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Harkin, John M.; Chen-Peng Chen

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Long-Term Transformation and Fate of Nitrogen in Mound-type Soil Absorption Systems for Septic Tank Effluent

A Final Report Submitted to:

State of Wisconsin Department of Natural Resources

by

John M. Harkin

Chen-Peng Chen

Department of Soil Science,

and Environmental Toxicology Center

University of Wisconsin-Madison

Madison, WI 53706

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ABSTRACT

The potential for groundwater contamination by fixed nitrogen forms originating from septic tank soil absorption systems is a widespread and growing concern. This concern is exacerbated by significant difficulties and uncertainties in predicting the long-term transformations and fate of nitrogen in any given soil-based wastewater infiltration system.

Twelve septic tank soil absorption systems of three different designs (conventional, pressurized-dosing, and mound systems) in Wisconsin previously studied in detail were selected for monitoring to assess their performances after years of service in attenuating the contamination of nitrate nitrogen to groundwater. Groundwater in the vicinity of these systems was sampled monthly from June 1993 to August 1994 and analyzed for its contents of total Kjeldahl nitrogen, ammonium nitrogen, and nitrate nitrogen entering from the septic systems. Indicator organisms (total coliforms, fecal coliforms, and fecal streptococci) were also examined to determine any potential threat of biological contamination to groundwater during the summer of 1994. Comparisons were made between data newly obtained and data from corresponding previous studies.

In general, nitrate nitrogen of the groundwater in the vicinity of most systems investigated was effectively reduced to a safe level, i.e. less than the 10mg/L Enforcement Standard, within a distance of 6.3 m (20.7 feet) from the edge of the soil absorption bed. No bacteria were found in the groundwater surrounding each system. Among systems of different designs, mound systems almost completely removed ammonium nitrogen from the septic tank effluent by chemical/bacterial transformation and immobilization during the infiltration of septic tank effluent through the mound and the underlying natural soil. Conventional and dosing systems did not achieve as much

ammonium nitrogen removal as mound systems. In terms of nitrate-nitrogen flux, mound systems generated the highest mean concentration of nitrate nitrogen entering groundwater among the 3 system designs, possibly as a result of biological mat formation at the gravel bed/sand fill interface in older mounds. The attenuation of nitrate nitrogen in groundwater over a distance of 6.3 m from the absorption bed was the most effective in the shallow aquifers with high water tables in the vicinity of mound systems, probably a consequence of increased hydrodynamic dispersion and enhanced denitrification in groundwater under the high water-table condition. With respect to data established in the previous studies, the current performances of most systems were as efficient as their initial operations in terms of nitrogen removal and bacteria attenuation before the treated effluent entered into groundwater. No significant variation in the long-term performance of the systems was observed.

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INTRODUCTION

Septic tank/soil absorption systems are economic alternatives to full-scale wastewater treatment systems for homes in sparsely populated rural areas as well as in numerous suburban counties. Geraghty and Miller (1978) indicated that in the USA there were four counties with more than 100,000 and an additional 23 counties with more than 50,000 septic systems. Septic systems have been indicted as the most frequently reported source of groundwater contamination (USEPA, 1977). Treatment of domestic wastewater therefore is receiving more attention, especially as the land suitable for conventional septic systems continuously decreases nowadays (Reneau et al., 1989).

The majority of septic systems in the USA are conventional gravity-flow systems. This system includes a septic tank, sometimes a distribution box, and a subsurface soil absorption field which may be in the configuration of a bed or an array of parallel trenches. In addition to the conventional design, other alternative systems have been created to selectively place the septic tank effluent (STE) in the soil profile or in fill materials above the soil profile in an attempt to overcome certain soil limitations. One common alternative for this purpose distributes the STE through a low-pressure distribution (LPD) system, i.e. a dosing system. The advantages of a dosing system are that the effluent can be applied uniformly to the soil at a given rate and at specific time intervals so that a better wastewater renovation can be achieved (Degan and Reneau, 1991). Another alternative utilized in situations where the local soils have limitations, e.g. short depth to a high or seasonally fluctuating water table, low soil permeability, or shallow soil underlain with a creviced bedrock, is the mound system. A mound system consists of an artificial mound filled with materials (normally sand) adequate for wastewater purification as an additional treatment before the natural soil is encountered. Harkin et al. (1979) discovered that the mound type system was superior to the conventional system in removing nitrate from the effluent before it entered the groundwater.

Domestic wastewaters contain bacteria, viruses, protozoa, and helminths pathogenic to humans (Burge and Marsh, 1978). Several investigators (Brooks and Cech, 1979; Sandhu et al., 1979) had reported biological contamination in the groundwater due to indiscriminate use of septic systems in soils unsuited for adequate domestic wastewater purification. Pathogenic viruses and bacteria present in the septic tank effluent are of primary concern. Other investigators (Harkin et al., 1979; Converse and Tyler, 1985) indicated that mound systems excellently removed the total and fecal coliforms present in the seepage water, and prevented them from entering groundwater. Stewart and Reneau (1984) also found no movement of bacteria beyond the base of a mound system installed in their experiment after fecal coliform analysis. This indicated that, through a proper dosing regime which results in an adequate rate and volume for wastewater filtration and a careful construction protocol which selects an appropriate design for the local soil formation, biological contamination of the groundwater from the septic system could be eliminated.

Chemical contamination of groundwater from septic tank is another major concern. Among a wide range of potential contaminants in the septic tank effluent, fixed nitrogen forms pose the greatest threat to groundwater because of the mobility of nitrate in soil. Contamination of drinking waters with nitrate increases the risks of methemoglobinemia and formation of carcinogenic nitrosamines (Fox and Harkin, 1985). Due to the aerobic condition in the natural soil underlying a conventional system as a result of unsaturated flow, most of the ammonium and organically-bound nitrogen applied is converted to nitrate nitrogen by nitrification (Bouma, 1979). The nitrate formed then moves readily with the soil solution. Denitrification, the sequential microbial reduction of nitrate to gaseous nitrogen under anaerobic condition, offers the best potential for reducing large quantity of nitrate from leaching into groundwater and transporting to surface water. However, denitrification in believed to be of little importance in a conventional system. The alternatives to the conventional system which use an effluent dosing system generate a fluctuating aerobic/anaerobic environment which promotes the nitrifying and subsequent denitrifying reactions as well as injecting biodegradable organic matter to fuel the denitrification process. In a mound system, nitrification occurs as the effluent moves through the sand fill. The nitrate then is denitrified when it reaches the saturated sand fill/natural soil interface, an anaerobic zone. A study by Harkin et al. (1979) of 33 operating mound systems in Wisconsin found an average of 44% denitrification of the septic tank effluent-borne nitrogen. Through selection of a proper dosing pattern, denitrification could be greatly enhanced in septic systems employing a dosing system.

This project examines the *long-term* ability of septic systems to conduct nitrogen transformations, and the fate in soil-based systems by establishing current data for several representative soil absorption systems of different designs in Wisconsin that were previously studied in detail. Groundwater in the vicinity of the systems was monitored to determine the contents of different nitrogen species entering from the septic systems as well as evaluating the bacteria attenuations by these systems. Comparisons were made between data obtained in this study and from previous studies to establish any change in performance of the systems during operation in the past years.

MATERIALS AND METHODS

Site Selection

Since the purpose of this study is to examine the long-term performance of existing septic tank/soil absorption systems, sites for investigation were therefore chosen from those previously studied in one of the following projects:

1. Groundwater Contamination from Septic Systems Receiving Detergents of Two Types of Formulation (Alhajjar, 1985; Alhajjar et al., 1988, 1989, 1990): A total of 17 systems of three designs (conventional system, pressurized dosing system, and mound system) located in central southern Wisconsin were selected to study the potential contamination of groundwater with nutrients from these systems, depending upon whether phosphate- (P) or carbonate- (CO_3) built detergent was used in households. All systems were installed with groundwater monitoring wells and studied for a period of 2 years. Septic tank effluent (STE) and leachate plume samples were examined monthly. Parameters including indicator bacteria counts (total coliforms, fecal coliforms, and fecal streptococci) and various nitrogen species contents in groundwater were examined. This study concluded that most of the ammonium nitrogen in STE was oxidized to nitrate in soil before reaching the underlying aquifer. Indicator bacteria in effluent did not reach groundwater. This study will be abbreviated as Study 1985 for the rest of the discussion.

2. Evaluation of Mound Systems for Purification of Septic Tank Effluent (Harkin et al., 1979): Thirty-three mound systems installed before October 1976 in Wisconsin were randomly selected

and monitored over a two-year period to determine whether mound systems were designed, installed, and operated according to official state guidelines and whether such systems achieved adequate wastewater purification. Boring samples from the sand fill in the mound and from the underlying natural soil profile were examined to evaluate the attenuation of nutrients and biological indicators through the system. Groundwater in the vicinity of four systems was also monitored to identify the influence of STE on groundwater quality. No evidence of serious bacterial or chemical contamination to groundwater was found from these four systems that were installed on permeable soils above high water tables. Among the fecal indicator organisms examined, it was concluded that total coliforms (TC) and fecal coliforms (FC) were most effectively attenuated in the soil in and below the mounds monitored, while fecal streptococci (FS) and *Pseudomonas aeruginosa* (*Ps. a*) were removed less efficiently. Denitrification removed on the average about 44% of nitrate nitrogen formed in the mound system. This project will be referred as Study 1979 for the rest of the discussion.

3. Ground water Quality Adjacent to a Septic Tank-Soil Absorption System (Polkowski and Boyle, 1970): A soil absorption system constructed in August 1964 serving the Wisconsin Heights High School (WHHS) was examined from 1967 to 1968 to determine its ability to retain or remove nutrients and other indicators of contamination from STE in groundwater. Twenty-four monitoring wells including three piezometer groups (four wells each) were installed so that both longitudinal and transverse dispersion of the leachate plume were determined. Test results showed low counts of coliforms in the groundwater during the summer of 1967. Nitrate nitrogen was found to move effectively through the soil, and traveled laterally with the groundwater flow

with a surge of 21 mg/L at a distance of 15 feet from the tile field during May 1967, probably a result of inappropriate distribution pattern due to the accumulation of effluent in the front header line (distribution pipe) extending from the distribution manhole. Dilution was concluded as the factor responsible for reducing nitrate nitrogen content in the groundwater. Vertical transport of contaminants was found to be limited since the contaminant concentration sharply reduced with increasing aquifer depth as revealed by samples taken from the piezometer nests. This study will be referred as Study 1970 for the rest of the discussion.

Site Location and Description

1. Study 1985: Seventeen septic systems were selected from five counties in south-central Wisconsin: Sites 1, 2, 6, and 16 in Juneau County; Sites 4 and 17 in Adams County; Sites 9, 10, 11, 12, and 13 in Columbia County; Sites 5 and 7 in Marquette County; Sites 3, 8, 14, and 15 in Sauk County. Locations of these systems are shown in Figure 1. Three different types of septic systems were represented in this study; conventional systems at Sites 4 to 8, 13, 16, and 17; pressurized dosing systems at Sites 3, 9, 11, and 12; and mound systems at Sites 1, 2, 10, 14, and 15. Ten of these 17 systems, Sites 1, 3, 6, 8, 9, 10, 12, 13, 14, and 15 were involved in our groundwater sampling (discussed in the Comprehensive Survey section). The soils were previously classified in accordance with the USDA soil taxonomy system (US Dept. of Agriculture Soil Conservation Service, 1988). Soils at Sites 6, 9, 10, and 12 to 14 were classified as Typic or Aquic Udipsamments. A Typic Udipsamment is an excessively drained, rapidly permeable soil that is formed in the sandy outwash of glacial lake deposits. An Aquic Udipsamment consists of deep, somewhat poorly drained, rapidly permeable soil that is

developed in sandy outwash of glacial lake deposits. Sites 3, 5, and 8 have soils that were classified as Hapludalfs; Site 1, Udiaqualf; and Site 15, Haplaquoll. The soil parent materials at Site 3 and 8 were loess overlying calcareous drift; Site 1, sandy outwash of glacial lake deposits underlying loess; and Site 15, loess.

In general, wide expanses of glacial lake deposits of former Lake Wisconsin and Lake Baraboo of mid-Wisconsinan age mantle the bedrock in the study area. Glaciofluvial deposits comprising sediments laid down in ephemeral fresh-water streams also exist in small parts of the study area. Thickness of the unconsolidated material varies from 8 to 40 m at the sites studied. The bedrock is of Cambrian age overlying the igneous and metamorphic rocks of the Precambrian age. The Cambrian rocks are primarily sandstones including some siltstones, shales, and dolomites. They are clean, poorly sorted, fine- to coarse-grained sandstones that are locally well-indurated and cemented by silica and iron oxides.

2. Study 1979: The mound systems examined in Study 1979 were randomly selected throughout Wisconsin. Of the 33 systems selected, twenty-four systems were on sites with seasonally high groundwater (Design 3); six were on sites with shallow bedrock (Design 2); and three on sites with slowly-permeable soils with or without high groundwater (Design 1). Each system was given a code number indicating the system type (Design 1, 2, or 3). Figure 2 shows the locations of these systems. The four systems equipped with groundwater monitoring wells were all on sites with seasonally high groundwater table. System 3-78, the site included in our project for groundwater sampling (discussed in the Comprehensive Survey section), is located on the north shore of Lake Koshkonong in Jefferson County, Wisconsin. The native soil underlying System

3-78 is a Keowns silt loam. This system serves a bar which in general attracts more patrons during the weekends.

3. Study 1970: The Wisconsin Heights High School (WHHS) is located between Black Earth and Mazomanie, Dane County, Wisconsin as shown in Figure 3. Geographically the school sits in the valley of Black Earth Creek. The geology of the basin consists of deeply buried crystalline rocks of the Precambrian age overlain by sedimentary rocks of the Cambrian and Ordovician age. Deposits of outwashed sand and gravel overly the bedrock and the outwash is covered by a few feet of alluvial silt and clay. In general, the soil in this area is composed of 6 to 8 feet of silty-clay over several feet of gravel underlain by sand. The soil surrounding the soil absorption system serving the school is generally a silty clay loam changing to sandy loam with fine sand occurring at the 5-feet depth. It is a Plano series soil, deep, moderately fine-textured, and with a moderate permeability. The moderate permeability should allow time for adsorption and biological action in the aerobic zone, and the underlying sand and gravel should allow efficient transport of the treated effluent to the groundwater.

   The wastewater treatment facilities at the school consist of a wet well equipped with duplicate submersible pumps, a concrete septic tank of the Imhoff design, a siphon-operated dosing chamber and a soil absorption system. The soil absorption system has two header lines extending from the distribution manhole, each header serving approximately one half of the distribution lines. The relative positions of the facilities at WHHS are shown in Figure 4.

A survey regarding the current status of the systems tentative for this study was conducted during the spring of 1993. Since most systems were constructed some 18-23 years ago, it was imperative to identify whether the system had failed and been replaced or not. Although a septic tank soil absorption system has an expected life of 15 to 20 years or longer if installed, maintained, and operated properly, some of these installations might not be candidates available for our study due to several reasons:

1. Termination due to centralization of sewage treatment in the local community.
2. System replacement due to failure caused by inappropriate operation or maintenance.
3. Alteration of system design in compliance with new regulations, or due to change of ownership.
4. The current owner's unwillingness to participate in this study.

To determine the availability of these systems and to obtain information associated with operation and maintenance, a survey was designed involving the following procedures:

1. Review of the records from the previous studies or from local organizations, e.g. the telephone company, libraries, or county code administrators, sanitarians and plumbing inspectors, for any change in ownership of the targeted property or to the original system.
2. Contact of owners or current occupants via telephone inquiry for permission to study their septic systems and for the current status of the original systems when the site information became available. Field visit was conducted if the information about the owner was incorrect

or the owner was not reached by telephone.

3. Interviews with system users to obtain information associated with the pattern of household water use, the number of occupants the system served, and the duration of occupants in the residence. This provided estimates of the hydraulic loading to each system.

Discovery of Wells Installed in Previous Studies

On-site inspection of the system for the remaining monitoring wells previously installed was performed systematically from March 1993 and continued throughout rest of the year. During inspection, patterns of well installation from the previous records were followed to estimate positions of the remaining wells on the property. The followings are brief introductions to the wells and the patterns of installation:

1. Study 1985: Four monitoring wells were installed at each site using Schedule 40, 1.5 inch inner diameter polyvinyl chloride (PVC) pipe manufactured by Timco Company, Sauk City, Wisconsin. The well screens were 30 cm in length and fitted with PVC points, each with four rows of slits 0.15 mm in width, 25 mm long, and spaced 5 mm apart (Timco Manufacturing, Sauk City, Wisconsin). Shallow wells were installed by hand-augering using a 76-mm diameter Soil Conservation Service stainless steel bucket auger and driven to 1 m below the water table using a post driver. After installation, each well was capped with a screw-on top.

   Three interceptor wells for groundwater monitoring were placed in the effluent plume downflow in the hydrologic gradient from the drainfields of each septic system. Wells labeled 1 were 30 cm from the edge of the drainfields and those labeled 2 and 3 were further downgradient at intervals of 3 m. Background (control) monitoring wells were 10 m or more upgradient from the edge of the drainfields at each site. Sites 3 and 8, however, shared the same background well located on Site 8 because they are next to each other. Figure 5 and 6 show the representative geometry of the monitoring network for the conventional/pressurized dosing system and the mound system respectively. Records for the precise direction of the local groundwater flow, and correspondingly, of the downgradient interceptor network was however unavailable. Extensive visual inspection and some soil excavation had to be conducted in some case where the installation plan did not enable us to locate a well.

2. Study 1979: Four mound systems with high groundwater (3-47, 3-72, 3-78, and 3-82) were installed with groundwater sampling wells using the same PVC well casings as described in Study 1985. However, the well screen had four 1-foot rows of 3/16 inch holes drilled 1 inch apart covered by a layer of Dupont Style 3404 Typar. Typar is a polypropylene filter fabric with an effective pore size of 120 μm and used to prevent the aquifer sand from entering the well screen. The wells were driven into the soil to a minimum of one foot below the water table to insure the samples could be obtained from the wells throughout the year. All wells were capped with a threaded PVC fitting and closed with a PVC cap. The positions of the monitoring wells, direction of groundwater flow, and absorption area for System 3-78, the only site used from this study, are shown in Figure 7.

3. Study 1970: The direction of the groundwater flow in the vicinity of WHHS is northerly and parallel to the railroad on the right of the drainfield. Twenty-four monitoring wells were installed

by the Geology Department of the University of Wisconsin (4 wells) and the Dane County Highway Department (20 wells) with hand-augering or with a pavement breaker machine when the hand driven method proved unsuccessful. The wells were 1-1/4 inch inner diameter black iron pipes jointed by couplings with sand points fitted at the lower end. Emergent pipes were left above the ground surface and screw-caps of the same material as the well casing were used to secure the installed wells. The wells were placed above, below and adjacent to the drainfield with most of the wells located on the downgradient side of the field to evaluate the horizontal transport of contaminants in the leachate plume. To measure vertical dispersion of the wastewater constituents, three piezometer groups with four wells each were constructed downgradient from the field. Each of the four wells in these groups was placed at a different depth below the prevailing groundwater surface. A total of 16 wells were discovered on the site, and their relative positions to the wastewater treatment facilities are shown in Figure 8.

Whenever the inspection following the installation patterns was unsuccessful, the local groundwater flow direction was determined using the method described by Heath (1982) to obtain a more accurate estimate of the well location. Wells discovered were subsequently labelled with the Wisconsin Unique Well Numbers in compliance with regulations of the Wisconsin Department of Natural Resources Water Resources Management Program.

Sampling Techniques

General features

Septic tank effluent (STE) and groundwater from the monitoring networks were sampled monthly from June 1993 to August 1994 at sites with monitoring wells successfully reconstituted. The depth of groundwater table from the ground surface in each well was also measured during the sampling period. Each month, samples were analyzed for total Kjeldahl nitrogen (TKN), ammonium nitrogen (NH_4-N), and nitrate nitrogen (NO_3-N) contents. During June and August of 1994, STE and groundwater were also sampled for bacteriological analyses including total coliforms (TC), fecal coliforms (FC), and fecal streptococci (FS) determinations.

Water Table Measurement

The depth of the water table in each well from the land surface was measured prior to groundwater sampling during each visit using a Solinst electrical groundwater measuring tape to determine the seasonal fluctuation of groundwater in the vicinity of each system. The probe of the measuring tape was rinsed with distilled water before and after measurement to avoid cross-contamination between monitoring wells. A "popper" (a plastic cylinder with a concave base which emits a popping sound when it impinges on a water surface) was used as an alternative when the electrical equipment randomly malfunctioned during January 1994, probably caused by the unusual near-record low temperature in that month. To verify the direction of local groundwater flow that cannot be determined by the gradient of water-table depth readings between wells at each site due to topographical changes, all depth values measured were transformed and reported as the vertical height of water table in each monitoring well relative to a local fixed datum. The datum selected at each site is the base of the monitoring-well screen at the lowest elevation among all well screens. To compensate for the influence of topographical variation on depth readings during data transformation, height gradients among well tops on ground surface at each site were surveyed using a Carl-Zeiss Ni2 level equipped with a stadia diaphragm and horizontal circle following the height of collimation method described by Ritchie et al. (1988).

Septic Tank Effluent and Groundwater Sampling

At sites with systems having a STE dosing pump, i.e. the mound and pressurized dosing systems, STE samples were taken by a gas and vacuum pump fitted with Masterflex silicone tubing dipped directly into the pumping chamber through a manhole. For the conventional systems from Study 1985, a STE sampling device had been previously installed by inserting a 1-cm diameter plexiglass tube into the effluent beyond the outlet baffle within the septic-tank itself and cementing the tube into the cleanout plug of the tank. A Tygon tubing was attached to the plexiglass tube and stored in a receptacle flush with the ground. However, such a construction was probably removed or deeply buried and thus not found at Sites 6 and 8, consequently STE was not sampled from these two systems. Samples were withdrawn through these tubes using a Cole-Parmer peristaltic pump connected with a Masterflex silicone tubing flushed five times prior to sample collection. All effluent samples were collected in 500-mL Nalgene bottles previously washed with acid and distilled water, and rinsed three times with STE.

For groundwater sampling, water was pumped from each monitoring well before collection using the Cole-Parmer peristaltic pump and different acid-washed Masterflex tubing until a clear sample could be obtained or at least until three to five times the volume of the well had been removed. This ensured that the sample came from the groundwater and not from the stagnant water in the well. Water samples (approximately 400 mL) were collected in new 500-mL Nalgene bottles washed with acid and distilled water, and rinsed three times with water from the well. Wells were sampled in the sequence: Background well (BG), 3, 2, then 1. Each sample was chilled in ice in an insulated picnic cooler during transport to the laboratory, where it was refrigerated at 4°C for analysis within 12 h after sampling for bacterial analyses, for chemical analyses if completed immediately or frozen for later analysis (within 3 days).

Analytical Methods

Nitrogen Analyses

Total Kjeldahl nitrogen (TKN) was determined using the semimicro Kjeldahl procedure described by Bremner and Keeney (1966). This method involves the digestion of 5 mL of effluent or 20 mL of groundwater with 3 mL of concentrated H_2SO_4 and 1.1 g of a potassium sulfate-catalyst mixture. Determinations were made by adding 15 mL of 10N NaOH and steam distilling the NH_3 formed into a boric acid indicator solution. The boric acid solution was then titrated with standardized H_2SO_4 using a Brickman digital buret.

Ammonium and nitrate nitrogen (NH_4-N, NO_3-N) were determined using direct steam distillation of 5 mL of effluent or 20 mL of groundwater as described by Bremner and Keeney (1965). The sample was treated with 1.1 g of MgO to release NH_3 which was distilled into 5 mL of a boric acid indicator solution. The addition of Devarda's alloy reduces the NO_3-N to NH_3, which was then collected in the boric acid indicator. Both solutions were then titrated with standardized H_2SO_4 using the Brickman digital buret.

Bacteriological Analyses

Total coliforms, fecal coliforms, and fecal streptococci populations were examined to investigate any transport of bacteria from STE to groundwater. Prior to sampling, sample bottles were wrapped with aluminum foil around the cap and neck and autoclaved with the Masterflex sampling tubing at 121°C for 15 minutes. After sampling, all samples were placed in ice for transport to the laboratory, where they were refrigerated at 4°C and processed within 12 h for bacteriological analyses. Bacterial analyses on STE and groundwater samples were performed using the membrane filtration techniques described in Standard Methods (1992). When appropriate, effluent samples were diluted/rinsed with sterilized pH 7.1 phosphate buffer prior to filtration with sterilized Millipore 47 mm Type HA/HC membrane filters. Filtered membranes were loaded with media and incubated 24 h at 35°C for total coliforms, 24 h at 44.5°C for fecal coliforms, and 48 h at 35°C for fecal streptococci using a Millipore portable single chamber incubator. Bacterial counts after incubation were expressed as the most probable numbers per 100 mL of liquid (MPN/100 mL).

RESULTS AND DISCUSSION

Survey Results

The survey was first conducted from November 1992 to June 1993. During the summer of 1994 a follow-up was performed at sites not reached during the first survey. Owners/users of 32 systems were successfully contacted among a total of 51 sites (15 of 17 from Study 1985; 16 of 33 from Study 1979; and the Wisconsin Height High School from Study 1970). Information collected regarding the current status of each system is tabulated in Table 1. Most systems reached are still operating, and no major maintenance or repair problems occurred in the past according to the owners. New information on hydraulic loading rate/volume in each system was not obtained since most owners had already removed the flow meter installed during previous studies.

Among sites from Study 1985, thirteen agreed to participate in this study. S-5 originally consented and withdrew later in January 1994 due to the owner's concern about privacy and any potential damage to property landscaping. Information for S-5 was still kindly provided. S-11, a dosing system, failed during mid-1992 and use was stopped. Ponding at the absorption field was the probable cause since surface run-off was observed during the site visit. The owner claimed that the system would be replaced by the summer of 1993. S-11 was not included in our groundwater sampling since no monitoring well was found around the system. In general, an average of 2.4 adults and 1.0 child (40 adults and 17 children for 17 sites) regularly resided at each site during the period of investigation in Study 1985. However, these figures reduced to an average of 2.2 adults and 0.4 children per site (31 adults and 6 children for 14 sites). Based on this occupancy information, a decline in hydraulic loading to the septic systems at each site compared to the loading during their initial operations can be assumed. Occupants at some sites stayed there only seasonally, and thus made even lower use of the systems.

In comparison with Study 1985, fewer sites were successfully located and reached in Study 1979. This might be a result of higher rate of household ownership change since more of the old records from Study 1979 were found out-of-date compared to that of Study 1985 during our verification effort. Among systems reached, four (2-243, 3-69, 3-73, and 3-123) decided not to participate in this study. Use of two systems had been terminated: 3-67 during 1989-1990 due to replacement and 3-82, one of the four sites with groundwater monitoring networks, during 1986 due to hookup of the household to a community sewage treatment. System 3-78, the other groundwater-monitored site from Study 1979 located in south Wisconsin, was successfully contacted; the original mound system was still operating, and thus was included in groundwater monitoring. Accurate occupancy data at this site was not achieved since System 3-78 served a tavern which routinely attracted uneven numbers of patrons during weekends and/or week nights.

The system serving Wisconsin Heights High School was unique in the way that the system received little use regularly during school recesses. Although Polkowski and Boyle (1970) indicated that the mottled soil condition under the trench bottom might keep the drainfield anaerobic and thus more subject to biological clogging and ponding, the long-term intermittent dosing pattern resulting from school recesses might help to decrease the chance of system failure since the soil absorption system could recover from saturation. This hypothesis was partly supported by a recent field observation (Parker, 1993) that complete saturation had not occurred within 3 feet of the bottom of the trenches. The school had an average of 450 persons during 1967 (the evaluation period for Study 1970) and 310 during 1993. The hydraulic load, however, should not be determined based on the number of students attending school since the system received frequent use only during the day for 5 days per week during school opening and therefore the actual loading from school attendants might be even less than what could be expected for a loading from household occupants of the same number.

Polkowski and Boyle (1970) reported that the effluent flow at WHHS was found to bypass the majority of the field in the fall of 1967 and dosed only the farthest two absorption lines. They speculated that the accumulation of effluent in these two tile absorption lines might be a result of a faster settlement of the two header lines than the tile field, which consequently caused the positions of these two header lines lower than the adjacent soil absorption lines. The last two absorption lines were installed lower than the remainder of the field and therefore received most of the flow.

However, this was not observed during the later inspection by Parker (1993). Polkowski and Boyle concluded that as the soil became clogged due to the increased use through late fall, the remaining tile lines would likely be utilized to a greater extent.

An on-site inspection was performed on February 15 and 16, 1993 by Parker and Associates, Inc. to evaluate the condition of the present system and determine if it could handle additional wastewater load generated by a proposed school building project for about 400 more students. The septic/Imhoff tank appeared to be functioning properly. The effluent distribution manhole was found to be ponded above the outlets and there was about 27 inches of STE ponded in the vent closest to the distribution manhole while the far vent was dry. Relative positions of these facilities are shown in Figure 4. This indicated that the closest drainfield was completely saturated while the other was receiving little wastewater (or allowing it to percolate effectively). Blockage of the outlet pipe to the far field was presumed. Over 1000 gallons of effluent was pumped from the distribution manhole, including flowback from the ponded drainfield, and the outlet pipe to the far field was cleaned by jetting on February 16, 1993. It was concluded that the existing system appeared to be operating properly but was loaded at near capacity. For long-term use, new septic tanks would be needed for the proposed building addition. Since suitable soil area is quite limited, a mound system would probably be required.

In general, most systems surveyed now have lower occupancy than when the previous study was performed. Proper operation and maintenance of the system, compared with other factors, plays a critical role in preventing system failure caused by hydraulic overloading, and increasing the long-term performance of the system.

Discovery of Wells Installed in Previous Studies

The fifteen sites where monitoring networks had been previously built and where access permission was granted were inspected from March to December 1993 for wells remaining available for study. This process turned out to be more complicated and time-consuming than originally contemplated since some wells were either buried to various depths under the ground surface, e.g. 15-20 cm below the surface for Wells 1 and 3 on Site 10, or removed by the previous/current owners or investigators. Use of Ground Penetrating Radar (GPR) owned by the Soil Science Department of the University of Wisconsin was originally planned for locating the wells. However, this plan was abandoned since GPR did not have a high enough resolution for wells vertically installed and with casings made of PVC pipes, as was the case to most of our monitoring wells. For sites with one or more wells found by visual inspection or by assistance of current residents, the pattern of well installation in the vicinity was followed to locate other remaining wells through further inspection and/or excavation. Wells on Sites 3, 6, 9, 12, 13, 3-78, and WHHS were discovered following this guideline. In cases where no well was located by visual inspection, local groundwater flow direction was firstly determined following the method described by Heather (1982) in order to obtain a more precise estimation for the area where our further effort should be directed. Wells on Sites 1, 8, 10, 14, and 15 were in this category. However, no well was found in Sites 7, 11 and 17 probably due to either the failure of our locating strategy or the removal of wells by the previous owners/investigators at the end of previous projects. These three sites were therefore excluded from further groundwater monitoring. At the WHHS, originally 18 wells were located. Two (one next to Wells 12 and 14 and the other 3 feet northwester of Well 8) were excluded later from groundwater sampling since their casings were found to be badly broken and the wells were completely plugged;

consequently no groundwater could be withdrawn from them. From March to December 1993, a total of 60 functioning wells had been rediscovered and labelled with the Wisconsin Unique Well Number (WUWN). The WUWNs corresponding to each well are shown in Table 2. Two monitoring wells on Site 13, Wells 1 (GP439) and 2 (GP440), were removed from the property during May 1994. These two wells were located in the middle of a path leading to a privately-owned antique museum, and the owner considered that reactivation of the wells might cause inconvenience to the visiting customers. Data from these two wells were not available after this date.

Water Table Measurement

Data for the monthly depths of the water table in each monitoring well from the land surface at each site are included in Appendix I, and also transformed and plotted as the monthly heights of the water table in each well relative to the local datum at each site to obtain information on the seasonal fluctuations of the water table in the vicinity of systems examined. Figure 9 and 10 are representative of the situation; the other plots (see Appendix II) exhibit similar patterns.

In general, the water table at the sites studied was generally within 12 ft, and not more than 16 ft (WHHS) from the land surface. Groundwater levels in the monitoring wells (Figure 9 and 10) fluctuated with a maximum of 102 cm/yr (40 inches/yr), with a decline in fall 1993 (August through September), a winter low period (November 1993 through January 1994), a spring rise (February to April 1994), another decline during summer (May to July 1994), and a slow increase at the end of August 1994. Presuming that the monthly water use in the households remained steady, fluctuations in the groundwater levels probably were due to climatic factors. Alhajjar (1985) indicated that the gravel bed/sand fill interface in a mound system and the absorption bed/natural soil interface in a conventional system usually restrict the volume and rate of the effluent percolating onto groundwater, consequently the recharge of groundwater by the cleaned effluent would have only limited influence on the water table fluctuations compared to the climatic factors. In general, the rise of water level during the spring was in response to the recharge from snowmelt and rainfall. The recharged groundwater then declined slowly throughout the summer because most of the precipitation was significantly evaporated by the high atmospheric temperature or transpired by plants and thus did not percolate into the underlying aquifer. Devaul and Green (1971) indicated that approximately 61.7% of rainfall in this area was lost as evaporation, and a net loss of water from the soil in the summer was observed. The small rise occurred following the summer decline was probably due to the recharge from fall rains, and the decline during the winter was reflecting the storage of precipitation on the land surface as snow. The groundwater levels were lower in the summer of 1994 than those in 1993.

Nitrogen analyses

Nitrogen (N) contamination of groundwater from septic system is of primary importance because N transformations within a septic system absorption field can cause leaching of nitrate into underlying groundwaters serving private and public wells. Nitrate nitrogen in potable water supplies are limited by law (Wisconsin Dept. of Natural Resources, 1994) to less than 10 mg/L since high nitrate may lead to methemoglobinemia in infants (Shuval and Gruener, 1972; Delfino, 1977).

