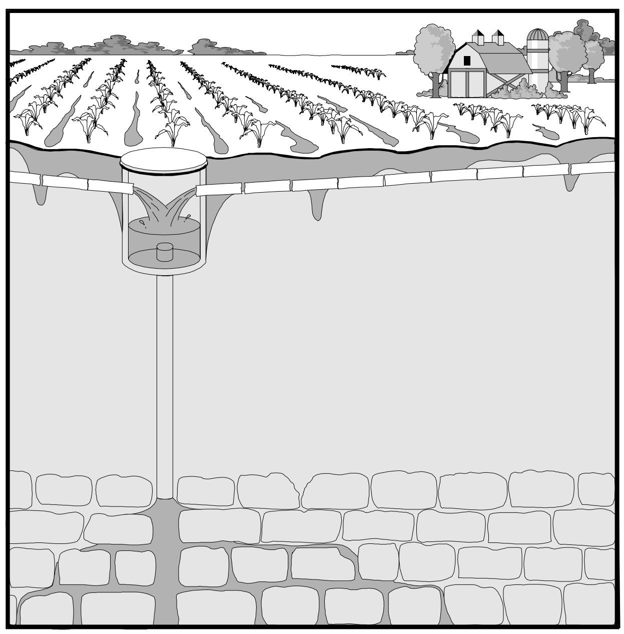
GROUNDWATER QUALITY RESPONSE

TO CLOSURE OF AGRICULTURAL DRAINAGE WELLS IN FLOYD COUNTY, IOWA

Geological Survey Bureau
Technical Information Series 40



Iowa Department of Natural Resources
Paul W. Johnson, Director
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Prepared by
L.S. Seigley, D.J. Quade, and M.P. Skopec

Energy and Geological Resources Division
Geological Survey Bureau

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ABSTRACT

Since 1984, the Iowa Department of Natural Resources — Geological Survey Bureau has monitored the effects of agricultural drainage wells (ADWs) on groundwater quality in three Devonian bedrock aquifer units beneath central Floyd County. Results from a nest of four bedrock piezometers drilled to various depths (103, 207, 297, and 360 feet) showed that ADWs were delivering agricultural contaminants, specifically nitrate and commonly used herbicides, into the groundwater of these aquifers. None of the ADWs had surface intakes. Without the ADWs, the Devonian aquifer beneath central Floyd County is naturally protected by about 30 feet of glacial till. In December 1994, the three ADWs (two 65-feet deep; one greater than 300 feet deep) nearest the bedrock piezometers were closed as part of the Floyd County Groundwater Protection Project, conducted by the Floyd County Soil and Water Conservation District. The tile lines previously draining to these three ADWs were connected and the tile water was diverted by a single tile line to a constructed drainage ditch. From the ditch the water travels approximately three miles before emptying into Beaver Creek. Two additional ADWs in close proximity to the piezometer nest were closed during the summer of 1995 (one ADW was greater than 300 feet deep and one ADW was approximately 70 feet deep).

In the fall of 1994, the Geological Survey Bureau initiated the Floyd County ADW Closure Project to monitor anticipated improvements in the groundwater quality of the Devonian aquifers following the closure of the ADWs. Four bedrock piezometers and one glacial till piezometer were monitored for nitrate, ammonia, and common herbicides. In addition, the combined tile drainage from the three ADWs was sampled after the ADWs were closed in December 1994, as well as water from the drainage ditch prior to its entering Beaver Creek. It was monitored to assess impacts on the receiving stream and to address concerns about the diverted drainage in Beaver Creek and its potential impact on groundwater quality. Five nearby private wells were monitored for nitrate.

The four bedrock piezometers all showed improvements in water quality immediately after closure of the three ADWs. Since closure, the median nitrate-N concentrations have declined for all the bedrock piezometers except FM3-3 (the median nitrate-N concentration for FM3-3 — 297 feet deep — remained unchanged at <0.1 mg/L during the pre- and post-closure periods). Median nitrate-N concentrations declined from 17.0 mg/L to 11.0 mg/L for FM3-1 (103 feet deep), decreased from 0.3 mg/L to <0.1 mg/L for FM3-2 (207 feet deep), and declined from 0.6 mg/L to <0.1 mg/L for FM3-4 (360 feet deep). The change in

nitrate-N concentrations from the pre- to post-closure period was statistically significant for FM3-1, FM3-2, and FM3-4. The frequencies of nitrate-N detection declined from the pre- to post-closure period for FM3-2 (65% to 23%), FM3-3 (40% to 23%), and FM3-4 (80% to 5%). The frequency of nitrate-N detection remained relatively unchanged for FM3-1 (95% for pre-closure and 97% for post-closure).

There was a decline from the pre- to post-closure period in the number of pesticides detected, the frequencies of detection, and the median concentrations in pesticides for all four bedrock piezometers. Since December 1994, only atrazine and two metabolites of atrazine (deethylatrazine and deisopropylatrazine) were detected at FM3-1. The frequency of atrazine detection increased from 84% to 92%, and the median concentration declined from 0.37 μg/L to 0.25 μg/L. The frequencies of both deethylatrazine and deisopropylatrazine declined from the pre- to post-closure period. No pesticides were detected in FM3-2 and FM3-3 during the post-closure period. In FM3-4, there was one detection of one pesticide (metolachlor) at a concentration of 0.10 μg/L. This detection occurred in April 1995, shortly after the ADWs were closed. Of the five pesticides detected in FM3-4 during the pre-closure period, metolachlor was the most frequently detected (33%). Only at FM3-1 was there a statistically significant difference between the atrazine concentrations for the pre- and post-closure periods.

Although the median nitrate-N concentration for FM3-1 declined from the pre- to post-closure period, the median concentration for the post-closure period was still >10 mg/L (11.0 mg/L). Nitrate-N concentrations have steadily declined at FM3-1 since reaching a high of 54 mg/L in May 1990. The range in nitrate-N concentrations has declined from the pre-closure period (<1.0 to 54 mg/L) to the post-closure period (<0.10 to 20 mg/L). Nitrate-N concentrations in tile water inputs to ADWs vary significantly, both temporally and spatially. As a result, the range in nitrate-N concentrations tends to be large. With closure of the ADWs, the more consistent, yet elevated, nitrate-N concentrations and the greater frequency of atrazine detection likely reflect the nonpoint-source inputs to the upper aquifer via nearby, geologically susceptible areas. Although the bedrock piezometers are located in an area identified as deep bedrock, shallow bedrock and karst regions occur a few miles west of the site. Previous studies have shown that these geologic regions are naturally susceptible to nonpoint source contamination from nitrate and pesticides.

Only the glacial till piezometer has shown an increase in the detection frequency of nitrate-N, the median nitrate-N concentration, the detection frequency of atrazine, and the median atrazine concentration from the pre- to post-closure period. The frequency of nitrate-N detection increased from 72% to 100%; nitrate-N concentrations increased from 2.6 mg/L to 8.5 mg/L; the frequency of atrazine detection increased from 36% to 72%; and the median atrazine concentration increased from <0.10 μg/L to 0.11 μg/L. With closure of the ADWs, no improvement in water quality at this piezometer was anticipated, as none of the ADWs were discharging water into the shallow groundwater monitored by this piezometer.

The private well located nearest the closed ADWs has shown the most significant decline in nitrate-N concentrations. Since closure of the ADWs, nitrate-N concentrations declined from greater than 15 mg/L to concentrations at or below 5 mg/L during most months. The other four private wells have not shown a similar response, suggesting that these wells were not previously impacted by the ADWs that were closed.

Nitrate-N concentrations in the tile drainage from the closed ADWs and the two surface water sites showed a seasonal trend with higher concentrations during the spring and summer months and lower concentrations during the winter months. The majority of concentrations were greater than 10 mg/L. At these three sites, three pesticides and two metabolites were detected, including acetochlor, atrazine, deethylatrazine, deisopropylatrazine, and metolachlor. Atrazine was the most frequently detected pesticide. The frequency of atrazine detection ranged from 72% to 100% at the three sites.

INTRODUCTION

Many of Iowa's rich agricultural soils, particularly those in north-central Iowa, are poorly drained and at times contain excess water that can interfere with field operations or ruin crops. In these areas, farm fields are often artificially drained by buried tiles leading to drainage ditches or streams. A less common way to remove excess water is the use of an agricultural drainage well (ADW), which is a drilled shaft that funnels drainage water into underlying bedrock (Figure 1).

The upper parts of the ADWs are often cistern-like structures that form the discharge point for one or more tile drainage lines; some wells are also designed to take surface runoff, either directly at the well or through surface intakes connected to the drainage tiles. ADWs are generally 5 to 10 inches in diameter and are cased into the underlying bedrock. ADWs are typically uncased through the entire bedrock section they penetrate. Virtually all ADWs in Iowa discharge into fractured carbonate aquifers, as these strata can accept large quantities of drainage water without clogging. These aquifers are also excellent sources of groundwater for domestic, industrial, and municipal water supplies.

Since 1984, the Iowa Department of Natural Resources - Geological Survey Bureau has monitored the effects of ADWs on groundwater quality in the Devonian bedrock aquifers beneath central Floyd County (Figure 2). In Floyd County, the Devonian strata comprise a three-part aquifer system (lower, middle, and upper aquifers). Samples from a nest of four bedrock piezometers, drilled to various depths, showed that ADWs were delivering agricultural contaminants (nitrate and pesticides) into the groundwater of these aquifers. Without the ADWs, the Devonian aquifer beneath central Floyd County is naturally protected by about 30 feet of glacial till (Libra et al., 1984; 1994). In December 1994, as part of the Floyd County Groundwater Protection Project, the three ADWs (two 65-feet deep; one >300-feet deep) nearest the bedrock piezometer nest were closed. Tile drainage to the ADWs was diverted to a constructed ditch that empties into Beaver Creek.

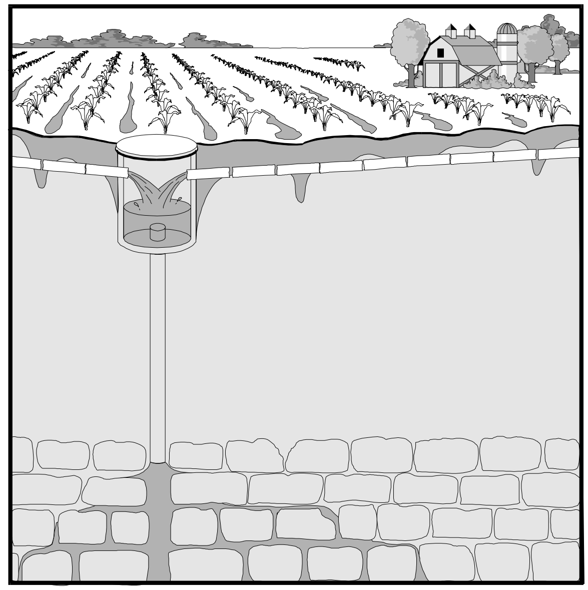

Figure 1. Schematic of an agricultural drainage well.

Closure of these ADWs provided an opportunity to monitor expected improvements in groundwater quality of the Devonian aquifers. This report summarizes the groundwater monitoring of the Devonian aquifers in central Floyd County, prior to and after closure of these ADWs. Preliminary results of the monitoring are found in Quade and Seigley (1997).

AGRICULTURAL DRAINAGE WELLS IN IOWA

It has been recognized that ADWs pose a threat to groundwater quality in Iowa, as contaminants such as nitrate, pesticides, bacteria, and sediment can be delivered to the underlying bedrock. In 1987, action was taken to address groundwater quality concerns associated with ADWs in Iowa. Passage of the 1987 Iowa Groundwater Protection Act established a goal to eliminate groundwater contamination from ADWs by 1995. The Act required registration of all ADWs in Iowa with the Iowa Department of Natural Resources (DNR) by January 1, 1988 (later extended to September 30, 1988). A total of 346

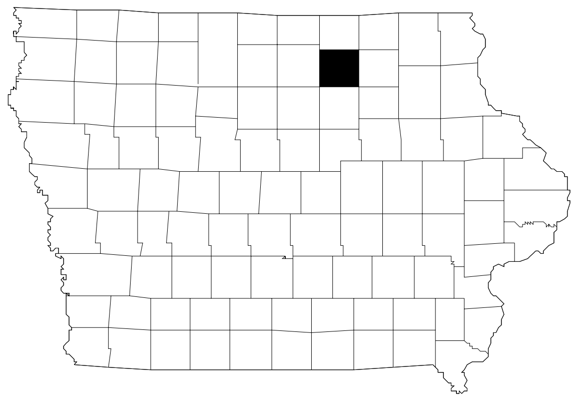

Figure 2. Location of Floyd County, Iowa.

ADWs in Iowa were registered with DNR.

ADWs are classified as Class V injection wells and are subject to regulation by the Underground Injection Control Program of the U.S. Environmental Protection Agency (EPA). The Safe Drinking Water Act required that all ADWs be registered with EPA by June 1985. A total of 230 ADWs in Iowa were registered with EPA. Merging of the EPA and DNR lists by the DNR — Geological Survey Bureau and Iowa Department of Agriculture and Land Stewardship (IDALS) staff resulted in a combined registration list of 442 ADWs in Iowa (Libra and Hallberg, 1993). This list was later revised to eliminate structures incorrectly registered as ADWs; the revised list included 340 ADWs (Heathcote, 1998).

Iowa is not the only state with ADWs. An EPA inventory completed in 1987 identified 19 states with at least one known ADW (Heathcote, 1998), and these inventory numbers will be updated in a future EPA publication on ADWs.

The number of ADWs in Iowa has never been precisely known. Mustermann and others (1981) estimated 700 ADWs in Iowa. Hallberg and others (1985) estimated 328 ADWs. Libra and Hallberg (1993) reported 442 unique ADWs in Iowa. In 1997, an updated inventory of ADWs in Iowa was completed. This inventory accounted for the ADWs that had been closed in Floyd County, wells that had been incorrectly registered as an ADW, and wells that were no longer functional. This inventory estimated 292 active ADWs in Iowa (Iowa DNR Natural Resources Geographic Information System Library coverage for ADWs, as of July 1998).

Figure 3 shows the distribution, by county, of known ADWs in Iowa. From a statewide perspective, these wells are relatively uncommon. However, over 90% of the known ADWs are concentrated in four counties: Floyd, Humboldt, Pocahontas, and Wright. The majority of ADWs in Humboldt, Pocahontas, and Wright counties discharge water into the underlying Mississippian aquifer, while most ADWs in Floyd County discharge into the underlying Devonian aquifer.

Nearly all of the ADWs in Iowa were constructed between 1900 and 1950. Beginning in 1957, a permit was required in Iowa to construct new agricultural drainage wells or expand the drainage area of existing wells. Iowa only issued two permits for new ADW construction from 1957 to 1982 (Heathcote, 1998).

Figure 4 illustrates the three types of flow into an ADW (Baker and Austin, 1984). Surface water can directly enter the tile lines through surface intakes or through cracks in the cistern. ADWs with surface intakes may deliver contaminants (bacteria, suspended matter, large particulates) that would not generally be found in normal infiltration recharge (Ludwig et al., 1990). Quasi surface flow occurs from the occasional ponding of water in low areas. Water travels through macropores and fractures or cracks that have developed in the soil profile, allowing rapid movement of ponded water into the tile system. The final type of flow is subsurface flow from tile lines.

MANAGEMENT ALTERNATIVES FOR ADWS

As part of the Iowa Groundwater Protection Act, the IDALS conducted a demonstration project to evaluate whether various management practices could reduce groundwater contamination from ADWs. From 1989 to 1993, the IDALS evaluated four management alternatives for ADWs: closure of ADWs and development of alternate

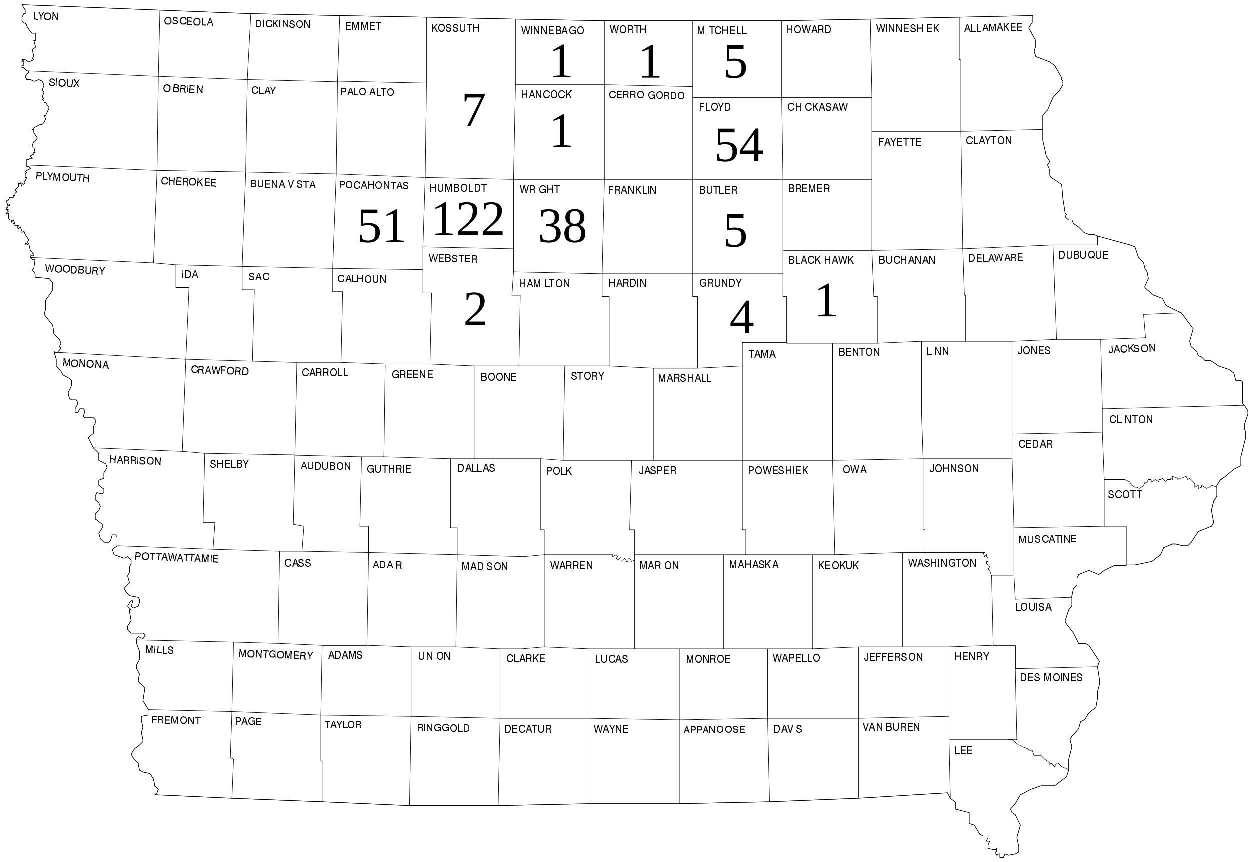

Figure 3. Location of active agricultural drainage wells in Iowa, by county, as of July 1998. Source: Iowa Department of Natural Resources - Natural Resources Geographic Information System Library.

outlets to surface water; closure of ADWs and conversion of cropland to wetlands; continued use of ADWs with chemical management of nutrients and pesticides applied to cropland drained by tiles discharging to ADWs; and continued use of ADWs with closure of surface intakes (IDALS, 1994). Evaluations of the four management alternatives for ADWs represented phase one of the Iowa Agricultural Drainage Well Research and Demonstration Project, a joint project of the Iowa Department of Agriculture and Land Stewardship and Iowa State University.

A second phase of research, which began in 1994, is evaluating newer generation herbicides and the new nitrogen management practices in reducing the movement of nitrate-nitrogen (nitrate-N) and herbicides from cropped fields to groundwater resources (IDALS, 1998). Also being evaluated is the benefit that placement of a wetland within the surface watershed has on reducing nitrate-N concentrations and losses to subsurface drainage. Phase two research will continue through 1999. Phase three will evaluate the physical and economic feasibility of establishing wetlands at specific locations in Iowa. Summaries of these research studies are presented in IDALS (1994; 1998), Lemke (1996), Baker and others (1996a; 1996b), and Melvin (1996).

Closure of ADWs and development of alternate drainage outlets to surface water is a management alternative that has been successfully used in Floyd County, Iowa. A total of 23 ADWs

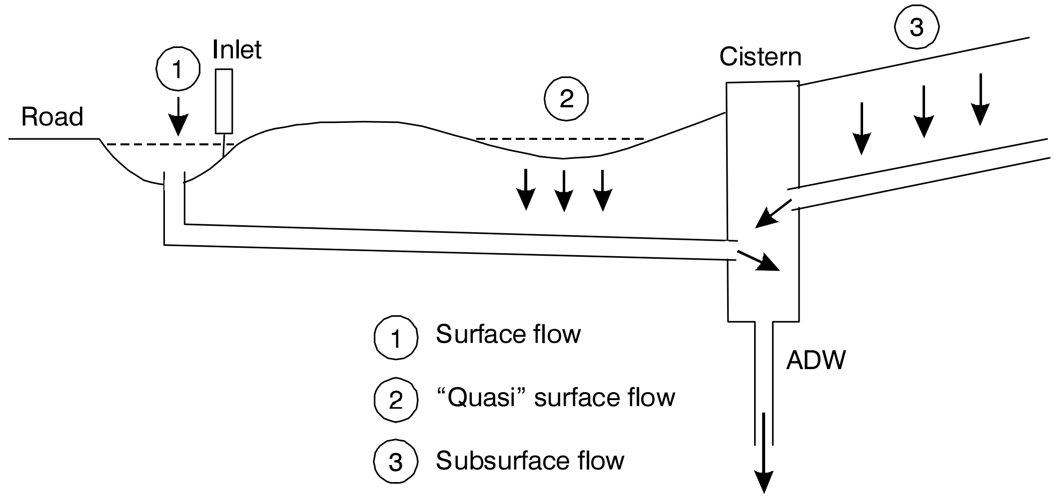

Figure 4. Schematic of an agricultural drainage well illustrating the three types of flow delivered to an ADW (from Baker and Austin, 1984).

were voluntarily closed and alternate outlets to surface water developed as part of the Floyd County Groundwater Protection Project (Moore, 1996). The average cost per closed ADW to develop alternate outlets was $9,061 (Moore, 1996); these costs were below initial project estimates.

Cost, however, has remained a barrier to implementing management alternatives to ADWs in other areas, especially if alternate drainage outlets were to be developed (Heathcote, 1998). In addition to high costs, closing of ADWs is complicated by geologic, wetland, and socioeconomic factors that differ for the various ADW areas (Lemke, 1996). Engineering studies estimated a cost of $22 million to close and develop alternate outlets for 225 ADWs in Iowa (IDALS, 1994; Lemke et al., 1995). The cost of closure ranged from $128 to $870 per acre of land drained. Cost per ADW, for those ADWs studied, ranged from $12,000 to $390,000. Of the four counties in Iowa with the greatest number of ADWs (Floyd, Humboldt, Pocahontas, and Wright counties), the estimated cost per acre to close ADWs and develop an alternate outlet was lowest for Floyd County (IDALS, 1994; Lemke et al., 1995). Current cost estimates to close all ADWs in Iowa is $40 million with an additional $20 million necessary for wetland mitigation (Dean Lemke, personal communication, 1999).

Outside of the areas influenced by ADWs, very few people were aware of the threat to groundwater contamination posed by ADWs. In Floyd County, the threat to groundwater was recognized and, through the Floyd County Groundwater Protection Project, cost-share money was provided to develop the necessary alternate outlets to surface water (Moore, 1996).

In the fall of 1994, Iowa State University Extension initiated an applied example of continued use of ADWs with management of nutrients and pesticides applied to land drained by tiles discharging to ADWs (Rieck-Hinz, 1996; Libra et al., 1996). Integrated Crop Management (ICM) programs were established for four “clusters” of ADW owners and users: one in Pocahontas County, two in Humboldt County, and one in Wright County. ICM is a planning process that allows producers to enhance crop management practices while protecting and sustaining natural resources and increasing production efficiency and productivity (Brown et al., 1994). Nitrogen and chemical (herbicide) management using the ICM program was evaluated on a field-by-field basis. The

Pocahontas County cluster had 8 cooperators who enrolled 1,349 acres and 11 ADWs; the Humboldt County clusters had 10 cooperators with 4,635 acres and 16 ADWs; and the Wright County cluster had 4 cooperators with 760 acres and 3 ADWs (Libra et al., 1996).

The issue of ADWs in Iowa was brought to the public's attention in the mid 1990s with the siting of large-scale animal confinement feeding operations (also known as concentrated animal feeding operations - CAFOs) in close proximity to ADWs. This risk was most evident in Lincoln Township in Wright County, southeast of Clarion. In Lincoln Township, there are 27 ADWs within one mile of a permitted animal confinement operation (Mumm and Heathcote, 1997; Heathcote, 1998). All of the ADWs in this area discharge into the Mississippian aquifer, the primary drinking water source for residents in the area.

In response to concerns about the placement of large confinement facilities in close proximity to ADWs, the Iowa Legislature enacted Senate File 473 in 1997. This legislation required closure of ADWs at risk from nearby earthen manure storage structures. All ADWs that are within a drainage area that includes a permitted earthen manure storage structure must be closed by December 31, 1999 (later extended to December 31, 2001). Many of the ADWs in Wright County are now scheduled for closure and alternate outlets to surface water will be developed. This law made any new construction or expansion of an earthen manure storage structure within an area that is drained by an ADW illegal.

Also as part of Senate File 473, repair and improvement of all ADWs is required for continued use (Heathcote, 1998). This includes removal of surface intakes, repair and maintenance of cistern sidewalls to prevent surface water from entering the ADW, and the addition of a locked cover to prevent unauthorized access. All septic system connections to ADWs must be removed and best management practices need to be implemented on land that drains to ADWs (Heathcote, 1998).

PREVIOUS INVESTIGATIONS OF ADWs IN IOWA

A number of previous investigations have studied the impact of ADWs on groundwater quality in Iowa. Mustermann and others (1981) identified three main areas in Iowa with high concentrations of ADWs and estimated the presence of 700 ADWs in Iowa. Mustermann and others also included numerical estimations of the effects ADWs have on nitrate concentrations in the main ADW areas located in Floyd, Humboldt, Pocahontas, and Wright counties.

Additional studies in the mid 1980s (Baker and Austin, 1984; Baker et al., 1985) determined that ADWs negatively impact groundwater quality. Results showed that the quality of water discharged to the ADWs depends on the management of the land drained by the ADWs, the type of drainage to the ADWs (surface runoff and/or subsurface flow), and climatic conditions that affect the volume and timing of infiltration and runoff. Soil adsorption of agricultural chemicals was important in determining the concentrations in surface runoff and subsurface flow. During periods of snowmelt or rainfall-runoff, nitrate concentrations were lower, as ADWs received both subsurface and surface runoff water. Nitrate concentrations were higher during periods between runoff events when all of the drainage to ADWs was subsurface flow. A survey of private wells in the study area of Humboldt and Pocahontas counties showed that where ADWs were within two km of a private well, nitrate concentrations were elevated (Baker et al., 1985).

Cherryholmes and Gockel (1987) monitored nitrate-N and pesticide concentrations of tile drainage water entering eight ADWs in Floyd County during June, July, and September of 1986. Nitrate-N concentrations ranged from 0.2 to 31 mg/L; 65% of the concentrations were >10 mg/L. The pesticides alachlor, atrazine, cyanazine, carbofuran, metolachlor, and metribuzin were detected in the tile drainage at concentrations from 0.12 to 5.90 µg/L.

Drake and Esling (1988) evaluated the impact of ADWs on the Mississippian aquifer beneath

Humboldt, Pocahontas, and Wright counties, and on the Devonian aquifer beneath Floyd County. Existing hydrogeologic data were used to calculate average groundwater flow conditions in these ADW areas. Results showed that if an ADW were plugged, the contaminant plume caused by inputs via the ADW should decay through time and space.

Libra and Hallberg (1993) summarized the hydrogeologic settings and water-quality implications for ADWs in Iowa. Based on data from the merged state and federal registration lists, an estimated 442 ADWs were present in Iowa. Each ADW drained from 2 to 720 acres (median 80 acres). Reported depths of the ADWs range from 12 to 400 feet (median 85 feet). The effects of ADWs on groundwater quality in a given area vary depending on the volume and quality of drainage water, the number of ADWs and acreage drained in a given area, and the hydrogeologic setting and hydraulic properties of the aquifer receiving the ADW discharge. The *"Groundwater Vulnerability Regions of Iowa"* map (Hoyer and Hallberg, 1991) was used to evaluate the impact of ADWs on various aquifers in differing geologic settings that have a range of *natural* vulnerability to contamination. The effects of ADWs are more readily recognized in areas where the aquifer receiving ADW inputs is naturally protected from surficial contamination. In areas more susceptible to contamination by surficially derived contaminants, the effects of ADW inputs is more difficult to discern.

Mohanty and others (1994) conducted a twenty-year simulation model of the potential impact of ADW closure in a watershed in Humboldt County, Iowa. Simulation results showed that closure of ADWs would result in ponding of low-lying areas and partial or total crop failure most years. There was also the potential for a decrease in the efficiency of crop production in the non-ponded areas as these areas became isolated fields because of ponding of low-lying areas. Crop yield loss in the non-ponded areas was estimated to be reduced by an annual mean of 18 percent.

Groundwater-quality studies in Floyd County have shown that ADWs were delivering agricultural contaminants, specifically nitrate and commonly used pesticides, into the Devonian bedrock aquifers. The Devonian aquifer in central Floyd County is naturally protected by about 30 feet of glacial till (Libra and Hallberg, 1985; Libra et al., 1994; Quade, 1995). These studies showed that while ADWs negatively impact groundwater and drinking water within one to two miles of several ADWs, not all wells within this distance show ADW impacts and the impacts vary with time. ADW impacts are most noticeable following runoff and/or infiltration generating conditions when surface and/or tile drainage is delivered to the groundwater via ADWs. ADW impacts are less, or not noticeable, during extended dry periods when drainage inputs are insignificant. These studies also show that ADW effects are difficult to identify in areas where the receiving aquifer is naturally susceptible to contamination.

For more detailed information on ADWs, see Heathcote (1998) for a chronology of ADW policy in Iowa and a discussion of regulations that have affected ADWs. Information on ADWs is also available on the Iowa Environmental Council's homepage at www.earthweshare.org.

HYDROGEOLOGIC SETTING OF FLOYD COUNTY

The hydrogeologic setting of Floyd County is briefly discussed below. For more detailed information, see Libra and others (1984; 1994).

