organic matter, total nitrogen, extractable nitrate-N, and ammonium-N for transect cores taken at the old homestead location (concentration means and one standard deviation values).

<table>
<thead>
<tr>
<th>Depth Interval (cm)</th>
<th>pH</th>
<th>Organic Matter (percent)</th>
<th>Total Nitrogen (ppm)</th>
<th>Nitrate-N (ppm)</th>
<th>Ammonium-N (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–30</td>
<td>5.80</td>
<td>2.13</td>
<td>1,809</td>
<td>1.93</td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td>± 0.30</td>
<td>± 0.1</td>
<td>± 156</td>
<td>± 0.54</td>
<td>± 0.13</td>
</tr>
<tr>
<td>30–60</td>
<td>5.48</td>
<td>0.52</td>
<td>1,090</td>
<td>1.93</td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td>± 0.38</td>
<td>± 0.1</td>
<td>± 156</td>
<td>± 0.54</td>
<td>± 0.13</td>
</tr>
<tr>
<td>60–90</td>
<td>4.83</td>
<td>0.31</td>
<td>676</td>
<td>1.93</td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td>± 0.19</td>
<td>± 0.1</td>
<td>± 156</td>
<td>± 0.54</td>
<td>± 0.13</td>
</tr>
<tr>
<td>90–105</td>
<td>4.86</td>
<td>0.22</td>
<td>460</td>
<td>1.93</td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td>± 0.25</td>
<td>± 0.1</td>
<td>± 156</td>
<td>± 0.54</td>
<td>± 0.13</td>
</tr>
</tbody>
</table>
Table 4.5. Correlations among sampling depths at the abandoned feedlot location for nitrogen-related parameters.

<table>
<thead>
<tr>
<th>Depth Intervals Correlated (cm)</th>
<th>Nitrate-N (R value)</th>
<th>Ammonium-N (R value)</th>
<th>Organic Matter (R value)</th>
<th>Organic Matter to Nitrate-N (R value)</th>
<th>Total Nitrogen to Nitrate-N (R value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–30 to 30–60</td>
<td>0.59</td>
<td>0.03</td>
<td>0.13</td>
<td>0.06</td>
<td>-0.01</td>
</tr>
<tr>
<td>0–30 to 60–90</td>
<td>0.54</td>
<td>0.00</td>
<td>0.16</td>
<td>0.43</td>
<td>0.35</td>
</tr>
<tr>
<td>0–30 to 90–105</td>
<td>0.56</td>
<td>-0.11</td>
<td>0.31</td>
<td>0.47</td>
<td>0.41</td>
</tr>
<tr>
<td>30–60 to 60–90</td>
<td>0.72</td>
<td>0.99</td>
<td>0.79</td>
<td>-0.03</td>
<td>0.06</td>
</tr>
<tr>
<td>30–60 to 90–105</td>
<td>0.60</td>
<td>0.92</td>
<td>0.60</td>
<td>-0.02</td>
<td>0.07</td>
</tr>
<tr>
<td>60–90 to 90–105</td>
<td>0.91</td>
<td>0.93</td>
<td>0.75</td>
<td>0.02</td>
<td>0.23</td>
</tr>
</tbody>
</table>

1 The R value is calculated for organic matter at the first depth interval with nitrate-N at the second depth interval.
2 The R value is calculated for total nitrogen at the first depth interval with nitrate-N at the second depth interval.

The kriging maps for 0- to 30-cm organic matter (Fig. 4.4) and 60- to 90-cm nitrate-N (Fig. 4.5) confirm the partial relationship between these two variates, showing their distribution in space. It is clear that the area of greatest organic matter accumulation is not completely defined, causing the hypothesis that surface organic matter from manure accumulation is the source of nitrate-N at deeper intervals to remain unconfirmed. A larger surface

\[ = \text{silo} \]

Figure 4.4. A kriging map of the abandoned feedlot area showing percent organic matter at 0 to 30 cm below land surface.
area needs to be sampled. Furthermore, the greatest nitrate-N concentrations observed are at the 90- to 105-cm interval. Samples need to be taken at greater depth intervals, at least 200 cm, in order to define the pulse of nitrate-N moving through the soil during the winter months.