Nitrogen forms in domestic wastewaters are primarily ammonium-N and organically-bound N: An average N content of 40-80 mg/L in Wisconsin wastewaters was suggested (IES, 1979). The major sources of N to a septic tank are feces and urine which contain urea, uric acid, ammonia, undigested proteinaceous foodstuffs, and bacterial septic cells (Witt et al., 1975). Upon entering an anaerobic septic tank, the transformation of N begins with the breakdown of organically bound N by microbial enzymes such as proteases, ureases, and deaminases. The resulting N products in the septic tank are predominantly ammonium and organic N; Otis et al. (1975) gave proportions of 75% and 25%, respectively, for these forms in STE. Harkin et al. (1979) reported that the effluent N in 33 monitored mound systems was primarily NH_4-N (64%), and organically bound (35%). Only 1% of the N in STE was NO_3-N. This indicated an anaerobic situation in the pump chamber, and that the nitrate found in the soil absorption field was the result of nitrification of the N in the effluent in the absorption field under aerobic conditions. In our study, an average of 79.4% NH_4-N, 13.4% organically-bound N, and 7.2% NO_3-N were found in the STE from ten septic systems monitored. Since all the systems from which STE was successfully sampled except that at Site 13 employed a dosing chamber, the relatively high NH_4-N and low organically-bound N level proportions might indicate a higher efficiency of anaerobic decomposition of organic-N in the septic tank/pump chamber combination, while the higher NO_3-N might be a result of aeration during spill over into or residence in the dosing chamber. The manhole covers on the systems serving Sites 1, 3, 9, 10, 14, and WHHS were either not tightly fitting on the manhole or damaged/cracked to various extents. Replacement of the cover with a locking device might reduce air access to the dosing chamber, but may not be necessarily beneficial. Nitrification-denitrification during septic tank/pumping chamber transfers may reduce N loadings to the absorption field.

Results of the NO_3-N, NH_4-N, and TKN contents in the STE or groundwater sampled from each monitored site are tabulated in Appendix I. Figures 11, 13, 15, and 17 show the mean concentrations of various nitrogen species in the STE and the groundwater from the four monitoring wells; Figures 12, 14, 16, and 18 exclude the STE data and show the means for the groundwater samples only to demonstrate the changes in groundwater N contents over distance.

Figures 11 and 12 show the mean TKN in the groundwater and/or STE samples from each monitored system except for WHHS. Table 3 compares the mean STE TKN contents for each system with values from the previous studies. Systems showed an increase of STE TKN content except at Sites 3, 10 and 12; this increase, however, did not result in a higher TKN content of groundwater in the vicinity of each system when compared to previous studies. In comparison with values obtained during previous examinations, Sites 3, 6, 10, 12, 13, 14, and 15 exhibited either lower or similar TKN levels in all monitoring wells. Site 1 had a higher TKN in Well 1, but, lower values in Wells 2 and 3. At sites 8, 9 and 3-78, although TKN in all monitoring wells were slightly higher than the recorded values, TKN contents decreased rapidly over a distance of 3.3 m (Sites 8 and 9) or 8.13 m (Site 3-78) from the edge of the absorption field to a value below the 10 mg/L Enforcement Standard (ES), for NO_3-N. Thus, the ES would not be exceeded at a distance of 6.3 m (20.7 feet; the distance to Well 3 from the drainfield at sites from Study 1985) or 8.13 m (26.8 feet; the distance to Well 1 from the drainfield at Site 3-78) from the absorption field, even in all the TKN were converted with loss to NO_3-N. In contrast, Site 3 presented a case where the groundwater TKN content in the immediate vicinity (Well 1) of the drainfield was lower than that from the early data, while higher concentrations were observed in the further downgradient monitoring wells (Wells 2 and 3). The TKN value at a distance of 6.3 m from the drainfield was approximately 5 mg/L, thus did not pose a concern of violating the NO_3-N ES. In general, most systems included in our study had a starting TKN level (Well 1) close to 10 mg/L, followed by a decline to a level below 8 mg/L at a distance of 6.3 m (Well 3). Systems 14 and 15 (mound systems) had the highest starting TKN concentrations, mostly in the form of NO_3-N (discussed later), probably due to the short percolating distance for the transformed nutrients from the distribution bed (gravel/sand fill interface) to the high groundwater table. Since TKN concentrations in Well 3 at both sites were lower than 10 mg/L, these two systems consequently represented the cases of most rapid TKN attenuation by the groundwater in the vicinity of the septic systems.

Figures 13 and 14 show the mean concentrations of NH_4-N in the groundwater and/or STE from each site except for WHHS. Most sites had groundwater NH_4-N values in the vicinity of the examined systems close to the background levels. Systems 12 and 13 had higher groundwater NH_4-N contents than their backgrounds at different distances (over 3 and 4 mg/L at Wells 1 and 3 respectively in Site 12; over 3 mg/L at Well 1 in Site 13). However, similar patterns were also observed in Study 1985. This might indicate a saturated condition of the soil underlying the drainfields of these two dosing systems. Harkin et al. (1979) indicated that an inappropriate dosing regime, i,e. higher dosing volume and frequency than the capacity designed, might contribute to the quasi-saturation of the soil absorption field in a pressurized dosing system, and correspondingly mobilize NH_4-N to travel further in the underlying soil. However, since the values observed were not substantially higher than the background values, these might also be a result of variation in the local soil-biota or use of lawn fertilizers (as was the case at Site 13). In general, most systems studied functioned well in terms of NH_4-N removal through nitrification and cation absorption in the drainfield and the underlying soil.

Figures 15 and 16 show the averages of NO_3-N contents in the groundwater and/or in the STE from each site except WHHS. All systems from Study 1985 had NO_3-N contents in groundwater at a distance of 6.3 m from the absorption field (Well 3) as well as System 3-78 at a distance of 8.13 m (Well 1) lower than the 10 mg/L ES level. Sites 1, 9, 14, and 15 had mean groundwater NO_3-N contents higher than ES in the immediate vicinity of the absorption fields (Well 1; 0.3 m ≈ 1 foot from the edge of the absorption bed). Sites 14 and 15 also had values exceeding 10 mg/L at a distance of 3.3 m (≈ 11 feet) from the drainfields (Well 2). However, higher concentrations at Well 1 were expected since this well was assumed to indicate the entering concentrations of NO_3-N onto shallow aquifer, and thus did not pose a potential of severe contamination to groundwater, given that the observed spatial attenuation of groundwater NO_3-N in the vicinity of these sites was still highly effective. Sites 14 and 15, among all systems, had the highest concentrations of NO_3-N entering the aquifer from the sources as well as the fastest rates of dissipation in the groundwater. The intrusion of high NO_3-N percolate into groundwater observed at these two sites were also reflected in the corresponding TKN changes discussed earlier (see Figures 12). The NO_3-N concentrations observed in all wells at these two locations were not higher than the corresponding values obtained in Study 1985. This reveals that, during the near 20-year operations, these two mound-type systems had retained at least the same level of efficacy in denitrifying the STE-borne NO_3-N before it was distributed in groundwater. Sites 6, 10, 12, 14, and 15 had lower mean NO_3-N contents in all wells monitored compared to their counterparts in the earlier study. Sites 1, 8, 9, and 3-78 had slightly higher NO_3-N concentrations (in Well 1 only for Site 1 and in all wells for Sites 8, 9, 3-78) than the previously recorded values. However, the variations were not significant enough to constitute a change of performance for these systems during the operation in the past. S-13 presented a case where a higher concentration at a farther downgradient location (Well 3) was observed. In addition, an occasional NO_3-N surge rather than a consistently high value in samples from this well was what was observed during monitoring. It is not known that whether the occasional high value observed at this location was due to another source of NO_3-N introduction other than the STE, or the inconsistence of the local groundwater flow around Well 3. On-site inspection revealed that Well 3 at Site 13 was close to a privy pit of an old homestead house.

Figures 17 and 18 show the mean TKN, NH_4-N, and NO_3-N contents in the groundwater and/or in the STE samples from the WHHS. NO_3-N averages in all wells were under 2 mg/L. Higher NH_4-N (4-5 mg/L compared to the normal level of 1-3 mg/L), and correspondingly higher TKN (6-7 mg/L compared to the normal level of 3-5 mg/L) were found in Wells 11, 14, and 16. This might reflect saturation in the drainfield and the underlying natural soil. Parker (1993) found an accumulation of STE in the header line close to the manhole while the front header line received little effluent during February 1993. Polkowski and Boyle (1970) also reported that the soil underlying the drainfield at WHHS might become saturated at a depth of 5 feet. Seasonal saturation of the drainfield/underlying soil could therefore be expected during the regular school operation and the winter, but off-site migration of TKN or NO_3-N levels leading to ES exceedences is extremely unlikely.

Wells 7, 11, and 12 (adjacent to the farther side of the front drainfield cell) had higher mean NO_3-N levels in Study 1970 (8.82, 6.99, and 6.76 mg/L for Wells 7, 11, and 12 respectively). Polkowski and Boyle concluded that this might be a result of the settlement of the header line to a position lower than the drainfield except in the area containing these wells, which eventually led to the overdosing of STE in the far drainfield cell. However, this situation was not observed in our study probably due to blockage of the header pipe to the far field as indicated by Parker's inspection. In general, groundwater monitored in our study presented groundwater quality close to or higher than that observed in Study 1970. The long-term performance of this system, however, might be in question given the possibility of a line blockage and the increasing loading contributed by the proposed building in the future.

A temporary surge of NO_3-N above 10 mg/L in the groundwater was found at Sites 3 and 8 (Well 1), 1, 14, and 15 (Wells 1 and 2), and 9 and 12 (Wells 1 to 3) from the late spring (April) to the mid-summer (July) of 1994 (see Appendix III). This might be a result of delayed increase of nitrification/denitrification activity in the soil absorption system due the unusually low temperatures in the 1993 winter and the late onset of the 1994 spring. The low temperature might slow the percolation of STE as well as lower the activity of N-transforming microbial enzymes and thus cause TKN accumulation in the drainfield before conditions became adequate for more rapid nitrification again in spring. Harkin et al. (1979) indicated that in general, in the sand fill of mound systems, the total organic carbon (TOC) and TKN increased during the winter, and returned to approximately previous levels during warmer weather. Upon return to warmer weather, TKN decreases sooner than TOC since bacteria incorporated N quickly when abundant organic carbon is available (Paul and Clark, 1988). Brown et al. (1977, 1978) found mean NO_3-N values above 10 mg/L in septic system seepage collected from lysimeters packed with sandy loam only during one summer over a period of 2 years. In addition to the enhancement of N-transforming microbial activity, the lower water tables under the absorption fields of these systems during the dry season also increased the unsaturated zone, consequently expanding the region for nitrification. Scrutiny of the groundwater NH_4-N in the wells, as discussed above, revealed that, except for Sites 9 and 12, NH_4-N in groundwater in months with high NO_3-N values was lower than that in other months, indicating higher rates of nitrification in the unsaturated zone (assuming that the proportion of STE-derived NH_4-N flux immobilized by cation exchange in the unsaturated zone remained constant). Reneau (1979) noted that the NO_3-N in groundwater was greatest as the water table rose in the fall, dissolving NO_3-N largely formed during the summer. Since the NO_3-N values slowly returned to normal levels after July, the surge of NO_3-N observed in our study probably represented a seasonal variation of the systems rather than a sign of malfunction.

Figures 19, 20, and 21 show the mean concentrations of TKN, NH_4-N, NO_3-N in the groundwater at sites with 3 system designs. Sites WHHS and 3-78 are excluded from the comparison since the geographical distribution of monitoring wells at the WHHS and the distance intervals between interceptor wells at System 3-78 (8.13 m≈27 feet between the edge of drainfield and Well 1; 5.18 m≈17 feet between Wells 1 and 2 and Wells 2 and 3) are at variance with those from Study 1985.

In general, NH_4-N levels in groundwater downgradient from the drainfields of conventional systems and dosing systems were higher than levels in the upgradient groundwater (2.06 mg/L in Well 1 vs. 1.21 mg/L in Well BG for conventional systems; 2.05 and 2.28 mg/L in Wells 1 and 3 respectively vs. 1.52 mg/L in Well BG for dosing systems). In contrast, mound systems sites did not release any substantial NH_4-N into groundwater downgradient from the systems. The distribution of STE-derived NH_4-N into groundwater by conventional and dosing systems may indicate higher rates of saturation of the soils underlying the drainfields of conventional and dosing systems compared to that of the fill materials in mound systems, possibly as a result of inappropriate dosing regimes and/or low percolation rate of the underlying soils. In a study of 15 septic systems comprising both conventional and dosing designs (Cogger and Carlile, 1984), systems continuously or seasonally saturated by high water tables released more NH_4-N to groundwater than others which were not. Mound systems performed best here in terms of NH_4-N removal from the STE percolate. This indicates that in general the fill materials in the mounds functioned properly, consequently providing an aerobic environment and facilitating the nitrification reaction. Mound fills in general have a porosity not less than that of the natural soils, thus will be less saturated than the soils underlying conventional and dosing systems even in the event of overdosing or formation of biological mats at the gravel bed/sand fill interfaces. The groundwater NH_4-N in the vicinity of conventional and dosing systems did not exceed 3 mg/L, levels likely to be retarded by aquifer sediments rather than move simultaneously with the groundwater NO_3-N plume. Ceazan et al. (1989) found in a sand-and-gravel aquifer that sewage-derived NH_4-N was retarded (retardation factor, R_f=2.0) as a result of cation exchange in the aquifer evidenced by the concomitant release of calcium (Ca^{2+}) , magnesium (Mg^{2+}), and sodium (Na^{+}) from aquifer sediments.

Comparisons between the mean TKN and NO_3-N in groundwater showed that, in general, most TKN in groundwater was in the form of NO_3-N. NO_3-N in the groundwater underlying systems of all 3 designs was lower than the 10 mg/L ES level at a distance of 6.3 m (20.7 feet) from the edge of the absorption field. Among different system designs, the levels of NO_3-N entering groundwater from the drainfields (concentrations at Well 1) were found to increase in the sequence of conventional, dosing, and then mound systems. Similar results for conventional and dosing systems were reported by Cogger and Carlile (1984). Among the 15 systems studied in North Carolina, the mean NO_3-N level of groundwater in the vicinity of conventional systems was lower than that of dosing systems at distances of 1.5 (4.9 feet) and 7.6 m (24.9 feet) from the edge of the absorption field. Cogger and Carlile concluded that this was a result of enhanced aerobicity in the natural soils underlying dosing systems contributed by the intermittent-dosing pattern. Compared to conventional and dosing systems, mound systems in our study generated the highest mean NO_3-N level in Well 1 even though a dosing mechanism was employed. This indicates that, after operation for a long period, the mound system might have had a biological mat formed at the gravel bed/sand fill interface, which subsequently eliminated the saturation between the artificial mound and the natural soil profile, reducing the efficiency of denitrifying NO_3-N built up in the mound before it penetrated into the natural soils, and eventually moved into groundwater.

In a conventional septic system, the STE trickles out of the septic tank and flows by gravity into the soil absorption field in a random pattern. As a result of this uneven flow, an organic crust rapidly forms at the absorption field/underlying natural soil interface and tends to pond STE in the seepage trench or bed (Harkin et al., 1976). In time, the crust slows infiltration into the natural soil and allows only unsaturated flow beyond the crust. The crust serves as an excellent filter medium for the removal of bacteria and the immobilization of ammonium nitrogen by bacteria (Walker et al., 1973a, b). A mound system does not tend to form this clogging mat if the dosing rate and volume are followed as the guideline specified (Harkin et al., 1979). However, with two or more years of operation, a heavily loaded mound system may slowly form a crust at the gravel/sand fill interface. Once the clogging mat is formed, the mound system will perform similarly to a conventional system: pursuing better bacterial attenuation by the crust, decreasing denitrification for the NO_3-N built up within the crust due to the loss of saturation at the mound/natural soil interface, and reducing the inputs of fresh carbon from STE surges for bacterial immobilization of NH_4-N since only unsaturated flow will be permitted in the sand fill under such conditions. Assuming that the discussed clogging mats had formed in the mound systems examined in this study, the entrance of higher concentrations of NO_3-N into groundwater from mound systems than from conventional systems would be expected, since most mound systems studied were underlain with high water tables and thus would be disadvantaged in terms of NO_3-N attenuation during the movement of STE in the soils.

A study (Murphy, 1992) investigating the contamination of public supply and private drinking-water wells by NO_3-N in Burlington and Mercer Counties, New Jersey found a median NO_3-N concentration of 1.23 mg/L from all wells sampled (concentrations ranging from below detection to 22.2 mg/L) at a distance of 15 m (50 feet) from the septic system, and 13 percent of the wells had elevated nitrate levels above 10 mg/L. Most samples with significantly higher NO_3-N levels were from the shallow wells (well depths lower than 15 m) rather than from deep wells (depths ranging from 16 m~53 feet to 244 m~800 feet). With data from the deep wells excluded, the median NO_3-N concentration was found to be 2.89 mg/L (concentrations ranging from below detection to 22.8 mg/L with a mean concentration lower than 3 mg/L) at a distance of 38 m (125 feet) from the septic tank. The efficiency of STE-derived-NO_3-N dissipation in groundwater in this study might be higher than the observed values since the wells were located in areas where fertilizer uses had been shown to be a joint source of NO_3-N contamination in groundwater. If the groundwater downgradient from the septic systems involved in Murphy's study were monitored at the distances employed in our study, the NO_3-N contents should be found to be similar to or no higher than our observations. This study provided another example of low contamination of groundwater by STE-derived NO_3-N. In Ontario, Canada, two conventional systems located on shallow unconfined aquifers (Robertson et al., 1991) were found to generate NO_3-N plumes with sharp lateral and vertical boundaries in the aquifers. The larger plume generated at the Cambridge site had a length of more than 130 m (426 feet) and a uniform width of about 10 m (33 feet), with the peak NO_3-N concentration in the plume above 35 mg/L. The other, at a Muskoka site, had a similar, but smaller shape (less than 20 m~66 feet in length before it recharged into a river) with the peak NO_3-N concentration above 30 mg/L. A Cambridge site was studied (Aravena et al., 1993; Cherry and Rapaport, 1994; Wilhelm et al., 1994; Shutter et al., 1994) for the unsaturated/saturated zone geochemistry and the fate and transport of various STE-derived chemicals in the aquifer. It was found that in the saturated zone NO_3-N occurred at more than 50 percent of the source concentrations 130 m downgradient from the septic system. Shutter et al. (1994) concluded that the low attenuation of NO_3-N in the plume was a result of minimal hydrodynamic dispersion. The transverse dispersivities were 10 cm for the longitudinal value (α_L) and 1 mm for the vertical value (α_T), reflecting a homogeneous nature of the aquifer materials. We propose three mechanisms for the difference observed in the groundwater NO_3-N occurrence and attenuation between our study and the Cambridge study. First, the Cambridge site was located at an agricultural research station, so groundwater in this area was constantly impacted by surrounding agricultural activities, and consequently was enriched with NO_3-N from agricultural chemicals. Avarena et al. (1993) identified the source of NO_3-N in groundwater near the septic system at the Cambridge site and delineated the nitrate plume of septic-system origin using signatures of stable isotopes, $\delta^{15}N$ and $\delta^{18}O$. Solid cattle manure, synthetic fertilizer (NH_4-NO_3), and solid organic nitrogen were found in the study to jointly contribute to the contaminant plume. Contrary to the Cambridge site, most systems in our study are serving private households not directly located in areas with frequent agricultural practices. Therefore low NO_3-N in groundwater near the systems contributed by sources other than the domestic wastewater disposal can be expected. Second is the enhanced transverse dispersion of NO_3-N in the aquifers underlying the systems involved in our study. At the Cambridge site, dilution of NO_3-N in the plume by groundwater in the area downgradient from the septic tank was determined to be insignificant. Unlike the flat terrain encountered at the Cambridge site, local topography at sites involved in our study are more variant, thus might facilitate the mixing of lateral groundwater with the STE-derived NO_3-N plume in the area downgradient from the septic system, e.g. systems serving Sites 1, 9, 13, and 14 were on the top of slopes/mounds. The influence of lateral transport on groundwater NO_3-N plumes in the vicinity of septic systems would be more significant when the systems were underlain by high water tables, such as is the case for mound systems, due to the formation of groundwater mounds underneath the absorption fields. A local groundwater mounding may occur to a shallow aquifer underneath the seepage bed of a septic system in response to the percolating effluent (Wilson et al., 1987; Finnemore, 1993), subsequently enhancing transverse as well as longitudinal hydraulic gradients of the aquifer and increasing the lateral movement of contaminants. In Wisconsin, the ambient temperature during the winter will detain percolation of the treated effluent into groundwater. As a result, formation of groundwater mound would most likely occur during the summer, which is also the season that higher nitrification activity occurs in the septic systems since the transformation of TKN will be greater in this season than that in the cold months due to the enhanced microbial activity. As a result of increased nitrification and groundwater mounding, high concentrations of NO_3-N will enter the groundwater in the vicinity of septic systems, followed by a rapid dissipation at sites where the septic systems are underlain by high water tables. This provides an explanation for the high source concentrations as well as rapid attenuation of groundwater NO_3-N observed at mound-system sites in our study. Cogger and Carlile (1984) reported that 5-10% gradients were present in the groundwater tables under two septic systems investigated during a summer as a result of groundwater mounding. In comparison with the depth of groundwater table at the Cambridge site (~3-4 m; 10-13 feet), the mound systems in our study would be more subject to the formation of groundwater mounds. Third is denitrification of NO_3-N in the shallow aquifer downgradient from the septic system, particularly at the mound-system sites. Starr and Gillham (1993) found that denitrification tends to occur in aquifers with high water tables, but not in aquifers with water tables deeper than about 2 m (6.6 feet) to 3 m (9.8 feet) from the ground surface. Starr and Gillham indicated that the occurrence of denitrification in shallow aquifers was a result of increased flux of labile organic carbon (OC) transported from the vadose zone to the aquifer, probably as a consequence of the decreased residence time of the labile OC in the diminished unsaturated zone under the higher water-table condition. The availability of readily biodegradable OC in the aquifer sediment has been reported (Bradley et al., 1992; Starr and Gillham, 1993) to be the limiting factor for denitrification when nitrate supply is sufficient, which is in general the case for a STE-generated NO_3-N plume. When sufficient organic carbon is present below the water table, oxidation of OC by aerobic heterotrophs will consume the dissolved oxygen (DO) available and generate reducing conditions (Ronen et al., 1987) followed by denitrification. Under the deep water-table condition, most of the labile OC will be oxidized in the vadose zone before reaching the aquifer. As the result, labile OC that reaches the aquifer is insufficient to deplete the DO present, inhibiting the anaerobic process of denitrification. Denitrification in a shallow aquifer, however, tends to decrease with the depth below water table (Geyer et al., 1992) since the labile OC introduced from the unsaturated zone will be gradually reduced with increase in depth, eventually becoming insufficient to deplete the appreciable DO in the water. The decrease of denitrification with the increase of depth below the water table, however, might not be a concern in our study since most of the STE-derived NO_3-N would likely remain on the top of the aquifer. Observation on denitrification of sewage-derived contaminant plume occurring in the shallow aquifer was reported by Smith and Duff (1988), supporting the possibility of substantial denitrification in the shallow aquifers underlying the mound systems in our study. In comparison with the depth of the water table underlying the Cambridge site, where the aquifer was found to have insignificant denitrification activity, mound-system sites underlain by high water tables in our study appear to be far superior in terms of NO_3-N removal in groundwater by denitrification.

Bacterial analyses

A primary concern for a septic system is the prevention of transmission of potential pathogens into the groundwater. The soil absorption field must be able to eliminate bacteria and viruses from the water before it enters groundwater or creviced bedrock. The bacteria flora of septic tank effluent (STE) are primarily those of intestinal or enteric origin. The human intestinal tract offers an excellent environment for anaerobic bacteria (both spore-forming and non-spore-forming organisms) and many other groups (McCoy and Ziebell, 1974). When fresh raw wastewater enters the septic system, conditions change from aerobic to anaerobic, and temperatures are lowered, so that new forms of bacteria can multiply to balance with the intestinal flora and form the primary agent in the biodegradation of the raw effluent. STE contains extremely high number of coliform bacteria as well as streptococci and is therefore as is unsafe for human contact (McCoy and Ziebell, 1975; Sauer et al., 1976) and must be treated before discharge to the underlying groundwater. The bacteriological parameters examined in this study are the standard indicator organisms, total coliforms (TC), fecal coliforms (FC), and fecal streptococci (FS) used to evaluate any potential human waste contamination to ground or surface water. FC and FS are commonly used as indicators of recent fecal pollution and possible presence of pathogens; these organisms are a part of human intestinal flora shed daily with feces.

Results of bacteriological analyses for samples taken during June 1994 are shown in Appendix I. While most systems did not show any existence of the tested bacterial species in the groundwater, Sites 3, 8, and 9 showed low counts of TC, FC, and FS and Site 13 of TC and FC in groundwater samples from all wells. At WHHS, Wells 5, 6, 13, 14, 15 also had low counts of TC and/or FC, while Wells 9 and 14 showed low FS counts. Higher but erratic counts of TC and FC were encountered in Well 1 at Site 1 as well as in the Wells 1 and 2 at Site 2. The random occurrences of the bacteria at these sites did not correspond to conventional patterns of bacterial contamination from septic systems. Furthermore, due to unsecured well caps or well damage, most wells showing high bacterial counts were found to be likely infected from other sources, e.g. ambient water penetrating from the surface or the soil solution. Most wells were found uncapped or capped with broken tops during our early locating effort. Although these wells were fitted with new plastic caps, removal of or damage to the replacement caps was still encountered during subsequent visits, perhaps due to the lawn mowing and the curiosity of children frequenting the properties. To determine the contamination source responsible for these indicator organisms, all sites were re-sampled during August 1994. Wells caps were checked and properly secured, and the well was shock-treated with sodium hypochlorite (Clorox Company, Oakland, CA) 3 days before sampling. Prior to sampling, all containers and tubes were sterilized on-site using a portable Millipore ultraviolet sterilizer and each well was redeveloped to assure that residual chlorine and bacteria from any ambient source was removed.

Table 4 to 7 show the results of sample analyses. No bacteria counts were found in any of the groundwater samples. This indicated that all systems examined were effective in removing the indicator bacteria as the septic tank effluent percolated through the soil absorption system and the natural soil profile. This further revealed that both the conventional and mound systems studied were functioning normally in terms of physical filtration of the bacteria suspended in the effluent solution, thus did not pose a threat of biological contamination to the groundwater quality.

Harkin et al. (1979) reported similar results on four mound systems monitored for groundwater quality, and concluded that the water quality in the vicinity of these systems was close to the drinking water standard in terms of the bacteria indexes. In that study, the mound fill alone was not capable of reducing the numbers of FS or *Pseudomanas aeruginosa* (*Ps. a.*) to great extent, and it was suggested that the high effluent dosing rates/volumes and the coarse-textured sand fills created a quasi-saturated zone in the mounds, which allowed the bacteria to travel through the sand fill and enter the natural soil with the percolating effluent. FS are enteric bacteria considered to have very limited survival times outside the human body (Clausen et al., 1976). The extensive downward movement of FS in the soil underlying a mound might be due the small size of streptococci (0.6-1.0 μm diameter) which allowed them to pass through the filtering sand fill. However, in our study FS were not observed in groundwater in the vicinity of any system, including the mound systems over a high water table (e.g. Sites 14 and 15). This suggested either that a soil clogging mat had probably developed at the gravel/sand fill interface in the mound systems or was being maintained effectively at the absorption field/natural soil contact in the conventional systems during past operation, or that the physical filtration in the sand fill/natural soil system (mound system) and in the drainfield/underlying soil system (conventional system) was still adequate under the current dosing regime. Either of the above cases would eliminate saturated flow, promoting removal by filtration of the bacteria during percolation, consequently inhibiting the movement of indicator organisms to groundwater. If the mound system examined did have a clogging mat, its performance would then be close to that of a conventional system which usually has a biological mat at the absorption bed/natural soil interface formed during the early stages of operation.

Ps. a. is a voracious heterotroph capable of growth on a large variety of carbon sources and able to use NO_3-N as a terminal electron acceptor in the absence of oxygen (Hoadley, 1976) and therefore appears to be capable of growth in the soil outside a septic system (Ziebell et al., 1975). *Ps. a.* is not a good indicator for determining the capability of a septic system to reduce bacterial populations and thus was not examined in this study.

CONCLUSIONS AND RECOMMENDATIONS

This project aims at estimating the long-term performance of septic tank/soil absorption systems in transforming and eliminating nitrogen before nitrate nitrogen derived from septic tank effluent poses a potential to contaminate groundwater. Twelve representative soil absorption systems (3 conventional, 4 dosing, and 5 mound type systems) previously studied in Wisconsin were monitored for various nitrogen species (total Kjeldahl nitrogen, ammonium nitrogen, and nitrate nitrogen) and indicator bacteria (total coliforms, fecal coliforms, and fecal streptococci) in groundwater and septic tank effluent for a period of 14 months. Nitrate nitrogen in groundwater in the vicinity of all systems investigated was effectively reduced to a safe level, below the 10 mg/L NO_3-N Enforcement Standard, within a distance of 6.3 m from the edge of the soil absorption bed. No bacteria counts were found in the groundwater surrounding each system when appropriate indicator organism counts were conducted. In general, these systems have maintained the same level of efficacy during operation over the years in terms of bacterial attenuation and nitrogen elimination.

Among systems of different designs, mound systems almost completely removed NH_4-N from the STE by chemical/bacterial transformation and immobilization during the infiltration of STE through the mound and the underlying soil profile, while conventional and dosing systems did not achieve as much NH_4-N removal as mound systems. Mound systems generated the highest mean concentration of NO_3-N entering groundwater, possibly due to the formation of biological mats at the gravel bed/sand fill interfaces which reduced the anaerobic zones existing at the sand fill/natural soil contacts and decreased the rates of denitrification of NO_3-N built up in the mounds. Mound systems underlain with high water tables also presented the highest efficiency of NO_3-N attenuation in groundwater. This was probably a result of increased hydrodynamic dispersion and enhanced denitrification in the groundwater near the systems.

If the study of mechanisms associated with transformations and fate of STE-derived NO_3-N in the unsaturated/saturated zones underlying the septic tank-soil absorption systems is desired, it is the opinion of the authors that the following three factors should be examined: 1. The formation of biological mats at the gravel/sand fill interface in mound systems and the persistence of the crust between the absorption field and the natural soil in a conventional system or dosing system. This evaluation would clarify the status of nitrogen transformations in each type of system under the current wastewater loading regimes. The existence of a clogging mat can be determined by examining the carbon:nitrogen (C:N) ratio at the interface. C:N ratio is one means of expressing the biodegradability of organic materials: a low C:N ratio (<20) indicates that the organic material is readily biodegradable, a high C:N ratio (>20) indicates that it is resistant to breakdown by soil microorganisms (Foth, 1990). The C:N ratio for STE and soil organic matter is approximately 10 (Sikora and Corey, 1976). Since most of the nitrogen in STE is in the NH_4-N form and is not associated or combined with high-carbon material (vegetable residues, toilet paper, etc.), any increase in the C:N ratio at the gravel/sand or drainfield/soil interface indicates the deposition of high carbon wastes while nitrogen in the soluble ionic forms is being transported with the percolating

STE into the fill (mound systems) or the soil (conventional/dosing systems). 2. Hydrogeological parameters associated with the transport of contaminant plume in groundwater. Determination of the hydraulic gradient of the water table and the hydraulic conductivity will provide a quantitative estimate of the dilution effect of the local groundwater on the distribution of STE-derived NO_3-N. Coupled with the determination of advective velocity using a conservative tracer-test approach (Fetter, 1992), e.g. Br^-, the longitudinal dispersivity can be obtained by the advection-dispersion simulation, which would then provide a description for the plume of NO_3-N in the groundwater near the septic system. With the information established, model simulations (Sara, 1993) could then be developed to explain and predict the movement of a NO_3-N plume in the groundwater and evaluate the distance necessary for STE-derived NO_3-N to be reduced to below the 10 mg/L ES level in the aquifer. 3. The extent of denitrification in the groundwater, since denitrification is the major geochemical process removing NO_3-N in the aquifer and is important in explaining the rapid dissipation of NO_3-N in the shallow aquifer underlying the septic system. During denitrification, NO_3-N is converted through a series of intermediate species to molecular nitrogen (Payne, 1981), therefore the denitrification potential of an aquifer could be determined using the acetylene inhibition method (Ryden et al., 1987; Geyer et al., 1992). Acetylene inhibits the reduction of N_2O to N_2, making N_2O the sole product of denitrification for measurement. With the application of ^{15}N tracer and the simultaneous measurements of dissolved oxygen level in groundwater and organic carbon content in groundwater/sediments, denitrification potential of STE-derived NO_3-N in the groundwater can be determined, and an evaluation of nitrogen transformations in the saturated zone can be achieved.

This study has established that the septic systems, coupled with local groundwater of high nitrogen-eliminating efficiency, are not posing a contamination potential of nitrate nitrogen to the domestic use of groundwater. However, it remains unclear whether the nitrate nitrogen of groundwater observed in the vicinity of the systems dominantly originated from the septic system, or was jointly contributed by other sources associated with agricultural practices, e.g. feedlots, barnyards, and fertilized fields. A study performed by the Wisconsin Dept. of Natural Resources and Dept. of Agriculture, Trade, and Consumer Protection (1991) found that 7 of 28 pesticide mixing and loading sites had NO_3-N concentrations in groundwater in the immediate vicinity higher than the 10 mg/L ES level, while 15 sites had values higher than the Preventive Action Limit (PAL) of 2 mg/L. In another study using nitrogen isotope as an indicator for the sources of NO_3-N in Minnesota sand-plain aquifers, Komor and Anderson (1993) identified that, among four different land settings, residential areas with septic systems had a mean NO_3-N concentration of 8.3 mg/L in the groundwater, which was the lowest value obtained from all land settings (livestock feedlots:12.7 mg/L; cultivated-irrigated fields:13 mg/L; cultivated-nonirrigated fields:15.5 mg/L). Murphy (1992) found that NO_3-N levels in groundwater from wells located within 38 m of a septic tank in the areas where no agricultural or lawn fertilizer was applied were significantly lower than those from the comparable wells in the areas where chemical fertilizer was applied. Differentiation of the sources of groundwater NO_3-N in the vicinity of septic systems as well as assessment of the STE-derived NO_3-N denitrification in groundwater can be achieved through the use of ^{15}N-based tracer. Currently several systems from this study are selected for dosing with ^{15}N-labelled ammonium chloride to demonstrate the nitrification mechanism associated with the long-operated septic systems under another project. Results of this follow-up study should complement our current understanding and present a clearer picture for the long-term performance of septic systems.