Stratigraphic and hydrogeologic studies suggest that the Devonian strata in Floyd County is a three-part aquifer system with the major water-producing carbonate strata separated by intervening shales and shaley carbonates (Witzke and Bunker, 1984; Witzke et al., 1988; Libra et al., 1984). Figure 5 is a northeast-southwest cross section of the Devonian strata in Floyd County. The Devonian strata form three major aquifers that are termed the "lower," "middle," and "upper" aquifers. The Spillville Formation forms the lower aquifer; the Basset Member of the Little Cedar Formation forms the middle aquifer; and the Hinckle and Eagle Center members of the Little Cedar Formation, and the Coralville, Litho-

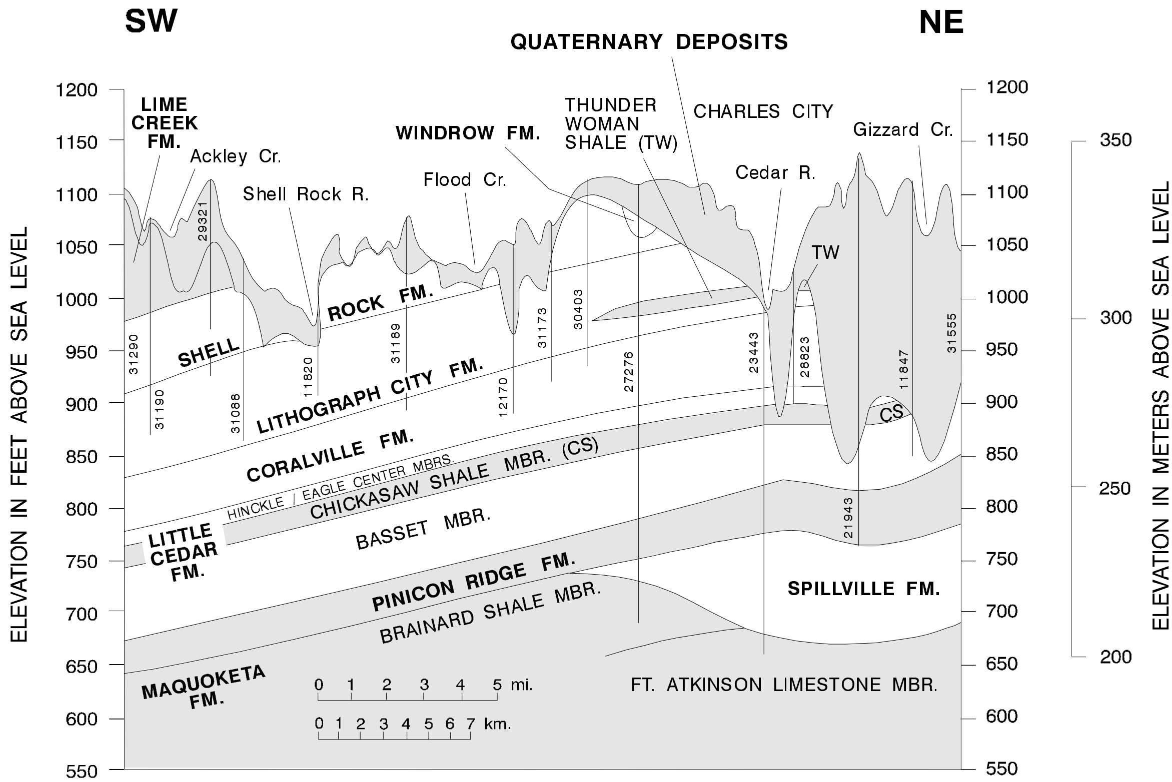

Figure 5. Geologic cross section of the Devonian system in Floyd County (from Libra and Hallberg, 1993). Well penetrations are denoted by the heavy vertical lines. Numbers associated with the vertical lines represent the unique identification number assigned by the Iowa Department of Natural Resources - Geological Survey Bureau.

graph City, and Shell Rock formations form the upper aquifer (Figure 6). The Chickasaw Shale Member of the Little Cedar Formation and the Pinicon Ridge Formation serve as confining units, and are regionally extensive units in north-central Iowa (Witzke and Bunker, 1985). The potentiometric surface of the Devonian aquifer was mapped by Horick (1984) and showed the regional groundwater flow from upland positions toward the large streams or rivers.

Figure 7 is a map of the four geologic regions of Floyd County. The Deep Bedrock, Shallow Bedrock, and Karst regions were initially used by Hallberg and Hoyer (1982) to evaluate water quality of the regional carbonate aquifers in 22 counties of northeast Iowa. The Incipient Karst region, a subcategory of Karst, was added by Libra and others (1984).

The Deep Bedrock regions are areas where the carbonate bedrock is buried by greater than 50 feet of Quaternary surficial material. These regions are relatively "protected" from infiltration of surface-applied chemicals. A Deep Bedrock region occurs in northeast Floyd County and represents a former bedrock channel now filled with low permeability glacial till. The other major Deep Bedrock region is located in central Floyd County on the upland divide between the Shell Rock and Cedar rivers.

Most of Floyd County is in the Shallow Bedrock region, an area characterized by 50 feet or less of Quaternary deposits overlying bedrock, and a Karst region. The Karst region contains very shallow bedrock generally at a depth of less than 25 feet, where numerous open sinkholes occur. This region usually occurs in rolling ter-

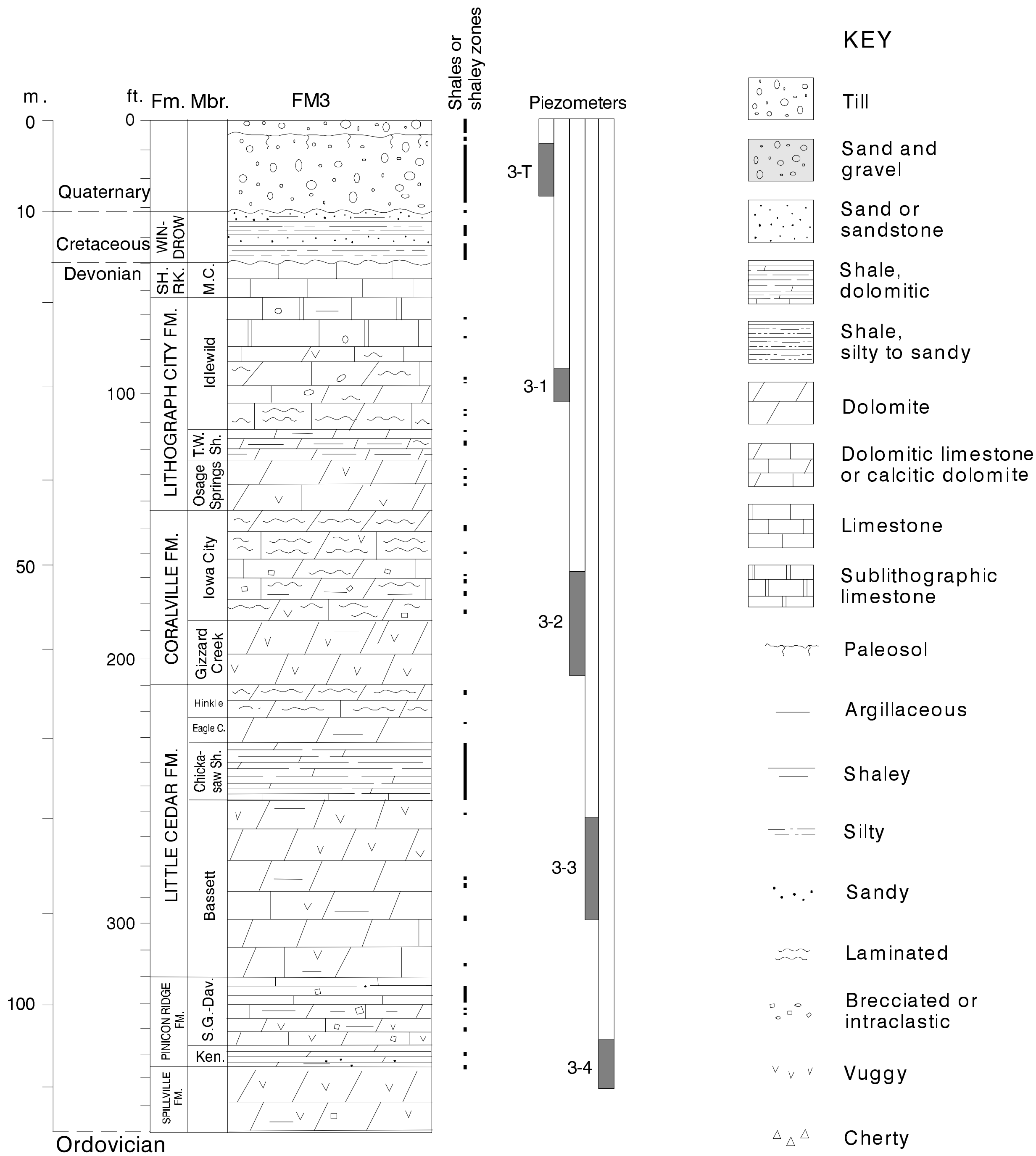

Figure 6. Stratigraphic column and completion interval for the four bedrock piezometers and glacial till piezometer at site FM3. All four bedrock piezometers are completed in Devonian age strata. Land surface elevation is 1102 feet.

rane. One of the largest Karst regions in Floyd County occurs in the north-central part of the county, east of the Cedar River. The Incipient Karst region is an area of very shallow bedrock, generally less than 20 feet, with numerous incipient sinkholes on broad, low-relief upland divide areas. It is marked by high rates of infiltration recharge and little, if any, surface water run-in recharge (Libra et al., 1984). An Incipient Karst region occurs in north-central Floyd County, west of the Cedar River.

These four geologic regions represent differing hydrogeologic settings which affect groundwater quality. Past investigations have shown that groundwater in Deep Bedrock areas are naturally protected from agricultural contaminants (Hallberg and Hoyer, 1982; Hallberg et al., 1983a, 1984; Hallberg and Libra, 1989; Libra et al., 1984, 1994). A December 1992 inventory of private wells in Floyd and Mitchell counties showed that groundwater in Deep Bedrock regions contained low or non-detectable concentrations of nitrate and pesticides (Libra et al., 1984). An exception is the Deep Bedrock region in central Floyd County. In this area, the presence of ADWs negatively affects groundwater quality (Libra and Hallberg, 1985; Libra et al., 1984, 1994). The ADWs allow surficially derived contaminants to bypass the protective surficial materials located near the land surface, and directly enter the underlying bedrock aquifers.

Groundwater in the other three regions shows varying degrees of susceptibility to contamination by nitrate and pesticides (Libra et al., 1984; 1994). Groundwater in the Shallow Bedrock region is susceptible to infiltration of contaminants, particularly in areas where the Quaternary deposits are thin. In the Karst region, groundwater reflects the impacts of both infiltration and direct run-in of surface water, and in Incipient Karst areas, groundwater only reflects the effects of infiltration.

Throughout Floyd County, the Chickasaw Shale appears to be a very effective confining unit for the lower Devonian aquifer, except in areas of ADWs. In the ADW area of Floyd County, some of the deep ADWs discharge tile effluent into strata below the Chickasaw Shale, directly into the lower aquifer. Water-quality samples from wells completed below the Chickasaw Shale showed no detectable levels of nitrate or pesticides, except in areas where ADWs are present (Libra et al., 1984; 1994).

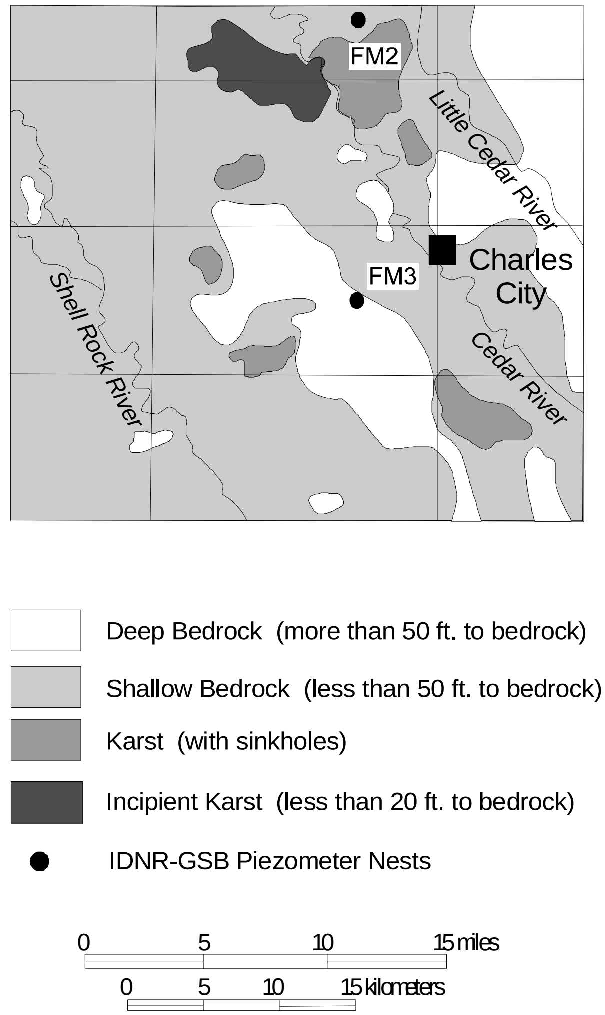

Figure 7. Map showing geologic regions for Floyd County. Piezometer nest FM3, located in the deep bedrock region, is one of the monitoring sites for the ADW Closure Project.

PREVIOUS INVESTIGATIONS OF WATER QUALITY IN THE FLOYD COUNTY ADW AREA

Initial studies in northeast and north-central Iowa identified areas where surficially derived contaminants, particularly nitrate and pesticides, had caused degradation of groundwater quality (Hallberg and Hoyer, 1982; Hallberg et al., 1983a, 1983b; Hallberg et al., 1984; Libra et al., 1984). These studies showed that the depth to bedrock and the presence or absence of karst features affected the susceptibility of groundwater to contamination.

In Floyd County, and adjacent Mitchell County to the north, the Devonian system carbonate strata form a three-part aquifer system that is widely used as a drinking water resource. Investigations in Floyd and Mitchell counties have shown a relationship between hydrogeologic setting and the distribution of agricultural contamination in the groundwater of the Devonian system (Libra et al., 1984; Libra and Hallberg, 1985; Libra et al., 1994). Where the aquitard cover of Quaternary material (glacial till) is thicker, contamination of the upper aquifer is relatively rare. Contamination generally decreases with depth within the upper aquifer, even below areas of thin Quaternary cover. Contamination is rare within the middle and lower Devonian aquifers (Libra and Hallberg, 1993).

Floyd County is one of four counties in northern Iowa where a significant number of ADWs are present (see Figure 3). The majority of ADWs in Floyd County are located in the Shallow Bedrock and Karst regions as defined by Libra and Hallberg (1993). To better understand the impacts of ADWs on groundwater contamination, multiple core holes were drilled at four locations in Floyd and Mitchell counties during the summer of 1984. These core holes completely penetrated the Devonian sequence. The coring allowed for detailed stratigraphic analysis and correlation of the Devonian strata across the two-county area. Packer tests, completed on three of the core holes, determined in situ information on aquifer hydraulics, the degree of interconnection of individual aquifers, and allowed for the water sampling of individual aquifers. These three holes were then completed as piezometer nests, allowing the continued monitoring of water levels and quality within individual aquifers at each site. Details of the packer tests can be found in Libra and Hallberg (1985) and Libra and others (1994). The three piezometer nests were located in differing hydrogeologic regions; one in a Karst region, another in a Shallow Bedrock region, and the third in a Deep Bedrock region with ADWs. Each nest contained four bedrock piezometers. At each nest, two piezometers were completed in the upper aquifer, one in the middle aquifer, and one in the lower aquifer.

Three ADWs are located near the piezometer nest (site FM3) in the deep bedrock/ADW region (Figures 7 and 8). ADW-1 (>300 feet deep) occurs within 500 feet of FM3 while the other two ADWs (ADW-2, ADW-3; both 65 feet deep) occur within a one-half mile radius (Figure 8). None of these ADWs have surface intakes. Previous research in Iowa has shown that the concentration of chemicals that adsorb to soil particles (e.g., most pesticides) is usually higher in surface runoff than in subsurface drainage. The concentration of chemicals that are more soluble (e.g., nitrate) is usually higher in subsurface drainage (Baker, 1980; Baker and Johnson, 1976; Baker and Laflen, 1983). Pesticide concentrations from the three ADWs are lower than what might be expected if surface intakes had been attached to the ADWs.

Results from the piezometer nest in the deep bedrock/ADW (site FM3) area indicated that these ADWs were delivering nitrate and pesticides to the Devonian aquifers (Libra et al., 1994). Several lines of evidence support this conclusion. (1) High potentiometric heads and rapid changes in head occurred during the relatively wet period of March to June 1986. Heads varied by 20 feet in the two upper aquifer piezometers at this site and varied by 30 feet in the middle and lower aquifers. During the same period, much smaller head changes and lower heads were measured at the other two piezometer nests that are not in ADW areas. (2) Nitrate-N concentrations were highly variable and changed very quickly in the

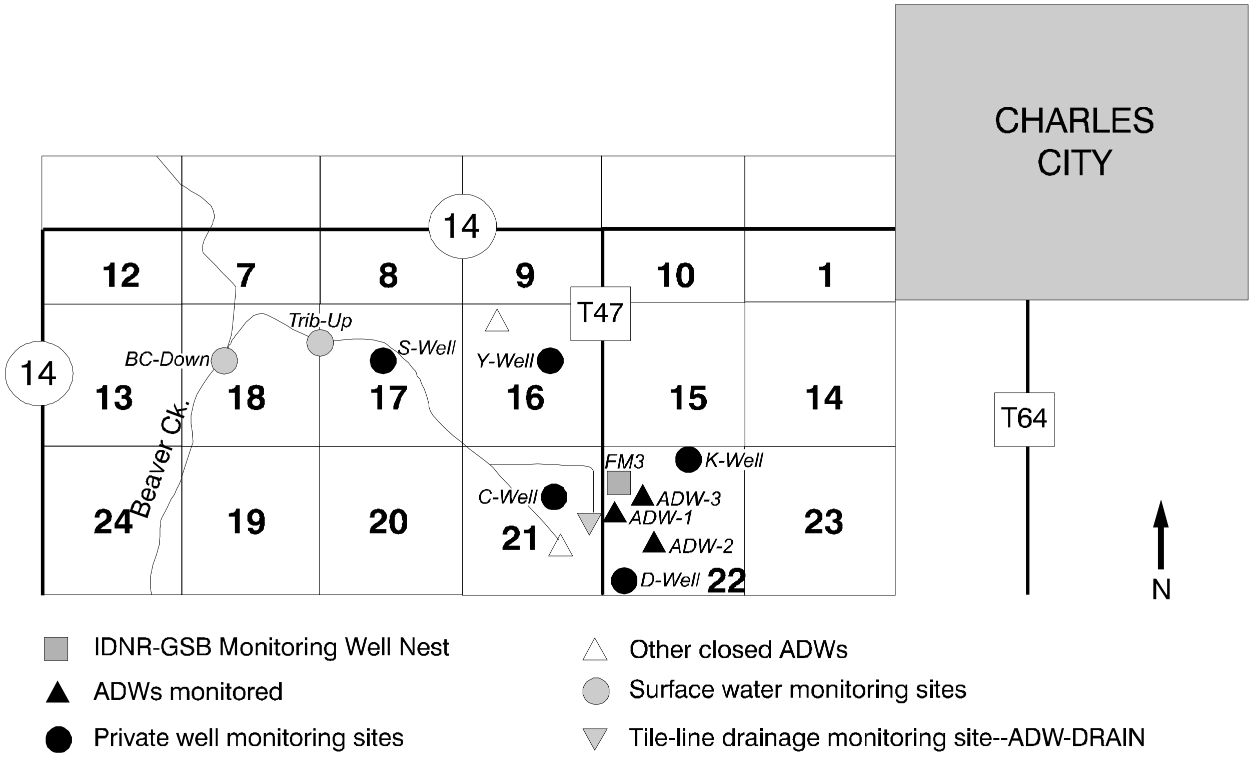

Figure 8. Location map of the sites monitored as part of the Floyd County ADW Closure Project. Bold numbers represent section numbers.

shallowest (site FM3-1; well depth 103 feet) and deepest piezometer (site FM3-4; well depth 360 feet). During relatively dry periods, nitrate-N concentrations in the uppermost piezometer were generally <2 mg/L. This corresponds to periods when tile lines were dry and did not provide nitrate to nearby ADWs. Nitrate-N concentrations were >20 mg/L at times, corresponding to tile line inputs to the ADWs. The deepest piezometer, located in the lower aquifer, also showed similar increases and decreases in nitrate concentrations corresponding to wet and dry periods, although the nitrate concentrations were lower than those in the upper aquifer. (3) Water-quality results from the nearby, deep ADW (site ADW-1; >300 feet deep) suggest that additional nearby ADWs were also impacting the water quality in the bedrock piezometers. Nitrate-N concentrations from ADW-1 during the wet March through May 1986 period were lower than concentrations found in piezometer FM3-1 during the same time, suggesting other ADWs might also be contributing to the upper aquifer. Also, pesticides not found in ADW-1 were detected in FM3-1, suggesting inputs from other ADWs. (4) The highest pesticide concentrations at FM3-1 and FM3-4 occurred during wet periods when tiles were discharging to the ADWs and high heads occurred in the piezometers. (5) Tritium samples collected in August 1985 and March 1986 reported 6 to 25 Tritium Units in the Devonian aquifers at FM3, suggesting the presence of post-1953 water in all three aquifers. The source of the tritiated water in the FM3 piezometers appears to be the nearby ADWs (Libra et al., 1994).

Water-quality results from the three ADWs near FM3 were variable. Median nitrate-N concentrations ranged from 8 to 28 mg/L. Alachlor, atrazine, cyanazine, deethylatrazine (a breakdown product of atrazine), metolachlor, and metribuzin were detected in tile lines discharging to the ADWs at concentrations ranging from 0.11 to 5.90 µg/L (Quade, 1995).

CLOSURE OF ADWS IN FLOYD COUNTY

In 1990, the Floyd County Soil and Water Conservation District initiated the Floyd County Groundwater Protection Project to address water-quality problems in Floyd County. Funding for this five-year project was provided by Water Quality Protection Funds administered by the Iowa Department of Agriculture and Land Stewardship - Division of Soil Conservation (IDALS-DSC) and the U.S. Environmental Protection Agency Section 319 funds administered by the Iowa Department of Natural Resources.

An objective of the Floyd County Groundwater Protection Project was to preserve and improve groundwater quality in the Devonian aquifers in Floyd County, primarily by addressing sinkholes and ADWs. Moore (1996) summarizes the Floyd County Groundwater Protection Project activities and accomplishments.

To address sinkholes, three areas containing 61% of all known sinkholes in Floyd County were targeted by the project. Efforts included an inventory of sinkhole location and description of the sinkholes; cost-share for filter strips around sinkholes with permanent easements or buffer zones with a maintenance agreement, or cost-share alternate tile outlets for field tile previously draining directly to sinkholes; sinkhole cleanouts; and implementation of Best Management Practices (BMPs) to reduce the movement of nutrients and pesticides to sinkholes. BMPs included Integrated Crop Management, manure management, and a nutrient management program.

ADW owners in Iowa were required to register their wells, both with the Iowa DNR and the U.S. EPA. From the two combined lists, an estimated 92 ADWs were present in Floyd County, second in number to Humboldt County (Libra and Hallberg, 1993). Beginning in March 1994, the Floyd County Groundwater Protection Project coordinator initiated an inventory of ADWs to determine proper ADW locations and owners; describe known tile systems, acres drained, and all users of these systems; determine the depth of each ADW, cistern size, casing depth, topographical features, and condition of the ADW; and identify the location of surface intakes, septic tank outlets, and potential manure run-off. The inventory identified 69 functioning ADWs in Floyd County, including four ADWs that serve as the outlet for four legal county drainage districts (Moore, 1996). During the inventory, owners of ADWs were asked about their interest in closing the ADWs and finding alternate outlets for the tile water. The Floyd County Groundwater Protection Project offered 75% cost-share to develop alternate outlets for the tile water draining to the ADWs, thus allowing closure of several ADWs.

A total of 23 ADWs were voluntarily closed in Floyd County as part of the Floyd County Groundwater Protection Project (Moore, 1996). Previous water-quality monitoring in the county showed that deep ADWs discharging into the lower aquifer were impacting this otherwise protected aquifer (Libra et al., 1994; Quade, 1995). ADWs discharging into the deep aquifer of the Devonian bedrock were designated a priority for closure; several ADWs deeper than 300 feet were closed as part of this project. Most of the ADWs in Floyd County occur in areas recognized as Shallow Bedrock or Karst (Libra and Hallberg, 1993). Moore (1996) estimated that an additional 23 ADWs would have suitable alternate outlets and could be closed if funding were available and owners were interested.

To develop alternate outlets, the average cost per closed ADW was $9,061 (Moore, 1996). The final costs for closure of the 23 ADWs were below initial project estimates.

MONITORING OF ADW CLOSURE SITE

In the fall of 1994, the Iowa Department of Natural Resources — Geological Survey Bureau initiated the Floyd County ADW Closure Project

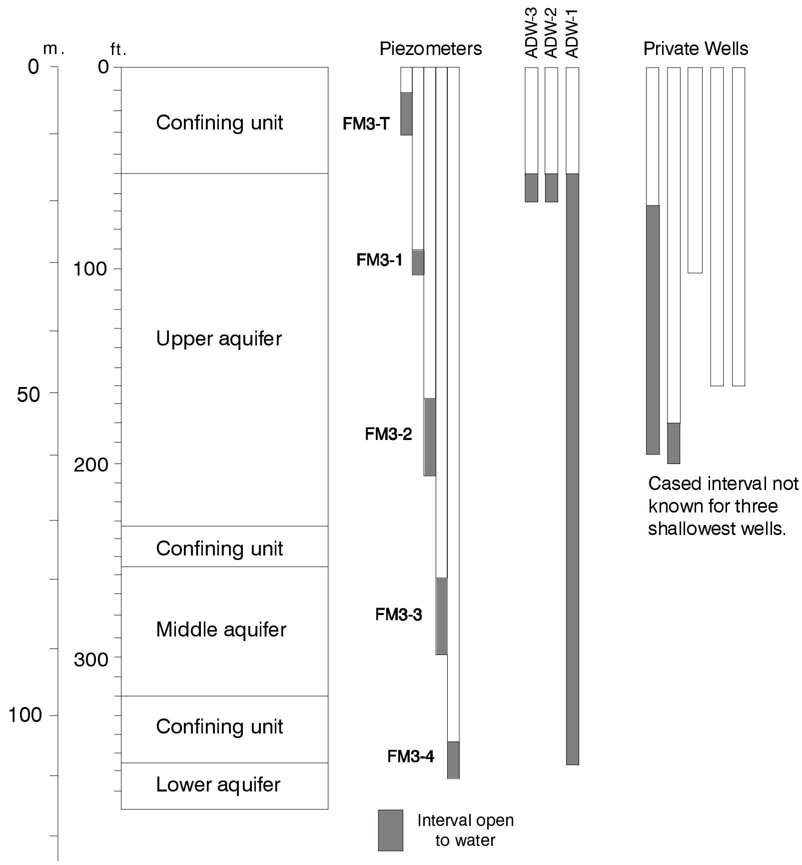

Figure 9. Generalized stratigraphic column and depths for piezometers at site FM3, three closed ADWs, and five private wells. In this part of Iowa, the Devonian strata is recognized as a three-part aquifer system (upper, middle, lower).

to monitor anticipated improvements in groundwater quality of the Devonian aquifers resulting from closure of the three agricultural drainage wells (ADW-1, ADW-2, ADW-3) nearest the bedrock piezometer nest (FM3) (Figure 8). Funding for the water-quality monitoring project was provided by Water Quality Protection Funds administered by the IDALS-DSC via the Floyd County Soil and Water Conservation District. Analytical services were provided by The University of Iowa Hygienic Laboratory.

In December 1994, the three drainage wells (ADW-1, ADW-2, and ADW-3) nearest the bedrock well nest were closed (Figure 8). None of the three ADWs had surface intakes. The Floyd County Groundwater Protection Project provided cost-share assistance to the owners of the three ADWs for development of an alternate surface water outlet for tile drainage. The tile lines previously draining to these three ADWs were connected, and the tile water diverted by a single tile line to a constructed drainage ditch. The water in the drainage ditch travels for approximately three miles before emptying into Beaver Creek (see Figure 8).

In addition to sampling the bedrock piezometer nest (FM3) and a nearby glacial till piezometer (site FM3-T), the combined tile drainage from the three ADWs was sampled (ADW-Drain) once the ADWs were closed in December 1994, as well as water from the drainage ditch just prior to its entering Beaver Creek. The quality of the diverted drainage was monitored to assess impacts on the receiving stream and address concerns that the diverted drainage from Beaver Creek would impact the shallow groundwater system. Five nearby private wells were also sampled; all were completed in the upper Devonian bedrock aquifer (Figure 9).

Two additional ADWs in close proximity to the monitored sites were closed in the summer of 1995 (see Figure 8). The southernmost ADW was >300 feet deep and the northernmost ADW was approximately 70 feet deep (Dennis Sande, Floyd County District Conservationist, personal communication). No background water-quality information is available for either of these ADWs. Neither ADW has surface intakes.

Piezometer Construction Information

Four nested bedrock piezometers and one glacial till piezometer are located at the FM3 site (Figure 6). All five piezometers were installed in 1984. The glacial till piezometer is 29 feet deep and is completed in pre-Illinoian till. A paleosol occurs above the screened interval of the piezometer (Figure 6). Sediment-filled wedges in the glacial till were described by Walters (1995) from an exposure created during the excavation of the drainage ditch to the west of FM3. These wedges were identified as ice-wedge casts that formed in a former periglacial environment with permafrost (Walters, 1995).

Depths of the four bedrock piezometers are 103 feet (FM3-1), 207 feet (FM3-2), 297 feet (FM3-3), and 360 feet (FM3-4), and all are completed in Devonian bedrock. The 103- and 207-feet deep piezometers are completed in the upper aquifer; the 297-feet deep piezometer is in the middle aquifer; and the 360-feet deep piezometer is in the lower aquifer. Specifically, FM3-1 is in the Lithograph City Formation; FM3-2 is in the Coralville Formation; FM3-3 is in the Little Cedar Valley Formation; and FM3-4 is in the Spillville Formation.