The highest nitrate-N (60 mg/L) and chloride (80 mg/L) concentrations in groundwater have been associated with samples collected from wells surrounding the abandoned feedlot area. Nitrate-N concentrations in the groundwater collected from the farmer’s water-supply well (DW03) have consistently been between 30 and 60 mg/L. Nitrate-N concentrations for water wells DW06, DW07, and DW08, installed this year in and around the feedlot (Fig. 4.1), were 1 mg/L, 12 mg/L, and 6 mg/L, respectively.

Preliminary water-level data collected from wells monitoring the sandstone aquifer indicate that groundwater, carrying high concentrations of nitrate-N (greater than 10 mg/L), is moving from the abandoned feedlot area toward the farmer’s water well (DW03).

Summary and Conclusions

At this location, groundwater is a viable water supply being used for domestic and agricultural purposes. The aquifer supplying the groundwater is a sandstone unit approximately 30 ft beneath land surface and approximately 25 ft thick. In this upland setting, the overlying material is loess, which has two major types of soil: Loring and Memphis. The Memphis is a silt loam, occurs on hilltops, and is very well drained. The Loring occurs along the sides of the hills and in the local swales of the landscape. It is moderately drained because of the presence of a fragipan, which some-
what inhibits downward recharge of water to the groundwater system.

Four agricultural land-use activities are being monitored at the site: corn-soybean field, alfalfa field, pasture, and abandoned feedlot. Twenty-three monitoring wells, three domestic wells, two lysimeters, and four spring seeps are being monitored to assess water quality at the site. Concerning the cropped fields, nitrate-N decreases with depth at the Memphis-soil site and increases with depth at the Loring-soil site where the fragipan is present. Atrazine was not applied and not found in water samples, indicating that there was no residual atrazine in the soils from application in previous years. Nitrate-N concentrations at the pasture site mimic those of the cropped site in that nitrate-N concentrations are high in the vadose zone immediately after nitrogen application, but concentrations decrease shortly thereafter. With depth, nitrate-N concentrations generally follow the same pattern with regard to Memphis versus Loring soils as seen at the cropped site. At present, insufficient water-quality data have been collected at the alfalfa site to make definite conclusions.

At the abandoned feedlot site, interval soil analyses to 105 cm in depth indicate elevated concentrations of phosphorus, potassium, calcium, magnesium, zinc, nitrogen in various forms, and organic matter when compared to the old homestead site. Concentrations of phosphorus, potassium, and various forms of nitrogen with depth in the soil profile indicate downward movement of these variates toward the groundwater system. Correlation analysis helps to substantiate this interpretation. Kriging-map analysis indicates that both a wider soil sampling area and deeper samples are needed to help define the movement of variates from the near-surface environment to the groundwater system.

Work to date indicates that additional data are needed to substantiate the movement of pesticides and nutrients in the corn/soybean and alfalfa settings. Additional monitoring wells and chemical analysis of soil cores are needed to define the movement of potential groundwater contaminants from the abandoned feedlot and to suggest potential best management practices to minimize the effects of this agricultural practice on the groundwater system.
Chapter 5: Project Year 1999-2000

Brief Project Summary

The continued goal of this project is to evaluate the impact of past and present agricultural land use and the fate of agricultural contaminants on groundwater resources in a Western Kentucky Coal Field upland setting. This physiography consists of rolling hills covered by loess-derived soils and underlain by interbedded sandstone, siltstone, limestone, and coal. Bedrock-derived groundwater continues to be an important domestic water source in this region. More than half of the domestic wells are located on broad uplands, hilltops, or hillslopes and derive water from bedrock as opposed to unconsolidated deposits. The study site was initially chosen for an SB-271 Phase II project (1995–98) because of the intensive use of groundwater as a domestic water supply and the presence of a shallow sandstone aquifer. During this initial investigation, it was discovered that the local groundwater system being used for drinking water contained nitrate-nitrogen (nitrate-N) levels in the range of 60 mg/L (the U.S. Environmental Protection Agency maximum contaminant level is 10 mg/L). Groundwater with the highest nitrate-N concentrations is suspected to be affected by an abandoned dairy feedlot. The present investigation is focused on:

(1) Determining the impact of the abandoned feedlot on the local groundwater system
(2) Creating a working conceptual model for groundwater flow in western Kentucky upland aquifers that can be applied to similar areas in the region
(3) Interpreting the relationship of nitrate-N and pesticide mechanisms for this hydroagronomic setting.