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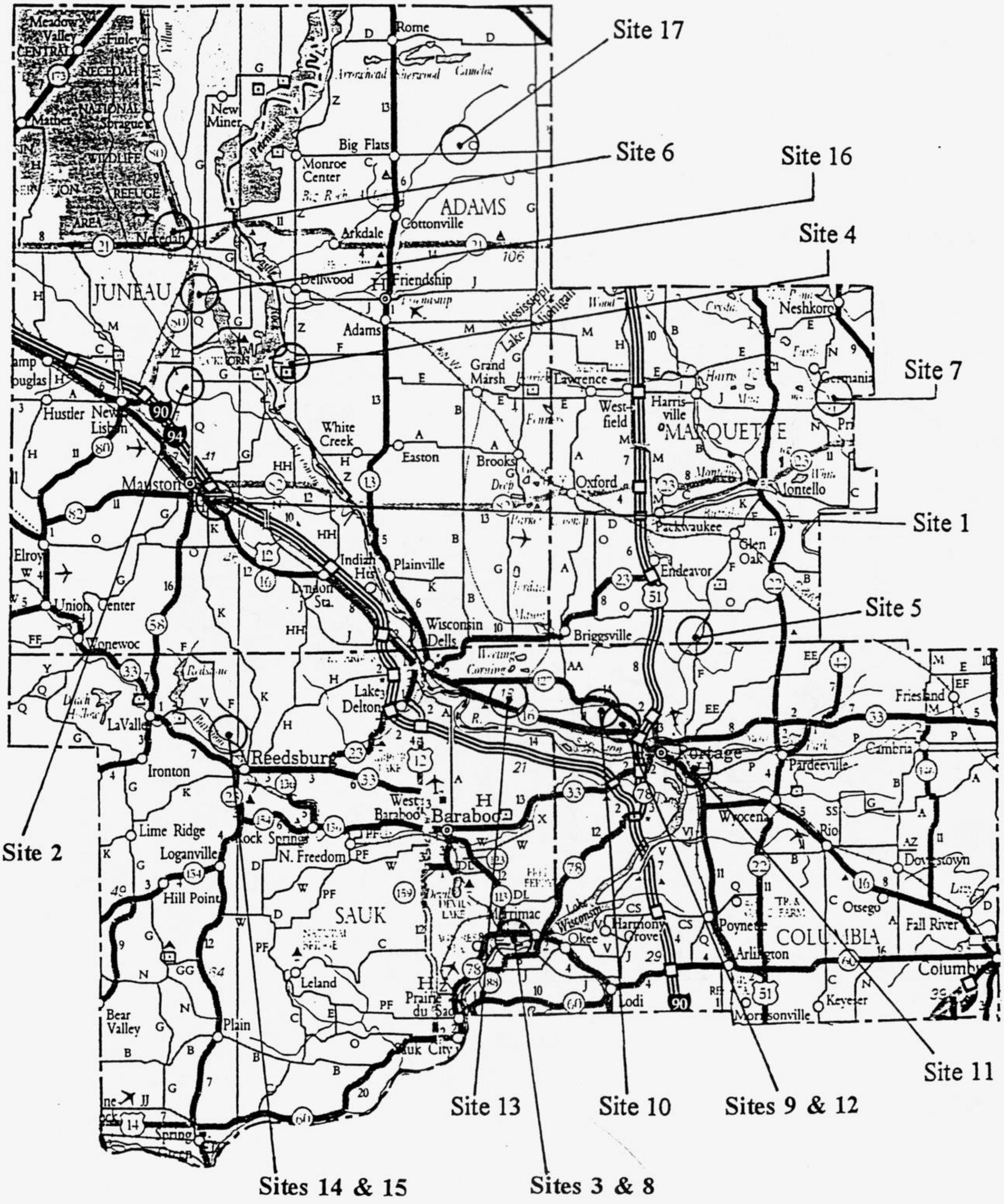


SCALE: 1 INCH = 10.08 MILES

Figure 1. Locations of the septic systems from Study 1985 in south-central Wisconsin.

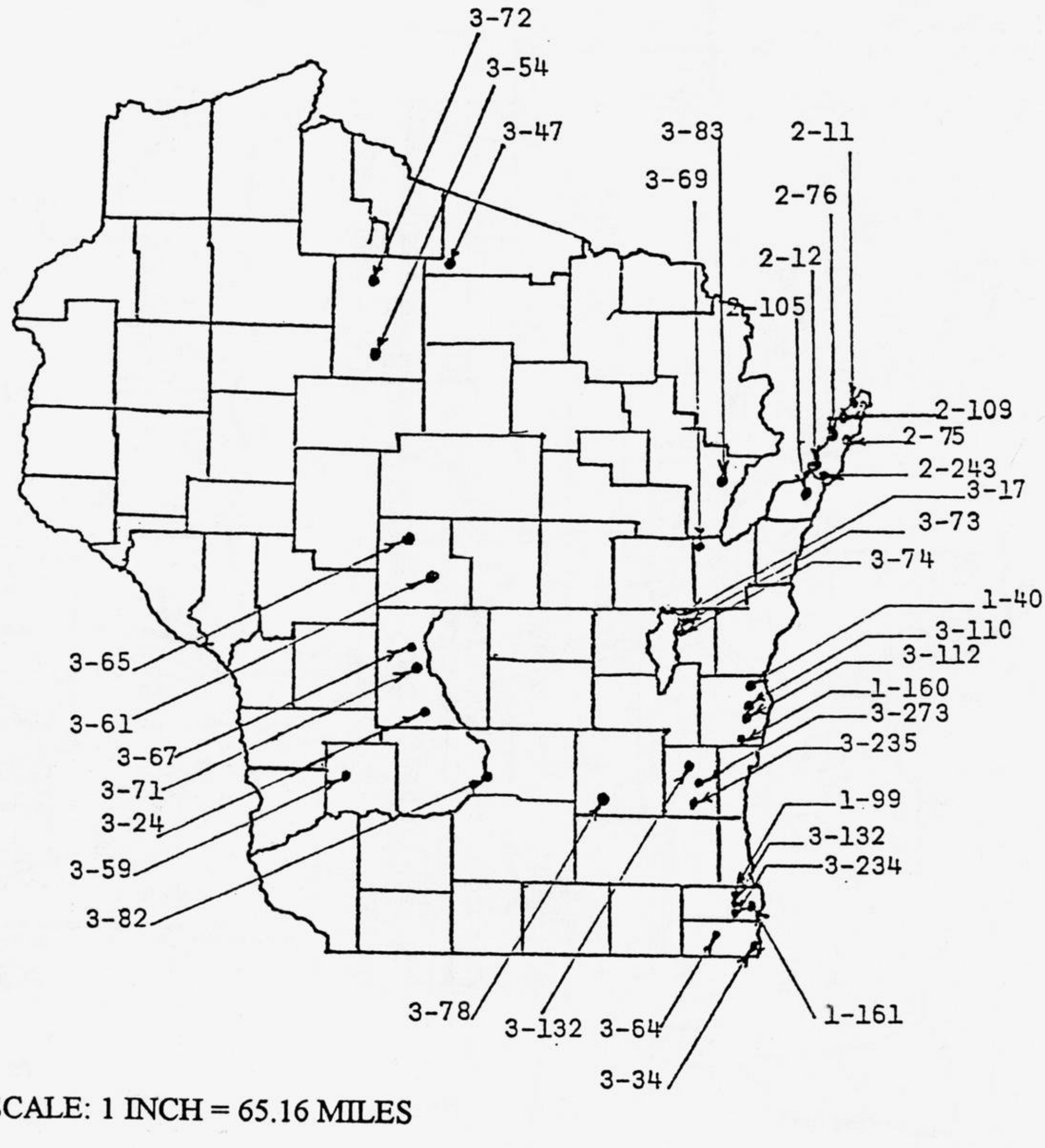
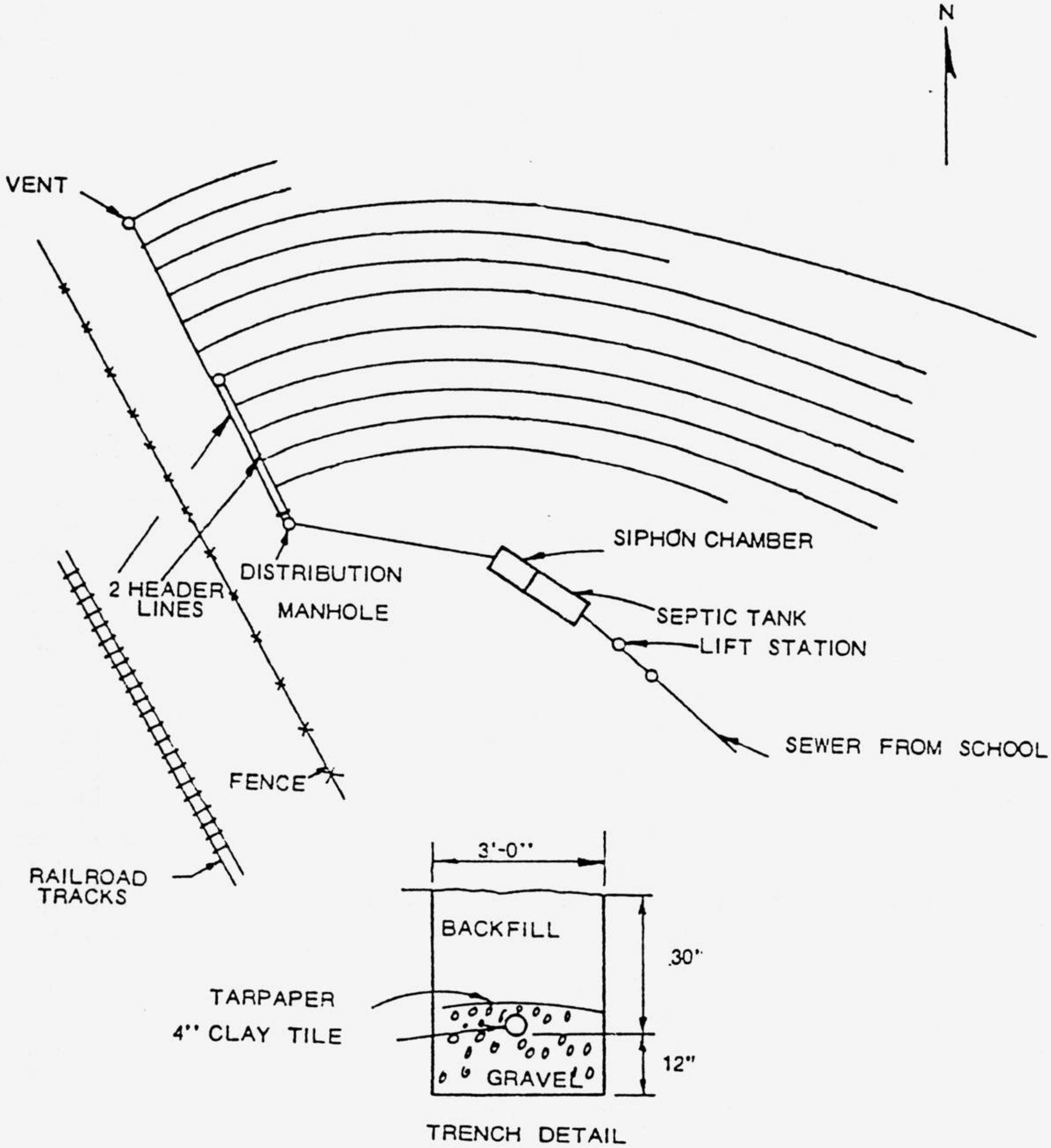


Figure 2. Locations of the mound-type septic systems from Study 1979 in Wisconsin.

Figure 3. Location of the Wisconsin Heights High School in Dane County, Wisconsin (Study 1970).



SCALE: 1 INCH = 60 FEET

Figure 4. Locations of the wastewater treatment facilities at Wisconsin Heights High School.

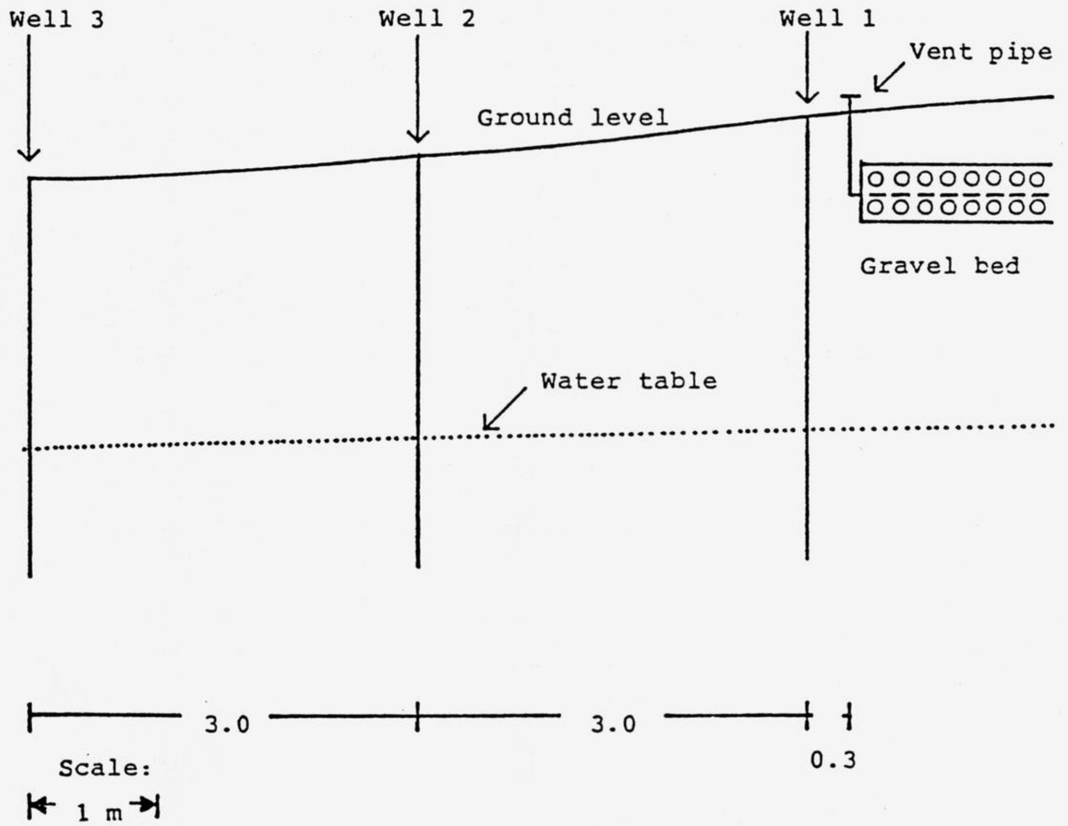


Figure 5. Transect view showing locations of groundwater monitoring wells downflow at sites served by conventional or dosing systems from Study 1985.

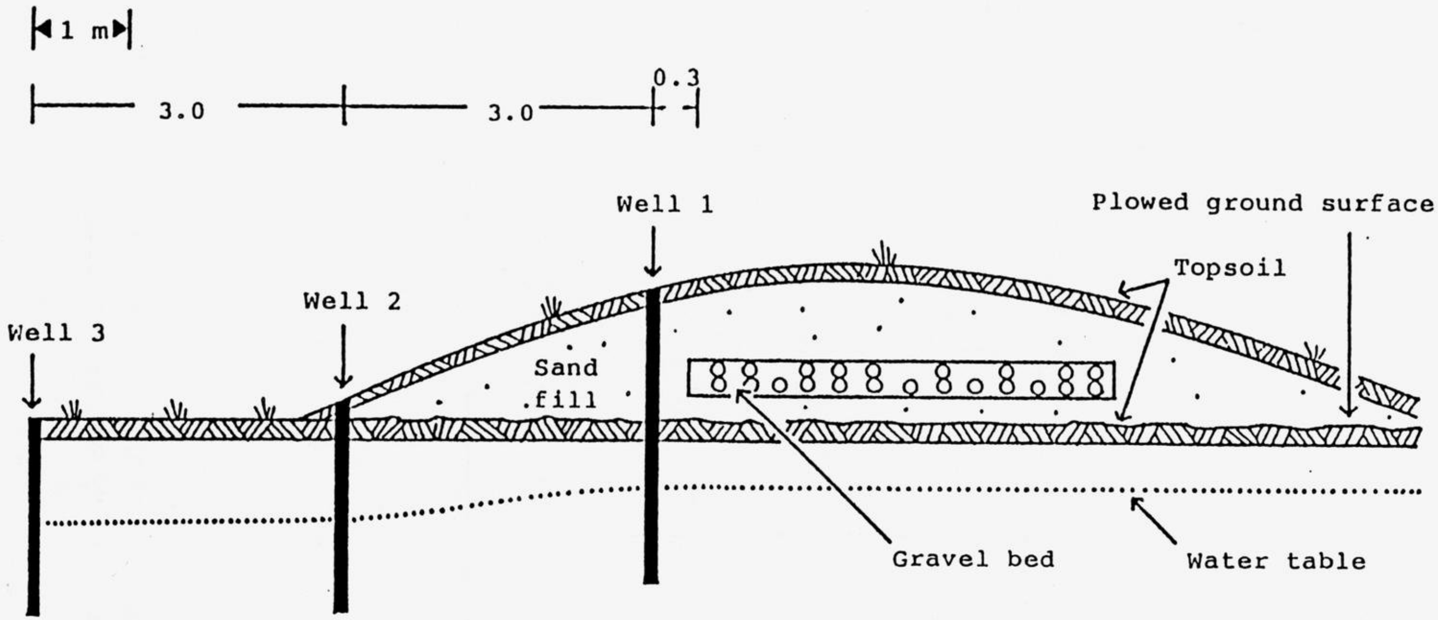


Figure 6. Transect view showing locations of groundwater monitoring wells downflow at sites served by mound systems from Study 1985.

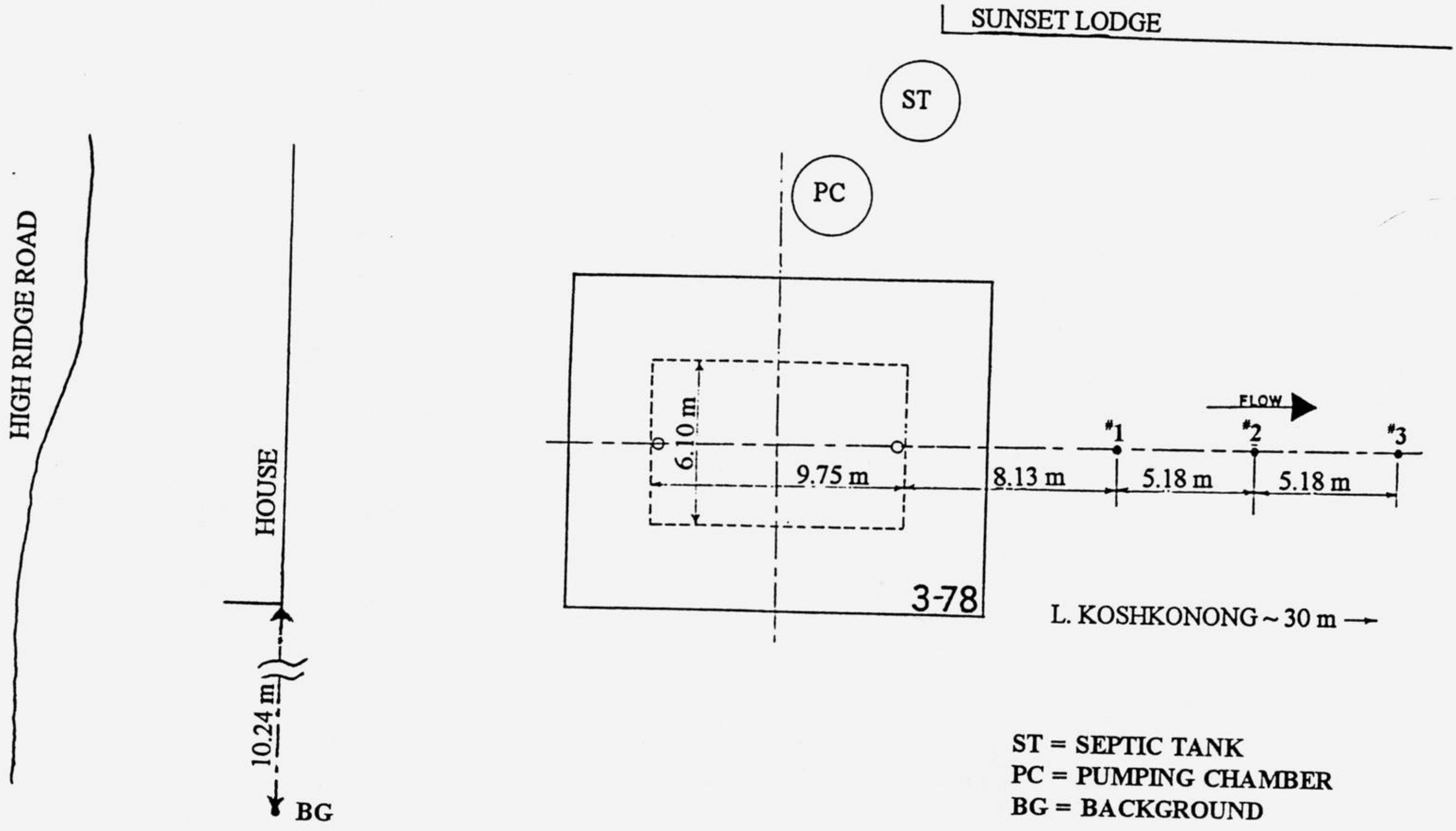


Figure 7. Locations of groundwater monitoring wells, direction of groundwater flow and absorption area for System 3-78 from Study 1979.

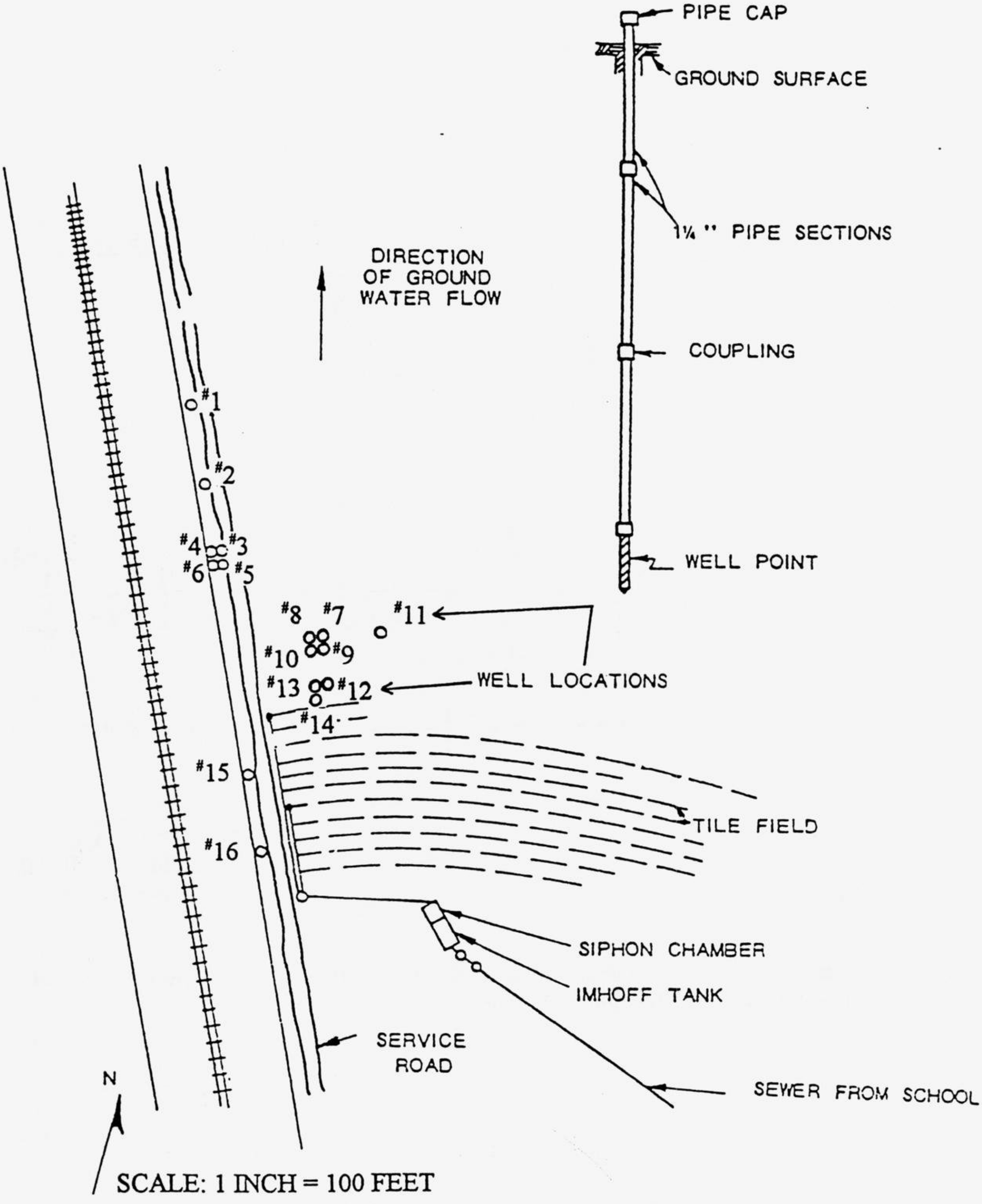


Figure 8. Locations of groundwater monitoring wells discovered and their relative positions to the soil absorption system at Wisconsin Heights High School.

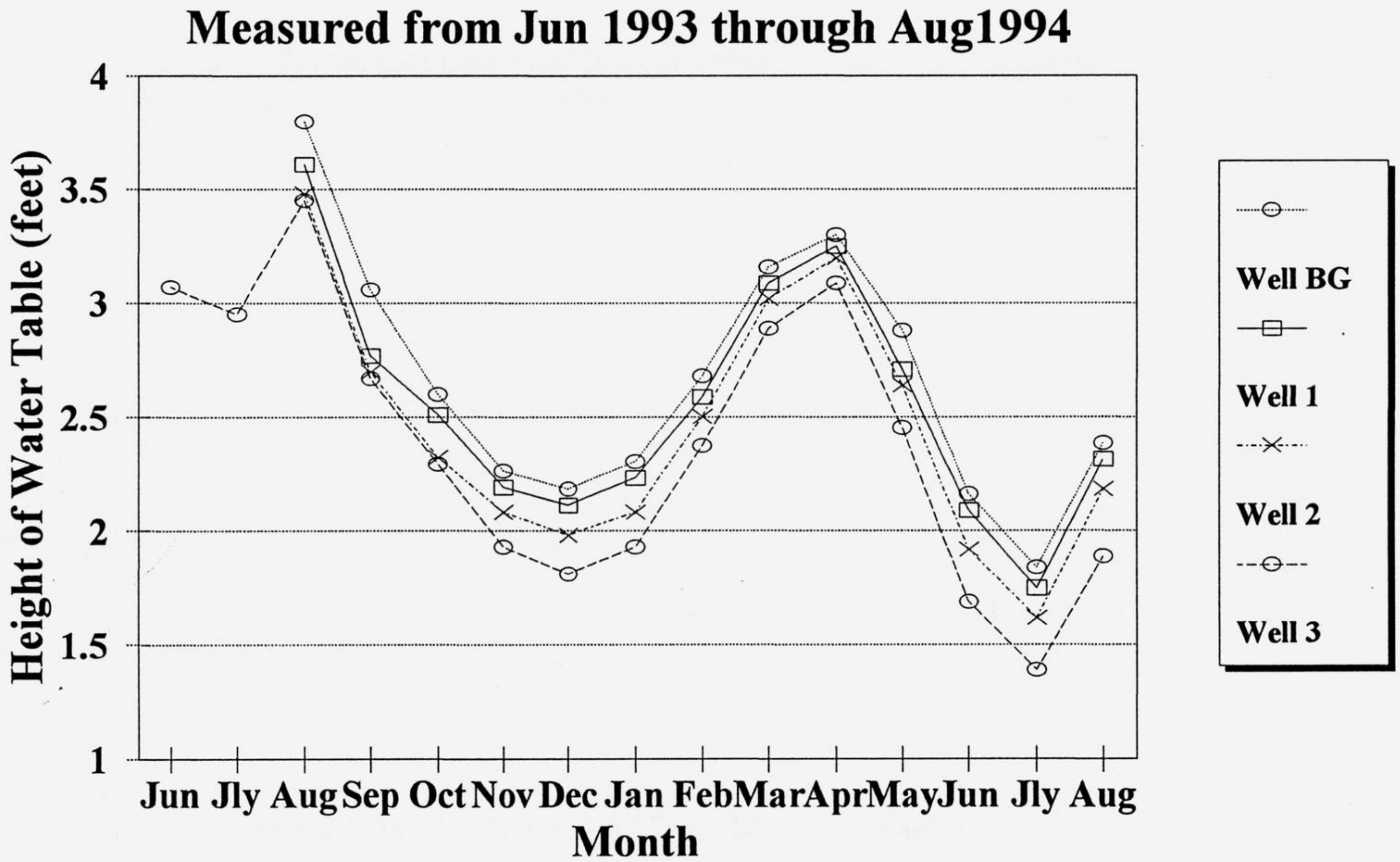


Figure 9. Monthly groundwater levels in four monitoring wells at Site 10 (Study 1985).

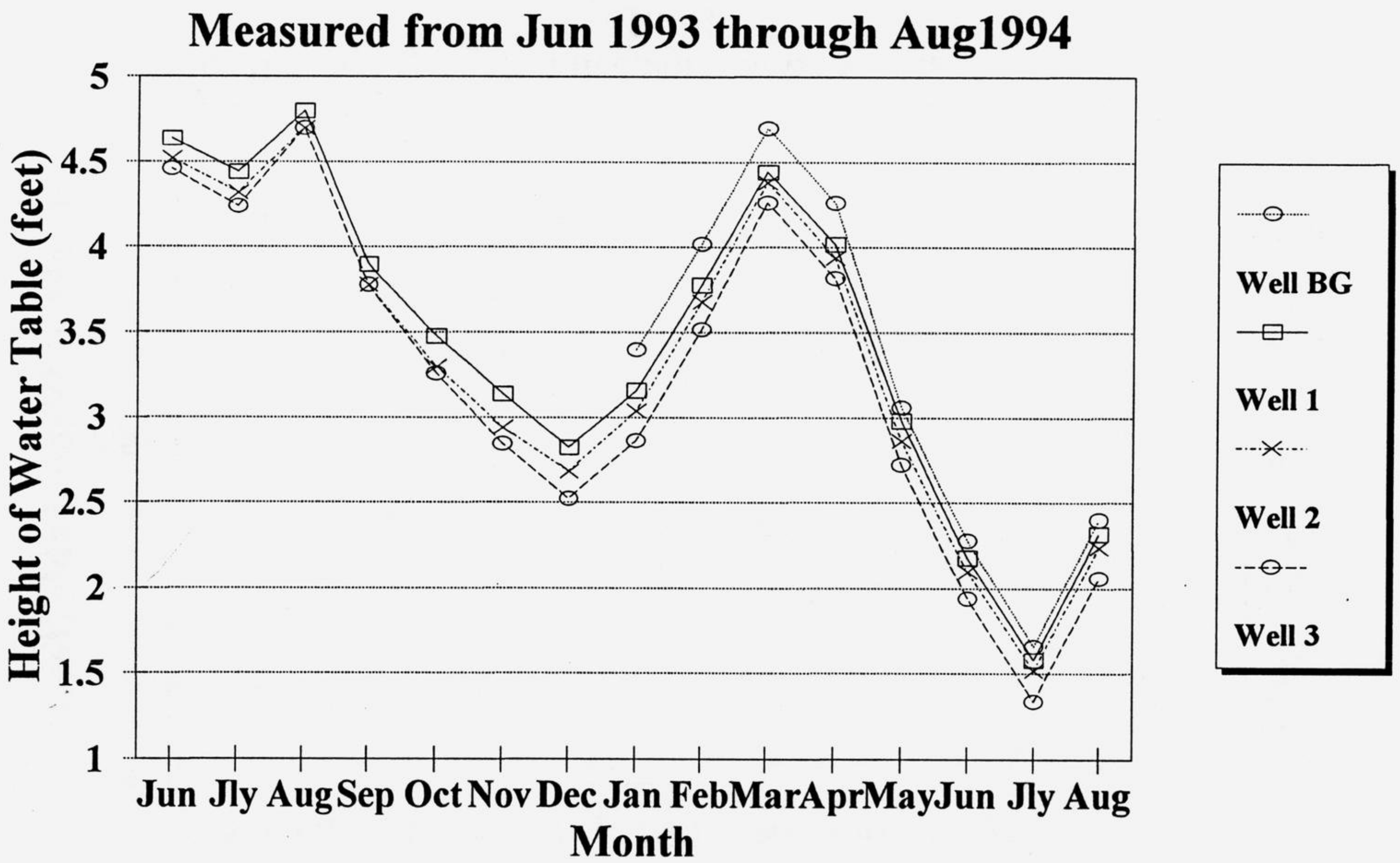


Figure 10. Monthly groundwater levels in four monitoring wells at Site 12 (Study 1985).