The three lower bedrock piezometers were constructed with 1 1/2" O.D. (outer diameter) polyvinyl chloride (PVC) pipe, the uppermost piezometer was constructed with 1" O.D. PVC, and the till piezometer was constructed with 2" O.D. PVC (Libra and Hallberg, 1985). All of the PVC pipe was flush-jointed and threaded. No glue or cements were used. Gravel packs were installed opposite the slotted intervals and bentonite/cement grout was used to isolate the bedrock intervals.

Private Well Construction Information

Well depth and casing information for the five private wells were provided by the respective landowners. Estimated well depths ranged from 102 to 200 feet, and known casing depths were from 66 to 180 feet. All five private wells were completed in the upper Devonian aquifer.

Monitoring Design and Frequency

The five private wells were monitored for nitrate on a monthly basis from November 1994 through September 1998. Because of the uncertainty of funding for the Floyd County ADW Closure Project, only two samples from each of the private wells were collected prior to closure of the ADWs. Also, the private well located directly west of FM3 needed to be sampled from a faucet inside the house during the winter months. The faucet was inaccessible during several of the winter months.

Sampling of ADW-Drain began in January 1995 after the three ADWs were closed. Sampling continued through September 1998. The site was sampled on a monthly basis for nitrate-N, ammonia-N, and common herbicides. No samples were collected during extended dry periods during some of the summer months, as the tile line discharging to ADW-Drain was not flowing. No samples were collected during some winter months due to frozen conditions.

The two surface water sites, BC-Down and Trib-Up, were sampled on a monthly basis from November 1994 through September 1998 for nitrate-N, ammonia-N, and common herbicides. No samples were collected from the sites when there was no flow or very little if any flow, and when water at the sites was frozen.

Sampling of the tile drainage to the three ADWs has varied through time. ADW-1 has been monitored since November 1984 for the common forms of nitrogen (nitrate-, organic-, and ammonia-N) and for common herbicides. The frequency of sampling was quarterly until July 1993 when sampling changed to monthly. Sampling of ADW-1 (and all of the piezometers at FM3) did not occur

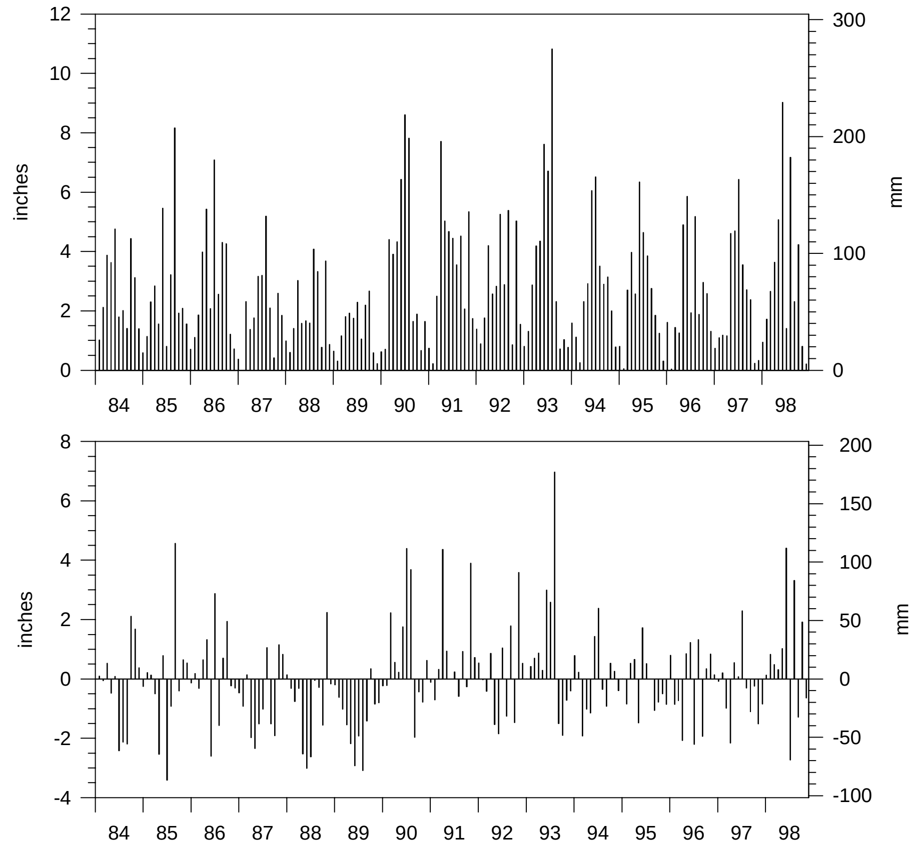

Figure 10. Monthly precipitation and departure from normal for the Charles City, Iowa, climatic station from 1984 through 1998. Departure from normal is based on the period 1951-1980.

from October 1986 through September 1988 because of lack of funding. The last sample collected from ADW-1 occurred in November 1994, prior to its closure in December 1994.

ADW-2 and ADW-3 were monitored monthly from August 1993 through November 1994 for the common forms of nitrogen and common herbicides. Both were closed in December 1994.

The five piezometers at FM3 have been monitored on a monthly to quarterly basis from November 1984 to September 1986, and from September 1988 to December 1989. Monitoring occurred monthly from January 1990 through September 1998. In addition to water level measurements, water samples were analyzed for the common forms of nitrogen and common herbicides.

HYDROLOGIC MONITORING

Climatic Data

Mean annual precipitation (based on the period 1951-1980) for the Charles City climatic station is 32.76 inches. Figure 10 shows the monthly precipitation from January 1984 through December 1998 and the departure from normal monthly precipitation for this period. Table 1 lists the annual rainfall totals and departure from normal (Source: Iowa Department of Agriculture and Land Stewardship, State Climatologist Office).

Table 1. Precipitation totals and departure from normal by year for the Charles City, Iowa, climatic station. Departure from normal is based on the period 1951-1980.

Year	Precipitation inches (mm)	Departure from normal inches (mm)	Percent of normal precipitation
1984	29.87 (759)	-2.89 (73)	91%
1985	31.60 (803)	-1.16 (29)	96%
1986	35.27 (896)	2.51 (64)	108%
1987	24.28 (617)	-8.48 (215)	74%
1988	23.54 (598)	-9.22 (234)	72%
1989	16.57 (421)	-16.19 (411)	51%
1990	42.59 (1,082)	9.83 (250)	130%
1991	42.59 (1,079)	9.73 (247)	130%
1992	34.55 (878)	1.79 (45)	105%
1993	43.48 (1,104)	10.72 (272)	133%
1994	33.04 (839)	0.28 (7)	101%
1995	31.06 (789)	-1.70 (43)	95%
1996	30.91 (785)	-1.85 (47)	94%
1997	29.07 (738)	-3.69 (94)	89%
1998	39.15 (994)	6.39 (162)	120%

During this period, annual rainfall varied from 51% of normal in 1989 to 133% of normal in 1993. The years 1988 and 1989 represent the driest consecutive two-year period on record for Iowa. Rainfall was 72% of normal in 1988, and 51% of normal in 1989. Iowa experienced the "Flood of 1993," as rainfall for all of Iowa was well above normal. The rainfall at the Charles City climatic station was 133% of normal. In response to the above normal rainfall, water levels in the bedrock piezometers during 1993 reached the highest level recorded during the monitoring period. It has only been since 1994 that rainfall has returned to more normal levels.

Potentiometric Monitoring

Figure 11 shows the potentiometric elevations within the glacial till piezometer and bedrock piezometers in the Devonian aquifers at site FM3. Water levels reflect the variation in precipitation patterns in Floyd County. Water levels also reflect differences in climatic conditions (snow cover, air temperature, precipitation) which in turn affects the volume of tile drainage to ADWs. During most of the monitoring period, water levels in the bedrock piezometers decreased with increasing depth. The upper aquifer at this location, the Lithograph City Formation, is not fully saturated.

Static water levels in piezometer FM3-2 closely parallel levels in FM3-1, and levels in FM3-3 parallel those in FM3-4 (Figure 11). Water levels in FM3-1 and FM3-2 were generally within a few tenths of a foot of each other, while water levels in FM3-3 and FM3-4 were within a tenth of a foot of each other. Water levels in the two shallower piezometers were 0.6 to 6.6 feet higher than the two deeper piezometers.

Potentiometric elevations were at an all-time low for all piezometers during late 1989 and early 1990. The shallowest bedrock piezometer, FM3-1, was dry from April 1989 through April 1990. Potentiometric elevations reached an all-time high in the upper aquifer (FM3-1) in May 1986 (within 53 feet of the land surface) and July 1993 (within 55 feet of the land surface). (The elevation of the land surface at the piezometer nest is 1102 feet.) The highest potentiometric elevation in the lower aquifer (FM3-4) was 53 feet below the land surface in August 1993 and was four feet higher than the water level elevation in FM3-1. This represented the only time during the monitoring program that the head in the lower aquifer was higher than in the upper aquifer. This occurred following ten months of normal to above normal precipitation. Water levels in FM3-T ranged from one foot above the land surface during March 1985 to 10.3 feet below the land surface during February 1990.

Potentiometric elevations varied at all five piezometers through time. Water levels varied by a maximum of 58 feet in the middle and lower aquifers and 54 feet in the upper aquifer. Water levels in the glacial till piezometer (FM3-T) varied by 11 feet during the monitoring period.

The greatest differences in head between FM3-1 and FM3-2 occurred during periods of snowmelt accompanied by heavy rains (March 1986) and following an extended drought (May and June 1990). Heads were higher in FM3-1 both times. The greatest differences in head between FM3-1 and both FM3-3 and FM3-4 occurred at the end of

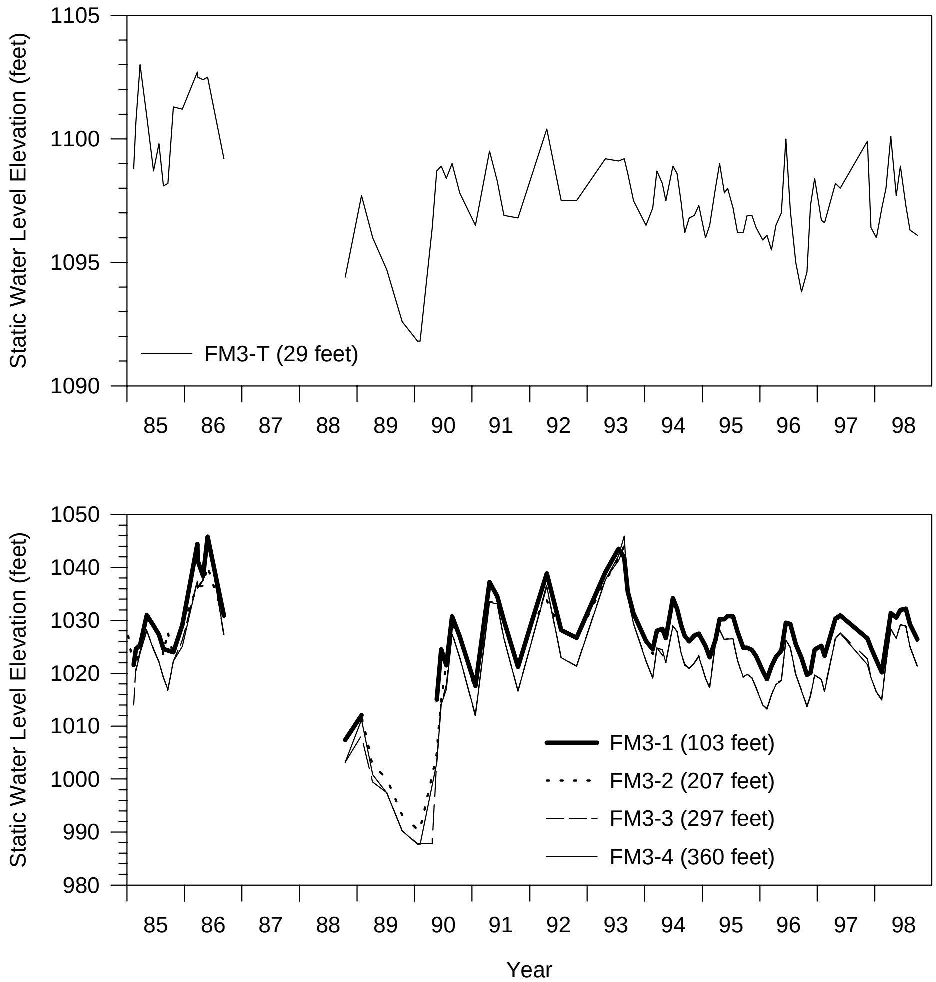

Figure 11. Static water level elevations for the four bedrock piezometers and glacial till piezometer at site FM3 from 1985 through 1998. The shallowest piezometer (FM3-1) was dry from April 1989 through April 1990. Land surface elevation is 1102 feet.

the drought (May and June 1990), after FM3-1 had been dry for one year. Heads were higher in FM3-1 relative to the other two piezometers. The greatest head differences between FM3-3 and FM3-4 occurred following periods of heavy rainfall (August 1993) or periods of unseasonably warm temperatures accompanying early snow melt (January 1989). Heads were higher in FM3-4 both times. The greatest difference in head between FM3-2 and FM3-3 occurred in September 1985. More than three inches of rain fell during the two weeks prior to the September 1985 sampling. The greatest difference in head between FM3-2 and FM3-4 also occurred in September 1985. Heads in FM3-4 were higher than FM3-2 on seven occasions. These occurred following heavy rains/snow melt during the spring of 1986 and following the heavy rains during the summer of 1993.

Libra and others (1994) showed that high heads and rapid changes in head at the bedrock piezometers at site FM3 reflect inputs from nearby ADWs. The range in water levels in the bedrock and glacial till piezometers has declined from the pre- to post-closure period. The decline in range for the bedrock piezometers reflects both the re-

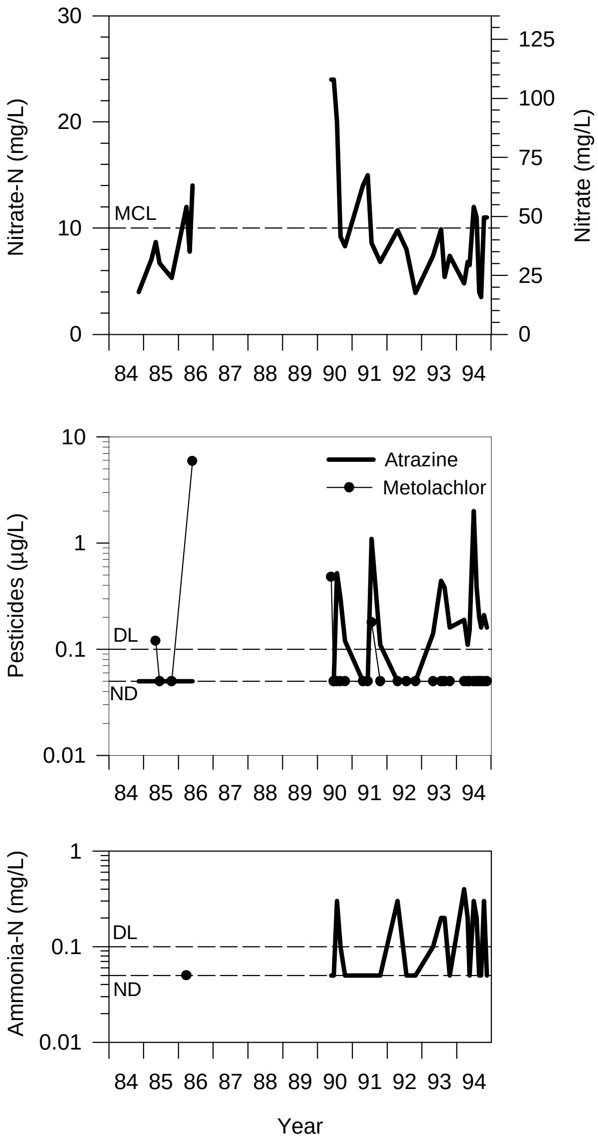

Figure 12. Nitrate-N and pesticide concentrations for ADW-1, from 1984 until closure in December 1994. MCL = Maximum Contaminant Level; DL = detection limit; ND = not detected (reported values were less than the detection limit and were assigned a value of 0.05).

moval of ADW inputs, and a return to more normal precipitation from 1995 through 1998. The decline in range for the glacial till piezometer reflects the return to more normal precipitation conditions, as FM3-T was unaffected by the ADWs. Water levels for all of the bedrock piezometers varied 53 to 58 feet prior to closure of the ADWs and varied 13 to 16 feet after closure. The variation in water levels in the glacial till piezometer was less, varying by 11 feet prior to closure of the ADWs and varying 6 feet after closure. Since closure, water levels in FM3-3 and FM3-4 have not risen above levels in FM3-1 and FM3-2. This likely reflects the removal of ADW inputs that infrequently increased heads in the deeper piezometers above those in the shallower piezometers.

WATER-QUALITY RESULTS

Shallow Groundwater Entering ADWs

The tile line water entering the three ADWs nearest the bedrock piezometer nest and glacial till piezometer were monitored prior to closure of the ADWs in December 1994. The deepest ADW, ADW-1, was monitored from November 1984 through November 1994 for nitrate and pesticides. The two shallowest ADWs, ADW-2 and ADW-3, were monitored from August 1993 through November 1994 for nitrate and pesticides. Data from all three ADWs is located in Appendix I. Typically, there was no water in the tile lines during very dry periods or in extremely cold weather. During these times, little or no water is delivered via the ADWs to the underlying bedrock.

Figures 12 through 14 show the nitrate-N, pesticide, and ammonia-N concentrations from the ADWs. The lack of data from 1987 through 1989 reflects a lack of funding, and as a result, no water-quality information was collected during this time. Nitrate-N concentrations in ADW-1 ranged from 3.5 to 24.0 mg/L, from 7.9 to 35.0 mg/L in ADW-2, and from 2.0 to 34.0 mg/L in ADW-3 (Table 2). The mean nitrate-N concentration for each of the ADWs was close to or above the drinking water standard of 10 mg/L. The mean nitrate-N concentration was 9.6 mg/L for ADW-1, 20 mg/L for ADW-2, and 23.7 mg/L for ADW-3 (Table 2). Nitrate-N concentrations varied through time in response to rainfall. The lowest nitrate-N concentration for each of the three ADWs occurred during September 1994. Rainfall for both August and September 1994 was below normal, thus limiting the inflow of nitrate-rich tile water to the ADWs.

The highest nitrate-N concentration in ADW-1 occurred May and June 1990 (24 mg/L). This elevated concentration can be explained by the climatic conditions preceding the May sampling. More than two inches of rain fell during the week preceding the date the sample was collected. Not only was rainfall above normal for May 1990, but it also was above normal for March and April 1990. This wet period occurred following the two drought years of 1988 and 1989. Studies in Iowa have shown that nitrate-N mass losses and concentrations are dependent on the volume of flow in shallow groundwater and tile systems (Baker and Johnson, 1981; Hallberg et al., 1986). Water-quality studies in other parts of Iowa showed lower nitrate-N concentrations in groundwater during drought years followed by higher nitrate-N concentrations in groundwater during the early 1990s (Rowden et al., 1993; Seigley et al., 1996). Burt and others (1988) showed that average nitrate-N concentrations typically decline during dry periods, often followed by a large increase in nitrate-N concentrations when recharge returns, hence mobilizing a greater than normal mass of nitrate that is stored in the soil system and available for potential transport.

The highest nitrate-N concentrations in ADW-2 and ADW-3 occurred in October 1993 and November 1994, respectively. Minimal rainfall occurred prior to sampling for both dates and it is unclear why concentrations were as high as they were at these particular sites and times.

In addition to nitrate-N, pesticides were also detected in the tile line water entering the ADWs. Table 2 summarizes the pesticide detections in the three ADWs. Alachlor, atrazine, cyanazine, deethylatrazine (a metabolite or breakdown prod-

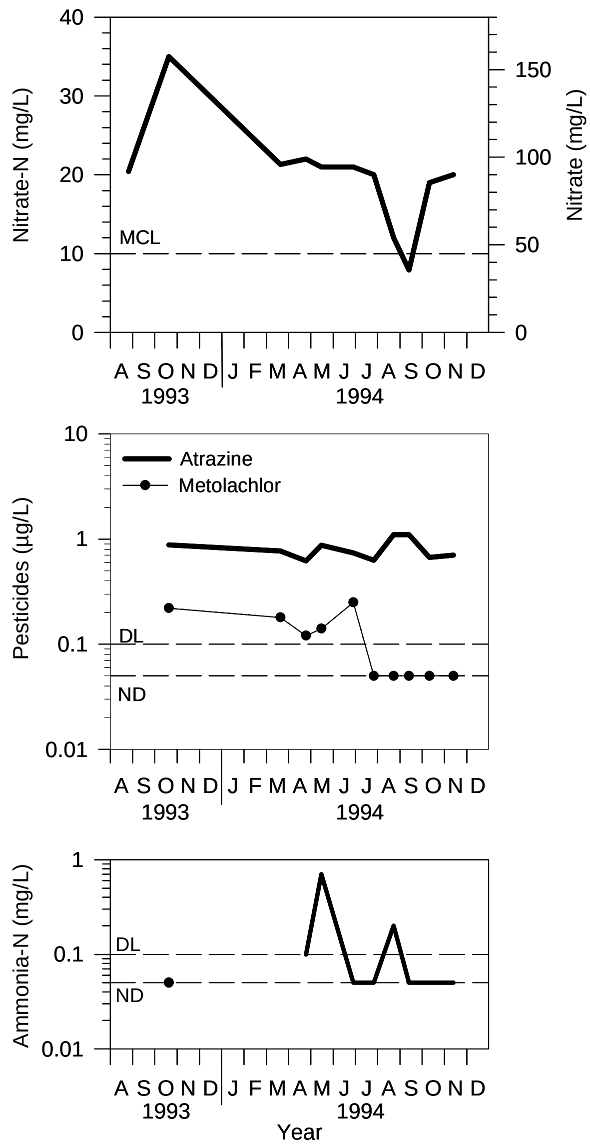

Figure 13. Nitrate-N and pesticide concentrations for ADW-2, from August 1993 until closure in December 1994. MCL = Maximum Contaminant Level; DL = detection limit; ND = not detected (reported values were less than the detection limit and were assigned a value of 0.05).

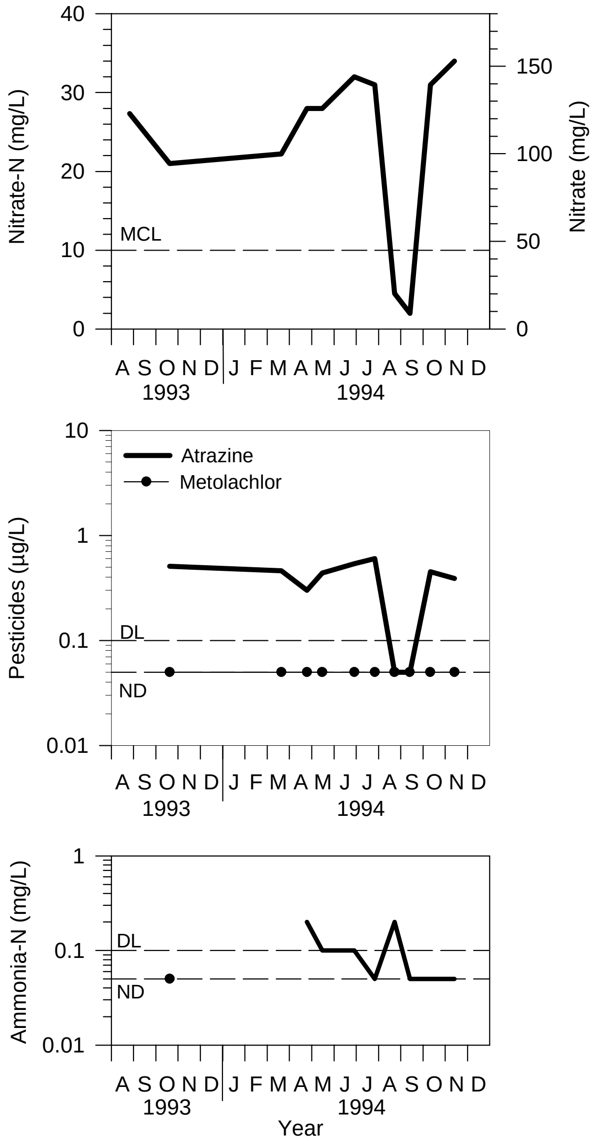

Figure 14. Nitrate-N and pesticide concentrations from ADW-3, from August 1993 until closure in December 1994. MCL = Maximum Contaminant Level; DL = detection limit; ND = not detected (reported values were less than the detection limit and were assigned a value of 0.05).

uct of atrazine), metolachlor, and metribuzin were detected at concentrations ranging from 0.11 to 5.90 µg/L. Atrazine, cyanazine, and deethylatrazine were the most frequently detected pesticides. (Note: The University of Iowa Hygienic Laboratory did not begin analyzing for the two atrazine metabolites, deethylatrazine and deisopropylatrazine, until 1993.)

Ammonia-N and organic-N concentrations were also measured in the tile drainage to the ADWs. Ammonia-N concentrations ranged from <0.1 to 0.7 mg/L, and organic-N concentrations varied from <0.1 to 1.6 mg/L (Appendix I). The frequencies of detection were 41% for ammonia-N and 87% for organic-N.

Piezometers at FM3

Water-quality results for the five pizeometers at FM3 are located in Appendix II. Figure 15 shows the nitrate-N concentrations from the one glacial till and four bedrock piezometers at site FM3. Figures 16 through 20 show the static water level and the nitrate-N, atrazine, and ammonia-N concentrations for piezometers FM3-T, FM3-1, FM3-2, FM3-3, and FM3-4, respectively. Table 3 shows the nitrate-N concentrations for the piezometers during the pre- and post-closure periods. Table 4 summarizes for the pre- and post-closure periods, the pesticide detections in the piezometers, number of samples, range in pesticide concentrations, and mean and median concentrations. Table 5 compares the frequencies of pesticide detections for each piezometer during the pre- and post-closure periods.

Glacial Till Piezometer

Of the five research piezometers, only at the glacial till piezometer has the mean nitrate-N concentration increased from the pre-closure to the post-closure period. Similarly, only at FM3-T has the percent detection of atrazine and mean atrazine concentration increased from the pre- to post-closure period. No improvements in water quality at the FM3-T piezometer were expected with closure of the ADWs, as none of the ADWs were

Table 2. Nitrate-N and pesticide concentrations from ADW-1, ADW-2, and ADW-3.

Site	Range in Nitrate-N Concentration (mg/L)	Mean Nitrate-N Concentration (mg/L)	Pesticides Detected	% Detection of Pesticide	Range in Pesticide Detections (µg/L)
ADW-1	3.5 - 24.0	9.6	Alachlor	7%	0.12 - 0.36
			Atrazine	60%	0.11 - 2.00
			Cyanazine	67%	0.11 - 2.80
			Deethylatrazine	92%	0.11 - 0.40
			Metolachlor	14%	0.12 - 5.90
			Metribuzin	3%	0.73
ADW-2	7.9 - 35.0	20.0	Atrazine	100%	0.62 - 1.10
			Deethylatrazine	100%	0.80 - 1.40
			Metolachlor	50%	0.12 - 0.25
ADW-3	2.0 - 34.0	23.7	Atrazine	80%	0.30 - 0.60
			Deethylatrazine	80%	0.60 - 0.83

discharging water into the shallow water table monitored by this piezometer.

Figure 16 shows the static water level and nitrate-N, atrazine, and ammonia-N concentrations for the glacial till piezometer. Table 3 shows the nitrate-N and ammonia-N concentrations for FM3-T during the pre- and post-closure periods. Prior to closure of the ADWs, nitrate-N concentrations ranged from <0.1 to 22.0 mg/L with a mean concentration of 4.5 mg/L. During the post-closure period, nitrate-N concentrations ranged from 3.2 to 19.0 mg/L with a mean concentration of 9.9 mg/L (Figure 21).

Atrazine and two of its metabolites (deethylatrazine and deisopropylatrazine) were detected in FM3-T (Table 4). (Note: Pesticide results below the detection limit were assigned a value of 0.05 for statistical analyses.) Deisopropylatrazine was detected only during the pre-closure period (Table 5). The detection frequency of atrazine increased from 33% during the pre-closure period to 72% during the post-closure period (Table 4 and Figure 22). The detection frequency of deethylatrazine remained the same from the pre- to post-closure period. Pesticide concentrations ranged from <0.10 to 8.90 µg/L. Most concentrations were less than 1.00 µg/L.

Prior to closure, ammonia-N concentrations ranged from 0.02 to 1.20 mg/L with a mean concentration of 0.11 mg/L (Table 3). During the post-closure period, ammonia-N concentrations ranged from <0.10 to 0.70 mg/L with a mean concentration of <0.10 mg/L. The frequency of ammonia-N concentrations declined from 46% to 8% from the pre- to post-closure period.