Project Objectives

The continued goal of this study is to evaluate the impact of agricultural land use on groundwater in an upland bedrock setting. The objectives are to:

(1) Define groundwater conditions in this upland bedrock setting. The ultimate goal is to define the groundwater flow system so that the movement and fate of agriculturally related chemicals and nutrients may be studied.
(2) Evaluate movement and fate of nitrate-N and pesticides in a farmed, upland bedrock setting. The selected site utilizes farming practices typical of the region. The long-term movement and fate of agricultural chemicals in this setting will be measured.
(3) Identify future research needs concerning the fate and transport of agricultural chemicals in this hydrogeologic setting.
(4) Evaluate best management practices that would mitigate present or past agricultural practices, if they are determined to contribute to evaluated nitrate-N concentrations in groundwater.

Methods

The present study site is a 560-acre farm located southwest of Henderson in Henderson County (Fig. 3.1) and was initially used during an SB-271 Phase II project. The reasons for the continued use of this site are:

(1) It represents the only major hydrogeologic setting that has not been intensively studied under the SB-271 program (an upland setting in the Western Kentucky Coal Field)
(2) It contains a bedrock aquifer used for domestic and livestock water supply that has nitrate-N concentrations above drinking water MCL’s
(3) There are a variety of soil conditions, including the presence of a fragipan, that may have significant control on nutrient and pesticide behavior
(4) Cultivated crops, including alfalfa, represent the norm for much of western Kentucky, for which environmental studies are not available
(5) There is an abandoned dairy area within the site, and continued livestock operations, which may have significant impact on groundwater quality.

All existing monitoring wells (23), domestic wells (four), seeps (three), and hydrogeologic data will be used during the present SB-271 project to continue the evaluation of the movement and fate of nitrate-N and pesticides in four agricultural settings: corn/soybean, pasture, alfalfa, and an abandoned dairy feedlot.

Groundwater sampling of existing wells and seeps was initiated in April 1999. Eight monitor-
ing wells and one seep in a corn/soybean setting was sampled biweekly (when conditions permitted) during the growing season and monthly during fall and winter for field parameters (pH, Eh, electrical conductivity, dissolved oxygen, temperature, turbidity, and salinity), nitrate-N, and chloride. The corn/soybean wells and seep were periodically sampled for total metals, inorganic anions, nutrients, triazines and other herbicides, nitrogen isotopes, and oxygen isotopes. Data have been collected for three and a half growing seasons (1996–99) for the corn/soybean setting, but drought conditions during the 1999 growing season hindered the sampling of a lysimeter (2 ft below land surface), a seep, and shallow monitoring wells (5 to 20 ft below land surface). Experience from the other six sites studied under the SB-271 program indicate that at least 3 years of complete data are needed to effectively evaluate the role of cropping systems, soil, and geology with respect to generation of nitrate-N and its movement.

Eight monitoring wells and one seep in a pasture setting were sampled once a month (when conditions permitted) for field parameters, nitrate-N, and chloride. The pasture wells and seeps were also periodically sampled for total metals, inorganic anions, nutrients, triazines and other herbicides, nitrogen isotopes, and oxygen isotopes.

In May 2000, one monitoring well tapping the shallow sandstone aquifer (60 ft below land surface) was installed in the alfalfa field setting. The newly installed well, along with the existing three wells and seep, were sampled monthly (when conditions permitted) for field parameters, nitrate-N, and chloride. The wells were also periodically sampled for total metals, inorganic anions, nutrients, triazines and other herbicides, nitrogen isotopes, and oxygen isotopes. Alfalfa was not planted until August 1998 because of wet climatic conditions during the SB-271 project, which began in 1995.

To elucidate how existing surface soil characteristics may obscure the relationship between past land use and subsurface transport of a contaminant, soil cores were collected from an area thought to contain an abandoned feedlot. The abandoned feedlot is suspected of being a source of nitrate-N contamination to the shallow groundwater system and to delineate the direction of groundwater movement.