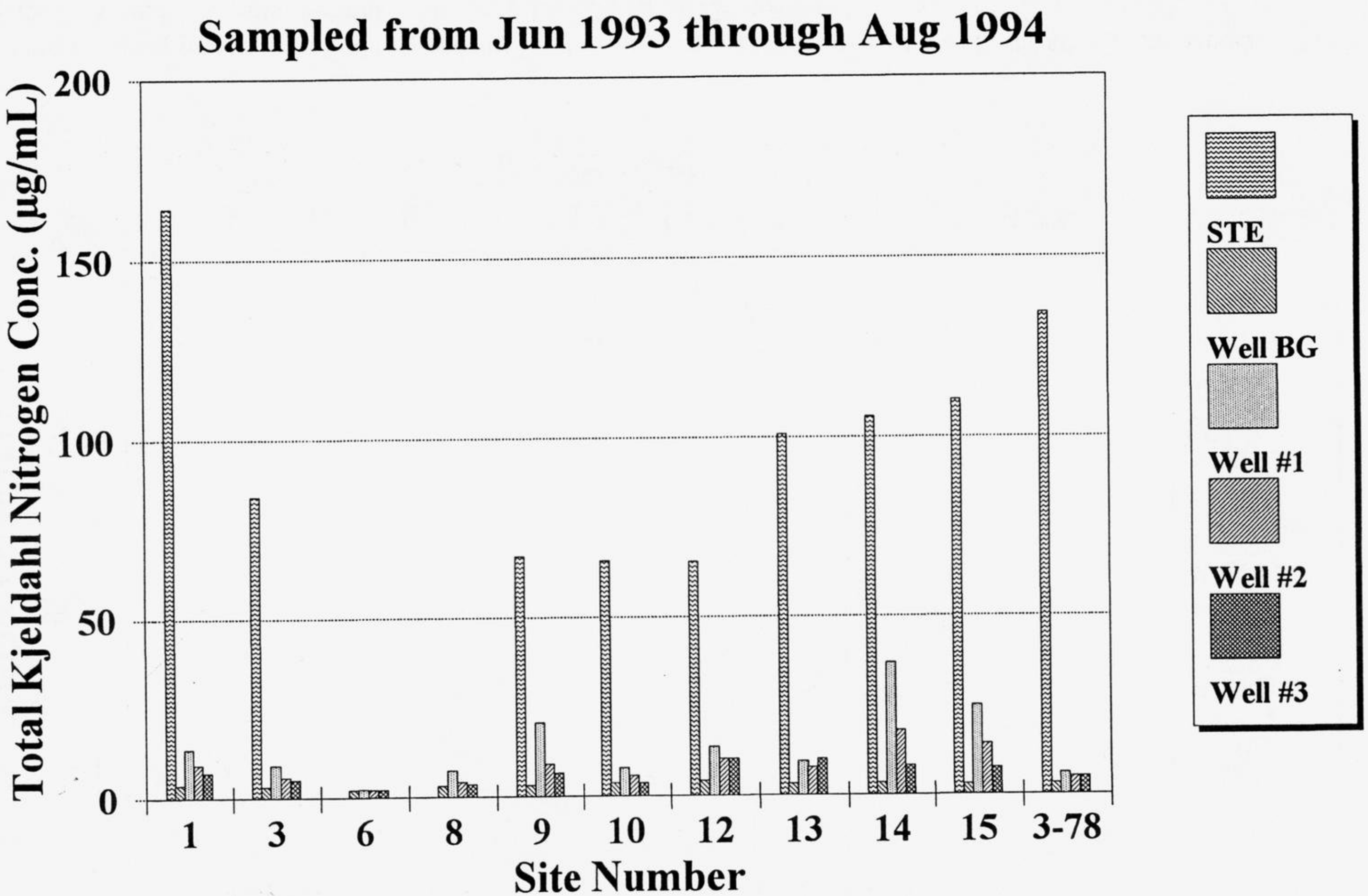


Figure 11. Average values of total Kjeldahl nitrogen (TKN) in septic tank effluent (STE) and groundwater monitoring wells at sites from Studies 1985 and 1979 (Sites 6, 8, and 13: conventional systems; Sites 3, 9, and 12: dosing systems; Sites 1, 10, 14, 15, and 3-78: mound systems).

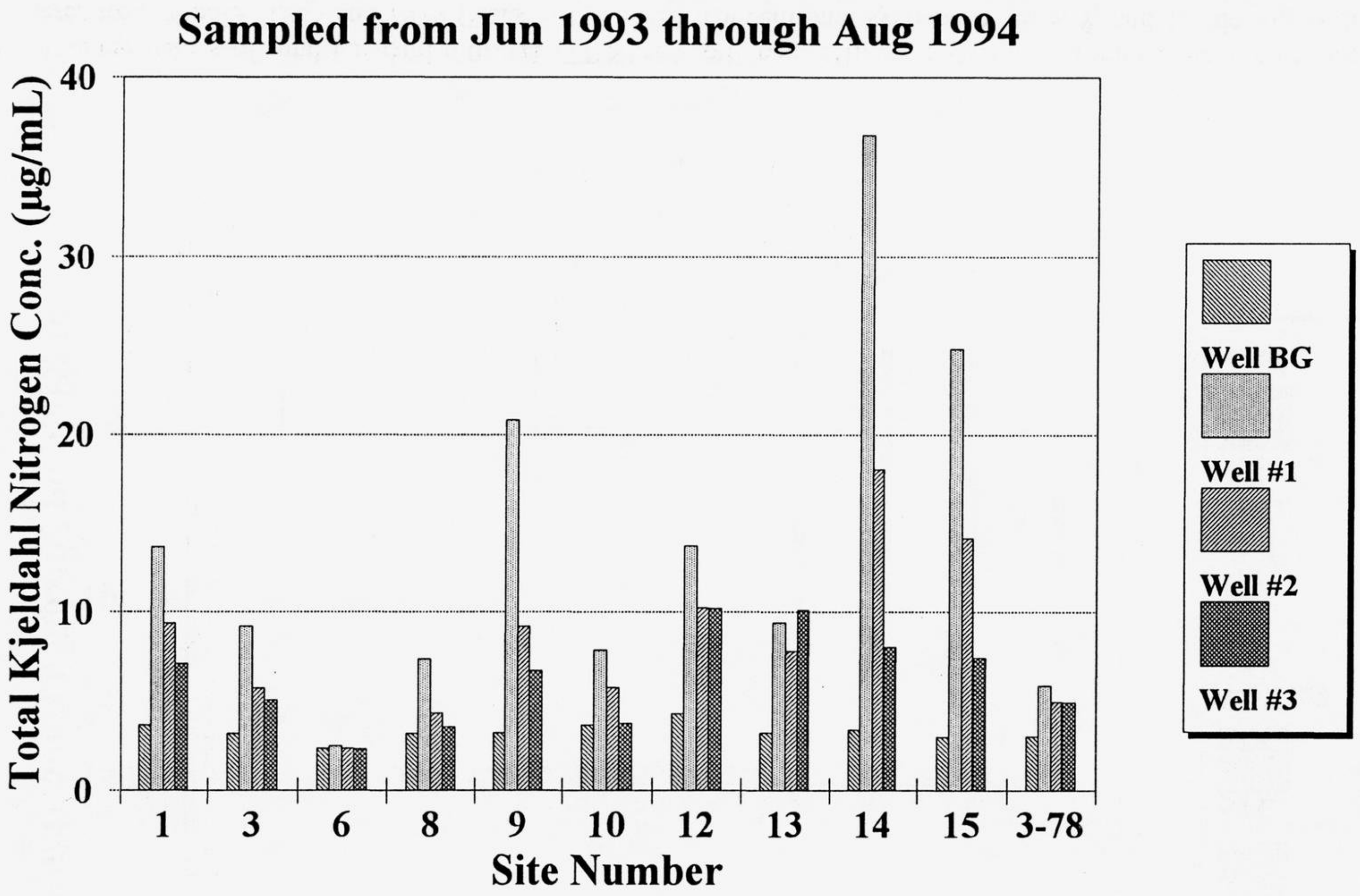


Figure 12. Average values of total Kjeldahl nitrogen (TKN) in groundwater monitoring wells at sites from Studies 1985 and 1979 (Sites 6, 8, and 13: conventional systems; Sites 3, 9, and 12: dosing systems; Sites 1, 10, 14, 15, and 3-78: mound systems).

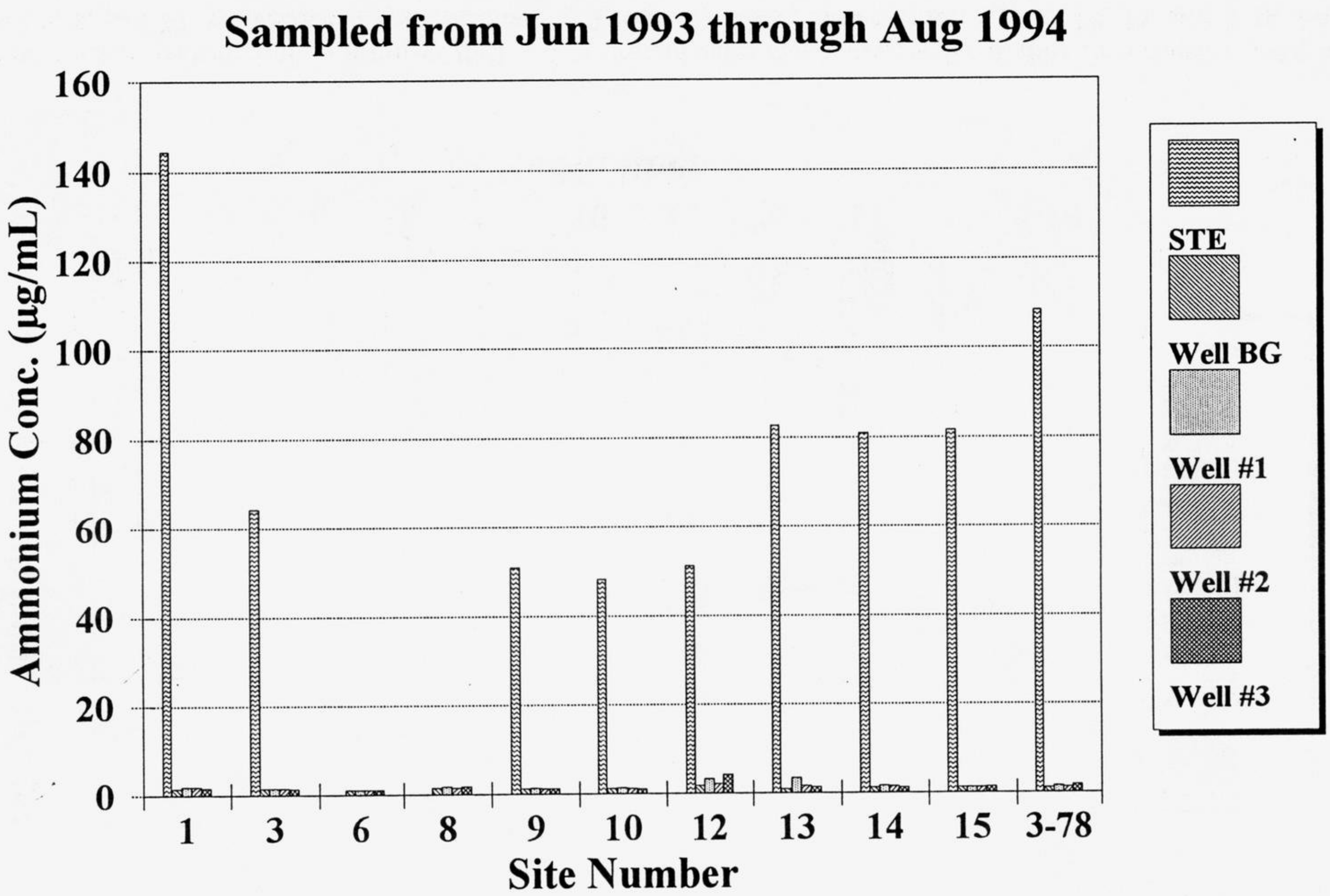


Figure 13. Average values of ammonium nitrogen (NH_4-N) in septic tank effluent (STE) and groundwater monitoring wells at sites from Studies 1985 and 1979 (Sites 6, 8, and 13: conventional systems; Sites 3, 9, and 12: dosing systems; Sites 1, 10, 14, 15, and 3-78: mound systems).

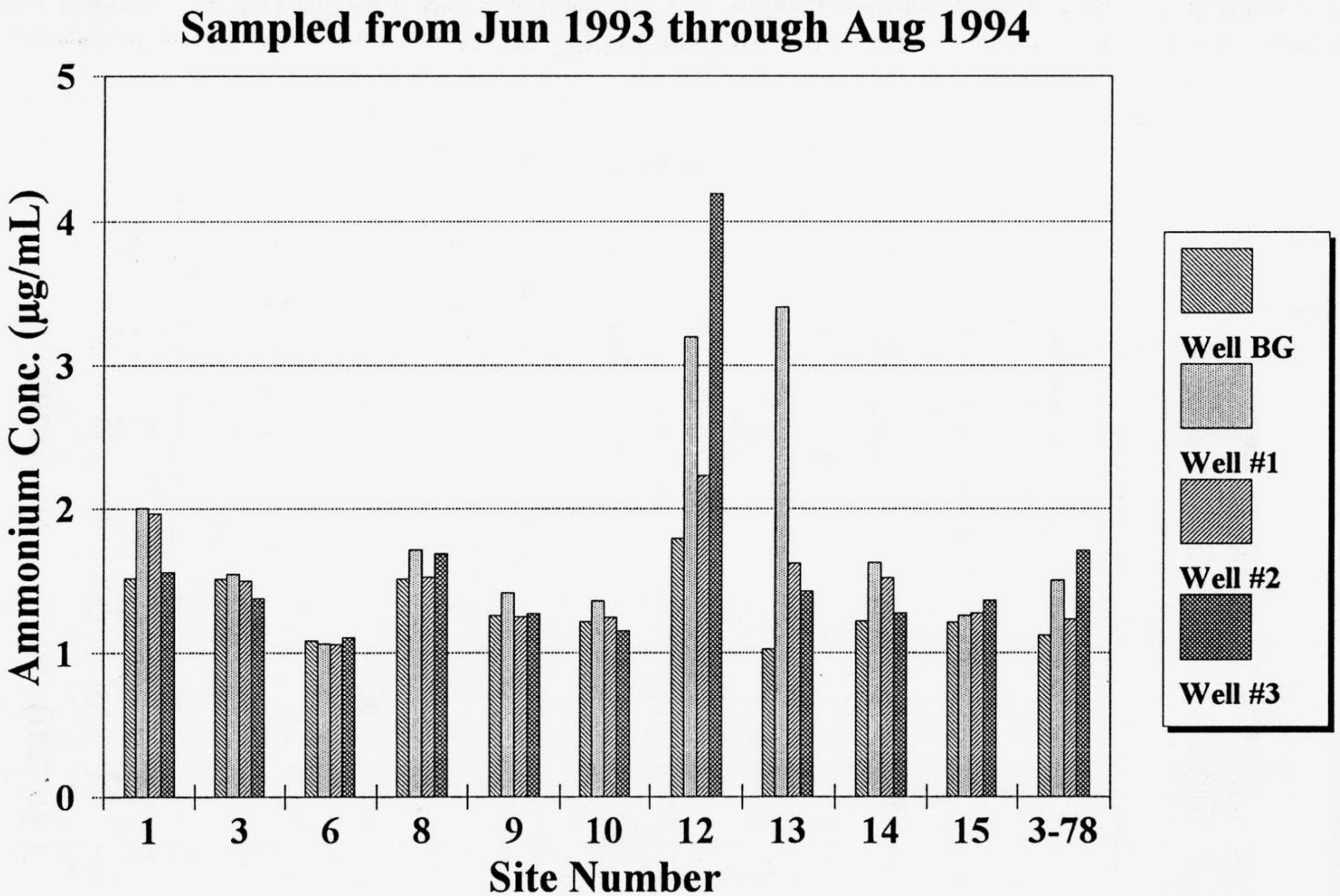


Figure 14. Average values of ammonium nitrogen (NH_4-N) in groundwater monitoring wells at sites from Studies 1985 and 1979 (Sites 6, 8, and 13: conventional systems; Sites 3, 9, and 12: dosing systems; Sites 1, 10, 14, 15, and 3-78: mound systems).

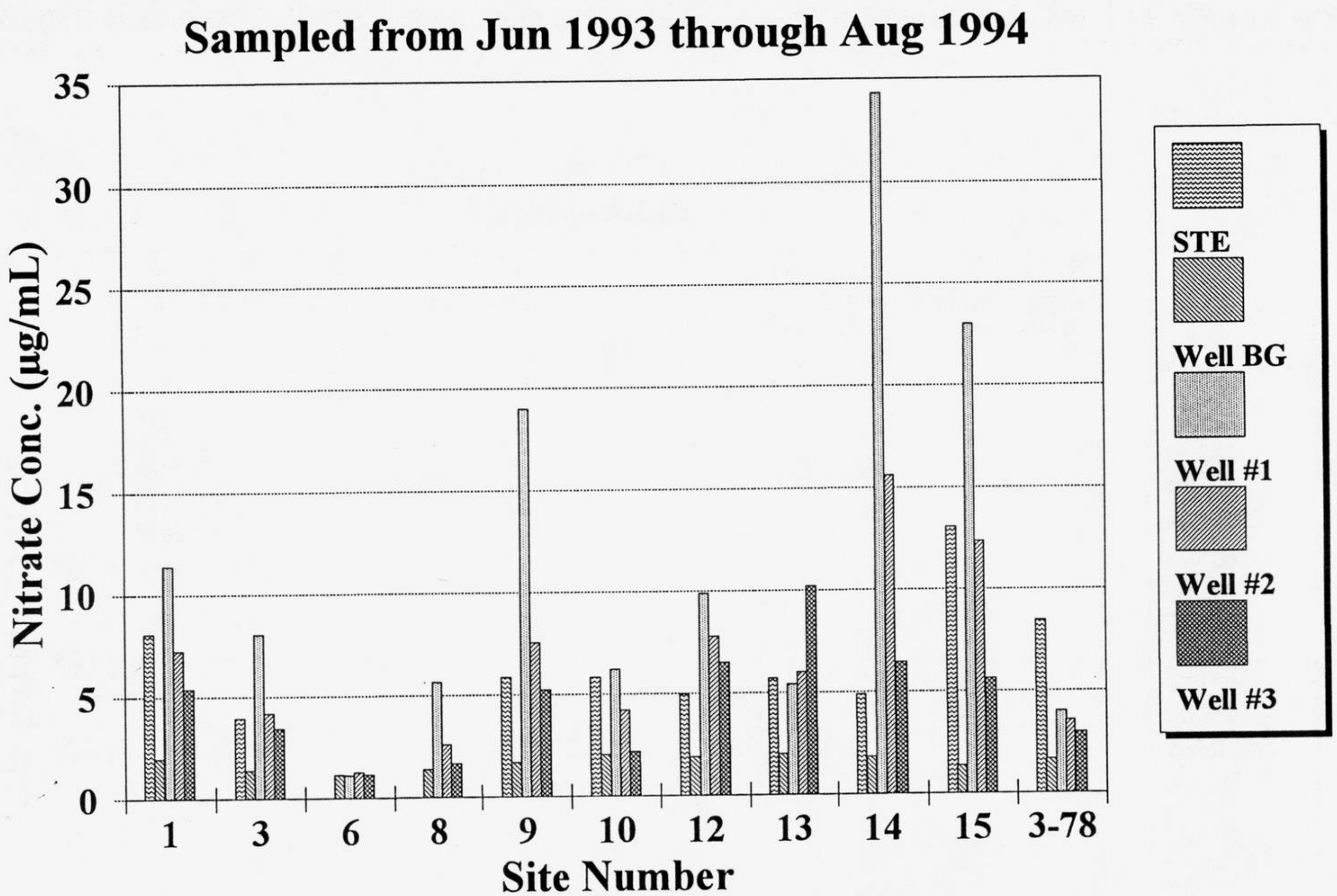


Figure 15. Average values of nitrate nitrogen (NO_3-N) in septic tank effluent (STE) and groundwater monitoring wells at sites from Studies 1985 and 1979 (Sites 6, 8, and 13: conventional systems; Sites 3, 9, and 12: dosing systems; Sites 1, 10, 14, 15, and 3-78: mound systems).

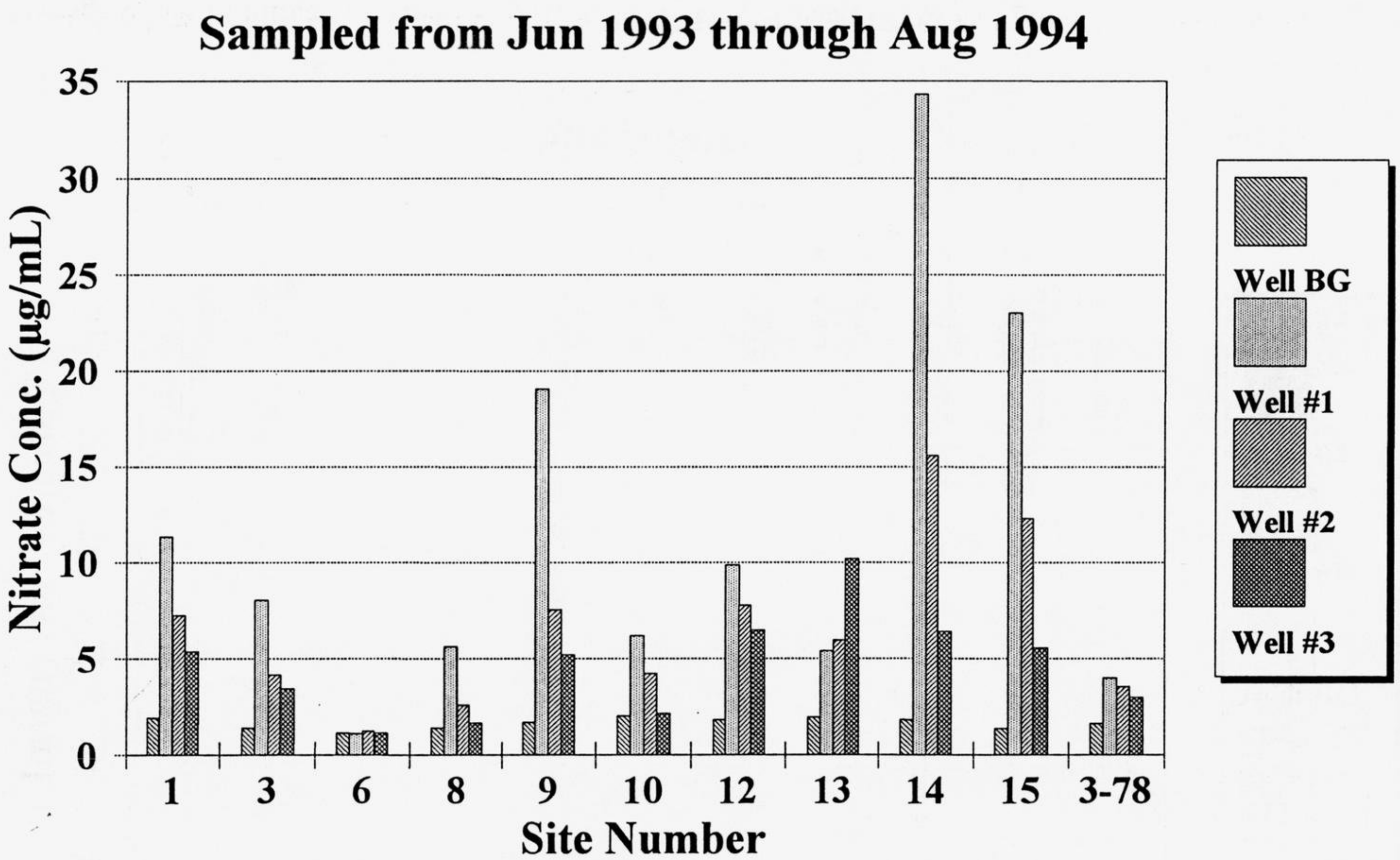


Figure 16. Average values of nitrate nitrogen (NO_3-N) in groundwater monitoring wells at sites from Studies 1985 and 1979 (Sites 6, 8, and 13: conventional systems; Sites 3, 9, and 12: dosing systems; Sites 1, 10, 14, 15, and 3-78: mound systems).

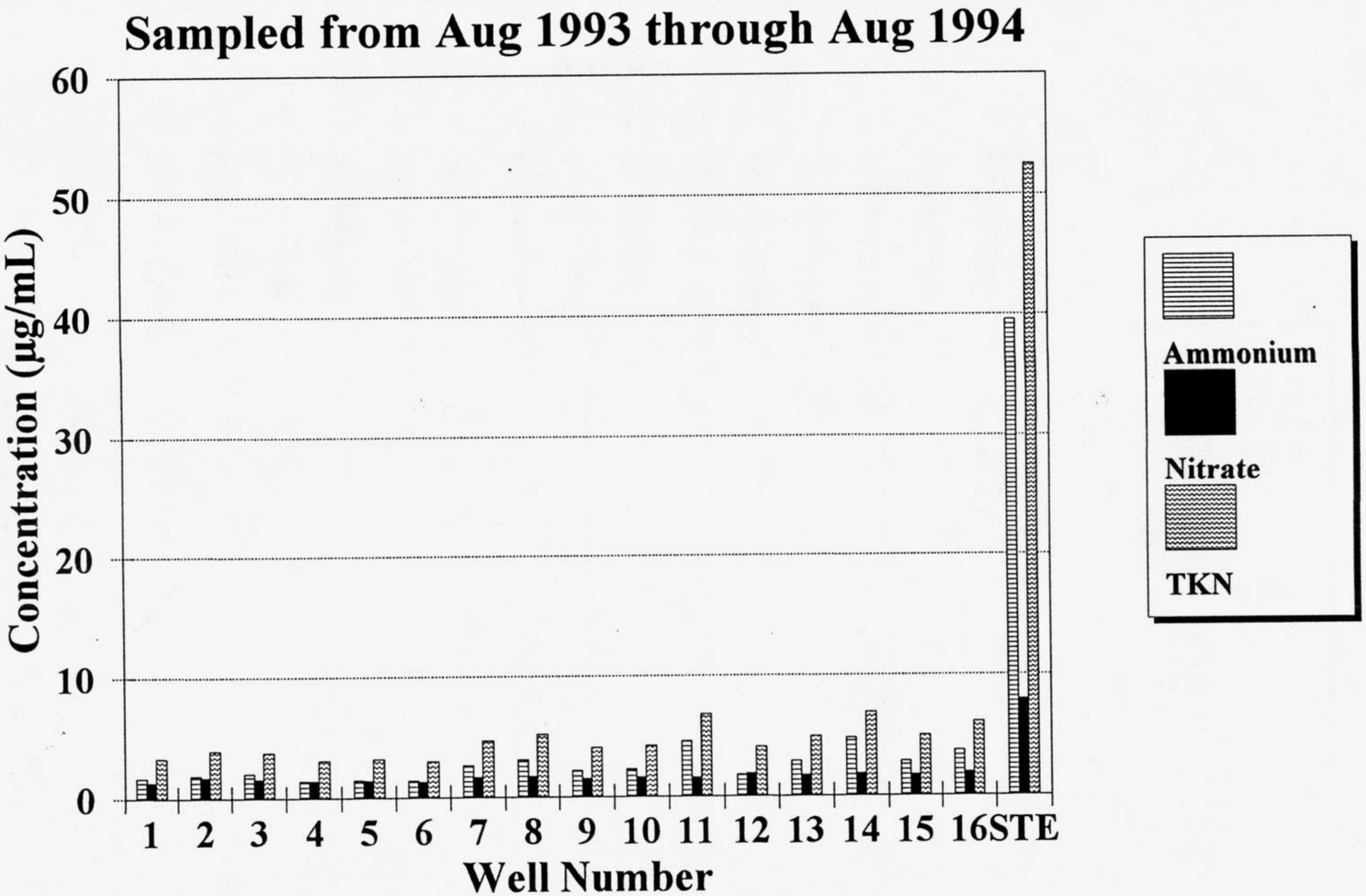


Figure 17. Average values of total Kjeldahl nitrogen (TKN), ammonium nitrogen (NH_4-N), and nitrate nitrogen (NO_3-N) in septic tank effluent (STE) and groundwater monitoring wells at Wisconsin Heights High School (Study 1970).

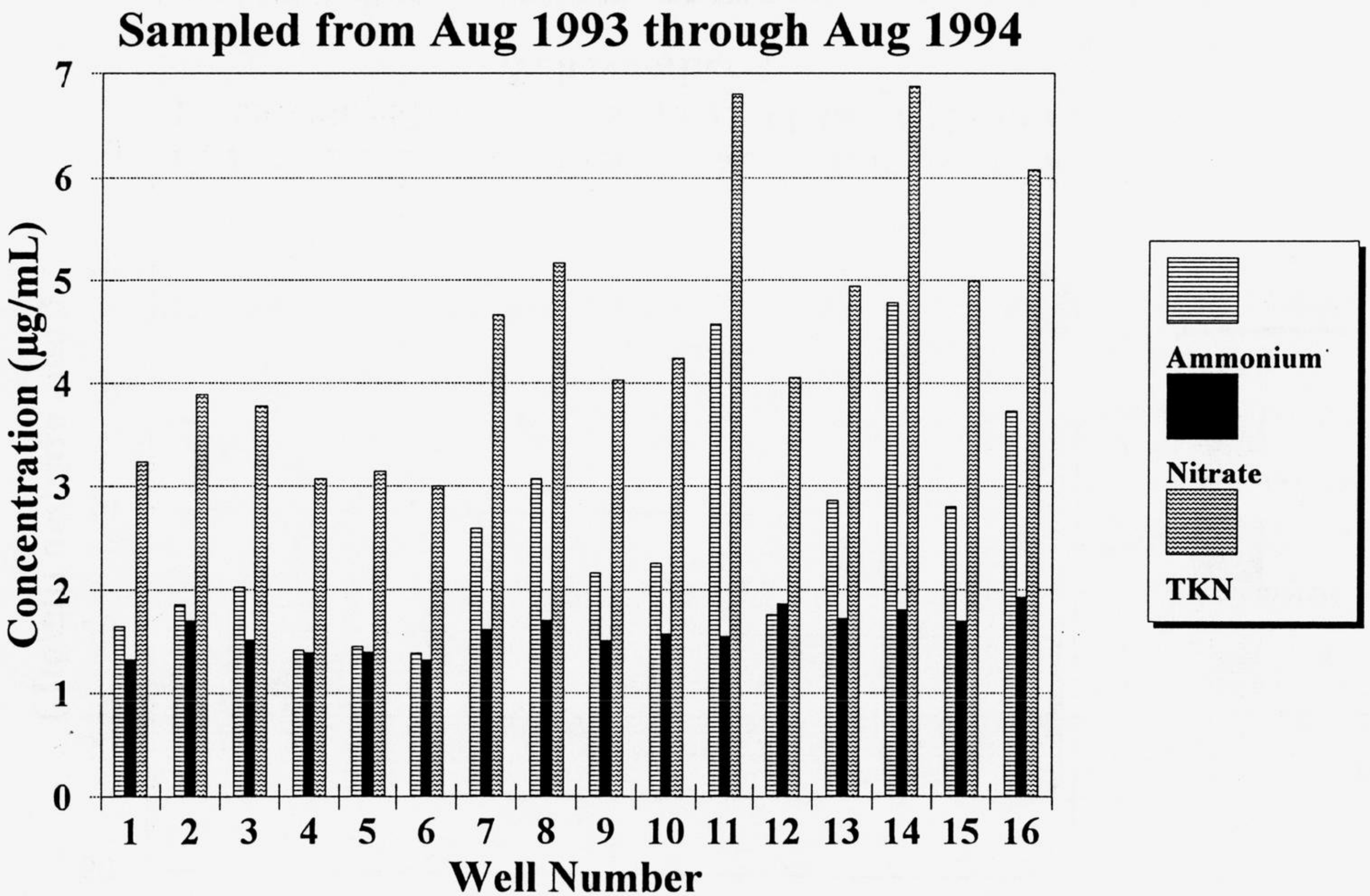


Figure 18. Average values of total Kjeldahl nitrogen (TKN), ammonium nitrogen (NH_4-N), and nitrate nitrogen (NO_3-N) in groundwater monitoring wells at Wisconsin Heights High School (Study 1970).