Bedrock Piezometers

Piezometer FM3-1. Figure 17 shows the static water level, and nitrate-N, atrazine, and ammonia-N concentrations for the FM3-1 piezometer. Table 3 shows the nitrate-N and ammonia-N concentrations for the four bedrock piezometers during the pre- and post-closure periods. Prior to the closure

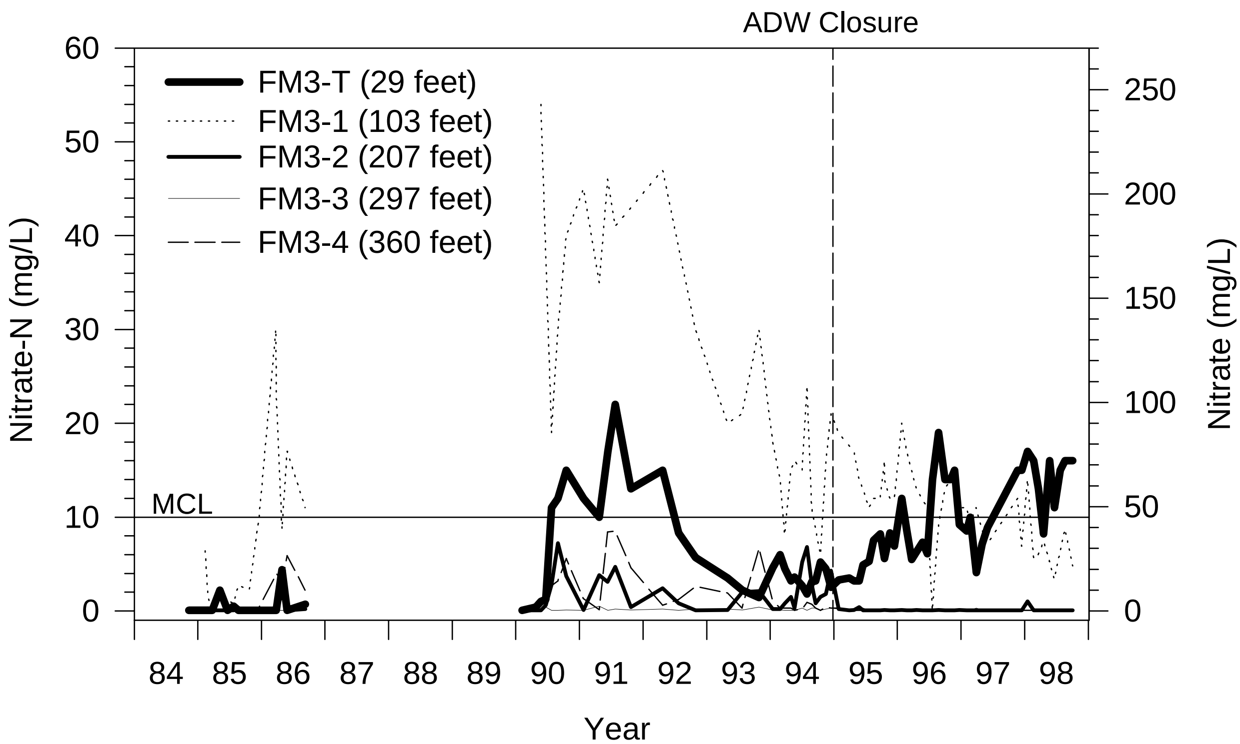

Figure 15. Nitrate-N concentrations from the four bedrock piezometers and one glacial till piezometer at site FM3. All four bedrock piezometers are completed in Devonian age strata. MCL = Maximum Contaminant Level.

of the ADWs, nitrate-N concentrations in FM3-1 ranged from <0.1 to 54.0 mg/L with a mean concentration of 19.4 mg/L. During the post-closure period, nitrate-N concentrations ranged from <0.1 to 20.0 mg/L with a mean concentration of 10.8 mg/L (Table 3 and Figure 21).

The greatest number of pesticides were detected at FM3-1 (Table 4). Alachlor, atrazine, butylate, cyanazine, deethylatrazine, deisopropylatrazine, metolachlor, metribuzin, and trifluralin were detected during the pre-closure period. Frequencies of detection ranged from 3% (metribuzin and trifluralin) to 84% (atrazine). Concentrations ranged from <0.10 to 18.00 µg/L; most concentrations were less than 1.00 µg/L. During the post-closure period, only atrazine and two of its metabolites, deethylatrazine and deisopropylatrazine, were detected (Tables 4 and 5). The frequency of detection for atrazine increased from the pre- to post-closure period (84% to 92%) and declined for the atrazine metabolites (Table 4 and Figure 22). Mean concentrations for all three compounds declined from the pre- to post-closure period.

Prior to closure, ammonia-N concentrations ranged from <0.01 to 0.60 mg/L with a mean concentration of 0.13 mg/L (Table 3). During the post-closure period, ammonia-N concentrations ranged from <0.10 to 0.20 mg/L with a mean concentration below the detection limit of 0.10 mg/L. The frequency of ammonia-N concentrations declined from 53% to 11% from the pre- to post-closure period.

Piezometer FM3-2. Figure 18 shows the static water level and nitrate-N, atrazine, and ammonia-N concentrations for the FM3-2 piezometer. Prior to the closure of the ADWs, nitrate-N concentrations in FM3-2 ranged from <0.1 to 7.2 mg/L with a mean concentration of 1.4 mg/L. During the post-closure period, nitrate-N concentrations ranged from <0.1 to 1.0 mg/L with a mean con-

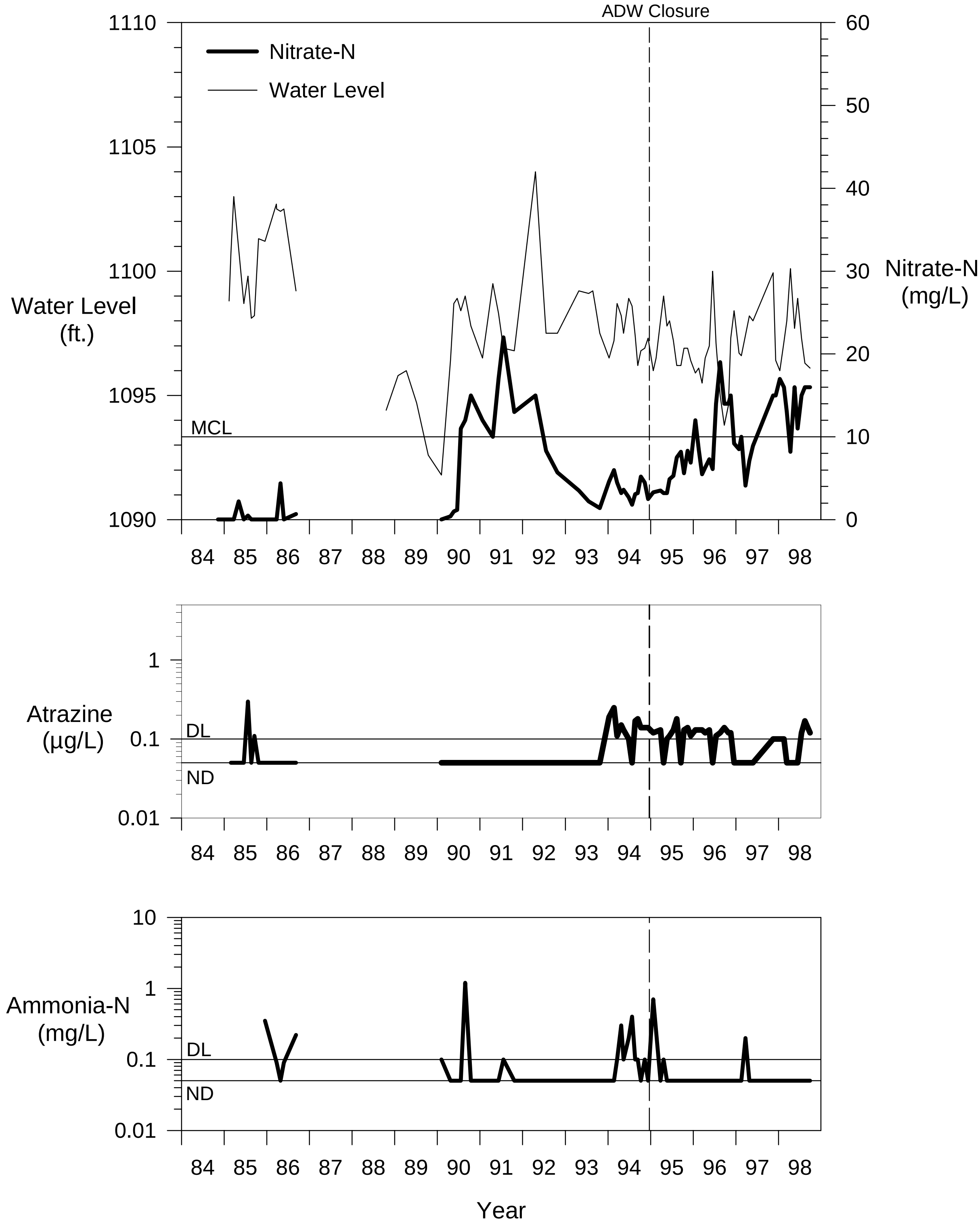

Figure 16. Static water levels (as elevation), nitrate-N, atrazine, and ammonia-N concentrations at the glacial till piezometer (FM3-T; 29 feet deep). MCL = Maximum Contaminant Level; DL = detection limit; ND = not detected (reported values were less than the detection limit and were assigned a value of 0.05).

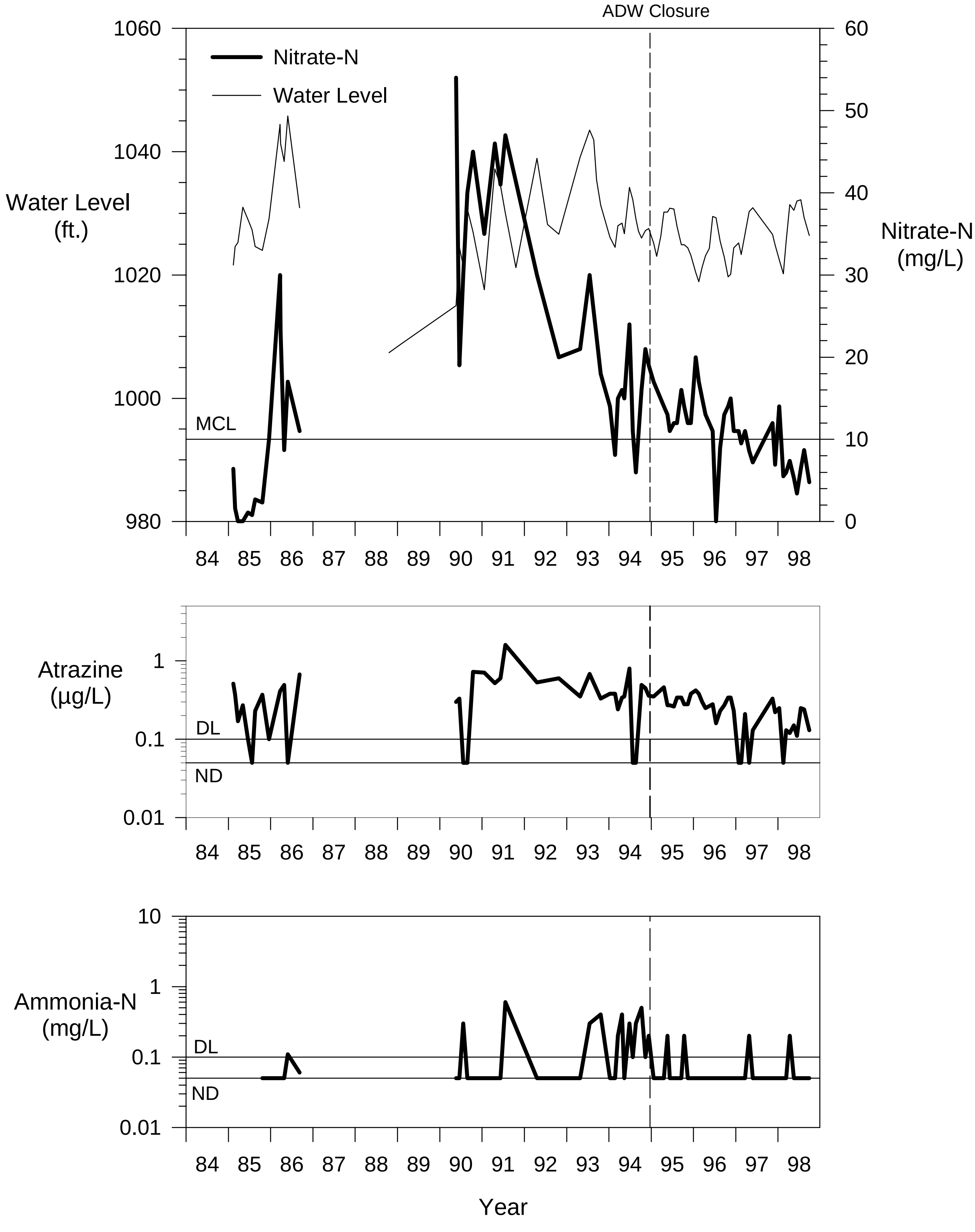

Figure 17. Static water levels (as elevation), nitrate-N, atrazine, and ammonia-N concentrations at the FM3-1 bedrock piezometer (103 feet deep). This piezometer is located in the upper part of the upper aquifer. MCL = Maximum Contaminant Level; DL = detection limit; ND = not detected (reported values were less than the detection limit and were assigned a value of 0.05).

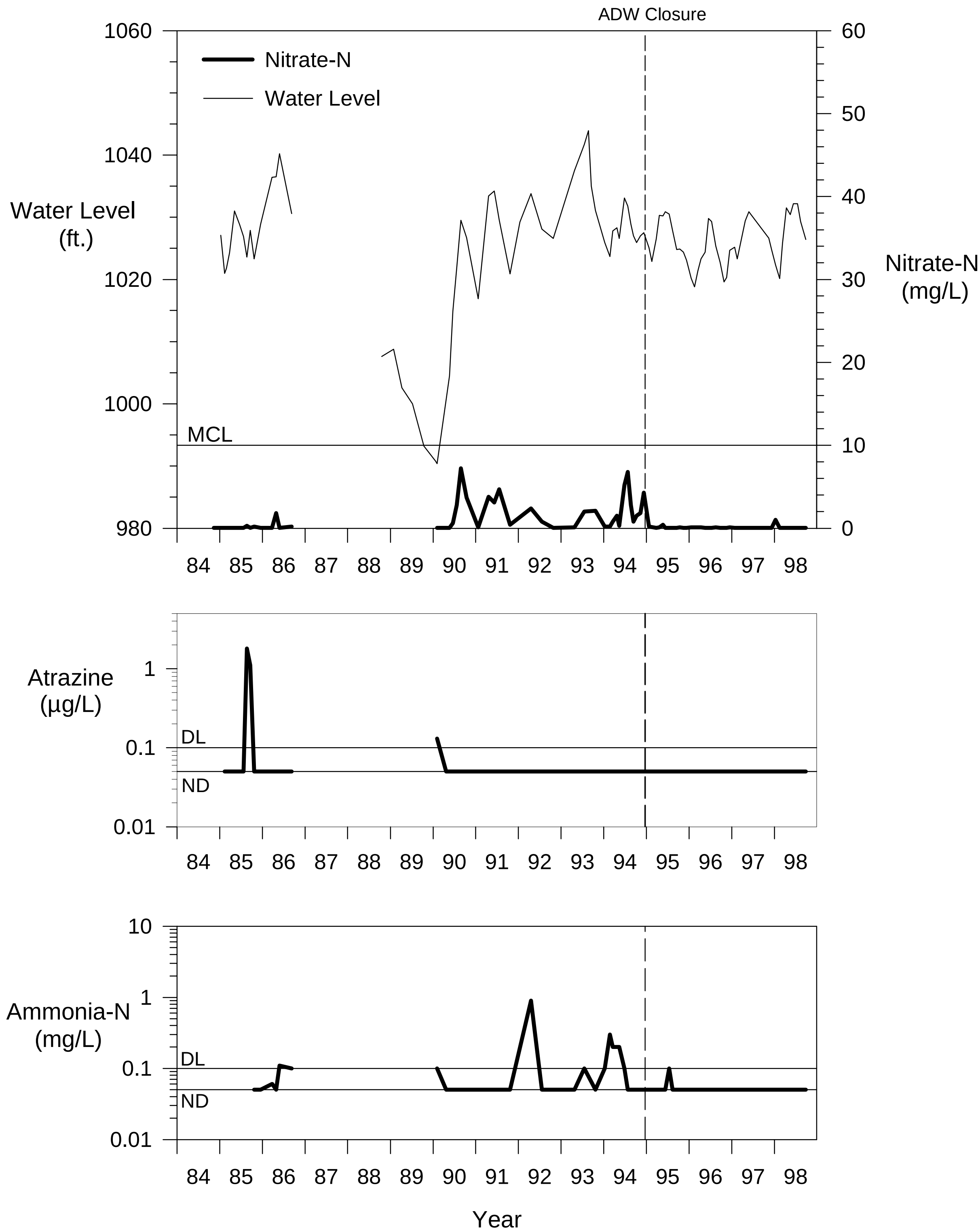

Figure 18. Static water levels (as elevation), nitrate-N, atrazine, and ammonia-N concentrations at the FM3-2 bedrock piezometer (207 feet deep). This piezometer is located in the lower part of the upper aquifer. MCL = Maximum Contaminant Level; DL = detection limit; ND = not detected (reported values were less than the detection limit and were assigned a value of 0.05).

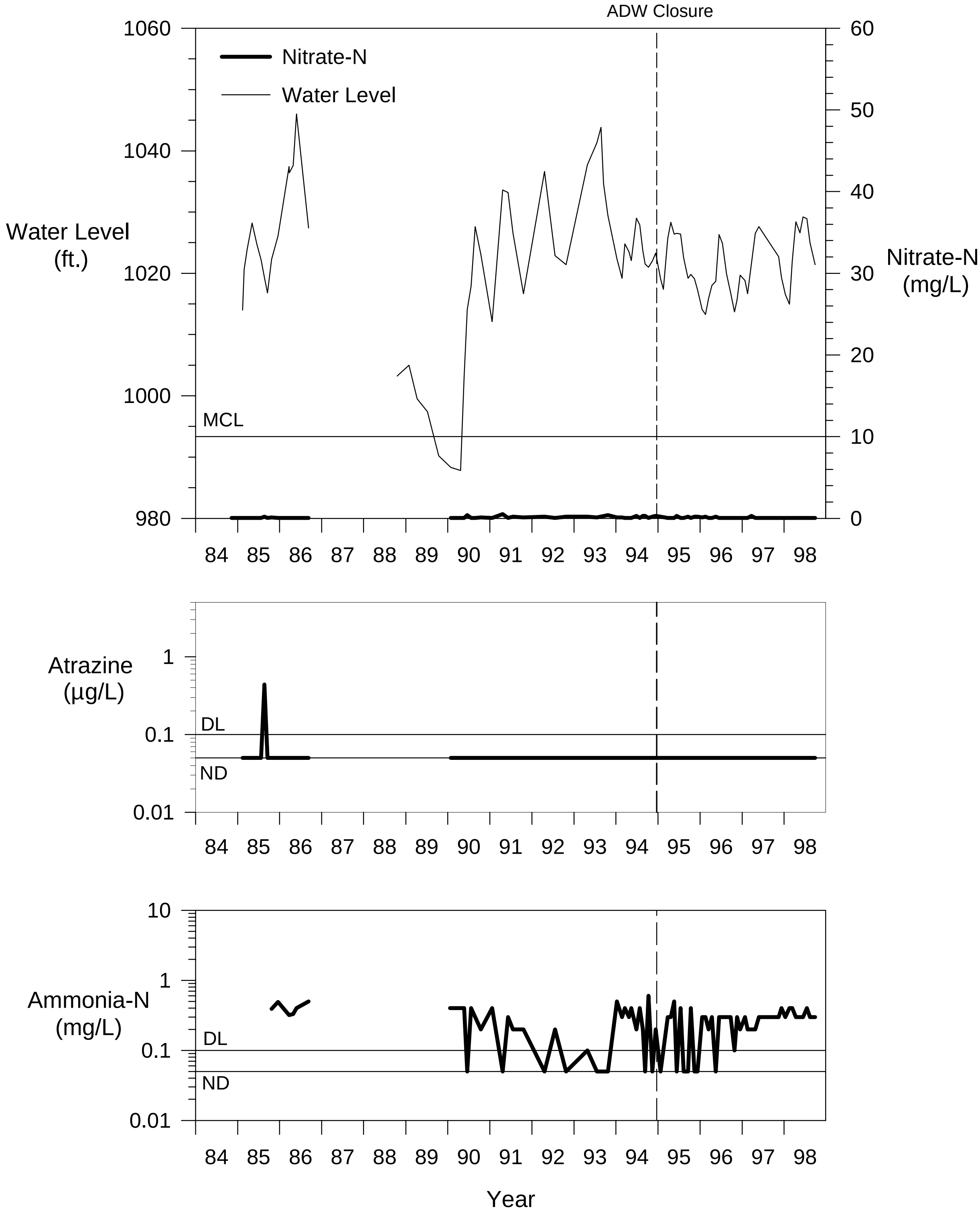

Figure 19. Static water levels (as elevation), nitrate-N, atrazine, and ammonia-N concentrations at the FM3-3 bedrock piezometer (297 feet deep). This piezometer is located in the middle aquifer. MCL = Maximum Contaminant Level; DL = detection limit; ND = not detected (reported values were less than the detection limit and were assigned a value of 0.05).

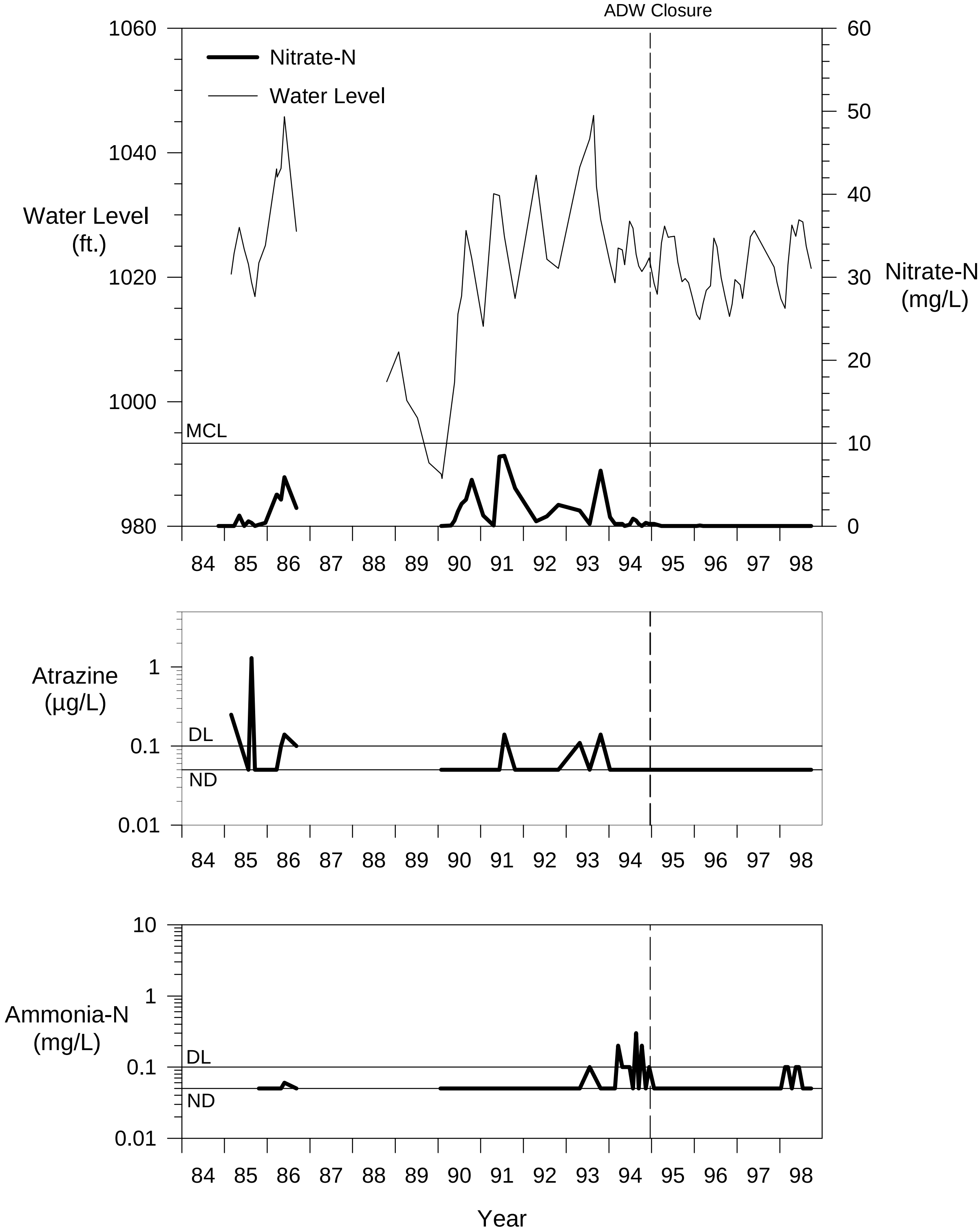

Figure 20. Static water levels (as elevation), nitrate-N concentrations, and atrazine concentrations at the FM3-4 bedrock piezometer (360 feet deep). This piezometer is located in the lower aquifer. MCL = Maximum Contaminant Level; DL = detection limit; ND = not detected (reported values were less than the detection limit and were assigned a value of 0.05).

Table 3. Nitrate- and ammonia-N concentrations in the glacial till and bedrock piezometers (site FM3) in Floyd County, both prior to and after closure of nearby ADWs.

	Pre-Closure of ADWs				***Post-Closure of ADWs***			
Piezometer	Number of Samples (%)	Range in Nitrate-N (mg/L)	Mean Nitrate-N (mg/L)	Median Nitrate-N (mg/L)	Number of Samples (%)	Range in Nitrate-N (mg/L)	Mean Nitrate-N (mg/L)	Median Nitrate-N (mg/L)
FM3-T *(29 feet)*	46 (72%)	<0.1 - 22.0	4.5	2.6	39 (100%)	3.2 - 19.0	9.9	8.5
FM3-1 *(103 feet)*	39 (95%)	<1.0 - 54.0	19.4	17.0	37 (97%)	<0.1 - 20.0	10.8	11.0
FM3-2 *(207 feet)*	46 (65%)	<0.1 - 7.2	1.4	0.3	39 (23%)	<0.1 - 1.0	<0.1	<0.1
FM3-3 *(297 feet)*	48 (40%)	<0.1 - 0.5	0.1	<0.1	39 (23%)	<0.1 - 0.3	<0.1	<0.1
FM3-4 *(360 feet)*	47 (80%)	<0.1 - 8.5	1.7	0.6	39 (5%)	<0.1 - 0.3	<0.1	<0.1

Note: Values below the detection limit were assigned a value of 0.05 for statistical analyses.

	Pre-Closure of ADWs				***Post-Closure of ADWs***			
Piezometer	Number of Samples (%)	Range in Ammonia-N (mg/L)	Mean Ammonia-N (mg/L)	Median Ammonia-N (mg/L)	Number of Samples (%)	Range in Ammonia-N (mg/L)	Mean Ammonia-N (mg/L)	Median Ammonia-N (mg/L)
FM3-T *(29 feet)*	35 (46%)	0.02 - 1.20	0.11	<0.10	39 (8%)	<0.10 - 0.70	<0.10	<0.10
FM3-1 *(103 feet)*	32 (53%)	<0.01 - 0.60	0.13	0.02	37 (11%)	<0.10 - 0.20	<0.10	<0.10
FM3-2 *(207 feet)*	37 (41%)	0.03 - 0.90	0.07	<0.10	39 (3%)	<0.10 - 0.10	<0.10	<0.10
FM3-3 *(297 feet)*	38 (79%)	<0.10 - 0.60	0.27	0.30	39 (82%)	<0.10 - 0.50	0.25	0.30
FM3-4 *(360 feet)*	37 (32%)	<0.01 - 0.30	0.04	<0.10	39 (10%)	<0.10 - 0.10	<0.10	<0.10

Note: Values below the detection limit were assigned a value of 0.005 for statistical analyses.

centration of <0.1 mg/L (Table 3 and Figure 21).

Atrazine and deethylatrazine were detected in FM3-2 during pre-closure at concentrations from <0.10 to 1.80 µg/L. The frequencies of detection were low (7% for atrazine, 8% for deethylatrazine) for both compounds. No pesticides were detected during the post-closure period (Tables 4 and 5, and Figure 22).

Prior to closure, ammonia-N concentrations ranged from 0.03 to 0.90 mg/L with a mean concentration of 0.07 mg/L (Table 3). During the post-closure period, ammonia-N concentrations ranged from <0.10 to 0.10 mg/L with a mean concentration below the detection limit of 0.10 mg/L. The frequency of ammonia-N concentrations declined from 41% to 3% from the pre- to post-closure period. Some of the decline reflects a change in detection limit, from 0.01 mg/L during

Table 4. Frequency of pesticides detected, range in concentration, and mean and median concentrations for pesticides detected in the glacial till and bedrock piezometers (site FM3) in Floyd County, both prior to and after closure of nearby ADWs.

Pre-Closure of ADWs					*Post-Closure of ADWs*				
Pesticides Detected	# of Pesticide Analyses (%)	Range in Conc. (µg/L)	Mean Conc. (µg/L)	Median Conc. (µg/L)	Pesticides Detected	# of Pesticide Analyses (%)	Range in Conc. (µg/L)	Mean Conc. (µg/L)	Median Conc. (µg/L)
FM3-T (29 feet)					**FM3-T (29 feet)**				
atrazine	36 (36%)	<0.10-0.30	<0.10	<0.10	*atrazine*	39 (72%)	<0.10-0.18	0.10	0.11
deethylatrazine	12 (85%)	<0.10-0.36	0.25	0.26	*deethylatrazine*	39 (86%)	<0.10-0.52	0.25	0.25
deisopropylatrazine	12 (8%)	<0.10-8.90	0.79	<0.10					
FM3-1 (103 feet)					**FM3-1 (103 feet)**				
alachlor	38 (8%)	<0.10-2.50	0.12	<0.10					
atrazine	38 (84%)	<0.10-1.60	0.40	0.37	*atrazine*	37 (92%)	<0.10-0.46	0.25	0.25
butylate	30 (6%)	<0.10-0.83	<0.10	<0.10					
cyanazine	38 (8%)	<0.10-0.55	<0.10	<0.10					
deethylatrazine	13 (69%)	<0.10-0.90	0.40	0.50	*deethylatrazine*	37 (59%)	<0.10-0.49	0.18	0.16
deisopropylatrazine	11 (9%)	<0.10-18.00	1.70	<0.10	*deisopropylatrazine*	37 (3%)	<0.10-0.15	<0.10	<0.10
metolachlor	31 (32%)	<0.10-0.49	0.12	<0.10					
metribuzin	29 (3%)	<0.10-0.42	<0.10	<0.10					
trifluralin	38 (3%)	<0.10-0.12	<0.10	<0.10					
FM3-2 (207 feet)					**FM3-2 (207 feet)**				
atrazine	36 (7%)	<0.10-1.80	0.13	<0.10					
deethylatrazine	12 (8%)	<0.10-0.10	<0.10	<0.10					
FM3-3 (297 feet)					**FM3-3 (297 feet)**				
alachlor	41 (2%)	<0.10-0.19	<0.10	<0.10					
atrazine	41 (2%)	<0.10-0.44	<0.10	<0.10					
FM3-4 (360 feet)					**FM3-4 (360 feet)**				
alachlor	40 (3%)	<0.10-0.48	<0.10	<0.10					
atrazine	40 (20%)	<0.10-1.30	0.10	<0.10					
cyanazine	40 (10%)	<0.10-0.63	<0.10	<0.10					
deethylatrazine	13 (15%)	<0.10-0.15	<0.10	<0.10					
metolachlor	37 (46%)	<0.10-0.87	0.12	<0.10	*metolachlor**	39 (3%)	<0.10-0.10	<0.10	<0.10

Note: Values below the detection limit were assigned a value of 0.05 for statistical analyses.
Analysis for atrazine metabolites, deethylatrazine and deisopropylatrazine, began in 1993.
* One detection during April 1995.

the early part of the pre-closure period, to 0.1 mg/L during the remainder of the pre-closure period and all of the post-closure period.