A correlation analysis, among depths for the same variate, and across depths for different vari-
ates, was performed on the soil core data collected in 1998. Furthermore, selected variates were subjected to a spatial analysis. The spatial structure of the variance was determined for each of the selected variates. Then, kriging was used to generate maps of each selected variate’s distribution in space.

Forty-nine additional soil cores were collected in May 1999 (Figs. 3.1 and 5.1) to confirm the observations and conclusions obtained by the 1998 soil core analysis and to better explain the negative relationship observed between organic matter and nitrate-N in some sampling regions. Soil cores were grid-sampled at 100-ft intervals to a depth of 8 ft. Cores were subdivided into 0- to 6-, 6- to 12-, 12- to 24-, 24- to 36-, 36- to 48-, 48- to 60-, 60- to 72-, 72- to 84-, and 84- to 96-in.-depth increments. All samples were analyzed for Mehlich 3 extractable nutrients (phosphorus, potassium, calcium, magnesium, manganese, and zinc) (Mehlich, 1984), pH in water, and organic matter by dry combustion (Nelson and Sommers, 1996). Also, potassium chloride extractable nitrate-N was determined for every sample (Technicon Corp., 1965; Keeney and Nelson, 1982).

For the 1999 soil cores, an elevation map was developed for the larger sampled area in order to model the landscape. Nonparametric geostatistics was used to develop a map describing the probability of perched water in the landscape. This map was then used to relate the spatial distribution of water-saturated subsoil with that of soil nitrate-N concentration. Simple linear correlation was performed between soil texture components (sand, silt, and clay); organic matter and nitrate-N concentrations; and the probability of perched water predicted for the 1998 and 1999 sampling points. Logistic regression was performed to determine the best model for predicting the relationship be-
between the probability of perched water and soil and landscape properties.

Fourteen continuous soil cores ranging in depth from 17 to 33 ft below land surface were collected (April 2000) in and around the abandoned feedlot area (Figs. 3.1 and 5.2). It is postulated that the deep soil cores will help to further determine the probability of perched water tables and soil and landscape properties with regard to the movement and fate of nitrate-N. Also, texture analysis from the cores will be utilized for vadose water and groundwater modeling in an attempt to predict travel and residence times of nitrate-N. Because of time constraints and the large number of soil samples collected, analytical data are not yet available. The soil cores are being stored in the UK Agronomy Department until analysis can be completed.

Results and Discussion

Crop Fields Findings. Vadose water and groundwater from eight wells in a corn/soybean setting have been monitored for nutrients and triazines. Four wells are in a Memphis soil site (corn-Memphis) and four are in a Loring soil site (corn-Loring). Nitrate-N concentrations in the corn-Memphis and corn-Loring wells range from 2 to 18 mg/L and 4 to 50 mg/L, respectively. The highest nitrate-N concentrations have been in the root-zone and paleosol wells (vadose zone) following application of nitrogen fertilizers. Chloride concentrations in the corn-Memphis and corn-Loring locations range from 1 to 17 mg/L and 9 to 34 mg/L, respectively. Chloride concentrations are also the highest in the root-zone and paleosol wells (vadose zone) following application of potash. Nitrate-N and chloride follow two distinct patterns in the corn-Memphis and corn-Loring sites as they move through the vadose zone to the saturated zone. Nitrate-N and chloride concentrations decrease with depth at the corn-Memphis site (Figs. 5.3a, b) and increase with depth at the corn-Loring site (Figs. 5.3c, d). Groundwater levels at each site indicate that during the wet season, a
perched water table is present at the corn-Loring site, which is not present at the corn-Memphis site. This perched water table may be caused by the presence of a weak fragipan and/or paleosol(s); both act as impermeable boundaries (Fig. 5.4). As the water level rises and falls at the corn-Loring site, nitrate-N and chloride may be flushed from the vadose zone, which may allow for higher nitrate-N and chloride concentrations to reach the shallow aquifer.

Atrazine, a triazine herbicide, was applied in 1999. Only one sample collected from April 1999 to June 2000 contained atrazine above the MCL of 3 µg/L. This sample was collected from the corn-Memphis paleosol well in May 1999 shortly after application. All other waters analyzed for atrazine from the corn-Memphis and corn-Loring sites during the year were below the MCL for atrazine. Triazine concentrations were much lower after the 1999 application than in 1997. This is probably because of the intense drought conditions that were present during the 1999 application and growing season. Since only two growing seasons (1997 and 1999) of data have been collected for atrazine, and one of these seasons (1999) under extreme drought conditions, further investigation is needed to determine the movement of atrazine within a western Kentucky upland bedrock setting.