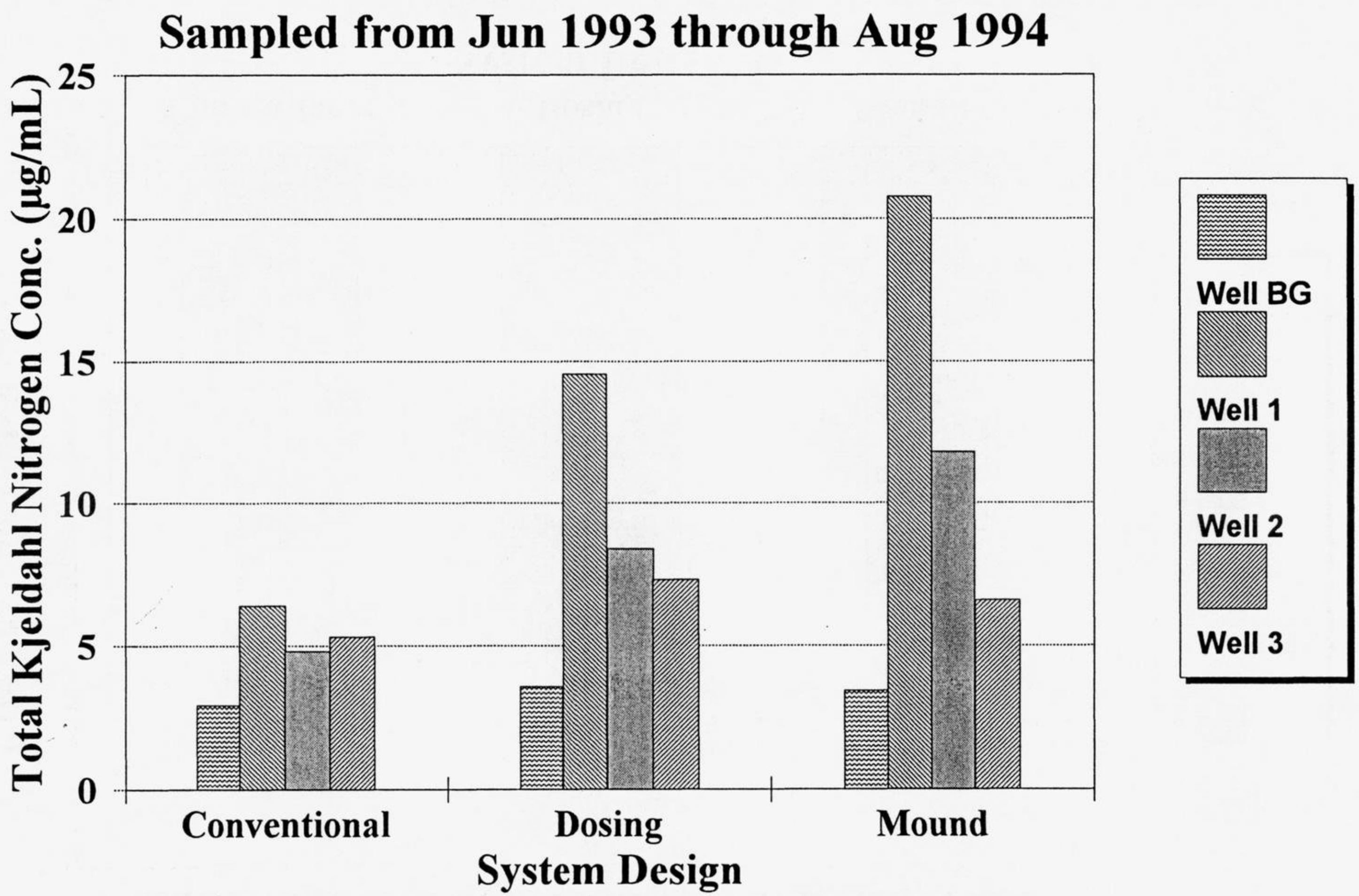


Figure 19. Average values of total Kjeldahl nitrogen (TKN) in groundwater monitoring wells at sites with septic systems of three different designs (conventional design: Sites 6, 8, and 13; dosing design: Sites 3, 9, and 12; mound design: Sites 1, 10, 14, and 15)

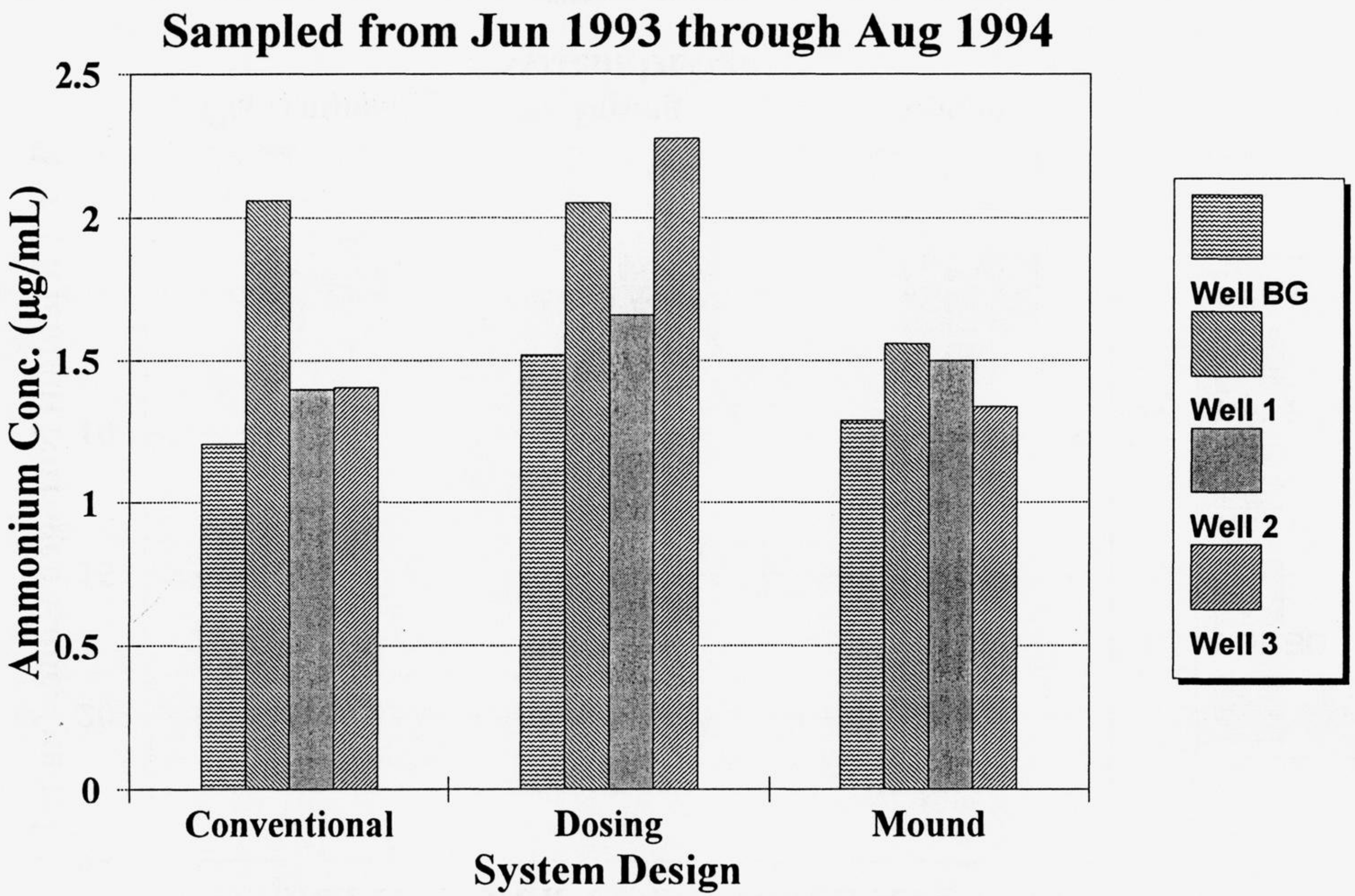


Figure 20. Average values of ammonium nitrogen (NH_4-N) in groundwater monitoring wells at sites with septic systems of three different designs (conventional design: Sites 6, 8, and 13; dosing design: Sites 3, 9, and 12; mound design: Sites 1, 10, 14, and 15)

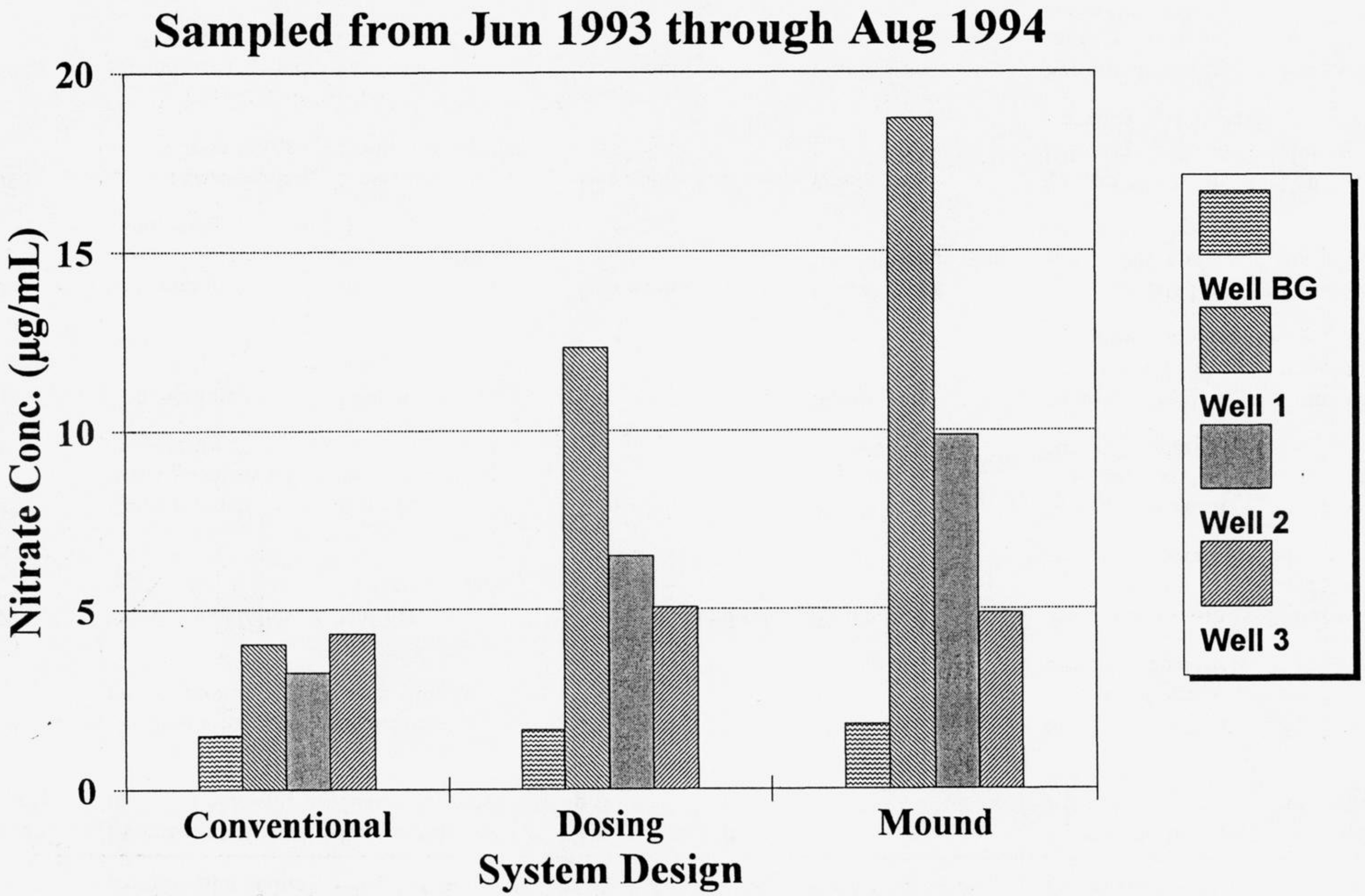


Figure 21. Average values of nitrate nitrogen (NO_3-N) in groundwater monitoring wells at sites with septic systems of three different designs (conventional design: Sites 6, 8, and 13; dosing design: Sites 3, 9, and 12; mound design: Sites 1, 10, 14, and 15)

Table 1. Information on the septic systems, groundwater monitoring wells, occupants, and duration of their tenancy during the year at sites studied

Site number/ original study	System type/ participation status	Site location	Occupants	Duration during the year	Septic system information	GW monitoring well[†] information
S-1/Study 1985	Mound/participated in GW monitoring	Lemonweir, Juneau County	Two adults and one girl	Whole year	System started in August 1980 and currently operational	Four wells installed and all discovered
S-3/Study 1985	Dosing/participated in GW monitoring	Merrimac, Sauk County	One adult	Whole year	System started in May 1980 and currently operational	Three wells installed and all discovered
S-5/Study 1985	Conventional/did not participate in this study	Buffalo, Marquette County	Two adults and one girl	Whole year	System started in May 1980 and currently operational	Four wells installed and one discovered during field visit
S-6/Study 1985	Conventional/ participated in GW monitoring	Necedah, Juneau County	Two adults	Whole year	System started in June 1980 and currently operational	Four well installed and all discovered
S-7/Study 1985	Conventional/agreed to participate in this study	Mecan, Marquette County	Two adults	Whole year	System started in September 1980 and currently operational	Four wells installed; none discovered
S-8/Study 1985	Conventional/ participated in GW monitoring	Merrimac, Sauk County	Two adults	June through October each year	System started in April 1980 and currently operational	Four wells installed and all discovered
S-9/Study 1985	Dosing/participated in GW monitoring	Lewiston, Columbia County	Two adults and two boys	Whole year	System started in February 1980 and currently operational	Four wells installed and all discovered
S-10/Study 1985	Mound/participated in GW monitoring	Lewiston, Columbia County	Two adults	Whole year	System started in January 1980 and currently operational	Four wells installed and all discovered

- continued -

Table 1. (continued)

Site number/ original study	System type/ participation status	Site location	Occupants	Duration during the year	Septic system information	GW monitoring well[†] information
S-11/Study 1985	Dosing/agreed to participate in this study	Pacific, Columbia County	Four adults	Three, whole year; one, half the year	System started in October 1980 and failed in mid-1992	Four wells installed; none discovered
S-12/Study 1985	Dosing/participated in GW monitoring	Lewiston, Columbia County	Two adults	Whole year	System started in September 1979 and currently operational	Four wells installed and all discovered
S-13/Study 1985	Conventional/ participated in GW monitoring	Lewiston, Columbia County	Two adults	Whole year	System started in November 1980 and currently operational	Four wells installed and found; two removed in 1994
S-14/Study 1985	Mound/participated in GW monitoring	Winfield, Sauk County	Two adults	Whole year	System started in October 1979 and currently operational	Four wells installed and all discovered
S-15/Study 1985	Mound/participated in GW monitoring	Winfield, Sauk County	Four adults	Whole year	System started in December 1980 and currently operational	Four wells installed and all discovered
S-16/Study 1985	Conventional/did not participate in this study	Necedah, Juneau County	Information not provided	Information not provided	System started in May 1980; current status not provided	Four wells installed; none discovered
S-17/Study 1985	Conventional/agreed to participate in this study	Big Flats, Adams County	Two adults and two children	Whole year	System started in May 1980 and currently operational	Four wells installed; none discovered
1-99/Study 1979	Mound/agreed to participate in this study	Caledonia, Racine County	Two adults	Whole year	System started in April 1976 and currently operational	Soil in the system examined; no GW well documented

- continued -

Table 1. (continued)

System number/ original study	System type/ participation status	Site location	Occupants	Duration during the year	Septic system information	GW monitoring well[†] information
1-160/Study 1979	Mound/agreed to participate in this study	Caledonia, Racine County	Three adults	Whole year	System started in July 1976 and currently operational	Soil in the system examined; no GW well documented
2-12/Study 1979	Mound/agreed to participate in this study	Sevastopol, Door County	Two adults	Seasonal duration	System started in October 1976 and currently operational	Soil in the system examined; no GW well documented
2-243/Study 1979	Mound/did not participate in this study	Sevastopol, Door County	Two adults	Whole year	System started in October 1976 and currently operational	Soil in the system examined; no GW well documented
3-34/Study 1979	Mound/agreed to participate in this study	Pleasant Prairie, Kenosha County	One of two adults in each duration (joint owners of property)	Occasional summer duration	System started in June 1976; currently not in steady use	Soil in the system examined; no GW well documented
3-61/Study 1979	Mound/agreed to participate in this study	Siegel, Wood County	Two adults	Whole year	System started in November 1975 and currently operational	Soil in the system examined; no GW well documented
3-67/Study 1979	Mound/system not available for this study	New Lisbon, Juneau County	Two adults (for the new system)	Whole year (for the new system)	System started in Dec. 1975; failed/ replaced in late 80'	Soil in the system examined; no GW well documented
3-69/Study 1979	Mound/did not participate in this study	Pittsville, Brown County	Three occupants	Whole year	System started in December 1975 and currently operational	Soil in the system examined; no GW well documented
3-71/Study 1979	Mound/agreed to participate in this study	Lemonweir, Juneau County	Two adults	Whole year	System started in October 1975 and currently operational	Soil in the system examined; no GW well documented

- continued -

Table 1. (continued)

Site number/ original study	System type/ participation status	Site location	Occupants	Duration during the year	Septic system information	GW monitoring well[†] information
3-73/Study 1979	Mound/did not participate in this study	Harrison, Calumet County	Four adults	Whole year	System started in November 1975 and currently operational	Soil in the system examined; no GW well documented
3-78/Study 1979	Mound/participated in GW monitoring	Sumner, Jefferson County	Estimate not achieved[‡]	Estimate not achieved[‡]	System started in November 1975 and currently operational	Four wells installed and all discovered
3-82/Study 1979	Mound/system not available for this study	Lodi, Columbia County	Two adults	Whole year	Started in Nov 1975; replaced in 1986 by centralized treatment	Four wells installed; removed upon the system termination
3-123/Study 1979	Mound/did not participate in this study	Lisbon, Waukesha County	Information not provided	Information not provided	System started in July 1976 and currently operational	Soil in the system examined; no GW well documented
3-132/Study 1979	Mound/agreed to participate in this study	Caledonia, Racine County	Two adults	Whole year	System started in July 1976 and currently operational	Soil in the system examined; no GW well documented
3-234/Study 1979	Mound/agreed to participate in this study	Caledonia, Racine County	Three adults	Whole year	System started in September 1976 and currently operational	Soil in the system examined; no GW well documented
3-273/Study 1979	Mound/agreed to participate in this study	New Berlin, Waukesha County	Five occupants	Whole year	System started in October 1976 and currently operational	Soil in the system examined; no GW well documented
Wisconsin Heights High School/Study 1970	Dosing/participated in GW monitoring	Mazomanie, Dane County	310 occupants during school year 1993	System received less use during school recession	System started in August 1967 and currently operational	Twenty-four wells installed and sixteen discovered

[†] GW monitoring wells = groundwater monitoring wells.

[‡] Estimate was not achieved for Site 3-78 since the system served a tavern which attracted uneven numbers of patrons during weekends and/or week nights.

Table 2. Wisconsin Unique Well Numbers assigned for previously installed groundwater monitoring wells discovered at sites studied

Site with monitoring network comprising of four wells				
Site Number	Well BG	Well #1	Well #2	Well #3
S-1 (Mound†)	GP401	GP402	GP403	GP404
S-3 (Dosing†)	GP405	GP406	GP407	GP408
S-6 (Conv'l†)	GP410	GP411	GP412	GP413
S-8 (Conv'l)	GP405	GP414	GP415	GP416
S-9 (Dosing)	GO848	GO849	GP417	GO850
S-10 (Mound)	GP418	GP419	GP420	GP421
S-12 (Dosing)	GO851	GP422	GP423	GP424
S-13 (Conv'l)	GP425	GP439‡	GP440‡	GP426
S-14 (Mound)	GP427	GP428	GP429	GP430
S-15 (Mound)	GP431	GP432	GP433	GP434
3-78 (Mound)	GP435	GP436	GP437	GP438
Wisconsin Heights High School (Dosing)				
Well #1	Well #2	Well #3	Well #4	Well #5
GO832	GO833	GO834	GO835	GO836
Well #6	Well #7	Well #8	Well #9	Well #10
GO837	GO838	GO839	GO840	GO841
Well #11	Well #12	Well #13	Well #14	Well #15
GO842	GO843	GO844	GO845	GO846
Well #16				
GO847				

† Conv'l = conventional septic system, Dosing = conventional system with a pump chamber and dosing system, and mound = mound-type system.
‡ GP439 and GP440 were removed from Site 13 during May 1994.

Table 3. Average values of total Kjeldahl nitrogen (TKN) in septic tank effluent obtained from the current study and the previous studies (Studies 1985, 1979, and 1970) for sites examined

Site number	Previous studies	Current study
	Total Kjeldahl nitrogen (TKN) concentration (μg/mL)	
S-1 (Mound†)	45‡	164.48
S-3 (Dosing†)	115‡	83.91
S-6 (Conv'l†)	105‡	Not applicable*
S-8 (Conv'l)	51‡	Not applicable*
S-9 (Dosing)	55‡	66.88
S-10 (Mound)	112‡	65.43
S-12 (Dosing)	76‡	65.13
S-13 (Conv'l)	72‡	100.74
S-14 (Mound)	72‡	105.58
S-15 (Mound)	52‡	110.21
3-78 (Mound)	104.68§	134.20
WHHS† (Dosing)	30.98¶	52.57

† WHHS = the Wisconsin Heights High School; Conv'l = conventional system, Dosing = conventional system with a pump chamber and dosing system, and Mound = mound-type system.
‡ Values obtained from Study 1985.
§ Value obtained from Study 1979.
¶ Value obtained from Study 1970.
* Septic tanks no longer accessible.

Table 4. Results of bacterial analyses (total coliforms, fecal coliforms, and fecal streptococci counts) of August 1994 septic tank effluent and groundwater samples from Wisconsin Heights High School (Study 1970)

Sample source	Total coliforms	Fecal coliforms	Fecal streptococci
The most probable numbers per 100 mL of liquid (MPN/100 mL)			
Well #1	ND[†]	ND	ND
Well #2	ND	ND	ND
Well #3	ND	ND	ND
Well #4	ND	ND	ND
Well #5	ND	ND	ND
Well #6	ND	ND	ND
Well #7	ND	ND	ND
Well #8	ND	ND	ND
Well #9	ND	ND	ND
Well #10	ND	ND	ND
Well #11	ND	ND	ND
Well #12	ND	ND	ND
Well #13	ND	ND	ND
Well #14	ND	ND	ND
Well #15	ND	ND	ND
Well #16	ND	ND	ND
STE[‡]	6.5×10^5	1.7×10^5	4.3×10^3

† ND = No colony was detected in the sample.
‡ STE = Septic tank effluent.

Table 5. Results of bacterial analyses of August 1994 septic tank effluent and groundwater samples from sites originated in Studies 1985 and 1979: I. total coliforms counts

Site number	STE[†]	Well BG[†]	Well #1	Well #2	Well #3
	The most probable numbers per 100 mL of liquid (MPN/100 mL)				
S-1 (Mound[†])	$6.8x10^7$	ND[‡]	ND	ND	ND
S-3 (Dosing[†])	$2.5x10^7$	ND	ND	ND	ND
S-6 (Conv'l[†])	Not applicable[§]	ND	ND	ND	ND
S-8 (Conv'l)	Not applicable[§]	ND	ND	ND	ND
S-9 (Dosing)	$3.2x10^6$	ND	ND	ND	ND
S-10 (Mound)	$2.0x10^7$	ND	ND	ND	ND
S-12 (Dosing)	$8.7x10^4$	ND	ND	ND	ND
S-13 (Conv'l)	$7.3x10^5$	ND	Not applicable[¶]	Not applicable[¶]	ND
S-14 (Mound)	$5.8x10^5$	ND	ND	ND	ND
S-15 (Mound)	$8.1x10^7$	ND	ND	ND	ND
3-78 (Mound)	$4.1x10^6$	ND	ND	ND	ND

† STE = septic tank effluent; Well BG = background monitoring well; Conv'l = conventional septic system, Dosing = conventional system with a pump chamber and dosing system, and Mound = mound-type system.
‡ ND = No colony was detected in the sample.
§ Septic tanks no longer accessible.
¶ Wells removed in April 1994.

Table 6. Results of bacterial analyses of August 1994 septic tank effluent and groundwater samples from sites originated in Studies 1985 and 1979: II. fecal coliforms counts

Site number	STE[†]	Well BG[†]	Well #1	Well #2	Well #3
	The most probable numbers per 100 mL of liquid (MPN/100 mL)				
S-1 (Mound[†])	$1.4x10^6$	ND[‡]	ND	ND	ND
S-3 (Dosing[†])	$5.6x10^6$	ND	ND	ND	ND
S-6 (Conv'l[†])	Not applicable[§]	ND	ND	ND	ND
S-8 (Conv'l)	Not applicable[§]	ND	ND	ND	ND
S-9 (Dosing)	$4.1x10^5$	ND	ND	ND	ND
S-10 (Mound)	$5.2x10^6$	ND	ND	ND	ND
S-12 (Dosing)	$1.9x10^4$	ND	ND	ND	ND
S-13 (Conv'l)	$1.1x10^5$	ND	Not applicable[¶]	Not applicable[¶]	ND
S-14 (Mound)	$6.2x10^4$	ND	ND	ND	ND
S-15 (Mound)	$5.6x10^6$	ND	ND	ND	ND
3-78 (Mound)	$6.4x10^4$	ND	ND	ND	ND

† STE = septic tank effluent; Well BG = background monitoring well; Conv'l = conventional septic system, Dosing = conventional system with a pump chamber and dosing system, and Mound = mound-type system.
‡ ND = colony was detected in the sample.
§ Septic tanks no longer accessible.
¶ Wells removed in April 1994.

Table 7. Results of bacterial analyses of August 1994 septic tank effluent and groundwater samples from sites originated in Studies 1985 and 1979: III. fecal streptococci counts

Site number	STE†	Well BG†	Well #1	Well #2	Well #3
	The most probable numbers per 100 mL of liquid (MPN/100 mL)				
S-1 (Mound†)	$3.0x10^5$	ND‡	ND	ND	ND
S-3 (Dosing†)	$4.2x10^5$	ND	ND	ND	ND
S-6 (Conv'l†)	Not applicable§	ND	ND	ND	ND
S-8 (Conv'l)	Not applicable§	ND	ND	ND	ND
S-9 (Dosing)	$1.6x10^4$	ND	ND	ND	ND
S-10 (Mound)	$7.9x10^4$	ND	ND	ND	ND
S-12 (Dosing)	$6.5x10^2$	ND	ND	ND	ND
S-13 (Conv'l)	$1.4x10^3$	ND	Not applicable¶	Not applicable¶	ND
S-14 (Mound)	$1.7x10^4$	ND	ND	ND	ND
S-15 (Mound)	$9.4x10^4$	ND	ND	ND	ND
3-78 (Mound)	$2.1x10^4$	ND	ND	ND	ND

† STE = septic tank effluent; Well BG = background monitoring well; Conv'l = conventional septic system, Dosing = conventional system with a pump chamber and dosing system, and Mound = mound-type system.
‡ ND = No colony was detected in the sample.
§ Septic tanks no longer accessible.
¶ Wells removed in April 1994.

APPENDIX 1

DATA ON MONTHLY GROUNDWATER LEVELS IN MONITORING WELLS, MONTHLY NITROGEN CONTENTS (AMMONIUM, NITRATE, AND TOTAL KJELDAHL NITROGEN) AND JUNE 1994 BACTERIAL COUNTS (TOTAL COLIFORMS, FECAL COLIFORMS, AND FECAL STREPTOCOCCI) IN SEPTIC TANK EFFLUENT AND GROUNDWATER AT INDIVIDUAL SITES

Table 1. Depth to Groundwater from Soil Surface in Monitoring Wells in June 1993 at Sites from Studies 1985 & 1979.

Site Number	Well BG	Well #1	Well #2	Well #3
	Depth of groundwater table from ground surface (ft)			
S-1 (Mound)	Wells were not found.			
S-3 (Dosing)	Not found	10.00	9.84	Not found
S-5 (Conv'l)	3.54	Not found	Not found	Not found
S-6 (Conv'l)	Clogged	9.68	9.88	9.76
S-7 (Conv'l)	Wells were not found.			
S-8 (Conv'l)	Wells were not found.			
S-9 (Conv'l)	Not found	Not found	9.62	Not found
S-10 (Mound)	Not found	Not found	Not found	6.44
S-11 (Dosing)	Wells were not found.			
S-12 (Dosing)	Not found	8.86	8.70	8.56
S-13 (Conv'l)	4.32	Not found	Not found	6.04
S-14 (Mound)	5.90	Not found	Not found	Not found
S-15 (Mound)	2.32	Not found	Not found	Not found
1-99 (Mound)	Wells were not found.			
1-160 (Mound)	One clogged well suspected as Well #1 was found on the mound.			
3-71 (Mound)	One clogged well suspected as Well #1 was found on the mound.			

3-78 (Mound)	Not found	Not found	2.64	Not found
3-132 (Mound)	Wells were not found.			
3-234 (Mound)	Wells were not found.			
3-273 (Mound)	Wells were not found.			
3-34 (Mound)	Wells were not found.			

Notes:

1. "Well BG"= The background well; "Conv'l"= The conventional system, "Dosing"= The dosing system, and "Mound"= The Mound-type system.
2. Measurements of the groundwater table depths were performed using the Solinst ground water well tape through June, 1993.

Table 2. Depth to Groundwater from Soil Surface in Monitoring Wells in July 1993 at Sites from Studies 1985 & 1979.

Site Number	Well BG	Well #1	Well #2	Well #3
Depth of groundwater table from ground surface (ft)				
S-1 (Mound)	Wells not yet found			
S-3 (Dosing)	Not found	9.78	9.64	Not found
S-5 (Conv'l)	3.42	Not found	Not found	Not found
S-6 (Conv'l)	8.50	9.84	10.06	9.98
S-7 (Conv'l)	Wells not yet found			
S-8 (Conv'l)	Wells not yet found			
S-9 (Dosing)	Not found	Not found	9.82	Not found
S-10 (Mound)	Not found	Not found	Not found	6.56
S-11 (Dosing)	Wells not yet found			
S-12 (Dosing)	Not found	9.06	8.90	8.78
S-13 (Conv'l)	4.64	Not found	Not found	6.38
S-14 (Mound)	6.14	Not found	Not found	Not found
S-15 (Mound)	2.52	Not found	Not found	Not found
3-78 (Mound)	Not found	Not found	2.52	Not found

Notes:

1. "Well BG" = Background well; "Conv'l" = Conventional septic system, "Dosing" = Conventional system with a pump chamber and dosing system, and "Mound" = Mound-type system.
2. Measurements of the groundwater table depths were performed using the Solinst groundwater well tape from July 28-31,1993.

Table 3. Depth to Groundwater from Soil Surface in Monitoring Wells in August 1993 at Sites from Studies 1985 & 1979.

Site Number	Well BG	Well #1	Well #2	Well #3
Depth of groundwater table from ground surface (ft)				
S-1 (Mound)	6.34	7.94	7.60	6.98
S-3 (Dosing)	Not found	9.44	9.36	Not found
S-5 (Conv'l)	3.18	Not found	Not found	Not found
S-6 (Conv'l)	7.98	9.26	9.38	9.30
S-7 (Conv'l)	Wells not yet found			
S-8 (Conv'l)	Wells not yet found			
S-9 (Dosing)	Not found	Not found	9.42	Not found
S-10 (Mound)	5.10	6.54	6.10	6.06
S-11 (Dosing)	Wells not yet found			
S-12 (Dosing)	Not found	8.70	8.52	8.32
S-13 (Conv'l)	5.14	Not found	Not found	6.78
S-14 (Mound)	5.82	Not found	Not found	Not found
S-15 (Mound)	2.56	Not found	Not found	Not found
3-78 (Mound)	1.92	1.78	2.34	2.12

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Measurements of depths to groundwater were performed using the Solinst groundwater well tape from August 26-31, 1993.

Table 4. Depth to Groundwater from Soil Surface in Monitoring Wells in September 1993 at Sites from Studies 1985 & 1979.

Site Number	Well BG	Well #1	Well #2	Well #3
Depth of groundwater table from ground surface (ft)				
S-1 (Mound)	5.62	8.60	7.60	6.98
S-3 (Dosing)	9.34	9.98	9.88	9.54
S-5 (Conv'l)	3.60	Not found	Not found	Not found
S-6 (Conv'l)	9.04	10.24	10.42	10.34
S-7 (Conv'l)	Wells not yet found			
S-8 (Conv'l)	9.34	8.50	7.80	7.84
S-9 (Dosing)	Not found	Not found	10.34	Not found
S-10 (Mound)	5.84	7.38	6.88	6.84
S-11 (Dosing)	Wells not yet found			
S-12 (Dosing)	Not found	9.6	9.44	9.24
S-13 (Conv'l)	6.44	Not found	Not found	8.04
S-14 (Mound)	6.34	Not found	Not found	Not found
S-15 (Mound)	2.98	Not found	Not found	Not found
3-78 (Mound)	2.14	1.98	2.58	2.34

Notes:
1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Measurements of depths to groundwater were performed using the Solinst groundwater well tape from September 24-28, 1993.

Table 5. Depth to Groundwater from Soil Surface in Monitoring Wells in October 1993 at Sites from Studies 1985 & 1979.

SiteNumber	Well BG	Well #1	Well #2	Well #3
Depth of groundwater table from ground surface (ft)				
S-1 (Mound)	6.04	9.18	8.22	7.36
S-3 (Dosing)	9.70	10.46	10.32	9.50
S-6 (Conv'l)	9.70	10.92	11.08	11.04
S-8 (Conv'l)	9.70	8.88	8.14	8.08
S-9 (Dosing)	12.28	Not found	11.06	Not found
S-10 (Mound)	6.30	7.64	7.26	7.22
S-12 (Dosing)	Not found	10.02	9.92	9.76
S-13 (Conv'l)	7.50	Not found	Not found	8.56
S-14 (Mound)	6.46	Not found	Not found	Not found
S-15 (Mound)	3.08	Not found	Not found	Not found
3-78 (Mound)	2.40	2.24	2.82	2.56

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Measurements of the groundwater table depths were performed using a Solinst groundwater well tape October 26 & 29-31, 1993.

Table 6. Depth to Groundwater from Soil Surface in Monitoring Wells in November 1993 at Sites from Studies 1985& 1979.

SiteNumber	Well BG	Well #1	Well #2	Well #3
Depth of groundwater table from ground surface (ft)				
S-1 (Mound)	6.30	9.54	8.58	7.66
S-3 (Dosing)	10.12	10.80	10.62	9.66
S-6 (Conv'l)	10.14	11.28	11.46	11.42
S-8 (Conv'l)	10.12	9.24	8.58	8.20
S-9 (Dosing)	12.72	Not found	11.50	Not found
S-10 (Mound)	6.64	7.96	7.50	7.58
S-12 (Dosing)	Not found	10.36	10.28	10.18
S-13 (Conv'l)	8.16	Not found	Not found	8.82
S-14 (Mound)	6.70	5.20	3.24	3.14
S-15 (Mound)	3.30	3.62	2.08	1.68
3-78 (Mound)	2.62	2.48	3.02	2.72

Notes:
1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Measurements of the groundwater table depths were performed using a Solinst groundwater well tape a November 19-23,1993.

Table 7. Depth to Groundwater from Soil Surface in Monitoring Wells in December 1993 at Sites from Studies 1985 & 1979.

Site Number	Well BG	Well #1	Well #2	Well #3
Depth of groundwater table from ground surface (ft)				
S-1 (Mound)	6.36	9.64	8.66	7.72
S-3 (Dosing)	9.96	10.68	10.44	9.62
S-6 (Conv'l)	10.32	11.48	11.62	11.60
S-8 (Conv'l)	9.96	9.14	8.56	8.16
S-9 (Dosing)	13.10	Not found	11.86	Not found
S-10 (Mound)	6.72	8.04	7.60	7.70
S-12 (Dosing)	Not found	10.68	10.54	10.50
S-13 (Conv'l)	8.54	9.62	9.50	9.00
S-14 (Mound)	6.76	5.32	3.34	3.16
S-15 (Mound)	3.36	3.74	2.14	1.70
3-78 (Mound)	2.70	2.52	3.06	2.74

Notes:
1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Measurements of the groundwater table depths were performed using a Solinst groundwater well tape December 10-14, 1993.