Piezometer FM3-3. Figure 19 shows the static water level and nitrate-N, atrazine, and ammonia-N concentrations for the FM3-3 piezometer. Prior to the closure of the ADWs, nitrate-N concentrations in FM3-3 ranged from <0.1 to 0.5 mg/L with a mean concentration of 0.1 mg/L. During the post-closure period, nitrate-N concentrations ranged from <0.1 to 0.3 mg/L with a mean concentration of <0.1 mg/L (Table 3 and Figure 21).

Alachlor and atrazine were each detected once in FM3-3 during the pre-closure period (2% detection frequency for each). Alachlor was detected during July 1991 and atrazine was detected during August 1985. No pesticides were detected

Table 5. Frequency of pesticides detected in the glacial till and bedrock piezometers (site FM3) in Floyd County, both prior to and after closure of nearby ADWs.

Wells	Pesticides Detected	Frequency of Detection Pre-Closure	Frequency of Detection Post-Closure
FM3-T (29 feet deep) - control piezometer not impacted by ADWs			
	atrazine	33%	72%
	deethylatrazine	85%	86%
	deisopropylatrazine	8%	0%
FM3-1 (103 feet deep) - piezometer impacted by ADWs			
	alachlor	8%	0%
	atrazine	84%	92%
	butylate	6%	0%
	cyanazine	8%	0%
	deethylatrazine	69%	59%
	deisopropylatrazine	9%	3%
	metolachlor	32%	0%
	metribuzin	3%	0%
	trifluralin	3%	0%
FM3-2 (207 feet deep) - piezometer impacted by ADWs			
	atrazine	7%	0%
	deethylatrazine	8%	0%
FM3-3 (297 feet deep) - piezometer impacted by ADWs			
	alachlor	2%	0%
	atrazine	2%	0%
FM3-4 (360 feet deep) - piezometer impacted by ADWs			
	alachlor	3%	0%
	atrazine	20%	0%
	cyanazine	10%	0%
	deethylatrazine	15%	0%
	metolachlor	46%	3%*

* One detection during April 1995.

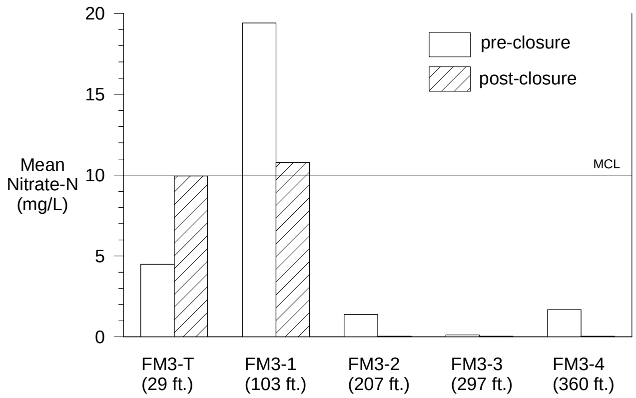

Figure 21. Pre-closure and post-closure mean nitrate-N concentrations for the glacial till and bedrock piezometers at site FM3. MCL=Maximum Contaminant Level.

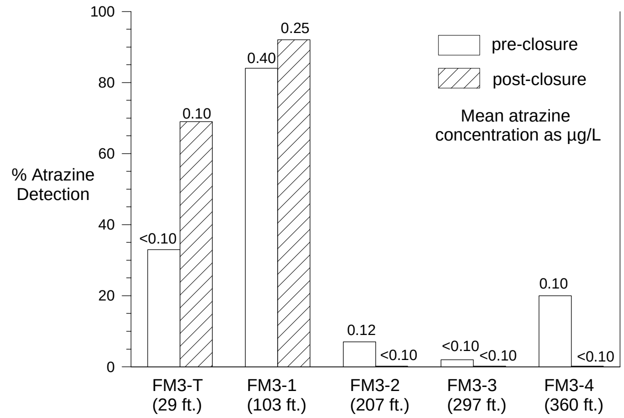

Figure 22. Percent dectection of atrazine and mean atrazine concentrations for the glacial till and bedrock piezometers at site FM3 during the pre- and post-closure periods.

during the post-closure period (Tables 4 and 5, and Figure 22).

The frequency of ammonia-N concentrations in FM3-3 has always been high relative to the other bedrock piezometers. Prior to closure, ammonia-N concentrations ranged from <0.10 to 0.60 mg/L with a mean concentration of 0.27 mg/L (Table 3). During the post-closure period, ammonia-N concentrations ranged from <0.10 to 0.50 mg/L with a mean concentration of 0.10 mg/L. The frequency of ammonia-N concentrations increased from 79% to 82% from the pre- to post-closure period.

Piezometer FM3-4. Figure 20 shows the static water level and nitrate-N, atrazine, and ammonia-N concentrations for the FM3-4 piezometer. Prior to the closure of the ADWs, nitrate-N concentrations in FM3-4 ranged from <0.1 to 8.5 mg/L with a mean concentration of 1.7 mg/L. During the post-closure period, nitrate-N concentrations ranged from <0.1 to 0.3 mg/L with a mean concentration of <0.1 mg/L (Table 3 and Figure 21).

Four pesticides and one metabolite were detected at FM3-4 during the pre-closure period. Concentrations ranged from <0.10 to 1.30 µg/L. Frequencies of detection ranged from 3% (alachlor) to 33% (metolachlor). One pesticide, metolachlor, was detected once (April 1995) during the post-closure period at a concentration of 0.10 µg/L. It is unclear why metolachlor was detected. Prior to April 1995, the most recent detection of metolachlor at FM3-4 occurred in October 1994, also at a concentration of 0.10 µg/L (see Appendix II).

Prior to closure, ammonia-N concentrations ranged from <0.01 to 0.30 mg/L with a mean concentration of 0.04 mg/L (Table 3). During the post-closure period, ammonia-N concentrations ranged from <0.10 to 0.10 mg/L with a mean concentration below the detection limit of 0.1 mg/L. The frequency of ammonia-N concentrations decreased from 32% (pre-closure) to 10% (post-closure). Some of the decline in frequency may be attributable to changes in the detection limit.

Private Wells

Five private wells, located within a two-mile radius of the closed ADWs, were sampled on a monthly basis from November 1994 through September 1998 (Figure 23). Water-quality results can be found in Appendix III. Based on the information provided by each landowner, all wells were drilled into the upper aquifer of the Devonian bedrock and range in depth from 100 to 200 feet.

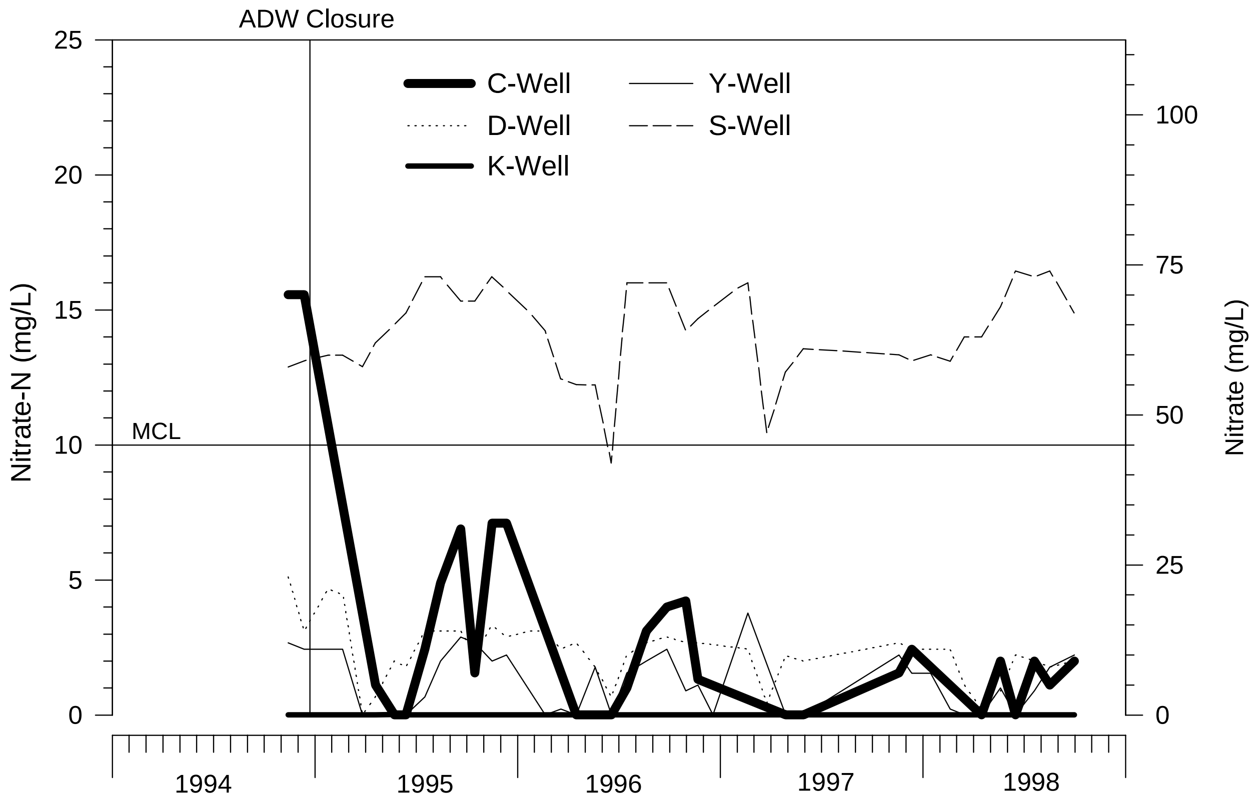

Figure 23. Nitrate-N concentrations from the five private wells monitored. MCL = Maximum Contaminant Level.

The casing depth for three of the private wells was not known. Figure 9 shows the open interval in two of the private wells.

Sampling of the private wells began one month prior to closure of ADW-1, ADW-2, and ADW-3, so trends related to ADW closures can not be evaluated. Trends can, however, be compared to the bedrock piezometers to determine similar responses.

C-Well has shown the most significant decline in nitrate-N concentrations during the monitoring period (Figure 23; Appendix III). C-Well is completed in the upper aquifer and pulls water from the bedrock above and below the Thunderwoman Shale. It also is the private well nearest the closed ADWs and is located directly west of the FM3 site (Figure 8). Since closure of the ADWs, nitrate-N concentrations declined from >15 mg/L to concentrations at or below 5 mg/L during most months (Figure 23). One water sample was collected from this site during a previous study. The nitrate-N concentration for this well was 26.9 mg/L on April 23, 1991 (unpublished data, IDNR-Geological Survey Bureau). The decline in nitrate-N concentrations at this site coincides with closure of the three ADWs and is probably the direct result of their closures.

Only once during the monitoring period has nitrate-N been detected in K-Well (0.2 mg/L in May 1995; Appendix III). The depth of K-Well is reported to be ~ 160 feet, but the casing depth is not known. At 160 feet, the bottom of the well would be below the Thunderwoman Shale; the open interval, however, may extend above this shale unit. Little is known about how effective the Thunderwoman Shale may be as a confining unit in this area. The lack of nitrate-N detections in this well may be the result of any of the following: (1) The upper aquifer may not have been impacted by the ADWs at this distance. (2) If the

Table 6. Summary of nitrate-N concentrations for the five private wells.

Private Well	Number of Samples	Range in Nitrate-N (mg/L)	Mean Nitrate-N (mg/L)	Median Nitrate-N (mg/L)	Detection Frequency of Nitrate-N	Frequency of Nitrate-N Concentrations >10 mg/L
C-Well	29	<0.2 - 15.6	2.9	1.3	69%	7%
D-Well	40	<0.2 - 5.1	2.4	2.4	98%	0%
K-Well	42	<0.2 - 0.2	<0.2	<0.2	2%	0%
S-Well	40	9.3 - 16.4	14.2	14.2	100%	98%
Y-Well	40	<0.2 - 3.8	1.2	1.0	65%	0%

Note: Values below the detection limit were assigned a value of 0.1 for statistical analyses.

well is cased below the Thunderwoman Shale, the shale may be serving as a fairly effective confining unit, limiting the downward movement of nitrate-rich water from the upper part of the upper aquifer to the lower part of the upper aquifer. (3) The infrequent occurrence of nitrate-N in this well may be the result of the lack of data prior to the ADW closures, combined with the distance of the private well from the ADWs. Sampling of K-Well began November 1994 and the ADWs were closed December 1994. If nitrate-N was present, sampling conducted prior to November 1994 may have detected it, whereas the sampling since November 1994 has not. (4) Nitrate-N concentrations from K-Well are similar to those for piezometer FM3-2 during the post-closure period. Nitrate-N did occur in FM3-2 prior to closure. Even though K-Well is pulling water from lower in the upper aquifer, it may have been too far from the closed ADWs to have shown nitrate-N concentrations similar to those at FM3-2 prior to closure of the ADWs.

Nitrate-N concentrations for two of the other wells, D-Well and Y-Well, have ranged from <0.2 mg/L to 5.1 mg/L. Y-Well is approximately 100 feet deep, placing it in the upper aquifer; casing depth is not known for this well. D-Well is reported to be ~200 feet deep with casing extending ~180 feet. This would place it below the Thunderwoman Shale. Other active ADWs do occur near D-well and may impact the water quality at this well. D-Well has a high frequency of nitrate-N detections (98%; Appendix III) compared to the other wells, but concentrations are generally below 5 mg/L.

Nitrate-N concentrations from Y-Well and D-Well responded similarly even though located in different parts of the upper aquifer. Several reasons may exist for this. (1) The casing in D-Well may be shallower than believed, hence both wells are pulling water from the same part of the upper aquifer, yielding similar trends in nitrate-N concentrations through time. (2) Y-Well and D-Well may be in different parts of the aquifer, and other active ADWs near D-Well may be impacting the lower part of the upper aquifer, the interval into which D-Well is cased.

The S-Well, located farthest from the closed ADWs, has shown no response to the ADW closures. Nitrate-N concentrations have remained elevated, ranging from 9.3 to 16.4 mg/L (Table 6 and Figure 23). Nitrate-N concentrations at S-

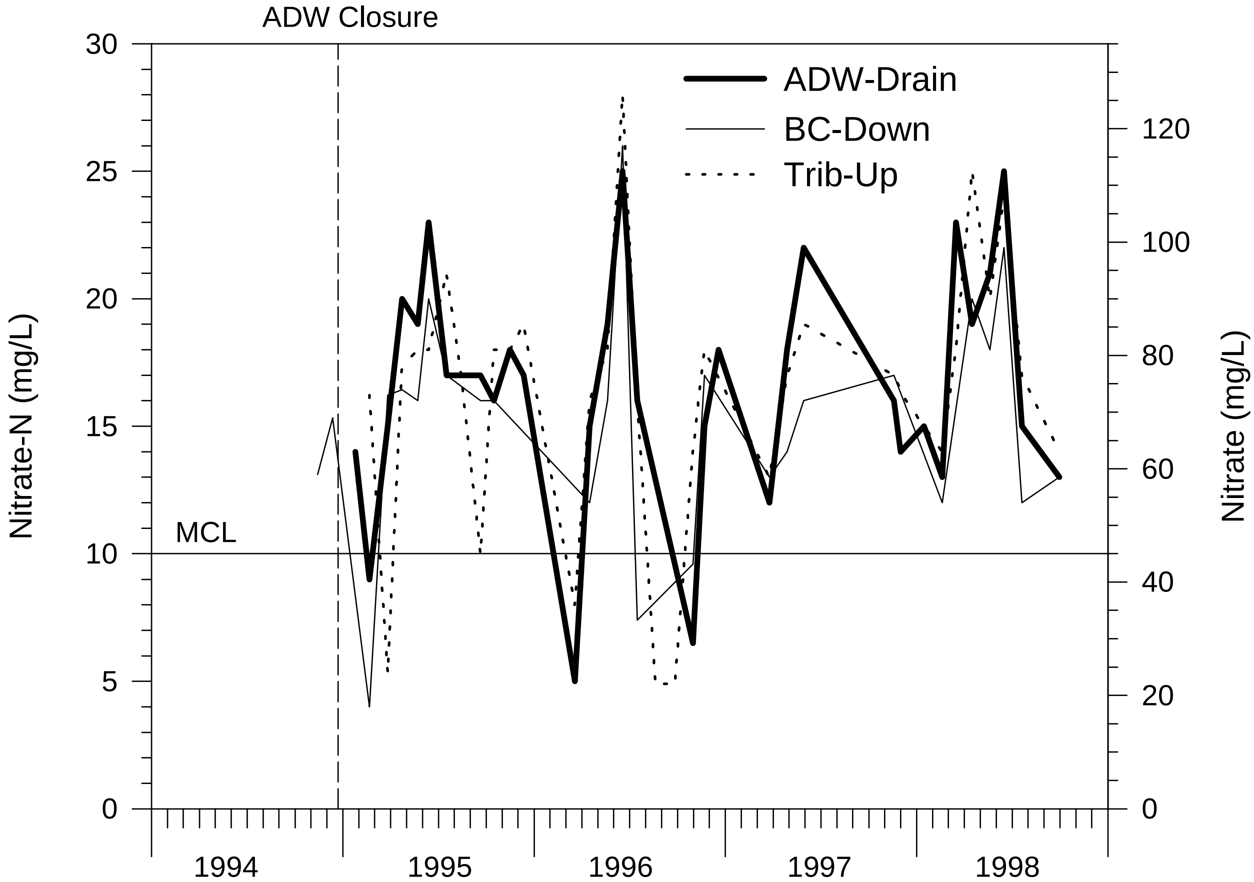

Figure 24. Nitrate-N concentrations from the combined ADW tile water (ADW-Drain) and the two surface water sites (BC-Down and Trib-Up). MCL = Maximum Contaminant Level.

Well were similar to those at piezometer FM3-1 shortly after closure of the ADWs (similar concentrations and similar range in concentrations), however, as monitoring continued, nitrate-N concentrations in FM3-1 continued to decline with time while nitrate-N concentrations in S-Well remained elevated. There are several explanations for the nitrate-N concentrations in S-Well. (1) This well may never have been impacted by the three ADWs that were closed. Of the five private wells, this well is located the farthest from the closed ADWs. Based on a generalized potentiometric surface map of the Devonian aquifer in Floyd County, groundwater at the S-Well location flows to the east or southeast toward the closed ADWs and toward the Cedar River (Libra et al., 1984). Because of the location of S-Well and the direction of groundwater flow, it is unlikely that the closed ADWs were impacting the water quality at this well. Also, S-Well does not have the variability in nitrate-N concentrations that would be expected for a well impacted by periodic inputs from ADWs. Although nitrate-N concentrations in S-Well range from 9.3 to 16.4 mg/L, the concentrations do not exhibit the extreme range in concentration, typical of an aquifer receiving ADW inputs, as is illustrated by piezometer FM3-1 (Figure 17) prior to December 1994. (2) Directly west of S-Well are regions mapped as shallow bedrock and karst, indicating that less than 50 feet of glacial till overlies bedrock, and in the case of karst areas, less than 25 feet of glacial till overlies bedrock. Since nitrate-N concentrations at site S-Well remain elevated through time, there must be

Table 7. Summary of nitrate- and ammonia-N concentrations, and detected pesticide concentrations for ADW-Drain, Trib-Up, and BC-Down sites.

Site	Analyte (includes only detected pesticides)	Number of Samples (%)	Range in Concentration	Mean Concentration	Median Concentration
ADW-Drain					
	Nitrate-N (mg/L)	32 (100%)	5.0 - 25.0	16.6	16.5
	Ammonia-N (mg/L)	32 (13%)	<0.1 - 0.2	<0.1	<0.10
	Acetochlor (µg/L)	31 (6%)	<0.10 - 0.78	<0.10	<0.10
	Atrazine (µg/L)	31 (100%)	0.11 - 5.10	0.36	0.19
	Deethylatrazine (µg/L)	31 (97%)	<0.10 - 0.51	0.28	0.28
Trib-Up					
	Nitrate-N (mg/L)	33 (100%)	4.9 - 28.0	16.4	17.0
	Ammonia-N (mg/L)	29 (14%)	<0.1 - 0.4	<0.1	<0.1
	Acetochlor (µg/L)	25 (4%)	<0.10 - 0.22	<0.10	<0.10
	Atrazine (µg/L)	25 (72%)	<0.10 - 2.00	0.21	0.13
	Deethylatrazine (µg/L)	25 (84%)	<0.10 - 0.33	0.18	0.16
	Deisopropylatrazine (µg/L)	25 (4%)	<0.10 - 0.15	<0.10	<0.10
	Metolachlor (µg/L)	25 (12%)	<0.10 - 1.10	0.11	<0.10
BC-Down					
	Nitrate-N (mg/L)	27 (100%)	4.0 - 26.0	15.3	16.0
	Ammonia-N (mg/L)	22 (18%)	<0.1 - 0.2	0.1	0.1
	Acetochlor (µg/L)	19 (5%)	<0.10 - 0.17	<0.10	<0.10
	Atrazine (µg/L)	19 (95%)	<0.10 - 1.90	0.26	0.14
	Deethylatrazine (µg/L)	19 (100%)	0.10 - 0.32	0.21	0.20
	Deisopropylatrazine (µg/L)	19 (5%)	<0.10 - 0.25	<0.10	<0.10
	Metolachlor (µg/L)	19 (42%)	<0.10 - 3.60	0.34	<0.10

Note: Values below the detection limit were assigned a value of 0.05 for statistical analyses.
Additional pesticides analyzed for, but not detected, include alachlor, butylate, cyanazine, metribuzin, and trifluralin.

a nearby, relatively continuous source of nitrate-N to the upper aquifer. Floyd County is one of the most intensively farmed counties in Iowa, as 94% of the land area is farmed (Iowa Agricultural Statistics, 1998). Past studies have shown that groundwater in shallow bedrock and karst regions are susceptible to nitrate and pesticide contamination (Libra et al., 1984; 1994). Groundwater in the shallow bedrock region is susceptible to infiltration, and in karst regions, is impacted by infiltration and direct run-in of surface water. The nitrate-N concentrations in S-Well likely reflect nonpoint source pollution inputs from shallow bedrock and karst regions that are naturally susceptible to groundwater contamination.

Tile Drainage from Closed ADWs and Surface Water Sites

Water-quality data from sites ADW-Drain, Trib-Up, and BC-Down can be found in Appendix IV. Figure 24 shows the nitrate-N concentrations for the three sites. Nitrate-N concentrations have ranged from 4.0 to 28.0 mg/L (Table 7). Concentrations show a seasonal trend with higher concentrations during the spring and summer months and lower concentrations during the winter months. The majority of concentrations were greater than 10 mg/L.

Ammonia-N concentrations were generally low, ranging from <0.1 to 0.4 mg/L (Table 7). Frequencies of detection ranged from 13% to 18%.

Three pesticides and two metabolites were detected at the three sites (Table 7; Appendix IV). Acetochlor, not previously detected at the bedrock piezometers, was detected at the ADW-Drain and two surface water sites. Concentrations of acetochlor ranged from <0.10 to 0.78 µg/L and frequencies of detection varied from 4% to 6%. Atrazine was the most frequently detected pesticide, as it was present in 72% of the Trib-Up samples, 95% of the BC-Down samples, and 100% of the ADW-Drain samples. Mean atrazine concentrations ranged from 0.21 to 0.36 µg/L. Two atrazine metabolites, deethylatrazine and deisopropylatrazine, were detected in Trib-Up and BC-Down. Only deethylatrazine was present in the ADW-Drain. The frequency of detection and mean concentration were higher for deethylatrazine than deisopropylatrazine at sites Trib-Up and BC-Down. Metolachlor was detected at Trib-Up and BC-Down at concentrations ranging from <0.10 to 3.60 µg/L.

DISCUSSION

Based on results from the four bedrock piezometers, water quality has improved in all three Devonian bedrock aquifers. Nitrate-N concentrations have declined, and the concentration of pesticides and the frequencies of detection have declined. The primary question is whether these improvements are the result of just ADW closures, or have changes in other factors during the monitoring period — climatic conditions, changes in nitrogen application rates, changes in pesticide use rates — affected the observed trends in water quality. Although the mean nitrate-N concentration from FM3-1 declined with the closure of nearby ADWs, it remained slightly above the U.S. EPA's Maximum Contaminant Level (MCL) of 10 mg/L (Table 3). The continuing elevated nitrate-N concentrations and high frequency of pesticide detection indicate that FM3-1 is still being impacted by contaminants entering the bedrock by a pathway other than the ADWs. Although FM3-1 is located in an area mapped as Deep Bedrock, suggesting that the underlying groundwater is relatively protected from surficially derived contaminants, Shallow Bedrock and Karst (Figure 7) areas are located a few miles west of the bedrock piezometer. The regional groundwater flow direction at FM3 is to the east or southeast toward the Cedar River (Libra et al., 1984). Past studies have shown that groundwater underlying Shallow bedrock and Karst regions are susceptible to contamination by infiltration and direct run-in (Libra et al., 1984; 1994). Although the frequency of atrazine detection at FM3-1 remains high since closure of the ADWs, the frequency of detection of other pesticides has declined. The range in nitrate-N concentrations has declined from the pre- (<1.0 to 54 mg/L) to post-closure period (<0.1 to 20 mg/L), and the decline reflects removal of intermittent pulses of nitrate-rich water to the aquifer, previously delivered via the ADWs.

Significance of Water Quality Trends

In order to evaluate the statistical significance of trends in the water quality data, an adequate data set is necessary. Only water-quality data from the piezometers can be used to evaluate the pre- versus post-closure trends. The data from the private wells can not be used, because only two samples were collected prior to closure of the ADWs.

The pre-closure period (November 1984 through December 1994) represent some of the most extreme climatic conditions in Iowa. Precipitation was below normal from 1987 through 1989 and above normal from 1990 through 1994. The years 1988 and 1989 represent the driest consecutive two-year period in Iowa's history. The early 1990s represent five years of above normal rainfall and include the "Flood of 1993." What impact did the extreme climatic conditions have on the water quality of the bedrock aquifers?

During the pre-closure period, monitoring of the five piezometers did not occur from October

Table 8. Results for the Mann-Whitney Rank Sum Test for nitrate-N, atrazine, and water level information from the piezometers at FM3.

Results for Mann-Whitney Rank Sum Test for early versus middle sampling periods.

	Nitrate-N (p value)	Atrazine (p value)	Water Level (p value)
FM3-T	Y (p<0.05)	N (p=0.11)	Y (p<0.05)
FM3-1	Y (p<0.05)	N (p=0.14)	N (p=0.69)
FM3-2	Y (p<0.05)	N (p=0.55)	N (p=0.99)
FM3-3	Y (p<0.05)	N (p=0.67)	N (p=0.49)
FM3-4	N (p=0.21)	N (p=0.06)	N (p=0.35)

Y = Yes, is statistically different
N = No, is not statistically different
Early period defined as 11/84 through 9/86.
Middle period defined as 1/90 through 12/94.

Results for Mann-Whitney Rank Sum Test for pre- (early + middle) versus post-closure sampling periods.

	Nitrate-N (p value)	Atrazine (p value)	Water Level (p value)
FM3-T	Y (p<0.05)	N (p=0.14)	Y (p<0.05)
FM3-1	Y (p<0.05)	Y (p<0.05)	Y (p<0.05)
FM3-2	Y (p<0.05)	N (p=0.60)	Y (p<0.05)
FM3-3	N (p=0.19)	N (p=0.85)	Y (p<0.05)
FM3-4	Y (p<0.05)	N (p=0.13)	Y (p<0.05)

Y = Yes, is statistically different
N = No, is not statistically different
Pre-closure defined as 11/84 through 9/86 and 1/90 through 12/94.
Post-closure defined as 1/95 through 9/98.

1986 through September 1988. Although measurement of water levels at the five piezometers resumed in October 1988, water-quality sampling did not resume until February 1990. What effect does this data gap have when comparing the pre-closure to the post-closure period? Water-quality data from other studies in Iowa showed lower nitrate-N concentrations in groundwater during the drought years followed by higher nitrate-N concentrations in groundwater during the early 1990s (Rowden et al., 1993; Seigley et al., 1996). Is the water-quality data from November 1984 through September 1986 statistically different from the data collected from February 1990 through December 1994, or can the data from these two periods be combined to analyze trends from the pre- to post-closure period?

Table 8 summarizes the statistical results for the Mann-Whitney Rank Sum Test that were used to compare the early (November 1984 through September 1986) versus the middle (January 1990 through December 1994) sampling periods. The results show that for the four bedrock piezometers (FM3-1, FM3-2, FM3-3, FM3-4), water levels and atrazine concentrations were not significantly different from the early to the middle period. Comparison of the nitrate-N concentrations for the pre- and post-closure periods, however, were statistically different for FM3-1, FM3-2, and FM3-3. For analysis of trends, it was decided to combine the early and middle sampling periods to represent the pre-closure period. This was done for several reasons. (1) The water level data showed no statistically significant difference between the early and middle periods. (2) Results from the Mann-Whitney Rank Sum Test suggest that nitrate-N concentrations differ from the early to middle period. The authors would argue that the elevated nitrate-N concentrations during the early 1990s are an artifact of the drought conditions of 1988 and 1989. By using data just from the middle period to represent the pre-closure period, it would be placing more emphasis on the elevated nitrate-N concentrations. Nitrate-N concentrations were elevated at FM3-1, FM3-2, and FM3-4 during the early 1980s (Figures 17, 18, and 20). Data from the early 1990s needs to be *balanced* with the water-quality data collected during the somewhat more normal climatic conditions of 1985 and 1986. This allows for the full range of the data record to be used. Additionally, statistical analysis of monthly precipitation showed no significant difference from the early to middle period, or from the pre- to post-closure period. Both the laboratory analyzing samples and the laboratory methods remained unchanged during the monitoring period.