Piper (1944) diagrams for the corn-Memphis and corn-Loring waters have been constructed to better delineate hydrochemical facies within the local hydrogeologic setting (Figs. 5.5a, b). The corn-Memphis and corn-Loring waters are very similar in that the vadose water is composed of a mixture of cations and anions, whereas the groundwater is composed of a mixture of cations and is bicarbonate rich.

Groundwater sampled from the corn-Memphis and corn-Loring bedrock wells was analyzed for nitrogen and oxygen isotopes to determine the source of nitrate-N present in the shallow sandstone aquifer. $\delta^{15}$N and $\delta^{18}$O values ranged between 3.4 and 8.5 per mil and 3.9 and 5.9 per mil, respectively, which indicate that nitrate-N in the groundwater at the corn sites is derived from nitrogen fertilizer and soil organic matter.

Nitrate-N concentrations at the pasture site mimic those of the cropped site in that nitrate-N concentrations are high in the vadose zone immediately after nitrogen application, but decrease shortly thereafter. With depth, nitrate-N concentrations generally follow the same pattern with regard to Memphis versus Loring soils as seen at the cropped site. Nitrogen and oxygen isotope data indicate that the nitrate-N in the groundwater at the pasture sites is derived from nitrogen fertilizer and soil organic matter.
Nitrate-N and chloride concentrations in the alfalfa-Loring waters range from 1.5 to 18 mg/L and 11 to 25 mg/L, respectively. The highest nitrate-N and chloride concentrations have been in the root-zone and paleosol wells (vadose zone) following application of nitrogen fertilizers and potash. Nitrate-N concentrations at the alfalfa site tend to decrease with depth, but only 2 months (May and June 2000) of data have been collected for the bedrock aquifer.

Additional sampling is required to adequately characterize the fate and movement of nitrate-N in the alfalfa setting.

**Abandoned Feedlot**

The analysis of the 46 soil cores collected in 1998 found that levels of organic matter quickly decreased with depth whereas nitrate-N levels slowly increased with depth (Fig. 5.6). This suggests movement of nitrate-N in the soil profile. Both variates reached levels that were excessive for similar soils in an agricultural setting. There was a significant correlation between nitrate-N at the 24- to 36-in. and 36- to 42-in. depths and surface (0- to 12-in.) organic matter (Table 5.1). This indicates a positive relationship between the probable source (organic matter associated with the abandoned dairy feedlot) and the elevated nitrate-N concentration detected in the farmer’s domestic water supply.

Comparisons between organic matter at 0 to 12 in. and nitrate-N at 24 to 36 in. (Fig. 5.7) show large areas where high organic matter levels overlap with high nitrate-N levels. However, certain areas contradict this general relationship (Fig. 5.7). Because of these contradictions, 49 additional soil cores were collected in May 1999 (Fig. 5.1).

Many environmental factors will affect nitrogen oxidation and reduction processes. Soil moisture is one of the more important, affecting the processes of mineralization, nitrification, and especially denitrification. Soil moisture is controlled by climate, soil properties, and landscape topography.

Denitrification caused by anaerobic conditions was suspected at the abandoned feedlot site for two reasons: (1) the presence of a Loring soil, which has a weak fragipan that would cause seasonally perched water, and (2) the presence of paleosols that will also impede vertical water movement. Both of these factors suggest that saturated subsoil layers will occur at the site at certain times of the year (mostly during the wet seasons). Fig-
Figure 5.5. Piper diagrams for the corn-Memphis (a) and corn-Loring (b) water samples. Samples were collected between 1996 and 2000.

Figure 5.8 shows the average values for clay, sand, and silt size fractions with depth for the sampled area (Fig. 5.1). The clay content increases in the Bt horizon. The sand content does not change, and its value was the least variable of all the fractions in the landscape. The silt content also increased with depth.