Table 8. Depth to Groundwater from Soil Surface in Monitoring Wells in January 1994 at Sites from Studies 1985 & 1979.

Site Number	Well BG	Well #1	Well #2	Well #3
Depth of groundwater table from ground surface (ft)				
S-1(Mound)	6.32	9.42	8.48	7.54
S-3 (Dosing)	9.84	10.64	10.40	9.60
S-6 (Conv'l)	9.92	11.04	11.18	11.16
S-8 (Conv'l)	9.84	9.06	8.46	8.08
S-9 (Dosing)	13.08	12.16	11.84	11.28
S-10 (Mound)	6.60	7.92	7.50	7.58
S-12 (Dosing)	10.32	10.34	10.18	10.16
S-13 (Conv'l)	8.12	9.40	9.28	8.76
S-14 (Mound)	6.66	5.24	3.26	3.08
S-15 (Mound)	3.28	3.64	2.06	1.64
3-78 (Mound)	2.58	2.42	2.94	2.62

Notes:
1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Measurements of the groundwater table depths were performed using a Solinst groundwater well tape January 25-28, 1994.

Table 9. Depth to Groundwater from Soil Surface in Monitoring Wells in February 1994 at Sites from Studies 1985 & 1979.

Site Number	Well BG	Well #1	Well #2	Well #3
Depth of groundwater table from ground surface (ft)				
S-1 (Mound)	6.08	9.14	8.24	7.36
S-3 (Dosing)	9.64	10.48	10.26	9.46
S-6 (Conv'l)	9.56	10.66	10.82	10.80
S-8 (Conv'l)	9.64	8.88	8.28	7.90
S-9 (Dosing)	13.04	12.16	11.80	11.26
S-10 (Mound)	6.22	7.56	7.08	7.14
S-12 (Dosing)	9.70	9.72	9.54	9.50
S-13 (Conv'l)	7.36	9.02	8.94	8.38
S-14 (Mound)	6.42	5.02	3.24	2.88
S-15 (Mound)	2.96	3.34	1.80	1.42
3-78 (Mound)	2.36	2.20	2.70	2.38

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Measurements of the groundwater table depths were performed using a Solinst groundwater well tape February 24-27, 1994.

Table 10. Depth to Groundwater from Soil Surface in Monitoring Wells in March 1994 at Sites from Studies 1985 & 1979.

Site Number	Well BG	Well #1	Well #2	Well #3
Depth of groundwater table from ground surface (ft)				
S-1 (Mound)	5.88	8.64	7.68	6.94
S-3 (Dosing)	9.52	10.20	9.96	9.18
S-6 (Conv'l)	9.22	10.34	10.50	10.46
S-8 (Conv'l)	9.52	8.56	8.00	7.62
S-9 (Dosing)	12.36	11.50	11.14	10.58
S-10 (Mound)	5.74	7.06	6.56	6.62
S-12 (Dosing)	9.02	9.06	8.84	8.76
S-13 (Conv'l)	6.46	8.60	8.52	7.98
S-14 (Mound)	6.10	4.68	2.92	2.58
S-15 (Mound)	2.60	3.02	1.58	1.36
3-78 (Mound)	2.14	2.06	2.54	2.24

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Measurements of the groundwater table depths were performed using a Solinst groundwater well tape March 25-28, 1994.

Table 11. Depth to Groundwater from Soil Surface in Monitoring Wells in April 1994 at Sites from Studies 1985 & 1979.

Site Number	Well BG	Well #1	Well #2	Well #3
Depth of groundwater table from ground surface (ft)				
S-1 (Mound)	5.70	8.52	7.60	6.86
S-3 (Dosing)	9.46	10.14	9.92	9.44
S-6 (Conv'l)	9.06	9.84	10.04	10.08
S-8 (Conv'l)	9.46	8.52	7.92	7.84
S-9 (Dosing)	13.02	12.54	11.86	10.94
S-10 (Mound)	5.60	6.90	6.38	6.42
S-12 (Dosing)	9.46	9.48	9.28	9.20
S-13 (Conv'l)	6.32	8.24	8.16	7.80
S-14 (Mound)	6.42	5.40	3.48	2.98
S-15 (Mound)	3.16	3.40	2.04	1.86
3-78 (Mound)	2.48	2.66	2.78	2.76

Notes:
1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound =Mound-type system.
2. Measurements of the groundwater table depths were performed using a Solinst groundwater well tape April 21-25, 1994.

Table 12. Depth to Groundwater from Soil Surface in Monitoring Wells in May 1994 at Sites from Studies 1985 & 1979.

Site Number	Well BG	Well #1	Well #2	Well #3
Depth of groundwater table from ground surface (ft)				
S-1 (Mound)	6.02	8.94	7.96	7.28
S-3 (Dosing)	9.70	10.28	10.18	9.74
S-6 (Conv'l)	8.92	9.48	9.66	9.78
S-8 (Conv'l)	9.70	8.76	8.24	8.38
S-9 (Dosing)	13.80	13.82	12.48	11.48
S-10 (Mound)	6.02	7.44	6.94	7.06
S-12 (Dosing)	10.66	10.52	10.36	10.30
S-13 (Conv'l)	6.68	7.90	7.64	8.26
S-14 (Mound)	6.98	6.44	4.44	3.90
S-15 (Mound)	4.48	4.22	3.12	2.92
3-78 (Mound)	3.06	3.78	3.32	3.72

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system,Dosing = Conventional system with a pump chamber and dosing system,and Mound = Mound-type system.
2. Measurements of the groundwater table depths were performed using a Solinst groundwater well tape May 23-38, 1994.

Table 13. Depth to Groundwater from Soil Surface in Monitoring Wells in June 1994 at Sites from Studies 1985 & 1979.

Site Number	Well BG	Well #1	Well #2	Well #3
Depth of groundwater table from ground surface (ft)				
S-1 (Mound)	6.40	9.24	8.20	7.60
S-3 (Dosing)	9.54	10.20	10.06	9.60
S-6 (Conv'l)	8.84	9.36	9.52	9.72
S-8 (Conv'l)	9.54	8.74	8.12	7.74
S-9 (Dosing)	14.24	14.26	13.38	12.38
S-10 (Mound)	6.74	8.06	7.66	7.82
S-12 (Dosing)	11.44	11.32	11.12	11.08
S-13 (Conv'l)	6.80	Removed	Removed	8.42
S-14 (Mound)	7.42	7.10	5.04	4.36
S-15 (Mound)	4.96	4.78	3.74	3.56
3-78 (Mound)	3.90	4.54	4.12	4.20

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing =Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Measurements of the groundwater table depths were performed using a Solinst groundwater well tape June 24-29, 1994.

Table 14. Depth to Groundwater from Soil Surface in Monitoring Wells in July 1994 at Sites from Studies 1985 & 1979.

Site Number	Well BG	Well #1	Well #2	Well #3
Depth of groundwater table from ground surface (ft)				
S-1 (Mound)	6.64	9.70	8.64	8.02
S-3 (Dosing)	9.92	10.52	10.36	9.96
S-6 (Conv'l)	9.58	10.32	10.44	10.52
S-8 (Conv'l)	9.92	9.16	8.52	8.14
S-9 (Dosing)	14.56	14.56	13.66	12.80
S-10 (Mound)	7.06	8.40	7.96	8.12
S-12 (Dosing)	12.06	11.92	11.70	11.68
S-13 (Conv'l)	7.14	Removed	Removed	8.78
S-14 (Mound)	7.64	7.38	5.30	4.60
S-15 (Mound)	5.16	5.02	3.96	3.78
3-78 (Mound)	4.04	4.70	4.28	4.34

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound =Mound-type system.
2. Measurements of the groundwater table depths were performed using a Solinst groundwater well tape July 23-26, 1994.

Table 15. Depth to Groundwater from Soil Surface in Monitoring Wells in August 1994 at Sites from Studies 1985 &1979.

Site Number	Well BG	Well #1	Well #2	Well #3
Depth of groundwater table from ground surface (ft)				
S-1 (Mound)	6.46	9.36	8.32	7.74
S-3 (Dosing)	9.60	10.28	10.10	9.68
S-6 (Conv'l)	9.70	10.56	10.68	10.70
S-8 (Conv'l)	9.60	8.90	8.24	7.88
S-9 (Dosing)	14.12	14.14	13.32	12.54
S-10 (Mound)	6.52	7.84	7.40	7.62
S-12 (Dosing)	11.32	11.18	10.98	10.96
S-13 (Conv'l)	6.92	Removed	Removed	8.58
S-14 (Mound)	7.22	6.94	4.84	4.14
S-15 (Mound)	4.78	4.60	3.56	3.36
3-78 (Mound)	3.28	3.92	3.48	3.52

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system,Dosing =Conventional system with a pump chamber and dosing system,and Mound = Mound-type system.
2. Measurements of the groundwater table depths were performed using a Solinst groundwater well tape August 17-21, 1994.

Table 16. Ammonium/Nitrate Contents in June 1993 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent		Well BG		Well #1		Well #2		Well #3	
Conc. (μg/mL)	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N
S-1 (Mound)	Wells were not found.									
S-3 (Dosing)	89.2	3.56	Not found		1.63	11.18	1.26	5.11	Not found	
S-5 (Conv'l)	23.2	3.44	2.12	1.00	Not found		Not found		Not found	
S-6 (Conv'l)	Not found		Clogged		0.86	0.79	0.98	1.61	1.05	1.12
S-7 (Conv'l)	Wells were not found.									
S-8 (Conv'l)	Wells were not found.									
S-9 (Conv'l)	28.6	3.56	Not found		Not found		0.75	1.10	Not found	
S-10 (Mound)	11.8	3.72	Not found		Not found		Not found		1.03	1.19
S-11 (Dosing)	Wells were not found.									
S-12 (Dosing)	38.2	3.44	Not found		1.07	2.08	0.82	1.49	1.00	1.61
S-13 (Conv'l)	55.2	2.88	0.98	2.03	Not found		Not found		0.91	26.53
S-14 (Mound)	80.7	3.56	1.12	1.47	Not found		Not found		Not found	

S-15 (Mound)	71.1	3.08	1.07	1.22	Not found		Not found		Not found
1-99 (Mound)	Wells were not found.								
1-160 (Mound)	One clogged well suspected as Well #1 was found on the mound.								
3-71 (Mound)	One clogged well suspected as Well #1 was found on the mound.								
3-78 (Mound)	99.2	4.03	Not found		Not found		1.13	2.34	Not found
3-132 (Mound)	Wells were not found.								
3-234 (Mound)	Wells were not found.								
3-273 (Mound)	Wells were not found.								
3-34 (Mound)	Wells were not found.								

Notes:

1. "Well BG"= The background well; "Conv'l"= The conventional system, "Dosing"= The dosing system, and "Mound"= The Mound -type system.
2. Sites with available wells were sampled from June 10 to June 17, 1993.
3. Ammonium and nitrate nitrogen (NH_4^+-N, NO_3^--N) were determined using direct steam distillation methods as described by Bremner and Keeney (1965). 5 mL of effluent or 20 mL of groundwater in each sample was used for analysis.

Table 17. Ammonium/Nitrate Contents in July 1993 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent		Well BG		Well #1		Well #2		Well #3	
Conc. (μg/mL)	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N
S-1 (Mound)	Wells not yet found									
S-3 (Dosing)	81.4	3.49	Not found		1.56	9.67	1.33	4.58	Not found	
S-5 (Conv'l)	39.9	3.61	2.07	0.98	Not found		Not found		Not found	
S-6 (Conv'l)	Not found		1.06	1.29	1.11	1.13	1.24	1.52	1.28	1.25
S-7 (Conv'l)	Wells not yet found									
S-8 (Conv'l)	Wells not yet found									
S-9 (Dosing)	46.5	3.55	Not found		Not found		0.99	1.53	Not found	
S-10 (Mound)	30.9	4.71	Not found		Not found		Not found		1.16	1.40
S-11 (Dosing)	Wells not yet found									
S-12 (Dosing)	53.6	3.62	Not found		1.51	3.09	1.18	2.68	1.09	2.04
S-13 (Conv'l)	71.3	6.81	0.88	2.57	Not found		Not found		1.75	7.71
S-14 (Mound)	90.2	4.75	1.10	1.83	Not found		Not found		Not found	
S-15 (Mound)	87.6	4.88	1.22	1.65	Not found		Not found		Not found	
3-78 (Mound)	134.8	8.07	Not found		Not found		1.72	2.81	Not found	

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled from July 28-31, 1993.
3. Ammonium and nitrate nitrogen (NH_4^+-N, NO_3^--N) were determined using the direct steam distillation method of Bremner and Keeney (1965) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 18. Ammonium/Nitrate Contents in August 1993 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent		Well BG		Well #1		Well #2		Well #3	
Conc. (µg/mL)	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N
S-1 (Mound)	150.2	9.14	1.37	2.44	2.39	6.90	2.65	8.31	1.92	9.26
S-3 (Dosing)	73.4	3.03	Not found		1.49	8.66	1.31	4.37	Not found	
S-5 (Conv'l)	37.7	3.52	1.92	0.95	Not found		Not found		Not found	
S-6 (Conv'l)	Not found		0.95	1.26	0.92	1.03	0.96	1.41	1.14	1.38
S-7 (Conv'l)	Wells not yet found									
S-8 (Conv'l)	Wells not yet found									
S-9 (Dosing)	32.9	3.64	Not found		Not found		0.97	1.46	Not found	
S-10 (Mound)	21.3	4.61	1.22	1.42	1.17	5.69	1.19	4.82	1.01	1.04
S-11 (Dosing)	Wells not yet found									
S-12 (Dosing)	45.6	3.56	Not found		1.37	2.94	1.09	2.35	0.97	1.96
S-13 (Conv'l)	62.5	5.14	0.82	2.51	Not found		Not found		1.74	4.21
S-14 (Mound)	87.1	4.52	1.08	1.81	Not found		Not found		Not found	
S-15 (Mound)	85.7	4.86	1.21	1.55	Not found		Not found		Not found	
3-78 (Mound)	106.4	4.41	1.16	1.62	1.84	3.56	1.59	2.68	2.57	2.43

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled from August 26-31, 1993.
3. Ammonium and nitrate nitrogen (NH_4^+-N, NO_3^--N) were determined using the direct steam distillation method of Bremner and Keeney (1965) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 19. Ammonium/Nitrate Contents in September 1993 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent		Well BG		Well #1		Well #2		Well #3	
Conc. (μg/mL)	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N
S-1 (Mound)	135.2	6.02	1.14	1.32	2.36	5.42	2.87	7.76	1.33	9.38
S-3 (Dosing)	62.31	2.74	1.08	0.89	1.44	8.46	1.29	4.03	0.92	2.80
S-5 (Conv'l)	37.2	3.91	1.84	0.91	Not found		Not found		Not found	
S-6 (Conv'l)	Not found		0.97	1.09	0.84	0.71	0.95	1.40	1.29	1.21
S-7 (Conv'l)	Wells not yet found									
S-8 (Conv'l)	Not found		1.08	0.89	2.59	1.47	1.74	1.26	3.08	1.79
S-9 (Dosing)	41.5	3.79	Not found		Not found		0.88	1.43	Not found	
S-10 (Mound)	28.6	5.39	1.06	1.35	1.09	5.17	1.15	4.69	0.93	1.08
S-11 (Dosing)	Wells not yet found									
S-12 (Dosing)	39.4	3.18	Not found		1.04	2.73	1.00	2.20	0.92	1.79
S-13 (Conv'l)	83.9	8.12	0.64	2.47	Not found		Not found		1.58	2.49
S-14 (Mound)	75.3	4.77	1.02	1.53	Not found		Not found		Not found	
S-15 (Mound)	50.7	3.68	1.17	1.18	Not found		Not found		Not found	
3-78 (Mound)	86.2	6.44	0.77	1.54	1.67	3.72	1.24	2.69	2.66	2.87

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled from September 24-28, 1993.
3. Ammonium and nitrate nitrogen (NH_4^+-N, NO_3^--N) were determined using the direct steam distillation method of Bremner and Keeney (1965) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 20. Ammonium/Nitrate Contents in October 1993 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent		Well BG		Well #1		Well #2		Well #3	
Conc. (μg/mL)	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N
S-1 (Mound)	166.3	8.03	1.47	1.78	2.38	6.71	2.08	5.76	2.13	7.31
S-3 (Dosing)	70.39	2.96	1.51	1.26	1.92	7.69	1.68	4.74	1.55	3.32
S-6 (Conv'l)	Not found		0.99	1.15	1.03	0.98	1.01	1.21	1.12	1.16
S-8 (Conv'l)	Not found		1.51	1.26	1.54	1.81	1.07	1.44	1.85	1.27
S-9 (Dosing)	52.71	9.24	1.79	2.01	Not found		1.36	2.14	Not found	
S-10 (Mound)	34.44	5.81	1.28	1.82	1.09	5.85	1.21	4.88	1.20	2.03
S-12 (Dosing)	42.53	4.24	Not found		1.94	4.12	1.46	3.84	1.43	3.26
S-13 (Conv'l)	72.41	5.37	0.79	1.53	Not found		Not found		1.42	3.71
S-14 (Mound)	64.32	4.96	1.31	1.89	Not found		Not found		Not found	
S-15 (Mound)	62.31	4.74	1.24	1.01	Not found		Not found		Not found	
3-78 (Mound)	90.41	5.37	1.28	1.63	1.69	3.54	1.16	2.84	1.16	2.41

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled October 26 & 29-31, 1993.
3. Ammonium and nitrate nitrogen (NH_4^+-N, NO_3^--N) were determined using the direct steam distillation method of Bremner and Keeney (1965) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 21. Ammonium/Nitrate Contents in November 1993 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent		Well BG		Well #1		Well #2		Well #3	
Conc. (μg/mL)	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N
S-1 (Mound)	146.3	7.24	1.56	1.72	2.16	5.63	2.21	5.43	1.52	4.93
S-3 (Dosing)	69.38	3.01	1.75	1.61	2.04	7.43	1.78	5.01	1.62	3.82
S-6 (Conv'l)	Not found		1.14	1.23	1.07	1.14	1.11	1.34	1.20	1.21
S-8 (Conv'l)	Not found		1.75	1.61	1.83	2.34	2.02	2.15	1.73	1.87
S-9 (Dosing)	46.27	8.03	1.16	1.42	Not found		1.46	2.08	Not found	
S-10 (Mound)	49.56	6.94	1.35	2.09	1.23	6.04	1.31	5.23	1.24	2.19
S-12 (Dosing)	60.72	7.13	Not found		2.67	6.42	2.50	6.24	1.96	5.11
S-13 (Conv'l)	77.63	5.28	0.82	1.84	Not found		Not found		1.58	4.32
S-14 (Mound)	72.16	5.63	1.43	2.04	1.29	29.16	1.37	8.72	1.49	4.33
S-15 (Mound)	88.46	6.79	1.38	1.12	1.33	22.39	1.29	9.71	1.30	4.86
3-78 (Mound)	102.5	6.44	1.35	1.88	1.81	3.83	1.41	2.70	1.52	2.77

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled November 19-23, 1993.
3. Ammonium and nitrate nitrogen (NH_4^+-N, NO_3^--N) were determined using the direct steam distillation method of Bremner and Keeney (1965) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 22. Ammonium/Nitrate Contents in December 1993 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent		Well BG		Well #1		Well #2		Well #3	
Conc. (µg/mL)	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N
S-1 (Mound)	157.5	8.18	1.96	2.64	2.66	6.15	2.54	6.07	1.96	5.74
S-3 (Dosing)	79.20	3.77	2.08	1.93	1.79	6.57	1.54	5.06	1.44	4.46
S-6 (Conv'l)	Not found		1.28	1.42	1.31	1.26	1.36	1.41	1.39	1.29
S-8 (Conv'l)	Not found		2.08	1.93	1.61	2.45	1.86	2.21	2.52	2.17
S-9 (Dosing)	43.12	6.44	1.54	2.07	Not found		1.75	2.35	Not found	
S-10 (Mound)	56.84	7.56	1.54	2.77	1.37	6.16	1.64	5.19	1.54	2.68
S-12 (Dosing)	58.29	7.42	Not found		3.74	8.32	2.96	7.78	2.23	6.38
S-13 (Conv'l)	82.15	6.04	1.13	2.06	3.14	6.44	2.06	4.96	1.77	4.85
S-14 (Mound)	78.97	6.02	1.51	2.1	1.44	38.01	1.85	11.13	1.54	6.06
S-15 (Mound)	76.14	5.27	1.51	1.37	1.58	26.85	1.43	10.62	1.44	5.20
3-78 (Mound)	113.9	5.43	1.47	1.89	2.18	4.07	1.76	3.13	1.91	3.02

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled December 10-14,1993.
3. Ammonium and nitrate nitrogen (NH_4^+-N, NO_3^--N) were determined using the direct steam distillation method of Bremner and Keeney (1965) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 23. Ammonium/Nitrate Contents in January 1994 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent		Well BG		Well #1		Well #2		Well #3	
Conc. (μg/mL)	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N
S-1 (Mound)	133.4	5.65	1.84	2.05	2.28	5.62	2.44	4.36	2.05	4.71
S-3 (Dosing)	67.68	3.69	2.03	1.94	2.27	6.31	2.23	5.17	1.92	3.86
S-6 (Conv'l)	Not found		1.27	1.19	1.18	1.26	1.24	1.22	1.19	1.13
S-8 (Conv'l)	Not found		2.03	1.94	1.81	2.16	2.07	2.04	2.04	1.85
S-9 (Dosing)	51.92	6.59	1.38	1.86	1.76	3.44	1.63	2.16	1.62	1.67
S-10 (Mound)	58.44	7.13	1.29	2.36	1.23	5.82	1.17	3.79	1.08	3.03
S-12 (Dosing)	55.31	6.84	2.17	2.71	2.98	6.53	2.41	4.81	2.36	4.45
S-13 (Conv'l)	76.48	6.72	1.31	1.82	3.29	5.52	1.65	4.36	1.29	3.81
S-14 (Mound)	81.25	6.81	1.36	2.04	2.18	26.40	1.74	9.56	1.39	6.18
S-15 (Mound)	73.05	5.83	1.43	1.14	1.20	23.85	1.65	9.13	1.44	6.16
3-78 (Mound)	116.5	5.83	1.37	1.70	2.03	3.86	1.76	3.25	1.71	3.07

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled January 25-28, 1994.
3. Ammonium and nitrate nitrogen (NH_4^+-N, NO_3^--N) were determined using the direct steam distillation method of Bremner and Keeney (1965) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 24. Ammonium/Nitrate Contents in February 1994 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent		Well BG		Well #1		Well #2		Well #3	
Conc. (μg/mL)	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N
S-1 (Mound)	162.9	11.26	1.81	2.18	2.53	7.39	2.34	4.67	1.89	5.03
S-3 (Dosing)	86.02	5.41	1.94	2.18	1.94	6.64	1.88	6.22	1.83	4.39
S-6 (Conv'l)	Not found		1.06	1.21	1.15	1.23	1.07	1.14	1.11	1.06
S-8 (Conv'l)	Not found		1.94	2.18	1.75	2.58	1.94	2.31	1.89	2.13
S-9 (Dosing)	64.71	9.13	1.21	2.01	1.12	4.06	1.15	3.20	1.09	2.33
S-10 (Mound)	73.62	9.46	1.16	2.77	2.19	8.41	1.67	6.93	1.41	5.51
S-12 (Dosing)	51.61	4.72	1.86	3.16	2.65	8.76	2.23	7.43	2.08	5.88
S-13 (Conv'l)	85.26	8.07	0.98	2.27	2.88	7.17	1.20	5.69	1.01	5.40
S-14 (Mound)	88.09	7.43	1.21	2.27	1.63	27.26	1.29	11.73	1.32	8.44
S-15 (Mound)	68.68	4.12	1.16	1.68	1.39	20.00	2.06	7.59	1.57	4.87
3-78 (Mound)	121.7	7.46	1.05	2.17	1.26	3.91	1.38	3.44	1.24	3.12

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled February 24-27, 1994.
3. Ammonium and nitrate nitrogen (NH_4^+-N, NO_3^--N) were determined using the direct steam distillation method of Bremner and Keeney (1965) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 25. Ammonium/Nitrate Contents in March 1994 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent		Well BG		Well #1		Well #2		Well #3	
Conc. (μg/mL)	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N
S-1 (Mound)	149.7	7.31	2.13	2.27	2.77	6.77	2.49	5.30	1.91	4.82
S-3 (Dosing)	83.14	4.90	2.06	2.05	1.75	6.82	1.78	5.97	1.76	5.16
S-6 (Conv'l)	Not found		1.13	1.07	1.25	1.15	1.16	0.96	1.08	1.08
S-8 (Conv'l)	Not found		2.06	2.05	2.19	2.26	2.11	2.27	1.99	2.09
S-9 (Dosing)	50.39	7.62	1.34	1.93	1.31	3.76	1.47	2.82	1.40	1.94
S-10 (Mound)	52.38	6.35	1.31	2.53	1.62	8.27	1.55	6.36	1.29	4.84
S-12 (Dosing)	67.52	7.43	2.11	2.49	3.16	6.17	2.96	4.67	2.48	3.72
S-13 (Conv'l)	81.35	5.96	1.18	1.95	3.41	5.86	1.62	5.03	1.58	4.78
S-14 (Mound)	66.92	4.96	1.29	2.06	1.97	21.38	1.77	7.39	1.46	5.61
S-15 (Mound)	62.11	4.70	1.22	1.09	1.28	16.37	1.64	6.92	1.45	4.36
3-78 (Mound)	94.05	4.29	1.22	1.83	1.65	3.28	1.41	2.31	1.38	1.83

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled March 25-28, 1994.
3. Ammonium and nitrate nitrogen (NH_4^+-N, NO_3^--N) were determined using the direct steam distillation method of Bremner and Keeney (1965) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 26. Ammonium/Nitrate Contents in April 1994 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent		Well BG		Well #1		Well #2		Well #3	
Conc. (μg/mL)	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N
S-1 (Mound)	135.2	8.71	1.74	1.36	2.16	11.87	1.92	5.60	1.37	3.26
S-3 (Dosing)	57.41	6.02	1.45	1.12	1.21	2.38	1.04	4.26	1.07	3.14
S-6 (Conv'l)	Not found		1.42	0.94	1.13	1.21	1.03	1.08	1.04	1.11
S-8 (Conv'l)	Not found		1.45	1.12	1.67	5.26	1.49	1.81	1.23	1.30
S-9 (Dosing)	51.77	6.24	1.36	1.69	1.83	4.85	1.64	4.45	1.59	2.56
S-10 (Mound)	58.57	4.16	1.37	2.49	1.46	5.89	1.06	3.93	1.16	1.74
S-12 (Dosing)	56.64	5.27	1.98	1.52	4.17	9.35	2.84	8.94	3.69	6.72
S-13 (Conv'l)	87.43	4.52	1.34	1.66	2.32	4.41	1.69	6.30	1.64	16.88
S-14 (Mound)	73.81	3.16	1.48	1.56	1.92	39.27	1.82	22.68	1.59	6.86
S-15 (Mound)	87.27	22.81	1.38	1.22	1.34	26.53	1.44	14.18	1.26	5.19
3-78 (Mound)	147.6	17.43	1.12	1.33	1.36	5.94	0.94	4.71	1.69	2.39

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled April 21-25, 1994.
3. Ammonium and nitrate nitrogen (NH_4^+-N, NO_3^--N) were determined using the direct steam distillation method of Bremner and Keeney (1965) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 27. Ammonium/Nitrate Contents in May 1994 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent		Well BG		Well #1		Well #2		Well #3	
Conc. (μg/mL)	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N
S-1 (Mound)	122.1	5.74	1.16	1.12	0.81	33.62	1.05	8.41	1.09	3.95
S-3 (Dosing)	33.32	4.20	1.02	0.88	1.23	8.65	0.91	1.12	0.81	3.08
S-6 (Conv'l)	Not found		1.17	1.03	1.05	1.47	0.99	1.24	0.97	1.07
S-8 (Conv'l)	Not found		1.02	0.88	1.09	7.32	0.63	1.12	0.88	0.84
S-9 (Dosing)	53.06	4.62	0.88	1.26	0.98	13.35	1.12	5.72	0.91	3.51
S-10 (Mound)	64.26	6.16	0.98	2.10	1.09	7.32	0.67	1.44	1.23	1.54
S-12 (Dosing)	48.72	4.90	1.58	0.91	10.31	12.46	4.41	16.47	14.57	12.88
S-13 (Conv'l)	91.28	4.06	1.16	1.65	5.37	3.01	1.48	9.49	1.79	21.62
S-14 (Mound)	98.14	4.62	1.19	1.68	1.16	51.07	1.54	30.46	0.84	7.49
S-15 (Mound)	100.1	47.48	1.12	1.89	1.12	32.27	0.58	23.8	1.33	8.69
3-78 (Mound)	123.8	4.90	0.95	0.84	0.81	5.60	0.28	7.35	1.12	4.31

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled May 23-28, 1994.
3. Ammonium and nitrate nitrogen (NH_4^+-N, NO_3^--N) were determined using the direct steam distillation method of Bremner and Keeney (1965) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 28. Ammonium/Nitrate Contents in June 1994 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent		Well BG		Well #1		Well #2		Well #3	
Conc. (μg/mL)	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N
S-1 (Mound)	141.5	16.24	1.09	2.54	1.23	15.41	1.09	14.43	0.88	4.52
S-3 (Dosing)	31.08	4.06	0.94	0.77	0.95	11.73	1.98	1.93	1.54	2.52
S-6 (Conv'l)	Not found		0.86	1.05	1.09	1.16	1.01	0.98	0.94	1.04
S-8 (Conv'l)	Not found		0.94	0.77	1.68	19.13	1.31	2.99	0.84	1.16
S-9 (Dosing)	75.32	5.46	0.72	1.46	1.40	47.99	0.91	39.48	1.17	16.73
S-10 (Mound)	64.41	5.04	1.23	1.19	1.33	6.44	1.40	2.38	0.98	1.02
S-12 (Dosing)	59.64	4.06	1.23	1.44	4.51	31.12	3.71	15.41	17.37	19.39
S-13 (Conv'l)	131.0	6.16	1.04	2.53	Removed		Removed		0.91	17.02
S-14 (Mound)	91.32	5.28	0.97	1.83	1.31	40.23	1.24	19.46	1.02	8.81
S-15 (Mound)	115.4	26.95	1.03	1.65	1.10	23.38	0.76	17.54	1.25	5.79
3-78 (Mound)	79.24	23.32	1.09	2.21	1.03	2.43	1.02	5.67	2.45	5.11

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled June 24-29, 1994.
3. Ammonium and nitrate nitrogen (NH_4^+-N, NO_3^--N) were determined using the direct steam distillation method of Bremner and Keeney (1965) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 29. Ammonium/Nitrate Contents in July 1994 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent		Well BG		Well #1		Well #2		Well #3	
Conc. (μg/mL)	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N
S-1 (Mound)	132.5	5.16	1.15	2.07	0.94	21.62	0.76	11.24	1.12	3.75
S-3 (Dosing)	37.47	3.23	1.21	1.05	1.03	9.58	1.26	3.15	1.17	2.03
S-6 (Conv'l)	Not found		0.87	1.08	0.96	1.25	0.89	1.03	0.77	1.09
S-8 (Conv'l)	Not found		1.21	1.05	1.24	12.34	1.07	7.63	0.96	1.89
S-9 (Dosing)	67.21	5.34	1.29	1.56	1.79	46.54	1.53	27.26	1.32	8.95
S-10 (Mound)	51.52	4.67	1.06	1.78	1.34	4.23	0.98	1.86	1.07	1.49
S-12 (Dosing)	44.62	4.83	1.84	1.44	3.86	20.43	2.07	19.68	8.03	13.51
S-13 (Conv'l)	96.52	5.65	1.31	1.58	Removed		Removed		1.43	19.34
S-14 (Mound)	87.79	3.21	1.20	1.65	1.75	41.54	1.42	18.29	1.18	6.02
S-15 (Mound)	93.83	21.48	0.92	1.22	1.13	18.49	0.89	12.38	1.24	5.11
3-78 (Mound)	96.14	10.80	0.83	1.46	1.04	4.47	0.66	3.70	1.23	3.24

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled July 23-26, 1994.
3. Ammonium and nitrate nitrogen (NH_4^+-N, NO_3^--N) were determined using the direct steam distillation method of Bremner and Keeney (1965) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 30. Ammonium/Nitrate Contents in August 1994 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent		Well BG		Well #1		Well #2		Well #3	
Conc. (μg/mL)	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N
S-1 (Mound)	145.2	6.19	1.23	1.86	1.39	14.36	1.12	6.94	1.07	3.28
S-3 (Dosing)	41.67	5.14	1.03	0.93	0.91	8.76	1.18	1.64	0.87	2.41
S-6 (Conv'l)	Not found		1.05	0.97	1.04	1.12	0.91	1.02	1.01	0.91
S-8 (Conv'l)	Not found		1.03	0.93	1.42	8.65	0.95	3.68	1.21	1.61
S-9 (Dosing)	55.73	4.41	1.14	1.38	1.12	28.37	1.14	15.93	1.09	4.08
S-10 (Mound)	64.61	5.33	0.92	1.85	1.45	5.37	1.20	3.17	0.95	1.63
S-12 (Dosing)	42.14	3.76	1.56	1.24	2.96	23.51	1.83	12.48	2.71	8.72
S-13 (Conv'l)	83.74	4.85	1.02	1.27	Removed		Removed		0.97	10.26
S-14 (Mound)	76.35	3.22	1.08	1.47	1.56	28.65	1.13	16.84	0.94	4.59
S-15 (Mound)	100.2	28.64	1.10	1.34	1.08	20.03	1.02	11.40	1.35	5.69
3-78 (Mound)	113.3	12.51	0.97	1.19	1.14	3.85	1.02	3.73	1.56	2.08

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled August 17-21, 1994.
3. Ammonium and nitrate nitrogen (NH_4^+-N, NO_3^--N) were determined using the direct steam distillation method of Bremner and Keeney (1965) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 31. Total Kjeldahl Nitrogen Contents in June 1993 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent	Well BG	Well #1	Well #2	Well #3
The Total Kjeldahl Nitrogen (TKN) concentration (µg/mL)					
S-1 (Mound)	Wells were not found.				
S-3 (Dosing)	151.2	Not found	1.89	2.45	Not found
S-5 (Conv'l)	42.81	4.48	Not found	Not found	Not found
S-6 (Conv'l)	Not found	Clogged	1.89	2.03	1.68
S-7 (Conv'l)	Wells were not found.				
S-8 (Conv'l)	Wells were not found.				
S-9 (Conv'l)	49.0	Not found	Not found	2.8	Not found
S-10 (Mound)	22.96	Not found	Not found	Not found	1.68
S-11 (Dosing)	Wells were not found.				
S-12 (Dosing)	66.64	Not found	4.2	1.96	1.89
S-13 (Conv'l)	91.28	2.10	Not found	Not found	1.96
S-14 (Mound)	131.88	2.10	Not found	Not found	Not found

S-15 (Mound)	116.14	2.07	Not found	Not found	Not found
1-99 (Mound)	Wells were not found.				
1-160 (Mound)	One clogged well suspected as Well #1 was found on the mound.				
3-71 (Mound)	One clogged well suspected as Well #1 was found on the mound.				
3-78 (Mound)	170.22	Not found	Not found	2.17	Not found
3-132 (Mound)	Wells were not found.				
3-234 (Mound)	Wells were not found.				
3-273 (Mound)	Wells were not found.				
3-34 (Mound)	Wells were not found.				