Table 8 summarizes the statistical results for the Mann-Whitney Rank Sum Test that was used to compare the pre-closure period (November 1984 through September 1986, and January 1990 through December 1994) to the post-closure period (January 1995 through September 1998). Results show a statistically significant decrease in nitrate-N concentrations from the pre- to post-closure period for FM3-1, FM3-2, and FM3-4. For FM3-T, there was a statistically significant increase in nitrate-N concentrations from the pre- to post-closure period. The change at FM3-T was not related to closure of the ADWs, as none of the ADWs were discharging water into the shallow water table monitored by this piezometer. The median nitrate-N concentration increased from the pre- (2.6 mg/L) to post-closure (8.5 mg/L) period (Table 3, Figure 21). The decline in nitrate-N concentrations at FM3-1, FM3-2, and FM3-4 appears to be related to closure of the ADWs. The frequency of detection and nitrate-N concentrations have always been low at FM3-3 (mean concentrations of 0.1 mg/L during pre-closure and <0.1 mg/L during post-closure). These numbers explain why the decline in nitrate-N concentrations at this piezometer was not statistically significant.

Only at FM3-1 was the difference between the atrazine concentrations from the pre- to post-closure period statistically significant (Table 8). The median atrazine concentration at FM3-1 was 0.37 µg/L during pre-closure and declined to 0.25 µg/L during post-closure (Table 4). The median atrazine concentration at all other piezometers was below the detection limit, and the detection frequency was low, ranging from 2% to 36% (Table 4). The detection frequency of atrazine for FM3-1 increased from 84% (pre-closure) to 92% (post-closure).

Results from the Mann-Whitney Rank Sum Test show that the water level measurements were significantly different from the pre- to post-closure period. Some of this difference between the pre- and post-closure periods is related to the more normal climatic conditions during the post-closure period. Some of the water level change observed in all of the bedrock piezometers, however, is related to the removal of tile drainage inputs via the ADWs to the bedrock aquifers.

Other Factors Potentially Affecting Trends

What impact did climatic conditions, changes in nitrogen application rates, or changes in pesticide use rates have on water quality trends? Monitoring occurred during a period of highly variable precipitation. Monthly rainfall totals were compared to determine if rainfall was significantly different between the pre- and post-closure periods. Results of the *t* test indicated that the monthly rainfall totals during the pre-closure period were not significantly different from those for the post-closure period (mean 2.707 inches pre-closure; mean 2.712 inches post-closure) ($p=0.987$). While rainfall does affect monthly and seasonal differences in water quality, rainfall alone does not explain the changes in water quality from the pre- to post-closure period.

Declines in nitrate-N concentrations occurred in all four bedrock piezometers from the pre- to post-closure period. This decline was statistically significant for FM3-1, FM3-2, and FM3-4. Figure 25 shows the estimated annual total fertilizer-N

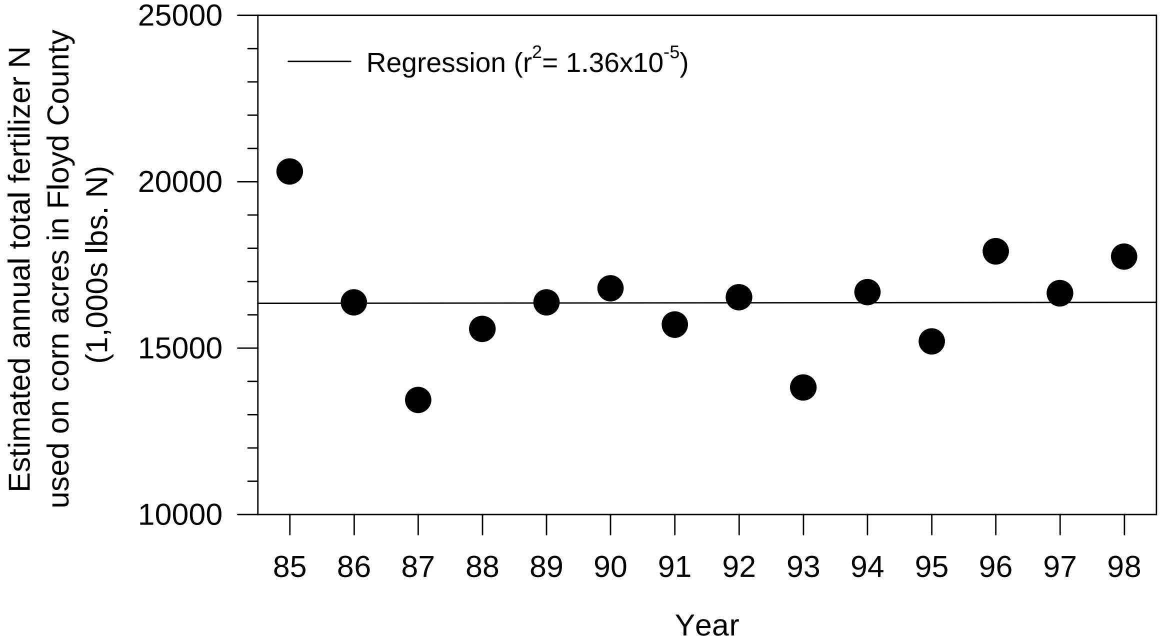

Figure 25. Estimated annual total fertilizer nitrogen used on corn acres in Floyd County from 1985 through 1997 (Sources: Iowa State University, Department of Agronomy; Iowa Agricultural Statistics and National Agricultural Statistics Service.)

used on corn acres in Floyd County. Annual numbers were calculated by using the average Iowa fertilizer-N rate for corn (as pounds of N per acre) determined by Iowa State University, Department of Agronomy (July 5, 1999; http://extension.agron.iastate.edu/soils/nuse.html). The annual number of corn acres harvested in Floyd County as corn for grain are from annual reports of the Iowa Agricultural Statistics and National Agricultural Statistics Service. During the period 1985 through 1998, a regression of estimated N application rates for Floyd County indicate that rates have remained relatively unchanged through time ($p=0.99$). It is unlikely that the slight decrease in total fertilizer N applied on corn acres in Floyd County caused the decline in nitrate-N concentrations in the bedrock piezometers. Other studies in Iowa have shown that even with significant reductions in total fertilizer N applied, it can still be a challenge to directly link those reductions to improved water quality. Results from the Big Spring basin in northeast Iowa (Clayton County) illustrate this point. Producers in the Big Spring basin reduced fertilizer-nitrogen rates on corn by 33% from 1981 to 1993 (Libra, 1998), yet flow-weighted mean nitrate-N concentrations reached an all time high in 1991. Nitrate-N concentrations have since declined, but the extreme climatic conditions that occurred during the late 1980s and early 1990s have confounded attempts to directly correlate reduced fertilizer inputs to improved water quality.

Are the declining frequencies of pesticide detection, and number of pesticides detected, based solely on the closure of the ADWs, or have changes in pesticide use or pesticide trends in groundwater affected the results from the bedrock piezometers at FM3? Since information on pesticide use near the now closed ADWs in Floyd County is not available, nor is county data available, statewide patterns will be used to provide some perspective.

The four most frequently detected pesticides at FM3 are alachlor, atrazine, cyanazine, and metolachlor. All four were detected in one or more of the piezometers prior to closure of the ADWs. Alachlor was not detected in any of the piezometers during the post-closure period; all detections occurred prior to 1992. Data from the Iowa Pesticide Water Resources Database (IAPEST), a compilation of all pesticide data from water-quality monitoring and research projects conducted in Iowa during the past 30 years (Skopec, 1998), shows that the frequency of detection of alachlor in groundwater declined from 1991 (13%) to 1995 (<1%). The use of alachlor in Iowa declined from 1979 to 1996. The decreased use is reflected in the declining frequency of detection in groundwater resources across Iowa. The lack of alachlor detections in the bedrock piezometers at FM3 since 1992 may be related to the statewide decline in alachlor use.

Atrazine was detected in all four bedrock piezometers prior to closure of the ADWs, and was detected only in the shallowest bedrock piezometer (FM3-1) after closure. For FM3-1, the mean concentration declined from the pre- to post-closure period, yet the frequency of detection increased from 84% to 92% (Table 4). There has been little change in atrazine use in Iowa since 1979 (Skopec, 1998). It remains one of the five most frequently used pesticides in Iowa based on total pounds. Although its total use has changed very little, atrazine detection rates in groundwater collected throughout Iowa have declined from 1990 (28%) to 1995 (12%) (Skopec, 1998). Some of this decline is attributed to restrictions placed on atrazine applications. The maximum rates of use have been reduced, fall application of atrazine has been eliminated, and its use has been restricted near ADWs, tile intakes, sinkholes, abandoned wells, drinking water wells, and lakes. Although the total pounds of atrazine applied in Iowa has not changed, the lower application rates appear to be resulting in a decreased frequency of occurrence in Iowa groundwater (Skopec, 1998).

All of Floyd County is located in an atrazine management area, and the application of atrazine is limited to no more than one and one-half pounds of active ingredient of atrazine per acre per calendar year. In 1994, the Geological Survey Bureau conducted a survey of 25 private wells in Floyd and Mitchell counties to evaluate the effectiveness of atrazine restrictions enacted on all of Floyd County and the western two-thirds of Mitchell County (Quade et al., 1994). All 25 wells had been sampled during a previous study conducted in 1986-1987. All 25 wells were sampled in May and June of 1994. At the same time, a questionnaire was given to the owners of the 25 wells and 75 landowners adjacent to the 25 well owners. Forty-three percent of the survey respondents indicated that their atrazine use had been reduced as a result of atrazine restrictions enacted in 1990. There was a statistically significant decline in atrazine concentrations from May 1986 (1.80 µg/L) to May 1994 (0.24 µg/L); the frequency of atrazine detection, however, remained elevated (72% in 1986 and 64% in 1994) (Quade et al., 1994). Most detections occurred in geologically susceptible areas. Although the survey was conducted prior to closure of the ADWs, results from FM3-1 show similar results (decline in mean atrazine concentration and continued high frequency of atrazine detection). Some of the atrazine trends at FM3-1 may be related to the atrazine restrictions in Floyd County. The lack of atrazine detections in FM3-2, FM3-3, and FM3-4 during the post-closure period, however, are likely the result of closure of the ADWs, and the fact that the lower part of the upper aquifer and the middle and lower aquifers are more protected from surficially derived contaminants.

Prior to closure of the ADWs, 8 to 10% of the samples from the FM3 piezometers contained cyanazine. Cyanazine has not been detected in any of the piezometers since closure of the ADWs. The last occurrence of cyanazine in a bedrock piezometer was July 1991 at FM3-1. Statewide trends of cyanazine occurrence in groundwater are not easily explained by statewide use patterns. The detection frequency of cyanazine declined in groundwater statewide during the early 1990s, but its occurrence has increased since 1993. Cyanazine use was an all-time low in 1996, and likely reflects the manufacturer's planned phase-out of the chemical (Skopec, 1998).

Metolachlor has been detected in one sample from FM3-4 since closure of the ADWs. This detection occurred shortly after the ADWs were closed (April 1995). Prior to closure, metolachlor was detected in 32 to 46% of the samples from FM3-1 and FM3-4, respectively. There were no detections of metolachlor in FM3-2 or FM3-3. Based on pounds of active ingredient, metolachlor has been the most frequently used pesticide in Iowa since 1990 (Skopec, 1998). Statewide, the frequency of detection in groundwater has remained relatively unchanged. If the use of metolachlor in Floyd County has remained unchanged, the decline in occurrence of metolachlor in FM3-1 and FM3-4 is the result of the closure of the ADWs.

CONCLUSIONS

Since closure of the ADWs, water quality has improved in the three-part Devonian aquifer system in Floyd County. Nitrate concentrations have declined, and the concentration of pesticides and number detected have declined in all four bedrock piezometers since the ADWs were closed. These trends reflect improvements in all three parts of the Devonian aquifer locally. Of the five private wells monitored, the well located nearest the closed ADWs showed the most dramatic decline in nitrate-N concentrations. The changes in water quality from the pre- to post-closure period for these sites can not be solely explained by rainfall variation, changes in nitrogen application rates, or changes in pesticide use, but rather the improved groundwater quality is directly related to the closure of the ADWs.

However, closure of the ADWs near FM3 showed that ADWs were not the only contaminant pathway to the upper aquifer. Although the mean nitrate-N concentration for the 103-feet deep piezometer in the upper aquifer has declined since the ADWs were closed, it remains slightly above the U.S. Environmental Protection Agency's established drinking water standard of 10 mg/L. The continued elevated nitrate concentrations, the decreased range in nitrate-N concentrations, and the continued high frequency of pesticide detection, indicate that this piezometer is still being impacted by contaminants entering the bedrock by a pathway other than the ADWs. Located a few miles west of the piezometers are areas of shallow bedrock (<25 feet of soil) and karst. These areas are more susceptible to surface-derived contaminants directly entering the groundwater through infiltration and surface-water recharge, and are likely contributing nitrate and pesticides to the shallow bedrock aquifer.

Based on results from this study, groundwater quality improvements would be anticipated with closure of ADWs in other locations, specifically in areas where the aquifer receiving the ADW discharge is not vulnerable to surficially derived contaminants through normal infiltration.

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APPENDIX I.

Water quality data from the monitored ADWs.

SITE	DATE	Nitrate mg/L	Nitrate-N mg/L	Ammonia-N mg/L	Organic-N mg/L	HERBICIDES								
						Alachlor µg/L	Atrazine µg/L	Butylate µg/L	Cyanazine µg/L	Deisopropyl-atrazine µg/L	Deethyl-atrazine µg/L	Metolachlor µg/L	Metribuzin µg/L	Trifluralin µg/L
ADW-1	11/10/84	18	4.0											
ADW-1*	3/25/85	32	7.1			<0.1	<0.1		<0.1					<0.1
ADW-1**	5/6/85	39	8.7			<0.1	<0.1		<0.1			0.12		<0.1
ADW-1**	6/19/85	30	6.7			<0.1	<0.1		<0.1			<0.1		<0.1
ADW-1*	10/23/85	24	5.3			<0.1	<0.1	<0.1	<0.1			<0.1		<0.1
ADW-1	3/25/86	54	12.0	0.06	0.50									
ADW-1	4/29/86	35	7.8											
ADW-1	5/28/86	63	14.0			0.12	<0.1	<0.1	2.80			5.90	0.73	<0.1
ADW-1***	5/24/90	108	24.0	<0.1	0.30	<0.1	<0.1	<0.1	<0.1			0.48	<0.1	<0.1
ADW-1***	6/20/90	108	24.0	<0.1	0.20	<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
ADW-1***	7/23/90	90	20.0	0.30	0.70	<0.1	0.52	<0.1	<0.1			<0.1	<0.1	<0.1
ADW-1***	8/29/90	41	9.2	0.10	0.30	<0.1	0.30	<0.1	<0.1			<0.1	<0.1	<0.1
ADW-1***	10/16/90	37	8.3	<0.1	0.20	<0.1	0.12	<0.1	<0.1			<0.1	<0.1	<0.1
ADW-1	4/23/91	63	14.0	<0.1	1.60	<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
ADW-1	6/11/91	68	15.0	<0.1	0.20	<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
ADW-1	7/23/91	39	8.6	<0.1	0.40	<0.1	1.10	<0.1	0.11			0.18	<0.1	<0.1
ADW-1	10/22/91	31	6.8	<0.1	0.20	<0.1	0.11	<0.1	<0.1			<0.2	<0.1	<0.1
ADW-1	4/21/92	44	9.8	0.30	0.30	<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
ADW-1	7/21/92	36	8.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
ADW-1	10/27/92	18	3.9	<0.1	0.40	<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
ADW-1	4/29/93	33	7.4	0.10	0.40	<0.1	0.14	<0.1	<0.1		0.12	<0.1	<0.1	<0.1
ADW-1	7/21/93	45	9.9	0.20	0.70	<0.1	0.44	<0.1	<0.1		0.21	<0.1	<0.1	<0.1
ADW-1	8/26/93	24	5.4	0.2	0.4	<0.1	0.38	<0.1	<0.1	<0.1	0.31	<0.1	<0.1	<0.1
ADW-1	10/20/93	33	7.4	<0.1	0.2	<0.1	0.16	<0.1	<0.1		0.16	<0.1	<0.1	<0.1
ADW-1	3/22/94	22	4.8	0.4	0.3	<0.1	0.19	<0.1	<0.1	<0.1	0.22	<0.1	<0.1	<0.1
ADW-1	4/26/94	31	6.8	0.2	<0.1	<0.1	0.11	<0.1	<0.1	<0.1	0.11	<0.1	<0.1	<0.1
ADW-1	5/17/94	29	6.5	<0.1		<0.1	0.15	<0.1	<0.1	<0.1	0.17	<0.1	<0.1	<0.1
ADW-1	6/30/94	54	12.0	0.3		0.36	2.00	<0.1	<0.1	<0.1	0.40	<0.1	<0.1	<0.1
ADW-1	7/28/94	50	11.0	0.2		<0.1	0.38	<0.1	<0.1	<0.1	0.22	<0.1	<0.1	<0.1
ADW-1	8/24/94	18	4.0	<0.1		<0.1	0.20	<0.1	<0.1	<0.1	<0.13	<0.1	<0.1	<0.1
ADW-1	9/15/94	16	3.5	<0.1		<0.1	0.16	<0.1	<0.1	<0.1	0.16	<0.1	<0.1	<0.1
ADW-1	10/13/94	50	11.0	0.3		<0.1	0.21	<0.1	<0.1	<0.1	0.13	<0.1	<0.1	<0.1
ADW-1	11/14/94	50	11.0	<0.1		<0.1	0.16	<0.1	<0.1	<0.1	0.17	<0.1	<0.1	<0.1

SITE	DATE	Nitrate mg/L	Nitrate-N mg/L	Ammonia-N mg/L	Organic-N mg/L	HERBICIDES ---------- Alachlor µg/L	Atrazine µg/L	Butylate µg/L	Cyanazine µg/L	Deisopropyl-atrazine µg/L	Deethyl-atrazine µg/L	Metolachlor µg/L	Metribuzin µg/L	Trifluralin µg/L
ADW-2	8/26/93	92	20.4											
ADW-2	10/20/93	158	35.0	<0.1	0.1	<0.1	0.88	<0.1	<0.1		1.1	0.22	<0.1	<0.1
ADW-2	3/22/94	96	21.3			<0.1	0.77	<0.1	<0.1	<0.1	1.30	0.18	<0.1	<0.1
ADW-2	4/26/94	99	22.0	0.10	<0.1	<0.1	0.62	<0.1	<0.1	<0.1	0.91	0.12	<0.1	<0.1
ADW-2	5/17/94	95	21.0	0.70		<0.1	0.87	<0.1	<0.1	<0.1	1.20	0.14	<0.1	<0.1
ADW-2	6/30/94	95	21.0	<0.1		<0.1	0.74	<0.1	<0.1	<0.1	0.97	0.25	<0.1	<0.1
ADW-2	7/28/94	90	20.0	<0.1		<0.1	0.63	<0.1	<0.1	<0.1	0.80	<0.1	<0.1	<0.1
ADW-2	8/24/94	54	12.0	0.20		<0.1	1.10	<0.1	<0.1	<0.1	1.40	<0.1	<0.1	<0.1
ADW-2	9/14/94	36	7.9	<0.1		<0.1	1.10	<0.1	<0.1	<0.1	1.30	<0.1	<0.1	<0.1
ADW-2	10/12/94	86	19.0	<0.1		<0.1	0.67	<0.1	<0.1	<0.1	1.10	<0.1	<0.1	<0.1
ADW-2	11/14/94	90	20.0	<0.1		<0.1	0.70	<0.1	<0.1	<0.1	1.20	<0.1	<0.1	<0.1
ADW-3	8/26/93	123	27.3											
ADW-3	10/20/93	95	21.0	<0.1	0.4	<0.1	0.51	<0.1	<0.1		0.83	<0.1	<0.1	<0.1
ADW-3	3/22/94	100	22.2			<0.1	0.46	<0.1	<0.1	<0.1	0.81	<0.1	<0.1	<0.1
ADW-3	4/26/94	126	28.0	0.2	0.1	<0.1	0.3	<0.1	<0.1	<0.1	0.6	<0.1	<0.1	<0.1
ADW-3	5/17/94	126	28.0	0.1		<0.1	0.44	<0.1	<0.1	<0.1	0.76	<0.1	<0.1	<0.1
ADW-3	6/30/94	144	32.0	0.1		<0.1	0.54	<0.1	<0.1	<0.1	0.82	<0.1	<0.1	<0.1
ADW-3	7/28/94	140	31.0	<0.1		<0.1	0.60	<0.1	<0.1	<0.1	0.83	<0.1	<0.1	<0.1
ADW-3	8/24/94	20	4.5	0.2		<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1
ADW-3	9/14/94	9	2.0	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
ADW-3	10/12/94	140	31.0	<0.1		<0.1	0.45	<0.1	<0.1	<0.1	0.83	<0.1	<0.1	<0.1
ADW-3	11/14/94	153	34.0	<0.1		<0.1	0.39	<0.1	<0.1	<0.1	0.80	<0.1	<0.1	<0.1

* Also analyzed for, but not detected, were acid herbicides, carbofuran, chlorinated hydrocarbon pesticides, and fonofos.

**Also analyzed for, but not detected, were carbofuran, chlorinated hydrocarbon pesticides, and fonofos.

*** Also analyzed for, but not detected, were chlorpyrifos, diazinon, dimethoate, ethoprop, fonofos, malathion, parathion, pendimethalin, phorate, propachlor, and terbufos.

APPENDIX II.

Water quality and water level data from the glacial till and bedrock piezometers at site FM3.

SITE	DATE	Water Level Elevation (feet)	Nitrate mg/L	Nitrate-N mg/L	Ammonia-N mg/L	Organic-N mg/L	Acetochlor µg/L	Alachlor µg/L	Atrazine µg/L	Butylate µg/L	Cyanazine µg/L	Deisopropyl-atrazine µg/L	Deethyl-atrazine µg/L	Metolachlor µg/L	Metribuzin µg/L	Trifluralin µg/L
FM3-1*	2/12/85	1021.60	29	6.4				<0.1	0.51		<0.1					<0.1
FM3-1*	2/27/85	1024.60	7	1.6				<0.1	0.37		<0.1					<0.1
FM3-1**	3/25/85	1025.30	<5	<1.0				<0.1	0.17		<0.1					<0.1
FM3-1*	5/6/85	1031.00	<5	<1.0				<0.1	0.27		0.16			0.30		<0.1
FM3-1*	6/19/85	1028.98	5	1.1				<0.1	0.10		0.20			0.20		<0.1
FM3-1*	7/24/85	1027.30	4	0.8				<0.1	<0.1		<0.1					<0.1
FM3-1*	8/21/85	1024.60	12	2.7				<0.1	0.23		<0.1					<0.1
FM3-1**	10/23/85	1024.00	10	2.3	<0.01	0.60		<0.1	0.37	<0.1	<0.1					<0.1
FM3-1*	12/18/85	1029.10	45	10.0	<0.01	0.15		<0.1	0.10	<0.1	<0.1					<0.1
FM3-1	3/24/86	1044.40	135	30.0	0.03	0.80										
FM3-1	3/27/86	1041.30	104	23.1	0.04	1.10		<0.1	0.41	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-1	4/29/86	1038.40	39	8.7	0.01	0.80		0.14	0.49	<0.1	<0.1			0.49	<0.1	<0.1
FM3-1	5/28/86	1045.80	77	17.0	0.11	0.50		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-1	9/9/86	1030.90	50	11.0	0.06	0.75		<0.1	0.67	<0.1	<0.1			0.12	<0.1	<0.1
FM3-1	10/19/88	1007.40														
FM3-1	1/30/89	1012.10														
FM3-1	4/11/89	DRY														
FM3-1	7/11/89	DRY														
FM3-1	10/16/89	DRY														
FM3-1	1/22/90	DRY														
FM3-1	2/5/90	DRY														
FM3-1	4/24/90	DRY														
FM3-1***	5/23/90	1015.04	243	54.0	<0.1	1.00		<0.4	0.30	<0.2	<0.2			<0.6	<0.2	<0.3
FM3-1***	6/20/90	1024.54	86	19.0	<0.1	0.50		<0.1	0.33	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-1***	7/23/90	1021.54	135	30.0	0.30	3.10		<0.7	<0.2	<0.4	<0.2			<0.7	<0.4	<0.4
FM3-1***	8/29/90	1030.74	180	40.0	<0.1	2.80		<0.3	<0.5		<0.2			<0.2	<0.2	<0.3
FM3-1***	10/16/90	1026.98	203	45.0	<0.1	0.80		<0.1	0.72	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-1***	1/23/91	1017.64	158	35.0	<0.1	0.60		<0.1	0.71	<0.1	<0.1			0.23	<0.1	<0.1
FM3-1	4/23/91	1037.20	207	46.0	<0.1	<0.1		<0.2	0.52	<0.1	<0.1			<0.3	<0.1	<0.1
FM3-1	6/11/91	1034.54	185	41.0	<0.1	0.70		0.21	0.60	0.46	<0.1			0.40	0.42	0.12
FM3-1	7/23/91	1029.99	212	47.0	0.60	7.30		2.50	1.60	0.83	0.55			<0.1	<0.1	<0.1
FM3-1	10/22/91	1021.20														
FM3-1	1/15/92	1029.52														
FM3-1	4/21/92	1038.88	135	30.0	<0.1	0.30		<0.2	0.53	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-1	7/21/92	1028.17														
FM3-1	10/27/92	1026.66	90	20.0	<0.1	2.90		<0.5	0.60	<1.0	<0.1			<0.5	<0.5	<1.0
FM3-1	4/29/93	1039.13	95	21.0	<0.1	0.40		<0.1	0.35	<0.1	<0.1		0.50	<0.1	<0.1	<0.1
FM3-1	7/21/93	1043.52	135	30.0	0.30	0.40		<0.1	0.68	<0.1	<0.1		0.80	0.16	<0.1	<0.1

SITE	DATE	Water Level Elevation (feet)	Nitrate mg/L	Nitrate-N mg/L	Ammonia-N mg/L	Organic-N mg/L	Acetochlor µg/L	Alachlor µg/L	Atrazine µg/L	Butylate µg/L	Cyanazine µg/L	Deisopropyl-atrazine µg/L	Deethyl-atrazine µg/L	Metolachlor µg/L	Metribuzin µg/L	Trifluralin µg/L
FM3-1	8/26/93	1041.86														
FM3-1	9/18/93	1035.40														
FM3-1	10/25/93	1031.30	81	18.0	0.40	2.70		<0.1	0.33	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-1	1/12/94	1026.08	63	14.0	<0.1	1.10		<0.1	0.38	<0.1	<0.1	<3.0	0.59	0.25	<0.2	<0.2
FM3-1	2/24/94	1024.52	36	8.1	<0.1	0.60		<0.1	0.38	<0.1	<0.1	<4.0	0.54	0.13	<0.1	<0.1
FM3-1	3/22/94	1028.02	68	15.0	0.20	1.20		<0.1	0.24	<0.1	<0.1	<2.0	0.28	<0.2	<0.1	<0.1
FM3-1	4/26/94	1028.40	72	16.0	0.40	1.20		<0.2	0.34	<0.1	<0.1	<100	<0.5	0.28	<0.2	<0.5
FM3-1	5/17/94	1026.68	68	15.0	<0.1			<0.1	0.35	<0.1	<0.1	18.00	0.53	<0.1	<0.1	<0.1
FM3-1	6/30/94	1034.20	108	24.0	0.30			<0.2	0.80	<0.1	<0.1	<2.0	0.90	<0.3	<0.1	<0.1
FM3-1	7/28/94	1032.21	50	11.0	0.10			<2	<0.2	<0.1	<0.1	<2	<5	<0.2	<0.1	<0.1
FM3-1	8/24/94	1029.08	27	6.0	0.30		<3.0	<3.00	<0.7	<0.7	<0.7	<0.7	<0.7	<3.00	<2.00	<0.7
FM3-1	9/14/94	1027.08														
FM3-1	10/13/94	1026.02	72	16.0	0.50		<0.1	<0.1	0.49	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-1	11/14/94	1027.16	95	21.0	0.10		<0.1	<0.1	0.45	<0.1	<0.1	<0.1	0.50	<0.1	<0.1	<0.1
FM3-1	12/13/94	1027.48	86	19.0	0.20		<0.1	<0.1	0.36	<0.1	<0.1	<0.2	0.40	<0.1	<0.1	<0.1
FM3-1	1/25/95	1025.16	77	17.0	<0.1		<0.1	<0.1	0.35	<0.1	<0.1	<0.1	0.49	<0.1	<0.1	<0.1
FM3-1	2/21/95	1023.02														
FM3-1	3/28/95	1026.30														
FM3-1	4/24/95	1030.20	63	14.0	<0.1		<0.1	<0.2	0.46	<0.1	<0.1	<0.4	0.45	<0.2	<0.4	<1.0
FM3-1	5/24/95	1030.20	59	13.0	0.20		<0.1	<0.1	0.27	<0.1	<0.1	<0.1	0.23	<0.1	<0.1	<0.1
FM3-1	6/14/95	1030.84	50	11.0	<0.1		<0.1	<0.1	0.27	<0.1	<0.1	<0.1	0.29	<0.1	<0.1	<0.1
FM3-1	7/18/95	1030.74	54	12.0	<0.1		<0.1	<0.1	0.26	<0.1	<0.1	<0.1	0.18	<0.1	<0.1	<0.1
FM3-1	8/15/95	1027.86	54	12.0	<0.1		<0.1	<0.1	0.34	<0.1	<0.1	<0.1	0.27	<0.1	<0.1	<0.1
FM3-1	9/21/95	1024.86	72	16.0	<0.1		<0.1	<0.1	0.34	<0.1	<0.1	<0.1	0.32	<0.1	<0.1	<0.1
FM3-1	10/16/95	1024.86	63	14.0	0.20		<0.1	<0.1	0.28	<0.1	<0.1	<0.1	0.24	<0.1	<0.1	<0.1
FM3-1	11/16/95	1024.38	54	12.0	<0.1		<0.1	<0.1	0.28	<0.1	<0.1	<0.1	0.38	<0.1	<0.1	<0.1
FM3-1	12/12/95	1023.22	54	12.0	<0.1		<0.1	<0.1	0.38	<0.1	<0.1	<0.1	0.42	<0.1	<0.1	<0.1
FM3-1	1/23/96	1020.40	90	20.0	<0.1		<0.1	<0.1	0.42	<0.1	<0.1	<0.1	0.44	<0.1	<0.1	<0.1
FM3-1	2/20/96	1018.92	77	17.0	<0.1		<0.1	<0.1	0.38	<0.1	<0.1	<0.1	<0.5	<0.1	<0.1	<0.1
FM3-1	3/19/96	1021.34	68	15.0	<0.1		<0.1	<0.1	0.30	<0.1	<0.1	<0.1	<0.4	<0.1	<0.1	<0.2
FM3-1	4/16/96	1023.07	59	13.0	<0.1		<0.1	<0.1	0.25	<0.1	<0.1	<0.3	<0.1	<0.1	<0.1	<0.1
FM3-1	5/20/96	1024.26														
FM3-1	6/18/96	1029.54	50	11.0	<0.1		<0.1	<0.1	0.28	<0.1	<0.1	<0.1	0.20	<0.1	<0.1	<0.1
FM3-1	7/16/96	1029.32	<0.5	<0.1	<0.1	0.40	<0.1	<0.1	0.16	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1
FM3-1	8/20/96	1025.47	41	9.0	<0.1	0.60	<0.1	<0.1	0.23	<0.1	<0.1	<0.1	<0.3	<0.1	<0.1	<0.2
FM3-1	9/26/96	1022.90	59	13.0	<0.1		<0.1	<0.1	0.27	<0.1	<0.1	<0.1	<0.3	<0.1	<0.1	<0.1
FM3-1	10/30/96	1019.66	63	14.0	<0.1		<0.1	<0.1	0.34	<0.1	<0.1	<0.2	<0.4	<0.1	<0.1	<0.2
FM3-1	11/21/96	1020.12	68	15.0	<0.1		<0.1	<0.1	0.34	<0.1	<0.1	<0.1	<0.3	<0.1	<0.1	<0.2