Assuming soil properties to be spatially continuous, and that soil moisture is generally related to landscape position, nonparametric geostatistics were used to describe the probable spatial distribution of water-saturated soil within the surface layer (0 to 8 ft) of the landscape in and surrounding the abandoned feedlot. When elevation was related to the prediction for perched water, the regression coefficient was −0.84. The correlation coefficient between surface organic matter (0 to 12 in.) and the probability of perched water was −0.22.
The correlation coefficient for nitrate-N at 24 to 36 in. and 36 to 42 in., and the probability of perched water was –0.38 and –0.40, respectively.

The predicted probability of perched water was plotted against elevation on a surface relief map (Fig. 5.9). The surface terrain and the probability of perched water showed an almost perfect coincidence. When compared to the Henderson County soil survey map (Converse and Cox, 1967), there is an excellent relationship between Loring soil map units and a greater probability of water-saturated subsoil.

The spatial relationship between the probability of perched water and soil nitrate-N (24 to 36 in.) clearly shows that the nitrate-N concentration decreases as the probability of saturated soil increases (Fig. 5.10). There was no relationship between surface organic matter and the probability of saturated soil. The spatial analysis of the distribution of saturated subsoil layers explains the specific sampling points in which surficial high organic matter was underlain by low nitrate-N concentrations. In these areas, nitrate-N is being attenuated by landscape-induced denitrification. These results differed from those reported by Pennock and others (1992), who indicated that topography was not a controlling factor for denitrification.

Of all the variables that were related to the probability of perched water, elevation had the best correlation. At the same time, the presence of a buried A horizon (paleosol) at a depth between 60 and 83 in. indicates that a possible discontinuity causes a decrease in water conductivity in the profile and increases the probability of forming a perched water table. Fifteen independent field observations were used to test the spatial probability model. The independent field observations of perched water were nearly 100 percent accurately predicted by the model; therefore, the model effectively predicts the likely location of a perched water table.

A logistic model was used to determine the most important variable explaining the observed probabilities of perched water in this landscape. The variables used for this model were the clay contents at nine depths in 12-in. increments from 0 to 8 ft and the land-surface elevation in feet above mean sea level. The calculated probability of perched water was the independent variable (0 for absent and 1 for present). The results of this analysis indicate that the intercept model explained 100 percent of the sample points absent perched water, but none of the points with perched water. The overall rate of correct prediction was 77.8 percent. A stepwise logistic regression selected only elevation as a significant variable.

### Table 5.1. Simple correlation coefficients (r) among organic matter and nitrate-N concentrations at different depths for soil cores collected in 1998 (Fig. 4.1).

<table>
<thead>
<tr>
<th>Depth (in.)</th>
<th>Organic Matter (0–12 in.)</th>
<th>Organic Matter (12–24 in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrate-N</td>
<td>0–12</td>
<td>0.03</td>
</tr>
<tr>
<td>Nitrate-N</td>
<td>12–24</td>
<td>0.05</td>
</tr>
<tr>
<td>Nitrate-N</td>
<td>24–36</td>
<td>0.43</td>
</tr>
<tr>
<td>Nitrate-N</td>
<td>36–42</td>
<td>0.46</td>
</tr>
</tbody>
</table>
significant variable in explaining the presence or absence of perched water. This variable increased the overall rate of correct prediction from 77.8 percent to 88.9 percent. This indicates that the model has value in predicting the actual field observations. The model correctly predicts 94.3 percent of points absent perched water and 70 percent of points with perched water. The elevation data increase the correct prediction of the existence of this profile property.

The highest nitrate-N (60 mg/L) and chloride (80 mg/L) concentrations have been associated with shallow groundwater in and around the abandoned feedlot (Fig. 5.2). Nitrate-N levels in the groundwater collected from the water well (DW03) used by the farmer for his water supply have consistently been between 30 and 60 mg/L.

Nitrogen isotope data collected for wells DW03, DW05, DW07, and DW08 (Fig. 5.2) are 12.00, 12.14, 10.27, and 9.00 per mil, respectively. These data indicate that the elevated nitrate-N in the local groundwater system is derived from organic matter associated with animal (livestock) waste.