Notes:

1. "Well BG"= The background well; "Conv'l"= The conventional system, "Dosing"= The dosing system, and "Mound"= The Mound -type system
2. Sites with available wells were sampled from June 10 to June 17, 1993.
3. Total Kjeldahl Nitrogen (TKN) was determined using the semimicro Kjeldahl procedure described by Bremner and Keeney (1966). 5 mL of effluent or 20 mL of groundwater from each sample was used for analysis.

Table 32. Total Kjeldahl Nitrogen Contents in July 1993 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent	Well BG	Well #1	Well #2	Well #3
The Total Kjeldahl Nitrogen (TKN) concentration (µg/mL)					
S-1 (Mound)	Wells not yet found				
S-3 (Mound)	99.23	Not found	11.41	6.32	Not found
S-5 (Conv'l)	53.55	3.17	Not found	Not found	Not found
S-6 (Conv'l)	Not found	2.48	2.40	2.29	2.56
S-7 (Conv'l)	Wells not yet found				
S-8 (Conv'l)	Wells not yet found				
S-9 (Dosing)	61.54	Not found	Not found	2.71	Not found
S-10 (Mound)	51.61	Not found	Not found	Not found	2.83
S-11 (Dosing)	Wells not yet found				
S-12 (Dosing)	65.87	Not found	4.90	3.95	3.44
S-13 (Conv'l)	88.01	3.56	Not found	Not found	9.37
S-14 (Conv'l)	129.72	2.94	Not found	Not found	Not found
S-15 (Conv'l)	102.84	2.97	Not found	Not found	Not found
3-78 (Mound)	157.23	Not found	Not found	4.79	Not found

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled from July 28-31, 1993.
3. Total Kjeldahl Nitrogen (TKN) was determined using the semimicro Kjeldahl procedure of Bremner and Keeney (1966) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 33. Total Kjeldahl Nitrogen Contents in August 1993 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent	Well BG	Well #1	Well #2	Well #3
The Total Kjeldahl Nitrogen (TKN) concentration (μg/mL)					
S-1 (Mound)	169.37	3.94	8.48	9.17	11.26
S-3 (Mound)	89.77	Not found	10.31	5.89	Not found
S-5 (Conv'l)	53.21	3.07	Not found	Not found	Not found
S-6 (Conv'l)	Not found	2.40	2.26	2.58	2.51
S-7 (Conv'l)	Wells not yet found				
S-8 (Conv'l)	Wells not yet found				
S-9 (Dosing)	49.35	Not found	Not found	2.64	Not found
S-10 (Mound)	41.19	3.20	7.15	6.28	2.53
S-11 (Dosing)	Wells not yet found				
S-12 (Dosing)	59.34	Not found	4.83	3.74	3.18
S-13 (Conv'l)	78.68	3.44	Not found	Not found	5.93
S-14 (Conv'l)	113.37	3.09	Not found	Not found	Not found
S-15 (Conv'l)	115.42	2.78	Not found	Not found	Not found
3-78 (Mound)	134.60	3.18	5.74	4.61	5.25

Notes:
1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled from August 26-31, 1993.
3. Total Kjeldahl Nitrogen (TKN) was determined using the semimicro Kjeldahl procedure of Bremner and Keeney (1966) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 34. Total Kjeldahl Nitrogen Contents in September 1993 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent	Well BG	Well #1	Well #2	Well #3
The Total Kjeldahl Nitrogen (TKN) concentration (μg/mL)					
S-1 (Mound)	153.64	2.71	8.02	10.83	10.87
S-3 (Mound)	89.34	2.34	9.98	5.71	3.95
S-5 (Conv'l)	44.48	2.90	Not found	Not found	Not found
S-6 (Conv'l)	Not found	2.26	1.94	2.07	2.51
S-7 (Conv'l)	Wells not yet found				
S-8 (Conv'l)	Not found	2.34	4.31	3.38	4.96
S-9 (Dosing)	60.29	Not found	Not found	2.60	Not found
S-10 (Mound)	54.10	3.05	6.79	6.14	2.44
S-11 (Dosing)	Wells not yet found				
S-12 (Dosing)	58.79	Not found	3.87	3.51	3.62
S-13 (Conv'l)	107.20	3.21	Not found	Not found	4.09
S-14 (Conv'l)	110.71	2.87	Not found	Not found	Not found
S-15 (Conv'l)	89.83	2.55	Not found	Not found	Not found
3-78 (Mound)	127.68	2.94	5.86	4.23	5.79

Notes:
1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled from September 24-28, 1993.
3. Total Kjeldahl Nitrogen (TKN) was determined using the semimicro Kjeldahl procedure of Bremner and Keeney (1966) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 35. Total Kjeldahl Nitrogen Contents in October 1993 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent	Well BG	Well #1	Well #2	Well #3
The Total Kjeldahl Nitrogen (TKN) concentration (μg/mL)					
S-1 (Mound)	181.58	3.32	9.33	8.16	9.59
S-3 (Dosing)	87.56	3.12	9.36	6.93	4.85
S-6 (Conv'l)	Not found	2.18	2.08	2.38	2.43
S-8 (Conv'l)	Not found	3.12	3.62	2.67	3.40
S-9 (Dosing)	74.10	3.97	Not found	3.91	Not found
S-10 (Mound)	52.78	3.32	7.27	6.36	3.53
S-12 (Dosing)	54.93	Not found	6.51	5.57	4.99
S-13 (Conv'l)	87.39	2.49	Not found	Not found	5.08
S-14 (Mound)	85.42	3.68	Not found	Not found	Not found
S-15 (Mound)	78.20	2.81	Not found	Not found	Not found
3-78 (Mound)	114.89	3.31	5.65	4.32	3.75

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled October 26 & 29-31, 1993.
3. Total Kjeldahl Nitrogen (TKN) was determined using the semimicro Kjeldahl procedure of Bremner and Keeney (1966) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 36. Total Kjeldahl Nitrogen Contents in November 1993 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent	Well BG	Well #1	Well #2	Well #3
The Total Kjeldahl Nitrogen (TKN) concentration (μg/mL)					
S-1 (Mound)	164.58	3.39	8.09	8.05	6.67
S-3 (Dosing)	90.45	3.77	9.91	7.42	5.41
S-6 (Conv'l)	Not found	2.54	2.33	2.62	2.58
S-8 (Conv'l)	Not found	3.77	0.48	4.37	3.91
S-9 (Dosing)	63.02	2.83	Not found	3.87	Not found
S-10 (Mound)	70.72	3.69	7.60	6.85	3.73
S-12 (Dosing)	77.06	Not found	9.58	9.05	7.56
S-13 (Conv'l)	93.25	2.84	Not found	Not found	5.91
S-14 (Mound)	97.10	3.99	31.28	10.63	6.15
S-15 (Mound)	109.27	3.02	24.40	11.53	6.90
3-78 (Mound)	132.23	3.71	6.04	4.46	4.54

Notes:
1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled November 19-23, 1993.
3. Total Kjeldahl Nitrogen (TKN) was determined using the semimicro Kjeldahl procedure of Bremner and Keeney (1966) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 37. Total Kjeldahl Nitrogen Contents in December 1993 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent	Well BG	Well #1	Well #2	Well #3
The Total Kjeldahl Nitrogen (TKN) concentration (μg/mL)					
S-1 (Mound)	179.93	4.74	9.13	8.96	7.86
S-3 (Dosing)	103.08	4.44	8.98	7.33	5.93
S-6 (Conv'l)	Not found	2.81	2.67	3.01	2.89
S-8 (Conv'l)	Not found	4.44	4.36	4.29	4.91
S-9 (Dosing)	61.25	3.82	Not found	4.56	Not found
S-10 (Mound)	80.58	4.62	7.88	7.17	4.57
S-12 (Dosing)	77.84	Not found	12.60	10.09	9.04
S-13 (Conv'l)	103.31	3.42	9.87	7.32	6.68
S-14 (Mound)	106.32	4.13	40.41	13.67	7.98
S-15 (Mound)	93.64	3.46	29.22	12.68	7.14
3-78 (Mound)	144.98	3.91	6.72	5.31	5.27

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled December 10-14, 1993.
3. Total Kjeldahl Nitrogen (TKN) was determined using the semimicro Kjeldahl procedure of Bremner and Keeney (1966) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 38. Total Kjeldahl Nitrogen Contents in January 1994 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent	Well BG	Well #1	Well #2	Well #3
The Total Kjeldahl Nitrogen (TKN) concentration (μg/mL)					
S-1 (Mound)	154.36	4.12	8.31	7.14	6.94
S-3 (Dosing)	80.24	4.16	9.07	7.76	6.25
S-6 (Conv'l)	Not found	2.61	2.63	2.64	2.51
S-8 (Conv'l)	Not found	4.16	4.17	4.29	4.06
S-9 (Dosing)	67.72	3.59	5.47	4.19	3.46
S-10 (Mound)	71.74	4.12	7.36	5.33	4.84
S-12 (Dosing)	67.75	5.36	9.78	7.62	7.34
S-13 (Conv'l)	92.48	3.69	9.38	6.12	5.25
S-14 (Mound)	102.74	3.88	29.02	11.93	7.95
S-15 (Mound)	93.16	2.99	25.28	11.03	7.82
3-78 (Mound)	137.06	3.28	6.23	5.30	4.96

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled January 25-28, 1994.
3. Total Kjeldahl Nitrogen (TKN) was determined using the semimicro Kjeldahl procedure of Bremner and Keeney (1966) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 39. Total Kjeldahl Nitrogen Contents in February 1994 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent	Well BG	Well #1	Well #2	Well #3
The Total Kjeldahl Nitrogen (TKN) concentration (μg/mL)					
S-1 (Mound)	196.71	4.13	10.25	7.21	7.01
S-3 (Dosing)	102.34	4.24	8.89	8.30	6.52
S-6 (Conv'l)	Not found	2.37	2.50	2.29	2.28
S-8 (Conv'l)	Not found	4.24	4.45	4.35	4.11
S-9 (Dosing)	86.69	3.41	5.17	4.56	3.43
S-10 (Mound)	91.67	4.25	10.72	8.79	7.42
S-12 (Dosing)	60.77	5.20	11.53	9.69	8.13
S-13 (Conv'l)	105.63	3.67	10.41	6.91	6.46
S-14 (Mound)	112.31	3.74	28.96	13.46	9.88
S-15 (Mound)	85.52	3.21	21.56	9.89	6.54
3-78 (Mound)	142.69	3.34	5.35	5.02	4.43

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled February 24-27, 1994.
3. Total Kjeldahl Nitrogen (TKN) was determined using the semimicro Kjeldahl procedure of Bremner and Keeney (1966) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 40. Total Kjeldahl Nitrogen Contents in March 1994 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent	Well BG	Well #1	Well #2	Well #3
The Total Kjeldahl Nitrogen (TKN) concentration (µg/mL)					
S-1 (Mound)	175.36	4.65	9.59	8.08	6.98
S-3 (Dosing)	97.23	4.31	8.92	8.07	7.39
S-6 (Conv'l)	Not found	2.31	2.52	2.23	2.26
S-8 (Conv'l)	Not found	4.31	4.61	4.55	4.26
S-9 (Dosing)	65.84	3.55	5.28	4.50	3.42
S-10 (Mound)	63.38	4.27	10.21	8.36	6.87
S-12 (Dosing)	83.16	4.97	9.65	7.96	6.64
S-13 (Conv'l)	98.15	3.68	9.72	6.75	6.53
S-14 (Mound)	82.46	3.91	23.95	9.90	7.60
S-15 (Mound)	76.43	2.87	18.08	8.98	6.07
3-78 (Mound)	98.14	3.23	5.26	3.88	3.34

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled March 25-28, 1994.
3. Total Kjeldahl Nitrogen (TKN) was determined using the semimicro Kjeldahl procedure of Bremner and Keeney (1966) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 41. Total Kjeldahl Nitrogen Contents in April 1994 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent	Well BG	Well #1	Well #2	Well #3
The Total Kjeldahl Nitrogen (TKN) concentration (µg/mL)					
S-1 (Mound)	155.12	3.24	14.40	7.96	4.83
S-3 (Dosing)	76.58	3.07	4.13	5.80	4.79
S-6 (Conv'l)	Not found	2.48	2.43	2.21	2.13
S-8 (Conv'l)	Not found	3.07	7.48	3.56	2.88
S-9 (Dosing)	62.36	3.52	6.92	6.47	4.31
S-10 (Mound)	71.03	4.35	7.60	5.49	3.77
S-12 (Dosing)	68.49	4.18	15.81	12.63	10.52
S-13 (Conv'l)	102.35	3.62	7.34	8.21	18.96
S-14 (Mound)	93.53	3.61	43.68	26.50	8.84
S-15 (Mound)	115.30	3.38	28.44	16.34	6.90
3-78 (Mound)	178.36	2.27	7.72	5.97	4.46

Notes:
1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled April 21-25, 1994.
3. Total Kjeldahl Nitrogen (TKN) was determined using the semimicro Kjeldahl procedure of Bremner and Keeney (1966) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 42. Total Kjeldahl Nitrogen Contents in May 1994 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent	Well BG	Well #1	Well #2	Well #3
The Total Kjeldahl Nitrogen (TKN) concentration (μg/mL)					
S-1 (Mound)	139.03	2.46	35.04	9.71	5.28
S-3 (Dosing)	48.71	1.97	10.59	2.44	4.50
S-6 (Conv'l)	Not found	2.28	2.61	2.33	2.15
S-8 (Conv'l)	Not found	1.97	8.96	2.00	2.17
S-9 (Dosing)	60.46	2.34	14.66	7.35	4.62
S-10 (Mound)	84.36	3.20	8.73	2.22	2.79
S-12 (Dosing)	61.72	3.22	22.88	21.34	31.65
S-13 (Conv'l)	105.46	2.83	9.75	11.56	24.28
S-14 (Mound)	116.89	3.54	53.03	33.47	8.53
S-15 (Mound)	156.43	3.78	34.09	25.26	10.65
3-78 (Mound)	142.65	1.98	6.77	7.92	5.84

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled May 23-28, 1994.
3. Total Kjeldahl Nitrogen (TKN) was determined using the semimicro Kjeldahl procedure of Bremner and Keeney (1966) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 43. Total Kjeldahl Nitrogen Contents in June 1994 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent	Well BG	Well #1	Well #2	Well #3
The Total Kjeldahl Nitrogen (TKN) concentration (μg/mL)					
S-1 (Mound)	166.38	4.13	17.24	15.71	5.59
S-3 (Dosing)	41.56	2.24	13.38	4.30	4.64
S-6 (Conv'l)	Not found	2.03	3.99	2.08	2.11
S-8 (Conv'l)	Not found	2.24	21.66	4.68	2.00
S-9 (Dosing)	85.54	2.53	49.62	40.85	18.23
S-10 (Mound)	82.32	2.97	8.07	4.19	3.71
S-12 (Dosing)	69.43	4.81	37.57	19.82	21.46
S-13 (Conv'l)	142.24	4.28	Removed	Removed	18.06
S-14 (Mound)	108.57	3.38	42.46	21.65	10.43
S-15 (Mound)	153.18	3.53	25.18	19.04	8.61
3-78 (Mound)	113.41	3.62	3.78	6.97	7.86

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled June 24-29, 1994.
3. Total Kjeldahl Nitrogen (TKN) was determined using the semimicro Kjeldahl procedure of Bremner and Keeney (1966) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 44. Total Kjeldahl Nitrogen Contents in July 1994 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent	Well BG	Well #1	Well #2	Well #3
The Total Kjeldahl Nitrogen (TKN) concentration (μg/mL)					
S-1 (Mound)	143.76	3.39	23.18	12.43	5.02
S-3 (Dosing)	48.74	2.44	10.94	4.51	3.40
S-6 (Conv'l)	Not found	2.22	2.46	2.22	2.12
S-8 (Conv'l)	Not found	2.44	14.05	9.01	3.04
S-9 (Dosing)	83.28	3.22	49.26	29.47	10.65
S-10 (Mound)	63.64	3.29	5.99	3.06	2.92
S-12 (Dosing)	54.11	3.57	24.77	22.10	21.94
S-13 (Conv'l)	115.45	2.94	Removed	Removed	21.35
S-14 (Mound)	103.81	3.27	44.02	20.40	7.51
S-15 (Mound)	125.23	2.45	20.13	13.65	6.57
3-78 (Mound)	114.53	2.52	5.72	4.66	4.74

Notes:
1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled July 23-26, 1994.
3. Total Kjeldahl Nitrogen (TKN) was determined using the semimicro Kjeldahl procedure of Bremner and Keeney (1966) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 45. Total Kjeldahl Nitrogen Contents in August 1994 Samples at Sites from Studies 1985 & 1979.

Site Number	Septic Tank Effluent	Well BG	Well #1	Well #2	Well #3
The Total Kjeldahl Nitrogen (TKN) concentration (μg/mL)					
S-1 (Mound)	158.48	3.33	16.22	8.38	4.54
S-3 (Dosing)	52.64	2.24	9.98	2.96	3.44
S-6 (Conv'l)	Not found	2.21	2.40	2.19	2.10
S-8 (Conv'l)	Not found	2.24	10.52	5.01	3.02
S-9 (Dosing)	72.70	2.77	30.09	17.42	5.40
S-10 (Mound)	79.42	3.14	7.11	4.62	2.89
S-12 (Dosing)	51.04	3.21	27.02	14.59	11.70
S-13 (Conv'l)	100.21	2.43	Removed	Removed	11.69
S-14 (Mound)	88.82	2.94	31.05	18.53	5.84
S-15 (Mound)	142.60	2.78	21.57	12.71	7.36
3-78 (Mound)	134.39	2.41	5.30	5.03	3.83

Notes:
1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled August 17-21, 1994.
3. Total Kjeldahl Nitrogen (TKN) was determined using the semimicro Kjeldahl procedure of Bremner and Keeney (1966) with 5 mL of effluent or 20 mL of groundwater per sample.

Table 46. Depth to Groundwater Level in Monitoring Wells, and Ammonium, Nitrate, and Total Kjeldahl Nitrogen Contents in August 1993 Groundwater Samples from Wisconsin Heights High School (Study 1970).

	GW level (ft)	NH_4^+-N (µg/mL)	NO_3^--N (µg/mL)	TKN (µg/mL)
Well #1	6.88	1.22	1.05	2.41
Well #2	6.72	1.26	1.40	2.73
Well #3	6.82	2.07	1.26	3.40
Well #4	7.14	1.70	1.27	3.11
Well #5	6.88	1.72	1.40	3.47
Well #6	7.10	1.69	1.03	2.94
Well #7	8.52	1.94	1.77	3.81
Well #8	8.74	2.13	1.69	4.20
Well #9	8.74	1.33	1.63	3.15
Well #10	8.70	1.31	1.54	2.97
Well #11	8.06	1.54	1.93	3.50
Well #12	8.86	1.18	1.72	2.94
Well #13	9.90	2.72	1.63	4.53
Well #14	8.78	7.28	1.58	8.87
Well #15	12.10	1.12	2.26	3.44
Well #16	12.12	1.40	3.15	4.79
Septic Tank Effluent	Not applicable	17.25	5.88	25.28

Notes:

1. Available wells measured and sampled August 23-24, 1993.

Table 47. Depth to Groundwater in Monitoring Wells, and Ammonium, Nitrate, and Total Kjeldahl Nitrogen Contents in September 1993 Samples from Wisconsin Heights High School (Study 1970).

	GW level (ft)	NH_4^+-N (µg/ml)	NO_3^--N (µg/mL)	TKN (µg/mL)
Well #1	7.68	2.17	1.31	3.62
Well #2	7.50	2.38	2.03	4.57
Well #3	7.64	4.20	1.42	5.69
Well #4	7.86	1.61	1.40	3.03
Well #5	7.72	1.61	1.68	3.49
Well #6	7.88	1.61	1.26	2.89
Well #7	9.42	3.82	1.65	5.50
Well #8	9.52	4.13	1.58	5.91
Well #9	9.54	2.73	1.51	4.33
Well #10	9.54	2.8	1.54	4.52
Well #11	8.88	14.25	1.47	17.21
Well #12	9.64	1.89	1.54	3.47
Well #13	9.76	4.06	1.51	5.88
Well #14	9.62	7.98	1.47	8.75
Well #15	12.88	3.75	1.47	6.11
Well #16	12.90	6.44	1.51	7.99
Septic Tank Effluent	Not applicable	43.4	5.88	52.72

Notes:
1. Available wells measured and sampled on September 28, 1993.

Table 48. Depth to Groundwater Level in Monitoring Wells, and Ammonium, Nitrate, and Total Kjeldahl Nitrogen Contents in October 1993 Groundwater Samples from Wisconsin Heights High School (Study 1970).

	GW level (ft)	NH_4^+-N (µg/mL)	NO_3^--N (µg/mL)	TKN (µg/mL)
Well #1	8.88	2.19	1.54	3.81
Well #2	8.72	2.47	2.06	4.66
Well #3	8.86	2.45	1.58	4.03
Well #4	9.02	1.81	1.63	3.49
Well #5	8.90	1.77	1.57	3.50
Well #6	9.04	1.80	1.66	3.58
Well #7	10.62	3.94	1.72	6.89
Well #8	10.68	4.72	1.70	6.65
Well #9	10.70	2.95	1.69	4.82
Well #10	10.74	3.03	1.65	4.84
Well #11	10.10	6.14	1.62	8.96
Well #12	10.86	2.35	1.73	4.23
Well #13	10.92	4.89	1.68	6.81
Well #14	10.80	7.63	1.60	9.54
Well #15	14.04	4.52	1.64	6.36
Well #16	14.06	6.87	1.76	8.94
Septic Tank Effluent	Not Applicable	56.13	8.43	68.14

Notes:
1. Available wells measured and sampled October 30-31, 1993.

Table 49. Depth to Groundwater Level in Monitoring Wells, and Ammonium, Nitrate, and Total Kjeldahl Nitrogen Contents in November 1993 Groundwater Samples from Wisconsin Heights High School (Study 1970).

	GW level (ft)	NH_4^+-N (μg/mL)	NO_3^--N (μg/mL)	TKN (μg/mL)
Well #1	9.76	2.18	1.48	3.84
Well #2	9.60	2.35	1.94	4.51
Well #3	9.74	2.71	1.31	4.27
Well #4	9.92	1.83	1.42	3.23
Well #5	9.84	1.82	1.57	3.55
Well #6	9.96	1.83	1.45	3.26
Well #7	11.50	4.06	1.81	6.04
Well #8	11.56	4.94	1.80	6.98
Well #9	11.62	3.07	1.63	4.92
Well #10	11.62	3.08	1.56	4.86
Well #11	11.02	5.97	1.69	8.02
Well #12	11.74	2.28	1.62	4.13
Well #13	11.84	4.15	1.58	5.91
Well #14	11.72	6.75	1.55	8.60
Well #15	14.84	3.59	1.67	5.49
Well #16	14.88	5.78	1.77	8.16
Septic Tank Effluent	Not Applicable	50.27	6.64	60.48

Notes:
1. Available wells measured and sampled November 20-21, 1993.

Table 50. Depth to Groundwater Level in Monitoring Wells, and Ammonium, Nitrate, and Total Kjeldahl Nitrogen Contents in December 1993 Groundwater Samples from Wisconsin Heights High School (Study 1970).

	GW level (ft)	NH_4^+-N (µg/mL)	NO_3^--N (µg/mL)	TKN (µg/mL)
Well #1	10.18	2.52	1.63	4.32
Well #2	9.98	2.71	2.11	5.14
Well #3	10.12	2.95	1.50	4.68
Well #4	10.34	2.08	1.52	3.47
Well #5	10.22	2.05	1.73	3.88
Well #6	10.36	2.11	1.55	3.85
Well #7	11.92	4.43	2.06	6.83
Well #8	11.96	4.62	2.11	6.89
Well #9	11.96	3.54	1.84	5.68
Well #10	11.98	2.81	1.77	4.90
Well #11	11.46	6.74	1.89	8.97
Well #12	12.12	2.82	1.96	5.01
Well #13	12.24	4.68	1.73	6.75
Well #14	12.10	7.03	1.68	9.16
Well #15	15.16	3.96	1.69	6.64
Well #16	15.18	6.27	1.68	8.27
Septic Tank Effluent	Not Applicable	57.62	6.71	69.61

Notes:
1. Available wells measured and sampled December 11-12, 1993.

Table 51. Depth to Groundwater Level in Monitoring Wells, and Ammonium, Nitrate, and Total Kjeldahl Nitrogen Contents in January 1994 Samples from Wisconsin Heights High School (Study 1970).

	GW level (ft)	NH_4^+-N (μg/mL)	NO_3^--N (μg/mL)	TKN (μg/mL)
Well #1	9.90	2.09	1.56	3.98
Well #2	9.50	2.38	2.31	4.96
Well #3	9.70	1.74	1.85	3.90
Well #4	9.88	1.42	1.43	3.07
Well #5	9.76	1.36	1.63	3.26
Well #6	9.84	1.63	1.65	3.55
Well #7	11.42	3.07	1.69	5.05
Well #8	11.48	3.45	1.74	5.49
Well #9	11.44	1.86	1.66	3.82
Well #10	11.46	2.41	1.58	4.26
Well #11	10.98	4.83	1.61	6.73
Well #12	11.62	1.26	1.87	3.41
Well #13	11.72	2.39	1.82	4.54
Well #14	11.60	5.68	1.74	7.69
Well #15	14.60	3.86	1.65	5.77
Well #16	14.64	4.02	1.77	6.08
Septic Tank Effluent	Not Applicable	43.19	11.63	58.41

Notes:
1. Available wells measured and sampled January 25-28, 1994.

Table 52. Depth to Groundwater Level in Monitoring Wells, and Ammonium, Nitrate, and Total Kjeldahl Nitrogen Contents in February 1994 Samples from Wisconsin Heights High School (Study 1970).

	GW level (ft)	NH_4^+-N (μg/mL)	NO_3^--N (μg/mL)	TKN (μg/mL)
Well #1	9.46	1.82	1.74	3.71
Well #2	8.74	2.15	2.55	4.88
Well #3	8.92	1.56	2.12	3.81
Well #4	9.12	1.21	1.86	3.27
Well #5	8.98	1.59	1.88	3.63
Well #6	9.06	1.40	1.92	3.52
Well #7	10.64	2.98	2.13	5.32
Well #8	10.74	3.18	2.35	5.69
Well #9	10.66	2.34	1.81	4.33
Well #10	10.68	2.70	1.69	4.54
Well #11	10.18	4.48	1.77	6.40
Well #12	10.82	1.72	1.96	3.86
Well #13	10.92	3.41	1.90	5.55
Well #14	10.82	5.34	1.83	7.34
Well #15	13.98	4.12	1.72	5.99
Well #16	14.04	3.67	1.96	5.78
Septic Tank Effluent	Not Applicable	61.31	17.36	82.76

Notes:

1. Available wells measured and sampled February 24-27, 1994.

Table 53. Depth to Groundwater Level in Monitoring Wells, and Ammonium, Nitrate, and Total Kjeldahl Nitrogen Contents in March 1994 Samples from Wisconsin Heights High School (Study 1970).

	GW level (ft)	NH_4^+-N (µg/mL)	NO_3^--N (µg/mL)	TKN (µg/mL)
Well #1	8.72	1.64	1.65	3.61
Well #2	7.54	1.87	2.03	4.24
Well #3	7.74	1.92	1.96	4.22
Well #4	8.28	1.06	1.68	3.06
Well #5	8.10	1.35	1.72	3.37
Well #6	8.00	1.15	1.79	3.25
Well #7	9.26	2.73	1.84	4.88
Well #8	9.70	3.16	1.80	5.29
Well #9	9.60	2.23	1.77	4.30
Well #10	9.50	2.38	1.61	4.31
Well #11	9.02	4.27	1.69	6.24
Well #12	9.42	1.35	1.93	3.58
Well #13	9.76	3.13	1.76	5.23
Well #14	9.60	4.98	1.66	6.94
Well #15	12.94	3.82	1.71	5.82
Well #16	12.98	3.61	2.17	6.10
Septic Tank Effluent	Not Applicable	50.67	14.59	69.60

Notes:
1. Available wells measured and sampled March 25-28, 1994.

Table 54. Depth to Groundwater Level in Monitoring Wells, and Ammonium, Nitrate, and Total Kjeldahl Nitrogen Contents in April 1994 Samples from Wisconsin Heights High School (Study 1970).

	GW level (ft)	NH_4^+-N (µg/mL)	NO_3^--N (µg/mL)	TKN (µg/mL)
Well #1	8.18	1.42	1.17	3.06
Well #2	7.24	1.73	1.96	4.59
Well #3	7.42	1.85	1.95	3.94
Well #4	7.86	1.28	1.32	3.81
Well #5	7.70	1.69	1.60	3.82
Well #6	7.68	1.34	1.19	3.13
Well #7	9.08	2.38	1.44	4.70
Well #8	9.36	2.96	1.73	5.81
Well #9	9.28	2.57	1.42	4.86
Well #10	9.22	2.71	1.14	4.98
Well #11	8.70	3.52	0.98	6.25
Well #12	9.34	2.34	1.49	5.07
Well #13	9.50	2.31	1.56	4.96
Well #14	9.42	3.23	1.75	5.72
Well #15	12.68	2.07	1.68	5.13
Well #16	12.70	3.26	1.27	5.44
Septic Tank Effluent	Not Applicable	41.06	8.32	61.14

Notes:
1. Available wells measured and sampled April 21-25, 1994.

Table 55. Depth to Groundwater Level in Monitoring Wells, and Ammonium, Nitrate, and Total Kjeldahl Nitrogen Contents in May 1994 Samples from Wisconsin Heights High School (Study 1970).

	GW level (ft)	NH_4^+-N (µg/mL)	NO_3^--N (µg/mL)	TKN (µg/mL)
Well #1	7.86	1.14	0.94	2.54
Well #2	7.56	1.36	1.19	3.12
Well #3	7.72	1.67	1.73	3.82
Well #4	8.08	1.42	1.50	3.46
Well #5	7.94	1.28	0.86	2.91
Well #6	7.96	0.94	1.08	2.59
Well #7	9.40	1.36	1.15	3.65
Well #8	9.64	2.34	1.63	4.53
Well #9	9.62	2.19	1.46	4.25
Well #10	9.62	2.25	1.31	4.46
Well #11	9.02	2.83	1.05	5.07
Well #12	9.80	2.14	1.67	4.82
Well #13	9.78	1.73	1.58	3.90
Well #14	9.72	2.05	1.84	4.17
Well #15	13.00	2.03	1.83	4.36
Well #16	13.02	2.77	1.52	4.94
Septic Tank Effluent	Not Applicable	25.93	4.22	36.89

Notes:
1. Available wells measured and sampled May 23-28, 1994.

Table 56. Depth to Groundwater Level in Monitoring Wells, and Ammonium, Nitrate, and Total Kjeldahl Nitrogen Contents in June 1994 Samples from Wisconsin Heights High School.

	GW level (ft)	NH_4^+-N (μg/mL)	NO_3^--N (μg/mL)	TKN (μg/mL)
Well #1	8.24	0.82	1.13	2.51
Well #2	8.04	1.04	0.75	2.46
Well #3	8.20	1.21	1.06	3.09
Well #4	8.42	0.96	1.05	2.48
Well #5	8.28	0.92	0.74	2.33
Well #6	8.46	0.88	0.81	2.49
Well #7	9.92	0.79	1.28	2.70
Well #8	10.14	1.48	1.32	3.65
Well #9	10.14	1.09	1.05	3.08
Well #10	10.14	1.20	1.84	3.98
Well #11	9.48	1.87	1.56	4.62
Well #12	10.38	1.19	3.41	5.73
Well #13	10.34	1.05	2.17	3.50
Well #14	10.26	1.36	3.78	6.07
Well #15	13.52	1.12	0.81	2.80
Well #16	13.54	1.53	1.90	4.28
Septic Tank Effluent	Not Applicable	30.08	5.34	44.81

Notes:
1. Available wells measured and sampled June 24-29, 1994.

Table 57. Depth to Groundwater Level in Monitoring Wells, and Ammonium, Nitrate, and Total Kjeldahl Nitrogen Contents in July 1994 Samples from Wisconsin Heights High School (Study 1970).

	GW level (ft)	NH_4^+-N (µg/mL)	NO_3^--N (µg/mL)	TKN (µg/mL)
Well #1	8.66	0.96	0.99	2.18
Well #2	8.74	1.10	0.83	2.11
Well #3	8.88	0.92	1.01	2.05
Well #4	9.08	0.99	1.03	2.29
Well #5	8.96	0.73	0.84	1.69
Well #6	9.06	0.75	0.87	1.83
Well #7	10.66	0.84	1.22	2.37
Well #8	10.86	1.17	1.25	2.71
Well #9	10.88	0.92	1.02	2.16
Well #10	10.90	1.34	1.63	3.30
Well #11	10.22	1.58	1.46	3.41
Well #12	11.14	1.10	1.70	3.15
Well #13	11.10	1.04	1.65	3.03
Well #14	11.02	1.23	1.61	3.20
Well #15	14.26	1.08	2.02	3.53
Well #16	14.26	1.35	2.14	3.92
Septic Tank Effluent	Not Applicable	15.47	4.62	24.08

Notes:
1. Available wells measured and sampled July 23-26, 1994.