SITE	DATE	Water Level Elevation (feet)	Nitrate mg/L	Nitrate-N mg/L	Ammonia-N mg/L	Organic-N mg/L	Acetochlor µg/L	Alachlor µg/L	Atrazine µg/L	Butylate µg/L	Cyanazine µg/L	Deisopropyl-atrazine µg/L	Deethyl-atrazine µg/L	Metolachlor µg/L	Metribuzin µg/L	Trifluralin µg/L
FM3-1	12/18/96	1024.44	50	11.0	<0.1		<0.1	<0.1	0.23	<0.1	<0.1	<0.1	0.21	<0.1	<0.1	<0.1
FM3-1	1/29/97	1025.22	50	11.0	<0.1		<0.1	<0.1	0.23	<0.1	<0.1	<0.2	0.16	<0.1	<0.2	<0.2
FM3-1	2/19/97	1023.30	43	9.5	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-1	3/25/97		50	11.0	<0.1		<0.1	<0.1	0.21	<0.1	<0.1	<0.2	0.22	<0.1	<0.1	<0.1
FM3-1	4/28/97	1030.32	39	8.6	0.20		<0.1	<0.1	<0.2	<0.1	<0.1	<0.2	<0.2	<0.1	<0.1	<0.2
FM3-1	5/30/97	1030.92	32	7.2	<0.1		<0.1	<0.1	0.13	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1
FM3-1	11/18/97	1026.58	54	12.0	<0.1		<0.1	<0.1	0.33	<0.1	<0.1	<0.1	0.33	<0.1	<0.1	<0.1
FM3-1	12/11/97	1024.85	31	6.9	<0.1		<0.1	<0.1	0.22	<0.1	<0.1	<0.2	<0.3	<0.1	<0.1	<0.1
FM3-1	1/14/98	1022.48	63	14.0	<0.1		<0.1	<0.1	0.25	<0.1	<0.1	<0.1	0.19	<0.1	<0.1	<0.1
FM3-1	2/18/98	1020.17	25	5.5	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.1	<0.1	<0.1
FM3-1	3/16/98	1025.46	27	6.0	<0.1		<0.1	<0.1	0.13	<0.1	<0.1	<2	<2	<0.1	<0.1	<0.1
FM3-1	4/16/98	1031.40	33	7.4	0.20		<0.1	<0.1	0.12	<0.1	<0.1	0.15	0.18	<0.1	<0.1	<0.1
FM3-1	5/20/98	1030.47	24	5.3	<0.1		<0.1	<0.1	0.15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-1	6/16/98	1032.02	15	3.4	<0.1		<0.1	<0.1	0.11	<0.1	<0.1	<0.1	0.10	<0.1	<0.1	<0.1
FM3-1	7/20/98	1032.24	29	6.4	<0.1		<0.1	<0.1	0.25	<0.1	<0.1	<0.4	0.13	<0.1	<0.1	<0.1
FM3-1	8/17/98	1029.27	39	8.7	<0.1		<0.1	<0.1	0.24	<0.1	<0.1	<0.2	0.20	<0.1	<0.2	<0.1
FM3-1	9/30/98	1026.39	22	4.8	<0.1		<0.1	<0.1	0.13	<0.1	<0.1	<0.1	0.10	<0.1	<0.1	<0.1
FM3-2	11/10/84		<5	<1.0												
FM3-2	1/9/85	1027.10	<5	<1.0												
FM3-2*	2/12/85	1021.00	<5	<1.0				<0.1	<0.1		<0.1					<0.1
FM3-2*	2/27/85	1021.80	<5	<1.0				<0.1	<0.1		<0.1					<0.1
FM3-2*	3/25/85	1024.30	<5	<1.0				<0.1	<0.1		<0.1					<0.1
FM3-2*	5/6/85	1031.00	<5	<1.0				<0.1	<0.1		<0.1					<0.1
FM3-2*	6/19/85	1028.82	<5	<1.0				<0.1	<0.1		<0.1					<0.1
FM3-2*	7/24/85	1026.90	<0.5	<0.1				<0.1	<0.1		<0.1					<0.1
FM3-2*	8/21/85	1023.60	1	0.3				<0.1	1.80		<0.1					<0.1
FM3-2*	9/18/85	1027.90	<0.5	<0.1				<0.1	1.10		<0.1					<0.1
FM3-2**	10/23/85	1023.30	1	0.2	0.05	0.37		<0.1	<0.1		<0.1					<0.1
FM3-2*	12/18/85	1028.90	<0.5	<0.1	0.03	0.17		<0.1	<0.1		<0.1					<0.1
FM3-2	3/24/86	1036.40	<0.5	<0.1	0.06	0.80										
FM3-2	3/27/86				0.06	0.80		<0.1	<0.1		<0.1			<0.1	<0.1	<0.1
FM3-2	4/29/86	1036.50	8	1.8	<0.1	0.20		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-2	5/28/86	1040.20	<0.5	<0.1	0.11	0.60		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-2	9/9/86	1030.60	1	0.2	0.10	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-2	10/19/88	1007.60														
FM3-2	1/30/89	1012.05														
FM3-2	4/11/89	1002.60														

SITE	DATE	Water Level Elevation (feet)	Nitrate mg/L	Nitrate-N mg/L	Ammonia-N mg/L	Organic-N mg/L	Acetochlor µg/L	Alachlor µg/L	Atrazine µg/L	Butylate µg/L	Cyanazine µg/L	Deisopropyl-atrazine µg/L	Deethyl-atrazine µg/L	Metolachlor µg/L	Metribuzin µg/L	Trifluralin µg/L
FM3-2	7/11/89	1000.00														
FM3-2	10/16/89	993.20														
FM3-2	1/22/90	990.35														
FM3-2***	2/5/90	990.35	<0.5	<0.1	0.10	0.40		<0.1	0.13	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-2***	4/24/90		<0.5	<0.1	<0.1	0.20		<0.1	<0.1	<0.1	<0.1			<0.2	<0.1	<0.1
FM3-2***	5/23/90	1004.46	<0.5	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-2***	6/20/90	1014.92	3	0.6	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-2***	7/23/90	1021.89	13	2.8	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-2***	8/29/90	1029.46	32	7.2	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-2***	10/16/90	1026.70	17	3.7	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-2***	1/23/91	1016.90	1	0.1	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-2	4/23/91	1033.42	17	3.8	<0.1	0.20		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-2	6/10/91	1034.24	14	3.1	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-2	7/23/91	1029.64	21	4.7	<0.1	0.30		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-2	10/22/91	1020.94	2	0.4	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1			<0.2	<0.1	<0.1
FM3-2	1/15/92	1029.18														
FM3-2	4/21/92	1033.84	11	2.4	0.90	0.30		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-2	7/21/92	1028.08	4	0.8	<0.1	<0.1		<0.2	<0.1	<0.1	<0.1			<0.2	<0.1	<0.1
FM3-2	10/27/92	1026.58	<0.5	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-2	4/29/93	1037.50	0.5	0.1	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-2	7/21/93	1041.68	9	2.0	0.10	0.90		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-2	8/26/93	1043.94														
FM3-2	9/18/93	1035.00														
FM3-2	10/25/93	1031.14	9	2.1	<0.1	0.10		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-2	1/12/94	1025.92	1	0.2	0.10	0.20		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	2/24/94	1023.68	1	0.2	0.30	0.20		<0.1	<0.1	<0.1	<0.1	<1.0	<0.1	<0.1	<0.1	<0.1
FM3-2	3/22/94	1027.76	4	0.8	0.20	0.30		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	4/26/94	1028.30	7	1.5	0.20	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	5/17/94	1026.64	1	0.3	0.20			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	6/30/94	1033.10	23	5.2	0.10			<0.1	<0.1	<0.1	<0.1	<0.2	0.10	<0.1	<0.1	<0.1
FM3-2	7/28/94	1031.82	31	6.8	<0.1			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	8/24/94	1028.88	13	2.8	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	9/15/94	1026.96	4	0.8	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1
FM3-2	10/13/94	1025.88	7	1.5	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	11/14/94	1027.04	8	1.8	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	12/13/94	1027.48	19	4.3	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	1/25/95	1025.08	1	0.2	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
FM3-2	2/21/95	1022.94														

SITE	DATE	Water Level Elevation (feet)	Nitrate mg/L	Nitrate-N mg/L	Ammonia-N mg/L	Organic-N mg/L	Acetochlor µg/L	Alachlor µg/L	Atrazine µg/L	Butylate µg/L	Cyanazine µg/L	Deisopropyl-atrazine µg/L	Deethyl-atrazine µg/L	Metolachlor µg/L	Metribuzin µg/L	Trifluralin µg/L
FM3-2	3/28/95	1026.52	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	4/24/95	1030.32	0.5	0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	5/24/95	1030.22	2	0.4	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	6/14/95	1030.90	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	7/18/95	1030.50	<0.5	<0.1	0.10		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	8/15/95	1027.86	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	9/21/95	1024.82	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	10/16/95	1024.92	0.5	0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	11/16/95	1024.36	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	12/12/95	1023.14	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	1/23/96	1020.24	0.5	0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	2/20/96	1018.82	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	3/19/96	1021.44	0.5	0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	4/16/96	1023.27	0.5	0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	5/20/96	1024.36	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	6/18/96	1029.82	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	7/16/96	1029.30	<0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	8/20/96	1025.37	0.5	0.1	<0.1	0.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	9/26/96	1022.68	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	10/30/96	1019.56	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	11/21/96	1020.34	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2
FM3-2	12/18/96	1024.72	0.5	0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	1/29/97	1025.20	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	2/19/97	1023.26	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	3/25/97		<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	4/28/97	1029.36	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	5/30/97	1030.93	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	11/18/97	1026.62	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	12/11/97	1024.77	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	1/14/98	1022.36	5	1.0	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	2/18/98	1020.12	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	3/16/98	1025.76	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	4/16/98	1031.53	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	5/20/98	1030.38	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	6/16/98	1032.17	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	7/20/98	1032.18	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	8/17/98	1029.15	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-2	9/30/98	1026.24	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

SITE	DATE	Water Level Elevation (feet)	Nitrate mg/L	Nitrate-N mg/L	Ammonia-N mg/L	Organic-N mg/L	Acetochlor µg/L	Alachlor µg/L	Atrazine µg/L	Butylate µg/L	Cyanazine µg/L	Deisopropyl-atrazine µg/L	Deethyl-atrazine µg/L	Metolachlor µg/L	Metribuzin µg/L	Trifluralin µg/L
FM3-3	11/10/84		<5	<1.0												
FM3-3	1/9/85		<5	<1.0												
FM3-3*	2/12/85	1014.00	<5	<1.0				<0.1	<0.1		<0.1					<0.1
FM3-3*	2/27/85	1020.60	<5	<1.0				<0.1	<0.1		<0.1					<0.1
FM3-3	3/25/85	1024.00	<5	<1.0												
FM3-3	5/6/85	1028.20	<5	<1.0												
FM3-3*	6/19/85	1024.65	<5	<1.0				<0.1	<0.1		<0.1					<0.1
FM3-3*	7/24/85	1022.20	<0.5	<0.1				<0.1	<0.1		<0.1					<0.1
FM3-3*	8/21/85	1019.30	1	0.2				<0.1	0.44		<0.1					<0.1
FM3-3*	9/18/85	1016.80	<0.5	<0.1				<0.1	<0.1		<0.1					<0.1
FM3-3*	10/23/85	1022.30	0.5	0.1	0.39	1.00		<0.1	<0.1		<0.1					<0.1
FM3-3*	12/18/85	1026.10	<0.5	<0.1	0.49	0.06		<0.1	<0.1		<0.1					<0.1
FM3-3	3/24/86	1037.40	<0.5	<0.1	0.32	1.30										
FM3-3	3/27/86	1036.40	<0.5	<0.1	0.32	0.40		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-3	4/29/86	1037.60	<0.5	<0.1	0.33	1.00		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-3	5/28/86	1046.00	<0.5	<0.1	0.40	0.10										
FM3-3	9/9/86	1027.40	<0.5	<0.1	0.50	0.32		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-3	10/19/88	1003.20														
FM3-3	1/30/89	1008.20														
FM3-3	4/11/89	999.50														
FM3-3	7/10/89	997.40														
FM3-3	10/16/89	990.20														
FM3-3***	1/29/90	987.80	<0.5	<0.1	0.40	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-3***	4/24/90		<0.5	<0.1	0.40	0.40		<0.1	<0.1	<0.1	<0.1			<0.2	<0.1	<0.1
FM3-3***	5/23/90	1002.90	<0.5	<0.1	0.40	0.10										
FM3-3***	5/24/90	1003.19	<0.5	<0.1	0.40	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-3***	6/20/90	1014.14	2	0.4	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-3***	7/23/90	1017.86	<0.5	<0.1	0.40	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-3***	8/29/90	1027.58	<0.5	<0.1	0.30	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-3***	10/16/90	1023.06	0.5	0.1	0.20	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-3***	1/23/91	1012.08	<0.5	<0.1	0.40	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-3	4/23/91	1033.58	2	0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-3	6/11/91	1033.18	<0.5	<0.1	0.30	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-3	7/23/91	1026.62	1	0.2	0.20	<0.1		0.19	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-3	10/22/91	1016.72	0.5	0.1	0.20	<0.1		<0.1	<0.1	<0.1	<0.1			<0.2	<0.1	<0.1
FM3-3	1/15/92	1025.92														
FM3-3	4/21/92	1036.62	1	0.2	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1

SITE	DATE	Water Level Elevation (feet)	Nitrate mg/L	Nitrate-N mg/L	Ammonia-N mg/L	Organic-N mg/L	Acetochlor µg/L	Alachlor µg/L	Atrazine µg/L	Butylate µg/L	Cyanazine µg/L	Deisopropyl-atrazine µg/L	Deethyl-atrazine µg/L	Metolachlor µg/L	Metribuzin µg/L	Trifluralin µg/L
FM3-3	7/21/92	1022.90	<0.5	<0.1	0.20	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-3	10/27/92	1021.38	1	0.2	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-3	4/29/93	1037.74	1	0.2	0.10	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-3	7/21/93	1041.28	0.5	0.1	<0.1	0.10		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-3	8/26/93	1043.76														
FM3-3	9/18/93	1034.60														
FM3-3	10/25/93	1029.36	2	0.4	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-3	1/12/94	1022.38	0.5	0.1	0.50	0.10		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	2/24/94	1019.16	0.5	0.1	0.30	<0.1		<0.1	<0.1	<0.1	<0.1	<0.5	<0.1	<0.1	<0.1	<0.1
FM3-3	3/22/94	1024.80	<0.5	<0.1	0.40	<0.1		<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
FM3-3	4/26/94	1023.46	<0.5	<0.1	0.30	<0.1		<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
FM3-3	5/17/94	1022.08	<0.5	<0.1	0.40			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	6/30/94	1028.98	1	0.3	0.20			<0.1	<0.1	<0.1	<0.1	<0.4	<0.1	<0.1	<0.1	<0.1
FM3-3	7/28/94	1027.92	<0.5	<0.1	0.40			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	8/24/94	1023.74	1	0.3	0.20		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	9/15/94	1021.54	1	0.3	<0.1		<0.1	<0.2	<0.2	<0.1	<0.1	<0.3	<0.1	<0.2	<0.3	<0.1
FM3-3	10/13/94	1020.96	<0.5	<0.1	0.60		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	11/14/94	1021.98	1	0.2	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	12/13/94	1023.28	1	0.3	0.20		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	1/25/95	1019.10	1	0.2	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	2/20/95	1017.36														
FM3-3	3/28/95	1025.68	<0.5	<0.1	0.30		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	4/24/95	1028.28	<0.5	<0.1	0.30		<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
FM3-3	5/24/95	1026.40	<0.5	<0.1	0.50		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	6/14/95	1026.54	1	0.3	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	7/18/95	1026.36	<0.5	<0.1	0.40		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	8/15/95	1022.48	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	9/21/95	1019.24	1	0.2	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	10/16/95	1019.80	<0.5	<0.1	0.40		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	11/16/95	1019.10	1	0.2	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	12/12/95	1017.32	1	0.2	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	1/23/96	1014.08	0.5	0.1	0.30		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	2/20/96	1013.32	1	0.2	0.30		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	3/19/96	1015.94	<0.5	<0.1	0.20		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	4/16/96	1018.00	<0.5	<0.1	0.30		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	5/20/96	1018.70	1	0.2	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	6/18/96	1026.32	<0.5	<0.1	0.30		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	7/16/96	1024.94	<0.5	<0.1	0.30	0.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

SITE	DATE	Water Level Elevation (feet)	Nitrate mg/L	Nitrate-N mg/L	Ammonia-N mg/L	Organic-N mg/L	Acetochlor µg/L	Alachlor µg/L	Atrazine µg/L	Butylate µg/L	Cyanazine µg/L	Deisopropyl-atrazine µg/L	Deethyl-atrazine µg/L	Metolachlor µg/L	Metribuzin µg/L	Trifluralin µg/L
FM3-3	8/20/96	1019.87	<0.5	<0.1	0.30	0.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	9/26/96	1016.75	<0.5	<0.1	0.30		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	10/30/96	1013.74	<0.5	<0.1	0.10		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	11/21/96	1015.70	<0.5	<0.1	0.30		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2
FM3-3	12/18/96	1019.70	<0.5	<0.1	0.20		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	1/29/97	1018.82	<0.5	<0.1	0.30		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	2/19/97	1016.70	<0.5	<0.1	0.20		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	3/25/97		1	0.3	0.20		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	4/28/97	1026.54	<0.5	<0.1	0.20		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	5/30/97	1027.63	<0.5	<0.1	0.30		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	11/18/97	1022.72	<0.5	<0.1	0.30		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	12/11/97	1019.30	<0.5	<0.1	0.40		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	1/14/98	1016.54	<0.5	<0.1	0.30		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	2/18/98	1014.97	<0.5	<0.1	0.40		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	3/16/98	1021.96	<0.5	<0.1	0.40		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	4/16/98	1028.39	<0.5	<0.1	0.30		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	5/20/98	1026.60	<0.5	<0.1	0.30		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	6/16/98	1029.18	<0.5	<0.1	0.30		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	7/20/98	1028.93	<0.5	<0.1	0.40		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	8/17/98	1025.03	<0.5	<0.1	0.30		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-3	9/30/98	1021.37	<0.5	<0.1	0.30		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	11/10/84		<5	<1.0												
FM3-4	1/9/85		<5	<1.0												
FM3-4	2/12/85		<5	<1.0												
FM3-4*	2/27/85	1020.50	<5	<1.0				<0.1	0.25		<0.1			0.20		<0.1
FM3-4	3/25/85	1023.80	<5	<1.0												
FM3-4	5/6/85	1028.00	5.9	1.3												
FM3-4	6/19/85	1024.49	<5	<1.0												
FM3-4*	7/24/85	1022.10	3	0.6				<0.1	<0.1		<0.1			0.18		<0.1
FM3-4*	8/21/85	1019.20	2	0.4				0.48	1.30		0.63					<0.1
FM3-4*	9/18/85	1016.90	<0.5	<0.1				<0.1	<0.1		<0.1					<0.1
FM3-4*	10/23/85	1022.30	1	0.2	<0.01	0.16		<0.1	<0.1		<0.1					<0.1
FM3-4*	12/18/85	1025.10	2	0.4	<0.01	0.04		<0.1	<0.1		0.12			0.12		<0.1
FM3-4	3/24/86	1037.40	17	3.8	0.01	0.20										
FM3-4	3/27/86	1036.10	17	3.8	0.01	0.30		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-4	4/29/86	1037.50	14	3.2	0.01	<0.1		<0.1	0.10	<0.1	<0.1			0.17	<0.1	<0.1
FM3-4	5/28/86	1045.80	27	5.9	0.06	<0.1		<0.1	0.13	<0.1	0.42			0.87	<0.1	<0.1

SITE	DATE	Water Level Elevation (feet)	Nitrate mg/L	Nitrate-N mg/L	Ammonia-N mg/L	Organic-N mg/L	Acetochlor µg/L	Alachlor µg/L	Atrazine µg/L	Butylate µg/L	Cyanazine µg/L	Deisopropyl-atrazine µg/L	Deethyl-atrazine µg/L	Metolachlor µg/L	Metribuzin µg/L	Trifluralin µg/L
FM3-4	9/9/86	1027.40	10	2.2	0.03	0.16		<0.1	0.10	<0.1	0.23			0.45	<0.1	<0.1
FM3-4	10/19/88	1003.20														
FM3-4	1/30/89	1011.20														
FM3-4	4/11/89	1000.80														
FM3-4	7/10/89	997.40														
FM3-4	10/16/89	990.20														
FM3-4***	1/29/90	987.70	<0.5	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1			0.21	<0.1	<0.1
FM3-4	2/5/90	987.65														
FM3-4***	4/24/90		0.5	0.1	<0.1	0.20		<0.1	<0.1	<0.1	<0.1			<0.2	<0.1	<0.1
FM3-4***	5/23/90	1003.10	3	0.7	<0.1	0.10		<0.1	<0.1	<0.1	<0.1			0.16	<0.2	<0.1
FM3-4***	6/20/90	1014.12	8	1.8	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-4***	7/23/90	1017.00	12	2.7	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-4***	8/29/90	1027.46	14	3.2	<0.1	0.30		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-4***	10/16/90	1022.98	25	5.6	<0.1	0.10		<0.1	<0.1	<0.1	<0.1			0.10	<0.1	<0.1
FM3-4***	1/23/91	1012.08	6	1.3	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-4	4/23/91	1033.42	0.5	0.1	<0.1	0.40		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-4	6/11/91	1033.10	38	8.4	<0.1	0.20		<0.1	<0.1	<0.1	<0.1			0.13	<0.1	<0.1
FM3-4	7/23/91	1026.62	38	8.5	<0.1	0.20		<0.1	0.14	<0.1	<0.1			0.18	<0.1	<0.1
FM3-4	10/22/91	1016.64	21	4.6	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1			<0.2	<0.1	<0.1
FM3-4	1/15/92	1025.84														
FM3-4	4/21/92	1036.38	3	0.6	<0.1	0.40		<0.1	<0.1	<0.1	<0.1			0.16	<0.1	<0.1
FM3-4	7/21/92	1022.92	5	1.2	<0.1	0.20		<0.1	<0.1	<0.1	<0.1			0.16	<0.1	<0.1
FM3-4	10/27/92	1021.36	12	2.6	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-4	4/29/93	1037.66	9	1.9	<0.1	<0.1		<0.1	0.11	<0.1	<0.1			0.17	<0.1	<0.1
FM3-4	7/21/93	1042.20	1	0.3	0.10	0.10		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-4	8/26/93	1045.98														
FM3-4	9/18/93	1034.60														
FM3-4	10/25/93	1029.34	30	6.7	<0.1	0.10		<0.1	0.14	<0.1	<0.1		0.14	<0.1	<0.1	<0.1
FM3-4	1/12/94	1022.32	5	1.1	<0.1	0.10		<0.1	<0.1	<0.1	<0.1	<0.1	0.15	0.11	<0.1	<0.1
FM3-4	2/24/94	1019.10	1	0.3	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.5	<0.1	<0.1	<0.1	<0.1
FM3-4	3/22/94	1024.74	1	0.3	0.20	<0.1		<0.1	<0.1	<0.1	<0.1	<0.3	<0.1	<0.1	<0.1	<0.1
FM3-4	4/26/94	1024.44	1	0.3	0.10	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	5/17/94	1022.00	<0.5	<0.1	0.10			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	6/30/94	1028.96	1	0.2	0.10			<0.1	<0.1	<0.1	<0.1	<0.3	<0.1	<0.1	<0.1	<0.1
FM3-4	7/28/94	1027.88	4	0.9	<0.1			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.10	<0.1	<0.1
FM3-4	8/24/94	1023.72	3	0.7	0.30		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	9/15/94	1021.76	1	0.3	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	10/13/94	1020.92	<0.5	<0.1	0.20		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.10	<0.1	<0.1

SITE	DATE	Water Level Elevation (feet)	Nitrate mg/L	Nitrate-N mg/L	Ammonia-N mg/L	Organic-N mg/L	Acetochlor µg/L	Alachlor µg/L	Atrazine µg/L	Butylate µg/L	Cyanazine µg/L	Deisopropyl-atrazine µg/L	Deethyl-atrazine µg/L	Metolachlor µg/L	Metribuzin µg/L	Trifluralin µg/L
FM3-4	11/14/94	1021.94	2	0.4	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	12/13/94	1023.12	1	0.3	0.10		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	1/25/95	1019.02	1	0.3	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	2/21/95	1017.26														
FM3-4	3/28/95	1025.52	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	4/24/95	1028.22	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.10	<0.1	<0.1
FM3-4	5/24/95	1026.36	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	6/14/95	1026.46	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	7/18/95	1026.56	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	8/15/95	1022.42	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	9/21/95	1019.28	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	10/16/95	1019.82	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	11/16/95	1019.12	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	12/12/95	1017.22	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	1/23/96	1014.00	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	2/20/96	1013.22		0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	3/19/96	1015.90	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	4/16/96	1017.87	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	5/20/96	1018.62	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	6/18/96	1026.27	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	7/16/96	1024.92	<0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	8/20/96	1019.86	<0.5	<0.1	<0.1	0.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	9/26/96	1016.70	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	10/30/96	1013.70	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	11/21/96	1015.66	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2
FM3-4	12/18/96	1019.62	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	1/29/97	1018.82	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	2/19/97	1016.62	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	3/25/97		<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	4/28/97	1026.52	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	5/30/97	1027.54	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	11/18/97	1021.64	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	12/11/97	1019.17	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	1/14/98	1016.52	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	2/18/98	1015.04	<0.5	<0.1	0.10		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	3/16/98	1021.97	<0.5	<0.1	0.10		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	4/16/98	1028.39	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

SITE	DATE	Water Level Elevation (feet)	Nitrate mg/L	Nitrate-N mg/L	Ammonia-N mg/L	Organic-N mg/L	Acetochlor µg/L	Alachlor µg/L	Atrazine µg/L	Butylate µg/L	Cyanazine µg/L	Deisopropyl-atrazine µg/L	Deethyl-atrazine µg/L	Metolachlor µg/L	Metribuzin µg/L	Trifluralin µg/L
FM3-4	5/20/98	1026.57	<0.5	<0.1	0.10		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	6/16/98	1029.24	<0.5	<0.1	0.10		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	7/20/98	1028.90	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	8/17/98	1025.00	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-4	9/30/98	1021.37	<0.5	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-T	11/10/84		<5	<1.0				<0.1	<0.1		<0.1			<0.1	<0.1	
FM3-T	1/9/85		<5	<1.0												
FM3-T	2/12/85	1098.80	<5	<1.0												
FM3-T*	2/27/85	1100.70	<5	<1.0				<0.1	<0.1		<0.1					<0.1
FM3-T*	3/25/85	1103.00	<5	<1.0				<0.1	<0.1		<0.1					<0.1
FM3-T	5/6/85	1100.90	10	2.2												
FM3-T*	6/19/85	1098.70	<5	<1.0				<0.1	<0.1		<0.1					<0.1
FM3-T*	7/24/85	1099.80	2	0.5				4.40	0.30		<0.1					<0.1
FM3-T*	8/21/85	1098.10	<0.5	<0.1				<0.1	<0.1		<0.1					<0.1
FM3-T*	9/18/85	1098.20	<0.5	<1.0				<0.1	0.11		<0.1					<0.1
FM3-T*	10/23/85	1101.30	<0.5	<1.0				<0.1	<0.1		<0.1					<0.1
FM3-T*	12/18/85	1101.20	<0.5	<0.1	0.35	2.30		<0.1	<0.1		<0.1					<0.1
FM3-T	3/24/86	1102.70														
FM3-T	3/27/86	1102.50	<0.5	<0.1	0.09	0.50		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-T	4/29/86	1102.40	20	4.4	0.02	1.10		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-T	5/28/86	1102.50	<0.5	<0.1	0.09	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-T	9/9/86	1099.20	3	0.7	0.22	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-T	10/19/88	1094.40														
FM3-T	1/30/89	1097.70														
FM3-T	4/11/89	1096.00														
FM3-T	7/10/89	1094.70														
FM3-T	10/16/89	1092.60														
FM3-T	1/22/90	1091.80														
FM3-T***	2/5/90	1091.75	<0.5	<0.1	0.10	3.20		<0.2	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-T***	4/24/90	1096.38	2	0.4	<0.1	1.00		<0.1	<0.1	<0.1	<0.1			<0.2	<0.1	<0.1
FM3-T***	5/23/90	1098.68	5	1.0	<0.1	0.50		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-T***	6/20/90	1098.94	5	1.2	<0.1	2.60		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-T***	7/23/90	1098.38	50	11.0	<0.1	0.40		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-T***	8/29/90	1098.96	54	12.0	1.20	2.10		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-T***	10/16/90	1097.80	68	15.0	<0.1	0.80		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-T	1/23/91	1096.50	54	12.0	<0.1	0.50										
FM3-T	4/23/91	1099.48	45	10.0	<0.1	0.30		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1