The Piper (1944) diagram for the domestic and monitoring wells (Fig. 5.11) indicate that the shallow groundwater throughout the farm site is composed of mixed cations and is bicarbonate rich. There is, however, a slight difference in the wells near the abandoned feedlot (DW03 and DW05). This difference can be attributed to the higher chloride concentrations (60 to 80 mg/L) seen in these waters, which are most likely derived from the livestock waste associated with the discontinued dairy operation.
Conclusions

At the Henderson County farm, groundwater is a viable water supply being used for domestic and agricultural purposes. The aquifer supplying the groundwater is a sandstone unit approximately 30 ft beneath land surface and approximately 25 ft thick. In this upland setting, the material overlying the sandstone is loess, which has two major types of soil: Loring and Memphis. The Memphis is a silt loam, occurs on hilltops, and is very well drained. The Loring occurs along the sides of the hills and in the local swales of the landscape. It is moderately drained because of the presence of a weak fragipan, which somewhat inhibits downward recharge of water to the groundwater system.

Four agricultural land-use activities are being monitored at the site: corn-soybean field, alfalfa field, pasture, and abandoned feedlot. Twenty-four monitoring wells, three domestic wells, two lysimeters, and four spring seeps are being monitored to assess water quality at the site.

Concerning the cropped fields, nitrate-N decreases with depth at the Memphis-soil site, and increases with depth at the Loring-soil site where the fragipan is present. Atrazine was below the MCL for all water samples collected except for one sample collected immediately after application (May
Acknowledgments

1999). Only two growing seasons (1997 and 1999) of data have been collected for atrazine, and one of these seasons (1999) was under extreme drought conditions. Therefore, additional data are needed to determine the fate and movement of atrazine in a Western Kentucky Coal Field upland setting. Nitrogen isotope data indicate that the nitrate-N present in the shallow bedrock aquifer beneath cropped fields is derived from nitrogen fertilizer and soil organic matter.

Nitrate-N concentrations at the pasture site mimic those of the cropped site in that nitrate-N concentrations are high in the vadose zone immediately after nitrogen application, but decrease shortly thereafter. With depth, nitrate-N concentrations generally follow the same pattern with regard to Memphis versus Loring soils, as seen at the cropped site.

Nitrate-N concentrations seem to be decreasing with depth at the alfalfa site, but at present, insufficient water-quality data have been collected to make definite conclusions.

At the abandoned feedlot site, interval soil analyses to 3.5 and 8 ft in depth have been collected. Using soil moisture properties from the soil cores, nonparametric geostatistics was successfully used to describe the probable spatial distribution of water-saturated subsoil in the landscape. The analysis helps explain the existence of areas of high surficial organic matter that were underlain by deeper soil layers with low nitrate-N concentrations. Comparisons with soil survey maps show an excellent relationship between Loring soil map units and a high probability of water-saturated subsoil. It appears that although surficial organic matter generated the nitrate-N found at the deeper intervals, in some areas the nitrate-N was being attenuated by landscape-induced denitrification. Nonparametric geostatistics proved to be an easy, fast, and reliable method to relate soil properties to previously mapped soil information. Additional deep cores (17 to 33 ft below land surface) have been collected, but because of time restraints and the large quantity of samples, results are not yet available.

Potentiometric-surface maps, groundwater-quality data, and nitrogen-isotope data indicate that the elevated nitrate-N in the farmer’s domestic water supply is most likely derived from the organic matter associated with the abandoned dairy feedlot.
Work to date indicates that additional data are needed to substantiate the movement of pesticides and nutrients in the corn/soybean and alfalfa settings. Additional monitoring wells are needed to define the movement of potential groundwater contaminants from the abandoned feedlot. Vadose and groundwater modeling is needed to better determine the residence time of nitrate-N in the soil column and shallow bedrock aquifer. These additional data will greatly aid in suggesting potential best management practices to minimize the effects of this agricultural practice on the local groundwater system.

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References Cited


Figure 5.12. Potentiometric-surface maps for the abandoned feedlot area for February 2000 (a) and June 2000 (b). Arrows indicate general groundwater flow direction calculated from three-point problem. Y-axis is latitude and X-axis is longitude. Contour interval is 0.20 ft.

Figure 5.12. Potentiometric-surface maps for the abandoned feedlot area for February 2000 (a) and June 2000 (b). Arrows indicate general groundwater flow direction calculated from three-point problem. Y-axis is latitude and X-axis is longitude. Contour interval is 0.20 ft.