SITE	DATE	Water Level Elevation (feet)	Nitrate mg/L	Nitrate-N mg/L	Ammonia-N mg/L	Organic-N mg/L	Acetochlor µg/L	Alachlor µg/L	Atrazine µg/L	Butylate µg/L	Cyanazine µg/L	Deisopropyl-atrazine µg/L	Deethyl-atrazine µg/L	Metolachlor µg/L	Metribuzin µg/L	Trifluralin µg/L
FM3-T	6/11/91	1098.30	77	17.0	<0.1	0.80										
FM3-T	7/23/91	1096.86	99	22.0	0.10	2.20										
FM3-T	10/22/91	1096.78	59	13.0	<0.1	1.70										
FM3-T	1/15/92															
FM3-T	4/21/92	1100.40	68	15.0	<0.1	1.20		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-T	7/21/92	1097.48	37	8.3	<0.1	0.50										
FM3-T	10/27/92	1097.46	26	5.7	<0.1	0.30										
FM3-T	4/29/93	1099.22	16	3.5	<0.1	0.90		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-T	7/21/93	1099.08	10	2.2	<0.1	0.20		<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1
FM3-T	8/26/93	1099.16														
FM3-T	9/18/93	1098.64														
FM3-T	10/25/93	1097.53	6	1.4	<0.1	1.80		<0.1	<0.1	<0.1	<0.1		0.16	<0.1	<0.1	<0.1
FM3-T	1/12/94	1096.50	21	4.6	<0.1	1.10		<0.1	0.19	<0.1	<0.1	<0.1	0.28	<0.1	<0.1	<0.1
FM3-T	2/24/94	1097.22	27	6.0	<0.1	0.50		<0.1	0.25	<0.1	<0.1	<0.1	0.29	<0.1	<0.1	<0.1
FM3-T	3/22/94	1098.72	20	4.5	0.10	0.50		<0.1	0.11	<0.1	<0.1	<0.5	0.20	<0.1	<0.1	<0.1
FM3-T	4/26/94	1098.20	14	3.2	0.30	1.30		<0.1	0.15	<0.1	<0.1	<4.0	0.23	<0.1	<0.1	<0.1
FM3-T	5/17/94	1097.48	16	3.6	0.10			<0.1	0.13	<0.1	<0.1	8.90	0.27	<0.1	<0.1	<0.4
FM3-T	6/30/94	1098.88	12	2.7	0.20			<0.1	0.10	<0.1	<0.1	<0.3	0.25	<0.1	<0.1	<0.1
FM3-T	7/28/94	1098.58	8	1.8	0.40			<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.1	<0.1	<0.1
FM3-T	8/24/94	1097.38	14	3.1	0.10		<0.1	<0.1	0.17	<0.1	<0.1	<0.1	<0.24	<0.1	<0.1	<0.1
FM3-T	9/15/94	1096.16	14	3.2	0.10		<0.1	<0.1	0.18	<0.1	<0.1	<1.0	0.22	<0.1	<0.1	<0.1
FM3-T	10/13/94	1096.78	23	5.2	<0.1		<0.1	<0.1	0.14	<0.1	<0.1	<0.1	0.30	<0.1	<0.1	<0.1
FM3-T	11/14/94	1096.90	20	4.5	0.10		<0.1	<0.1	0.14	<0.1	<0.1	<0.1	0.35	<0.1	<0.1	<0.1
FM3-T	12/13/94	1097.26	11	2.5	<0.1		<0.1	<0.1	0.14	<0.1	<0.1	<0.1	0.36	<0.1	<0.1	<0.1
FM3-T	1/25/95	1095.96	15	3.3	0.70		<0.1	<0.1	0.12	<0.1	<0.1	<0.1	0.34	<0.1	<0.1	<0.1
FM3-T	2/21/95	1096.50														
FM3-T	3/28/95	1097.96	16	3.5	<0.1		<0.1	<0.1	0.13	<0.1	<0.1	<0.1	0.28	<0.1	<0.1	<0.1
FM3-T	4/24/95	1098.96	14	3.2	0.10		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.19	<0.1	<0.1	<0.1
FM3-T	5/24/95	1097.82	14	3.2	<0.1		<0.1	<0.1	0.10	<0.1	<0.1	<0.1	0.23	<0.1	<0.1	<0.1
FM3-T	6/14/95	1098.00	22	4.9	<0.1		<0.1	<0.1	0.11	<0.1	<0.1	<0.1	0.25	<0.1	<0.1	<0.1
FM3-T	7/18/95	1097.20	24	5.3	<0.1		<0.1	<0.1	0.13	<0.1	<0.1	<0.1	0.23	<0.1	<0.1	<0.1
FM3-T	8/15/95	1096.24	34	7.5	<0.1		<0.1	<0.2	0.18	<0.1	<0.1	<0.1	0.33	<0.1	<0.1	<0.1
FM3-T	9/21/95	1096.24	37	8.2	<0.1		<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	0.32	<0.1	<0.1	<0.1
FM3-T	10/16/95	1096.94	25	5.6	<0.1		<0.1	<0.1	0.13	<0.1	<0.1	<0.1	0.28	<0.1	<0.1	<0.1
FM3-T	11/16/95	1096.86	37	8.3	<0.1		<0.1	<0.1	0.14	<0.1	<0.1	<0.1	0.50	<0.1	<0.1	<0.1
FM3-T	12/12/95	1096.37	31	6.9	<0.1		<0.1	<0.1	0.11	<0.1	<0.1	<0.1	0.22	<0.1	<0.1	<0.1
FM3-T	1/23/96	1095.92	54	12.0	<0.1		<0.1	<0.1	0.13	<0.1	<0.1	<0.1	0.35	<0.1	<0.1	<0.1
FM3-T	2/20/96	1096.06	38	8.5	<0.1		<0.1	<0.1	0.13	<0.1	<0.1	<0.1	0.31	<0.1	<0.1	<0.1

SITE	DATE	Water Level Elevation (feet)	Nitrate mg/L	Nitrate-N mg/L	Ammonia-N mg/L	Organic-N mg/L	Acetochlor µg/L	Alachlor µg/L	Atrazine µg/L	Butylate µg/L	Cyanazine µg/L	Deisopropyl-atrazine µg/L	Deethyl-atrazine µg/L	Metolachlor µg/L	Metribuzin µg/L	Trifluralin µg/L
FM3-T	3/19/96	1095.45	25	5.5	<0.1		<0.1	<0.1	0.13	<0.1	<0.1	<0.1	0.27	<0.1	<0.1	<0.1
FM3-T	4/16/96	1096.48	28	6.3	<0.1		<0.1	<0.1	0.12	<0.1	<0.1	<0.1	0.25	<0.1	<0.1	<0.1
FM3-T	5/20/96	1096.96	33	7.3	<0.1		<0.1	<0.1	0.13	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-T	6/18/96	1100.04	27	6.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.20	<0.1	<0.1	<0.1
FM3-T	7/16/96	1097.11	63	14.0	<0.1	1.40	<0.1	<0.1	0.11	<0.1	<0.1	<0.1	0.26	<0.1	<0.1	<0.1
FM3-T	8/20/96	1094.96	86	19.0	<0.1	1.20	<0.1	<0.1	0.12	<0.1	<0.1	<0.1	0.28	<0.1	<0.1	<0.1
FM3-T	9/26/96	1093.76	63	14.0	<0.1		<0.1	<0.1	0.14	<0.1	<0.1	<0.2	0.25	<0.1	<0.1	<0.1
FM3-T	10/30/96	1094.58	63	14.0	<0.1		<0.1	<0.1	0.12	<0.1	<0.1	<0.2	<0.4	<0.1	<0.1	<0.1
FM3-T	11/21/96	1097.34	68	15.0	<0.1		<0.1	<0.1	0.12	<0.1	<0.1	<0.1	0.28	<0.1	<0.1	<0.2
FM3-T	12/18/96	1098.40	41	9.2	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FM3-T	1/29/97	1096.71	38	8.5	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.13	<0.1	<0.1	<0.1
FM3-T	2/19/97	1096.60	45	10.0	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<2.0	0.21	<0.1	<0.1	<0.1
FM3-T	3/25/97		18	4.1	0.20		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.16	<0.1	<0.1	<0.1
FM3-T	4/28/97	1098.18	32	7.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.21	<0.1	<0.1	<0.1
FM3-T	5/30/97	1098.02	40	8.9	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.17	<0.1	<0.1	<0.1
FM3-T	11/18/97	1099.93	68	15.0	<0.1		<0.1	<0.1	0.10	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1
FM3-T	12/11/97	1096.41	68	15.0	<0.1		<0.1	<0.1	0.10	<0.1	<0.1	<0.2	0.30	<0.1	<0.1	<0.1
FM3-T	1/14/98	1096.00	77	17.0	<0.1		<0.1	<0.1	0.10	<0.1	<0.1	<0.1	0.24	<0.1	<0.1	<0.1
FM3-T	2/18/98	1097.16	72	16.0	<0.1		<0.1	<0.1	0.10	<0.1	<0.1	<0.2	0.28	<0.1	<0.1	<0.1
FM3-T	3/16/98	1098.04	59	13.0	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<1.0	0.21	<0.1	<0.1	<0.1
FM3-T	4/16/98	1100.13	37	8.2	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.11	<0.1	<0.1	<0.1
FM3-T	5/20/98	1097.74	72	16.0	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.18	<0.1	<0.1	<0.1
FM3-T	6/16/98	1098.88	50	11.0	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.28	<0.1	<0.1	<0.1
FM3-T	7/20/98	1097.28	68	15.0	<0.1		<0.1	<0.1	0.12	<0.1	<0.1	<0.1	0.43	<0.1	<0.1	<0.1
FM3-T	8/17/98	1096.26	72	16.0	<0.1		<0.1	<0.1	0.17	<0.1	<0.1	<0.1	0.48	<0.1	<0.1	<0.1
FM3-T	9/30/98	1096.09	72	16.0	<0.1		<0.1	<0.1	0.12	<0.1	<0.1	<0.1	0.52	<0.1	<0.1	<0.1

* Also analyzed for, but not detected, were carbofuran, chlorinated hydrocarbon pesticides, and fonofos.

**Also analyzed for, but not detected, were acid herbicides, carbofuran, chlorinated hydrocarbon pesticides, and fonofos.

*** Also analyzed for, but not detected, were chlorpyrifos, diazinon, dimethoate, ethoprop, fonofos, malathion, parathion, pendimethalin, phorate, propachlor, and terbufos.

APPENDIX III.

Water quality data from the private wells.

	Nitrate-nitrogen (as nitrate), mg/L				
	Private Wells				
DATE	C-Well	D-Well	K-Well	S-Well	Y-Well
11/14/94	15.6 (70)	5.1 (23)	<0.2 (<1.0)	12.9 (58)	2.7 (12)
12/13/94	15.6 (70)	3.1 (14)	<0.2 (<1.0)	13.1 (59)	2.4 (11)
1/25/95	-----	4.7 (21)	<0.2 (<1.0)	13.3 (60)	2.4 (11)
2/21/95	-----	4.4 (20)	<0.2 (<1.0)	13.3 (60)	2.4 (11)
3/28/95	-----	<0.2 (<1.0)	<0.2 (<1.0)	12.9 (58)	<0.2 (<1.0)
4/20/95	1.1 (5)	0.7 (3)	<0.2 (<1.0)	13.8 (62)	<0.2 (<1.0)
5/24/95	<0.2 (<1.0)	2.0 (9)	0.2 (1.0)	14.4 (65)	<0.2 (<1.0)
6/14/95	<0.2 (<1.0)	1.8 (8)	<0.2 (<1.0)	14.9 (67)	<0.2 (<1.0)
7/18/95	2.4 (11)	3.1 (14)	<0.2 (<1.0)	16.2 (73)	0.7 (3)
8/15/95	4.9 (22)	3.1 (14)	<0.2 (<1.0)	16.2 (73)	2.0 (9)
9/21/95	6.9 (31)	3.1 (14)	<0.2 (<1.0)	15.3 (69)	2.9 (13)
10/16/95	1.6 (7)	2.2 (10)	<0.2 (<1.0)	15.3 (69)	2.7 (12)
11/16/95	7.1 (32)	3.3(15)	<0.2 (<1.0)	16.2 (73)	2.0 (9)
12/12/95	7.1 (32)	2.9 (13)	<0.2 (<1.0)	-----	2.2 (10)
1/23/96	-----	3.1 (14)	<0.2 (<1.0)	14.9 (67)	-----
2/20/96	-----	3.1 (14)	<0.2 (<1.0)	14.2 (64)	<0.2 (<1.0)
3/19/96	-----	2.4 (11)	<0.2 (<1.0)	12.4 (56)	0.2 (1.0)
4/16/96	<0.2 (<1.0)	2.7 (12)	<0.2 (<1.0)	12.2 (55)	<0.2 (<1.0)
5/20/96	<0.2 (<1.0)	1.8 (8)	<0.2 (<1.0)	12.2 (55)	1.8 (8)
6/18/96	<0.2 (<1.0)	0.7 (3)	<0.2 (<1.0)	9.3 (42)	<0.2 (<1.0)
7/16/96	0.9 (4)	2.2 (10)	<0.2 (<1.0)	16.0 (72)	1.6 (7)
8/20/96	3.1 (14)	2.7 (12)	<0.2 (<1.0)	16.0 (72)	2.0 (9)
9/26/96	4.0 (18)	2.9 (13)	<0.2 (<1.0)	16.0 (72)	2.4 (11)
10/30/96	4.2 (19)	2.7 (12)	<0.2 (<1.0)	14.2 (64)	0.9 (4)
11/21/96	1.3 (6)	2.7 (12)	<0.2 (<1.0)	14.7 (66)	1.1 (5)
12/18/96	-----	-----	<0.2 (<1.0)	-----	<0.2 (<1.0)
1/29/97	-----	-----	<0.2 (<1.0)	15.8 (71)	-----
2/19/97	-----	2.4 (11)	<0.2 (<1.0)	16.0 (72)	3.8 (17)
3/25/97	-----	0.4 (2)	<0.2 (<1.0)	10.4 (47)	<0.2 (<1.0)
4/28/97	<0.2 (<1.0)	2.2 (10)	<0.2 (<1.0)	12.7 (57)	<0.2 (<1.0)
5/30/97	<0.2 (<1.0)	2.0 (9)	<0.2 (<1.0)	13.6 (61)	<0.2 (<1.0)
11/18/97	1.6 (7)	2.7 (12)	<0.2 (<1.0)	13.3 (60)	2.2 (10)
12/11/97	2.4 (11)	2.4 (11)	<0.2 (<1.0)	13.1 (59)	1.6 (7)
1/14/98	-----	2.4 (11)	<0.2 (<1.0)	13.3 (60)	1.6 (7)
2/18/98	-----	2.4 (11)	<0.2 (<1.0)	13.1 (59)	0.2 (1)
3/16/98	-----	1.1 (5)	<0.2 (<1.0)	14.0 (63)	<0.2 (<1.0)
4/16/98	<0.2 (<1.0)	0.2 (1)	<0.2 (<1.0)	14.0 (63)	<0.2 (<1.0)
5/20/98	0.4 (2)	0.9 (4)	<0.2 (<1.0)	15.1 (68)	0.2 (1)
6/16/98	<0.2 (<1.0)	2.2 (10)	<0.2 (<1.0)	16.4 (74)	<0.2 (<1.0)
7/20/98	0.4 (2)	2.0 (9)	<0.2 (<1.0)	16.2 (73)	0.9 (4)
8/17/98	1.1 (5)	1.8 (8)	<0.2 (<1.0)	16.4 (74)	1.8 (8)
9/30/98	2.0 (9)	2.0 (9)	<0.2 (<1.0)	14.9 (67)	2.2 (10)

----- no sample collected

APPENDIX IV.

Water quality data from the tile drainage associated with the closed ADWs and the surface water sites.

SITE	DATE	Nitrate mg/L	Nitrate-N mg/L	Ammonia-N mg/L	HERBICIDES Acetochlor µg/L	Alachlor µg/L	Atrazine µg/L	Butylate µg/L	Cyanazine µg/L	Deisopropyl-atrazine µg/L	Desethyl-atrazine µg/L	Metolachlor µg/L	Metribuzin µg/L	Trifluralin µg/L
ADW-DRAIN	1/25/95	63	14.0	0.1	<0.1	<0.1	0.19	<0.1	<0.1	<0.1	0.32	<0.1	<0.1	<0.1
ADW-DRAIN	2/21/95	41	9.0	<0.1	<0.2	<0.2	0.27	<0.1	<0.1	<0.1	0.39	<0.2	<0.1	<0.1
ADW-DRAIN	3/28/95	68	15.0	<0.1	<0.1	<0.1	0.18	<0.1	<0.1	<0.1	0.28	<0.1	<0.1	<0.1
ADW-DRAIN	4/24/95	90	20.0	0.1	<0.1	<0.1	0.20	<0.1	<0.1	<0.1	0.41	<0.1	<0.1	<0.1
ADW-DRAIN	5/24/95	86	19.0	<0.1	<0.1	<0.1	0.21	<0.1	<0.1	<0.1	0.29	<0.1	<0.1	<0.1
ADW-DRAIN	6/14/95	104	23.0	<0.1	<0.1	<0.1	0.35	<0.1	<0.1	<0.1	0.46	<0.1	<0.1	<0.1
ADW-DRAIN	7/18/95	77	17.0	<0.1	<0.1	<0.1	0.31	<0.1	<0.1	<0.1	0.33	<0.1	<0.1	<0.1
ADW-DRAIN	9/21/95	77	17.0	<0.1	<0.1	<0.1	0.23	<0.1	<0.1	<0.1	0.35	<0.1	<0.1	<0.1
ADW-DRAIN	10/16/95	72	16.0	<0.1	<0.1	<0.1	0.22	<0.1	<0.1	<0.1	0.33	<0.1	<0.1	<0.1
ADW-DRAIN	11/16/95	81	18.0	<0.1	<0.1	<0.1	0.18	<0.1	<0.1	<0.1	0.31	<0.1	<0.1	<0.1
ADW-DRAIN	12/12/95	77	17.0	<0.1	<0.1	<0.1	0.16	<0.1	<0.1	<0.1	0.28	<0.1	<0.1	<0.1
ADW-DRAIN	3/19/96	23	5.0	<0.1	<0.1	<0.1	0.16	<0.1	<0.1	<0.1	0.21	<0.1	<0.1	<0.1
ADW-DRAIN	4/16/96	68	15.0	<0.1	<0.1	<0.1	0.21	<0.1	<0.1	<0.1	0.38	<0.1	<0.1	<0.1
ADW-DRAIN	5/20/96	86	19.0	<0.1	<0.1	<0.1	0.17	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
ADW-DRAIN	6/18/96	113	25.0	<0.1	0.78	<0.1	5.10	<0.1	<0.1	<0.1	0.51	<0.1	<0.1	<0.1
ADW-DRAIN	7/16/96	72	16.0	<0.1	<0.1	<0.1	0.43	<0.1	<0.1	<0.1	0.27	<0.1	<0.1	<0.1
ADW-DRAIN	10/30/96	29	6.5	<0.1	<0.1	<0.1	0.11	<0.1	<0.1	<0.1	0.11	<0.1	<0.1	<0.1
ADW-DRAIN	11/21/96	68	15.0	<0.1	<0.1	<0.1	0.23	<0.1	<0.1	<0.1	0.33	<0.1	<0.1	<0.2
ADW-DRAIN	12/18/96	81	18.0	0.2	<0.1	<0.1	0.12	<0.1	<0.1	<0.1	0.28	<0.1	<0.1	<0.1
ADW-DRAIN	3/25/97	54	12.0	<0.1	<0.1	<0.1	0.23	<0.1	<0.1	<0.1	0.24	<0.1	<0.1	<0.1
ADW-DRAIN	4/28/97	81	18.0	<0.1	<0.1	<0.1	0.13	<0.1	<0.1	<0.1	0.23	<0.1	<0.1	<0.1
ADW-DRAIN	5/30/97	99	22.0	<0.1	0.11	<0.1	0.12	<0.1	<0.1	<0.1	0.20	<0.1	<0.1	<0.1
ADW-DRAIN	11/18/97	72	16.0	<0.1	<0.1	<0.1	0.12	<0.1	<0.1	<0.1	0.17	<0.1	<0.1	<0.1
ADW-DRAIN	12/1/97	63	14.0	<0.1	<0.1	<0.1	0.11	<0.1	<0.1	<0.1	0.11	<0.1	<0.1	<0.1
ADW-DRAIN	1/14/98	68	15.0	<0.1	<0.1	<0.1	0.12	<0.1	<0.1	<0.1	0.13	<0.1	<0.1	<0.1
ADW-DRAIN	2/18/98	59	13.0	0.2	<0.1	<0.1	0.15	<0.1	<0.1	<0.1	0.22	<0.1	<0.1	<0.1

SITE	DATE	Nitrate mg/L	Nitrate-N mg/L	Ammonia-N mg/L	HERBICIDES Acetochlor µg/L	Alachlor µg/L	Atrazine µg/L	Butylate µg/L	Cyanazine µg/L	Deisopropyl-atrazine µg/L	Desethyl-atrazine µg/L	Metolachlor µg/L	Metribuzin µg/L	Trifluralin µg/L
ADW-DRAIN	3/16/98	104	23.0	<0.1	<0.1	<0.1	0.12	<0.1	<0.1	<0.1	0.22	<0.1	<0.1	<0.1
ADW-DRAIN	4/16/98	86	19.0	<0.1										
ADW-DRAIN	5/20/98	95	21.0	<0.1	<0.1	<0.1	0.13	<0.1	<0.1	<0.1	0.23	<0.1	<0.1	<0.1
ADW-DRAIN	6/16/98	113	25.0	<0.1	<0.1	<0.1	0.24	<0.1	<0.1	<0.1	0.37	<0.1	<0.1	<0.1
ADW-DRAIN	7/20/98	68	15.0	<0.1	<0.1	<0.1	0.30	<0.1	<0.1	<0.1	0.37	<0.1	<0.1	<0.1
ADW-DRAIN	9/30/98	59	13.0	<0.1	<0.1	<0.1	0.23	<0.1	<0.1	<0.1	0.30	<0.1	<0.1	<0.1
BC-DOWN	11/14/94	59	13.1											
BC-DOWN	12/13/94	69	15.3											
BC-DOWN	2/21/95	18	4.0											
BC-DOWN	3/28/95	73	16.2											
BC-DOWN	4/20/95	74	16.4											
BC-DOWN	5/24/95	72	16.0	<0.1	<0.1	<0.1	0.16	<0.1	<0.1	<0.1	0.22	0.10	<0.1	<0.1
BC-DOWN	6/14/95	90	20.0	<0.1	<0.1	<0.1	0.45	<0.1	<0.1	<0.1	0.32	<0.1	<0.1	<0.1
BC-DOWN	7/18/95	77	17.0	0.2	<0.1	<0.1	0.32	<0.1	<0.1	<0.2	0.24	<0.1	<0.1	<0.1
BC-DOWN	9/21/95	72	16.0	<0.1	<0.1	<0.1	0.23	<0.1	<0.1	<0.1	0.31	<0.1	<0.1	<0.1
BC-DOWN	10/16/95	72	16.0	<0.1	<0.1	<0.1	0.17	<0.1	<0.1	<0.1	0.27	<0.1	<0.1	<0.1
BC-DOWN	4/16/96	54	12.0	<0.1	<0.1	<0.1	0.12	<0.1	<0.1	<0.1	0.17	0.38	<0.1	<0.1
BC-DOWN	5/20/96	72	16.0	<0.1										
BC-DOWN	6/18/96	117	26.0	<0.1	0.17	<0.1	1.90	<0.1	<0.1	0.25	0.28	0.42	<0.1	<0.1
BC-DOWN	7/16/96	33	7.4	<0.1										
BC-DOWN	10/30/96	43	9.6	<0.1	<0.1	<0.1	0.11	<0.1	<0.1	<0.1	0.14	<0.1	<0.1	<0.1
BC-DOWN	11/21/96	77	17.0	<0.1	<0.2	<0.2	0.14	<0.1	<0.1	<0.1	0.26	0.20	<0.1	<0.2
BC-DOWN	12/18/96	77	17.0	<0.1	<0.1	<0.1	0.11	<0.1	<0.1	<0.1	0.20	<0.1	<0.1	<0.1
BC-DOWN	3/25/97	59	13.0	<0.1	<0.1	<0.1	0.10	<0.1	<0.1	<0.1	0.10	0.64	<0.1	<0.1
BC-DOWN	4/28/97	63	14.0	<0.1	<0.1	<0.1	0.13	<0.1	<0.1	<0.1	0.17	0.20	<0.1	<0.1

SITE	DATE	Nitrate mg/L	Nitrate-N mg/L	Ammonia-N mg/L	HERBICIDES Acetochlor µg/L	Alachlor µg/L	Atrazine µg/L	Butylate µg/L	Cyanazine µg/L	Deisopropyl-atrazine µg/L	Desethyl-atrazine µg/L	Metolachlor µg/L	Metribuzin µg/L	Trifluralin µg/L
BC-DOWN	5/30/97	72	16.0	<0.1										
BC-DOWN	11/18/97	77	17.0	0.1	<0.1	<0.1	0.10	<0.1	<0.1	<0.1	0.19	<0.1	<0.1	<0.1
BC-DOWN	2/18/98	54	12.0	0.2	<0.1	<0.1	0.10	<0.1	<0.1	<0.1	0.14	3.60	<0.1	<0.1
BC-DOWN	4/16/98	90	20.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.14	0.30	<0.1	<0.1
BC-DOWN	5/20/98	81	18.0	<0.1	<0.1	<0.1	0.15	<0.1	<0.1	<0.1	0.18	<0.1	<0.1	<0.1
BC-DOWN	6/16/98	99	22.0	<0.1	<0.1	<0.1	0.20	<0.1	<0.1	<0.1	0.18	<0.1	<0.1	<0.1
BC-DOWN	7/20/98	54	12.0	<0.1	<0.1	<0.1	0.23	<0.1	<0.1	<0.1	0.22	<0.1	<0.1	<0.1
BC-DOWN	9/30/98	59	13.0	0.1	<0.1	<0.1	0.14	<0.1	<0.1	<0.1	0.22	<0.1	<0.1	<0.1
TRIB-UP	12/13/94	73	16.2											
TRIB-UP	2/21/95	24	5.3											
TRIB-UP	3/28/95	78	17.3											
TRIB-UP	4/20/95	81	18.0											
TRIB-UP	5/24/95	81	18.0	<0.1	<0.1	<0.1	0.15	<0.1	<0.1	<0.1	0.21	<0.1	<0.1	<0.1
TRIB-UP	6/14/95	95	21.0	<0.1	<0.1	<0.1	0.39	<0.1	<0.1	<0.1	0.33	<0.1	<0.1	<0.1
TRIB-UP	7/18/95	77	17.0	<0.1	<0.1	<0.1	0.31	<0.1	<0.1	<0.2	0.23	<0.1	<0.1	<0.1
TRIB-UP	8/15/95	45	10.0	<0.1										
TRIB-UP	9/21/95	81	18.0	<0.1	<0.1	<0.1	0.21	<0.1	<0.1	<0.1	0.32	<0.1	<0.1	<0.1
TRIB-UP	10/16/95	81	18.0	<0.1	<0.1	<0.1	0.17	<0.1	<0.1	<0.1	0.26	<0. 1	<0.1	<0.1
TRIB-UP	11/16/95	86	19.0	<0.1	<0.1	<0.1	0.15	<0.1	<0.1	<0.1	0.22	<0.1	<0.1	<0.1
TRIB-UP	3/19/96	36	8.0	<0.1	<0.1	<0.1	0.12	<0.1	<0.1	<0.1	0.13	<0.1	<0.1	<0.1
TRIB-UP	4/16/96	72	16.0	<0.1	<0.1	<0.1	0.17	<0.1	<0.1	<0.1	0.24	<0.1	<0.1	<0.1
TRIB-UP	5/20/96	81	18.0	<0.1										
TRIB-UP	6/18/96	126	28.0	<0.1	0.22	<0.1	2.00	<0.1	<0.1	0.15	0.30	0.42	<0.1	<0.1
TRIB-UP	7/16/96	72	16.0	<0.1										

SITE	DATE	Nitrate mg/L	Nitrate-N mg/L	Ammonia-N mg/L	HERBICIDES ---- Acetochlor µg/L	Alachlor µg/L	Atrazine µg/L	Butylate µg/L	Cyanazine µg/L	Deisopropyl-atrazine µg/L	Desethyl-atrazine µg/L	Metolachlor µg/L	Metribuzin µg/L	Trifluralin µg/L
TRIB-UP	8/20/96	22	4.9	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.11	<0.1	<0.1
TRIB-UP	9/26/96	22	4.9	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
TRIB-UP	10/30/96	63	14.0	<0.1	<0.1	<0.1	0.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TRIB-UP	11/21/96	81	18.0	<0.1	<0.1	<0.1	0.14	<0.1	<0.1	<0.1	0.20	<0.1	<0.1	<0.2
TRIB-UP	12/18/96	90	20.0	0.4	<0.1	<0.1	0.10	<0.1	<0.1	<0.1	0.24	<0.1	<0.1	<0.1
TRIB-UP	3/25/97	59	13.0	0.2	<0.1	<0.1	0.12	<0.1	<0.1	<0.1	0.15	<0.1	<0.1	<0.1
TRIB-UP	4/28/97	77	17.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.16	<0.1	<0.1	<0.1
TRIB-UP	5/30/97	86	19.0	<0.1										
TRIB-UP	11/18/97	77	17.0	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.12	<0.1	<0.1	<0.1
TRIB-UP	12/11/97	72	16.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TRIB-UP	2/18/98	63	14.0	0.2	<0.1	<0.1	0.11	<0.1	<0.1	<0.1	0.13	1.10	<0.1	<0.1
TRIB-UP	3/16/98	81	18.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.13	<0.1	<0.1	<0.1
TRIB-UP	4/16/98	113	25.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.13	<0.1	<0.1	<0.1
TRIB-UP	5/20/98	90	20.0	<0.1	<0.1	<0.1	0.13	<0.1	<0.1	<0.1	0.20	<0.1	<0.1	<0.1
TRIB-UP	6/16/98	108	24.0	<0.1	<0.1	<0.1	0.19	<0.1	<0.1	<0.1	0.14	<0.1	<0.1	<0.1
TRIB-UP	7/20/98	77	17.0	<0.1	<0.1	<0.1	0.14	<0.1	<0.1	<0.1	0.14	<0.1	<0.1	<0.1
TRIB-UP	9/30/98	63	14.0	<0.1	<0.1	<0.1	0.15	<0.1	<0.1	<0.1	0.21	<0.1	<0.1	<0.1

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