Table 58. Depth to Groundwater Level in Monitoring Wells, and Ammonium, Nitrate, and Total Kjeldahl Nitrogen Contents in August 1994 Samples from Wisconsin Heights High School (Study 1970).

	GW level (ft)	NH_4^+-N (µg/mL)	NO_3^--N (µg/mL)	TKN (µg/mL)
Well #1	8.40	1.23	1.03	2.49
Well #2	8.36	1.41	0.95	2.58
Well #3	8.50	1.05	0.96	2.21
Well #4	8.78	1.01	0.98	2.14
Well #5	8.64	0.94	0.89	2.01
Well #6	8.72	0.89	0.93	2.06
Well #7	10.26	1.36	1.24	2.92
Well #8	10.48	1.62	1.40	3.35
Well #9	10.48	1.26	1.17	2.68
Well #10	10.46	1.31	1.56	3.20
Well #11	9.82	1.47	1.39	3.07
Well #12	10.72	1.28	1.68	3.32
Well #13	10.72	1.57	1.74	3.66
Well #14	10.64	1.68	1.43	3.43
Well #15	13.86	1.32	1.86	3.54
Well #16	13.88	1.54	2.43	4.35
Septic Tank Effluent	Not Applicable	21.56	3.81	29.54

Notes:
1. Available wells measured and sampled August 17-21, 1994.

Table 59. Results of Bacterial Analyses of June 1994 Septic Tank Effluent and Groundwater Samples from Sites Originated in Studies 1985 and 1979: I. Total Coliforms Counts.

Site Number	Septic Tank Effluent	Well BG	Well #1	Well #2	Well #3
S-1 (Mound)	$2.4x10^7$	8	$3.0x10^3$	ND	ND
S-3 (Dosing)	$2.6x10^7$	ND	17	5	8
S-6 (Conv'l)	Not found	ND	ND	ND	ND
S-8 (Conv'l)	Not found	ND	34	2	ND
S-9 (Dosing)	$1.5x10^7$	ND	8	ND	3
S-10 (Mound)	$1.6x10^6$	ND	ND	ND	ND
S-12 (Dosing)	$1.6x10^5$	25	$1.3x10^3$	790	35
S-13 (Conv'l)	$4.3x10^6$	ND	Removed	Removed	317
S-14 (Mound)	$1.2x10^7$	ND	ND	ND	ND
S-15 (Mound)	$6.8x10^6$	ND	ND	ND	ND
3-78 (Mound)	$1.3x10^6$	ND	ND	ND	ND

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled June 7-16, 1994.
3. Bacterial analyses on septic tank effluent and groundwater samples were performed using the membrane filtration techniques (Standard Methods, 1992) and expressed as most probable numbers per 100 mL of liquid (MPN/100 mL).
4. ND = No colony was detected in the sample.

Table 60. Results of Bacterial Analyses of June 1994 Septic Tank Effluent and Groundwater Samples from Sites Originated in Studies 1985 and 1979: II. Fecal Coliforms Counts.

Site Number	Septic Tank Effluent	Well BG	Well #1	Well #2	Well #3
S-1 (Mound)	1.1×10^6	1	232	ND	ND
S-3 (Dosing)	4.0×10^4	ND	3	18	1
S-6 (Conv'l)	Not found	ND	ND	ND	ND
S-8 (Conv'l)	Not found	ND	34	4	2
S-9 (Dosing)	7.3×10^5	ND	6	3	5
S-10 (Mound)	1.2×10^6	ND	ND	8	ND
S-12 (Dosing)	2.2×10^5	2	109	80	2
S-13 (Conv'l)	1.5×10^5	ND	Removed	Removed	106
S-14 (Mound)	7.2×10^5	ND	ND	ND	ND
S-15 (Mound)	4.9×10^5	ND	ND	ND	ND
3-78 (Mound)	1.45×10^5	ND	ND	ND	ND

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled June 7-16, 1994.
3. Bacterial analyses on septic tank effluent and groundwater samples were performed using the membrane filtration techniques (Standard Methods, 1992) and expressed as most probable numbers per 100 mL of liquid (MPN/100 mL).
4. ND = colony was detected in the sample.

Table 61. Results of Bacterial Analyses of June 1994 Septic Tank Effluent and Groundwater Samples from Sites Originated in Studies 1985 and 1979: III. Fecal Streptococci counts.

Site Number	Septic Tank Effluent	Well BG	Well #1	Well #2	Well #3
S-1 (Mound)	$2.4x10^4$	ND	ND	ND	ND
S-3 (Dosing)	$4.7x10^3$	ND	10	1	4
S-6 (Conv'l)	Not found	ND	ND	ND	ND
S-8 (Conv'l)	Not found	ND	16	4	1
S-9 (Dosing)	$6.1x10^3$	ND	4	5	1
S-10 (Mound)	$1.2x10^4$	ND	ND	2	ND
S-12 (Dosing)	$3.5x10^3$	ND	1	ND	ND
S-13 (Conv'l)	$2.4x10^3$	ND	Removed	Removed	ND
S-14 (Mound)	$5.3x10^4$	ND	ND	ND	ND
S-15 (Mound)	$1.5x10^4$	ND	ND	ND	ND
3-78 (Mound)	$1.1x10^4$	14	1	375	39

Notes:

1. Well BG = Background well; Conv'l = Conventional septic system, Dosing = Conventional system with a pump chamber and dosing system, and Mound = Mound-type system.
2. Sites with available wells were sampled June 7-16, 1994.
3. Bacterial analyses on septic tank effluent and groundwater samples were performed using the membrane filtration techniques (Standard Methods, 1992) and expressed as most probable numbers per 100 mL of liquid (MPN/100 mL).
4. ND = No colony was detected in the sample.

Table 62. Results of Bacterial Analyses (Total Coliforms, Fecal Coliforms, and Fecal Streptococci Counts) of June 1994 Septic Tank Effluent and Groundwater Samples from Wisconsin Heights High School.

	TC (MPN/100 mL)	FC (MPN/100 mL)	FS (MPN/100 mL)
Well #1	ND	ND	ND
Well #2	ND	ND	ND
Well #3	ND	ND	ND
Well #4	ND	ND	ND
Well #5	56	4	ND
Well #6	20	26	ND
Well #7	ND	ND	ND
Well #8	ND	ND	ND
Well #9	ND	ND	2
Well #10	ND	ND	ND
Well #11	ND	ND	ND
Well #12	ND	ND	ND
Well #13	15	3	ND
Well #14	18	2	10
Well #15	2	ND	ND
Well #16	ND	ND	ND
Septic Tank Effluent	3.3×10^7	2.5×10^6	2.6×10^3

Notes:

1. Available wells were sampled June 7-16, 1994.
2. Bacterial analyses on septic tank effluent and groundwater samples were performed using the membrane filtration techniques (Standard Methods, 1992) and expressed as most probable numbers per 100 mL of liquid (MPN/100 mL).
3. ND = No colony was detected in the sample.

APPENDIX 2

MONTHLY GROUNDWATER LEVELS IN MONITORING WELLS

AT INDIVIDUAL SITES

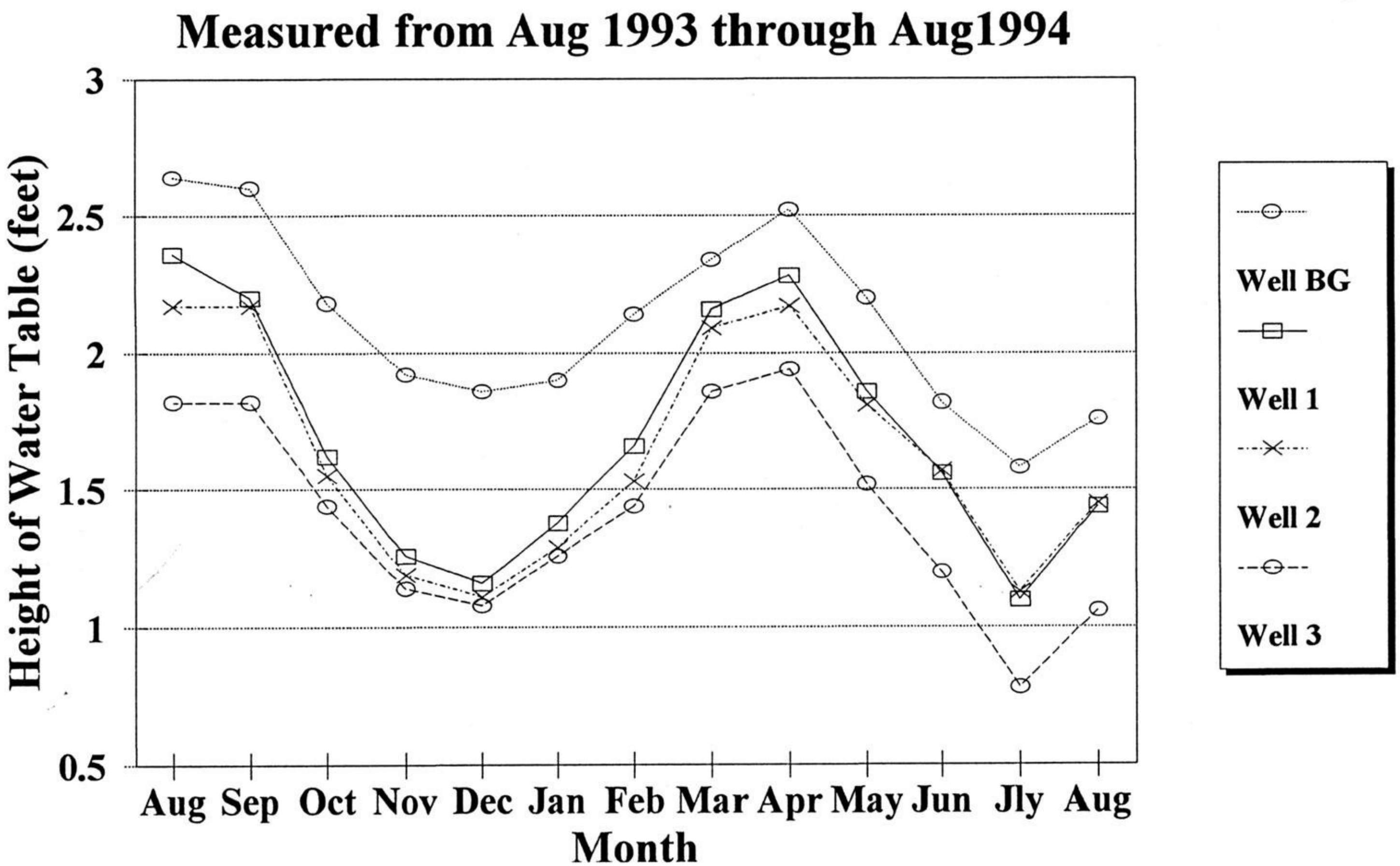


Figure 2.1. Monthly groundwater levels in four monitoring wells at Site 1 (mound system).

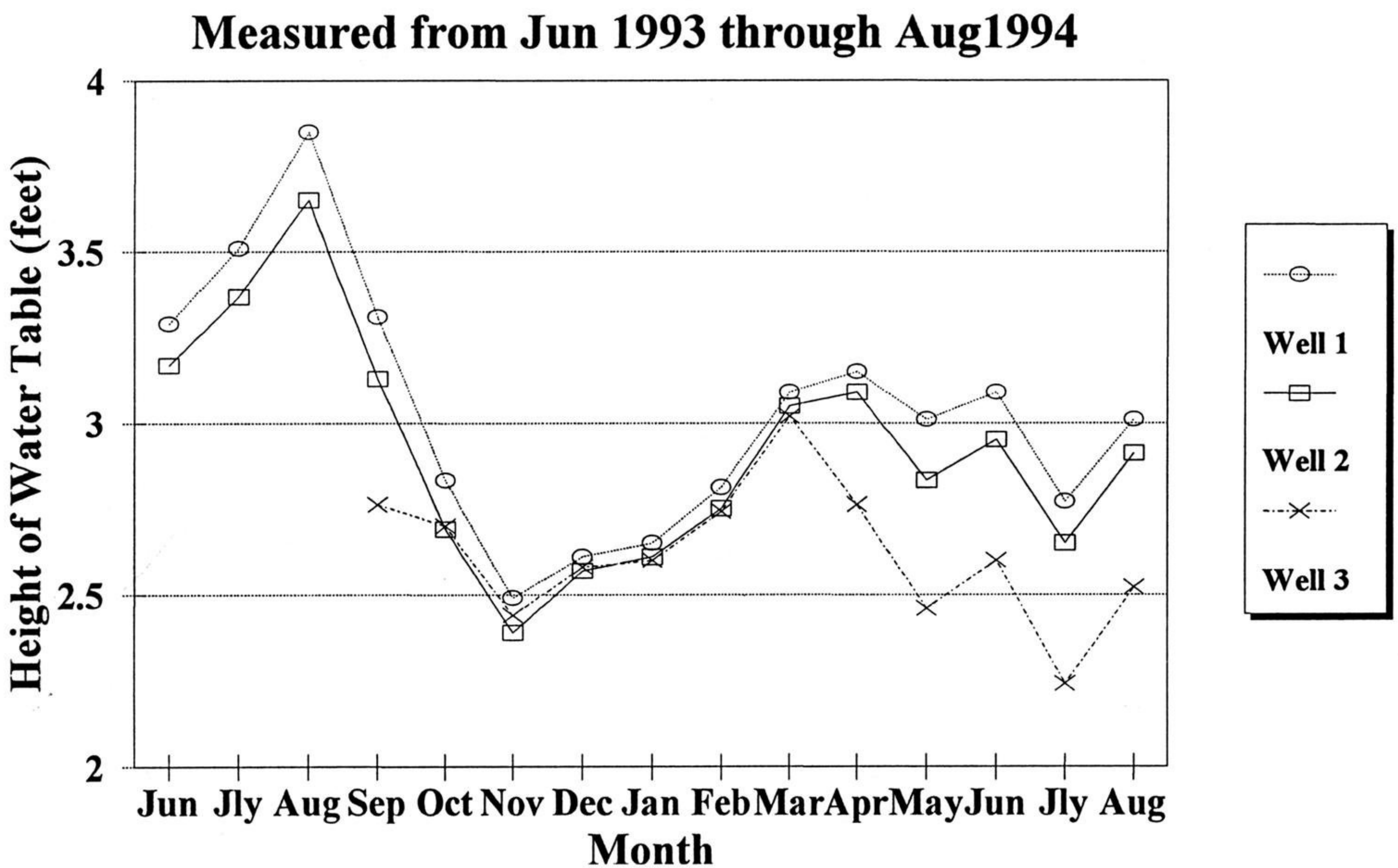


Figure 2.2. Monthly groundwater levels in four monitoring wells at Site 3 (dosing system).

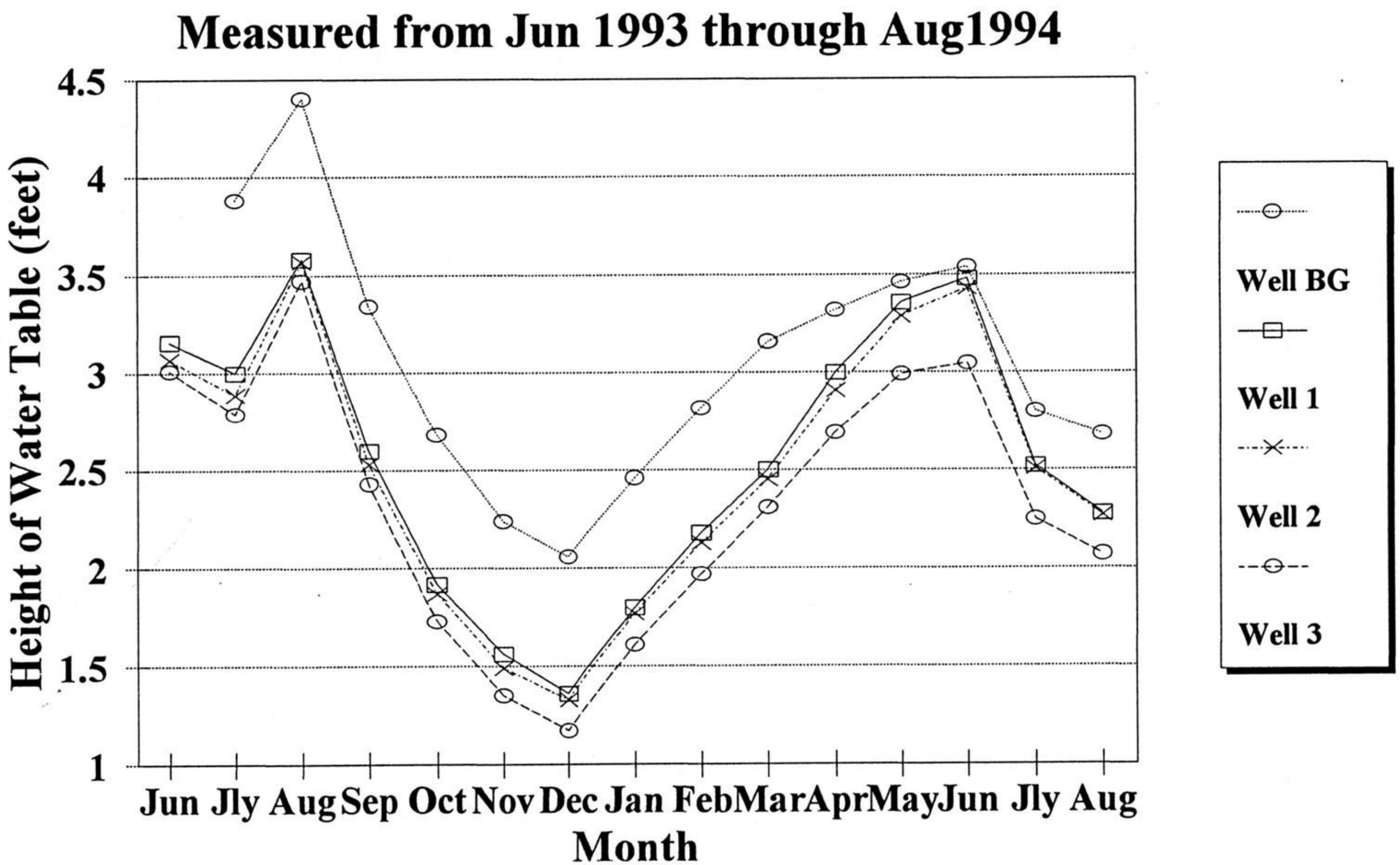


Figure 2.3. Monthly groundwater levels in four monitoring wells at Site 6 (conventional system).

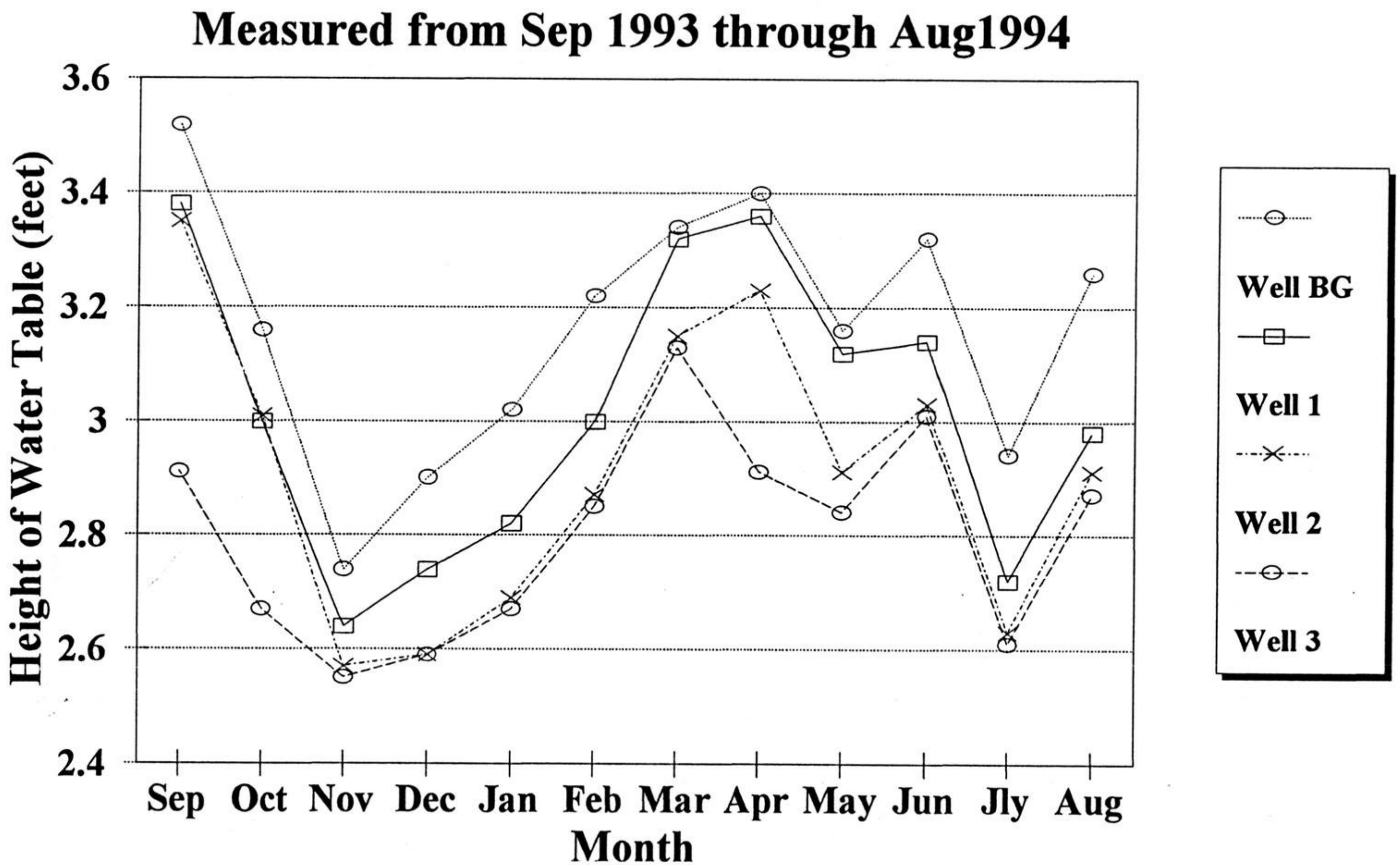


Figure 2.4. Monthly groundwater levels in four monitoring wells at Site 8 (conventional system).

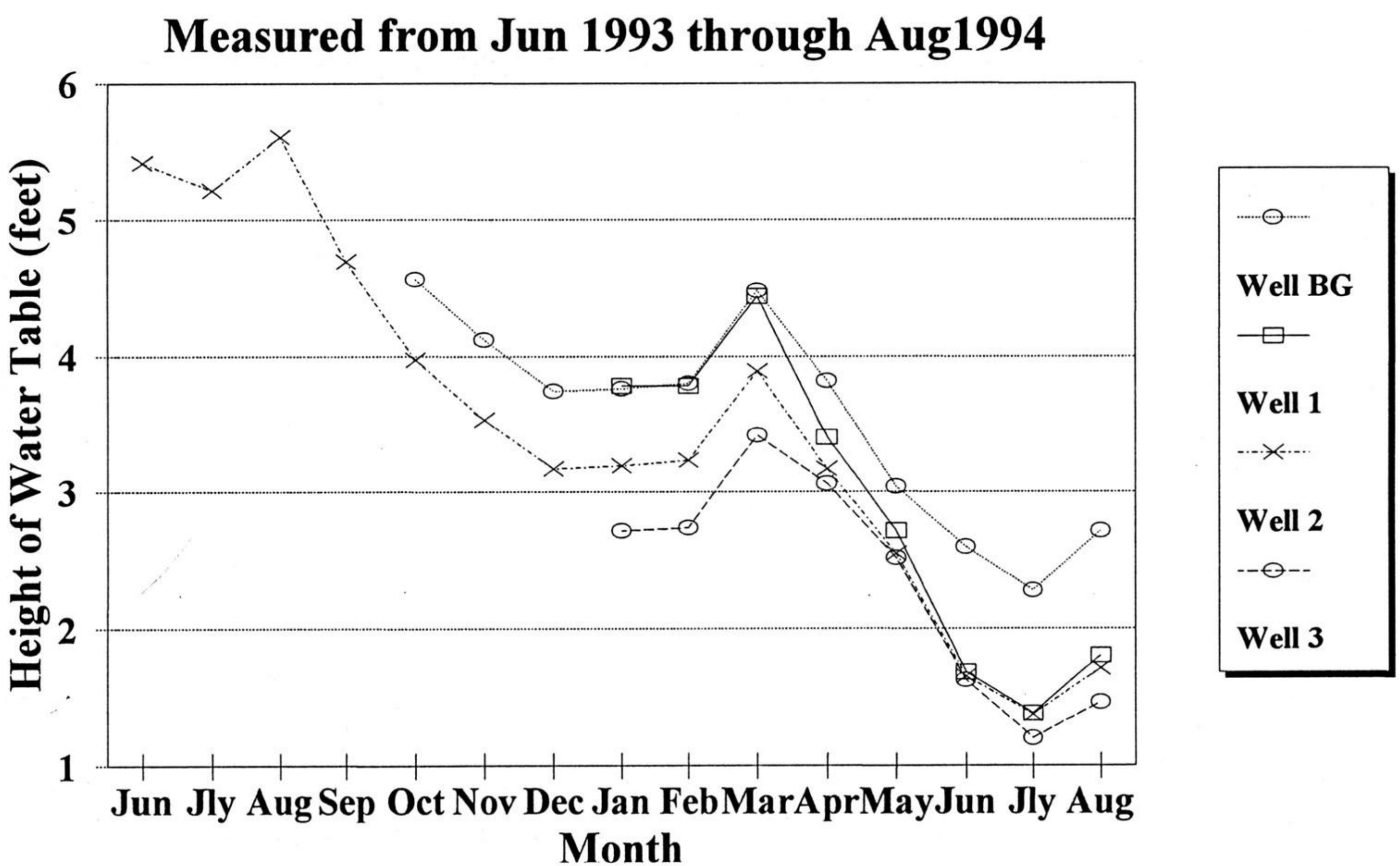


Figure 2.5. Monthly groundwater levels in four monitoring wells at Site 9 (dosing system).

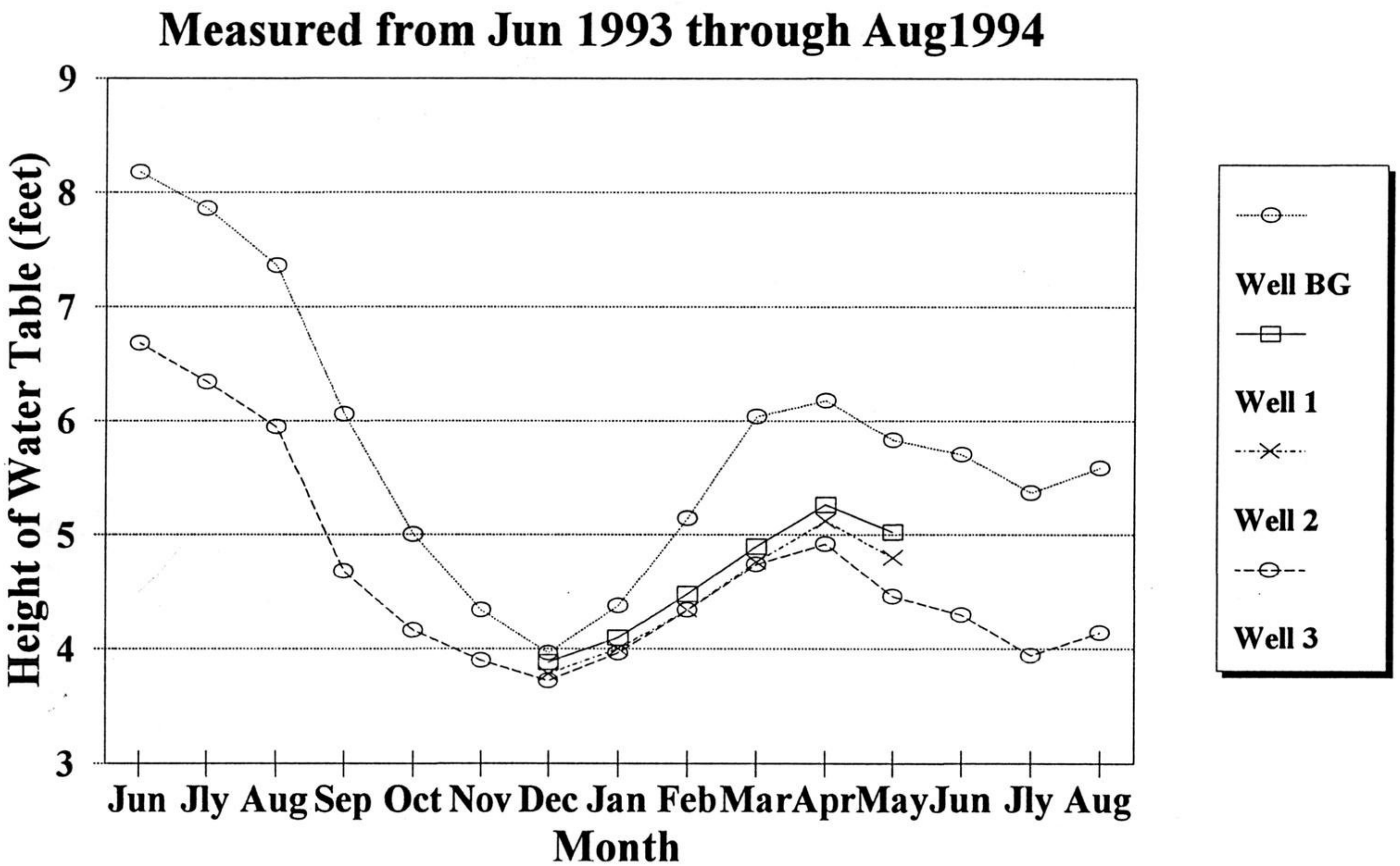


Figure 2.6. Monthly groundwater levels in four monitoring wells at Site 13 (conventional system).

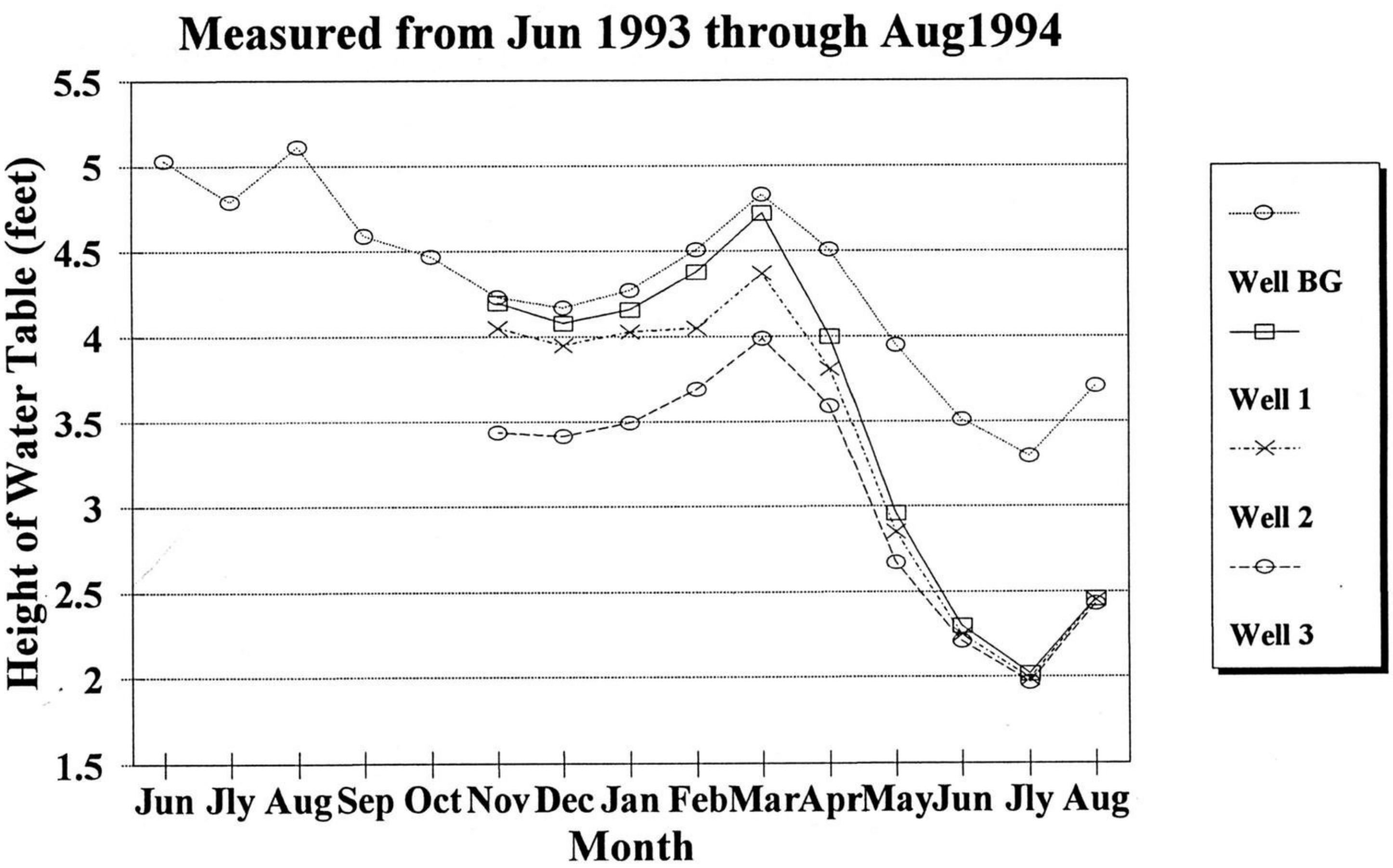


Figure 2.7. Monthly groundwater levels in four monitoring wells at Site 14 (mound system).

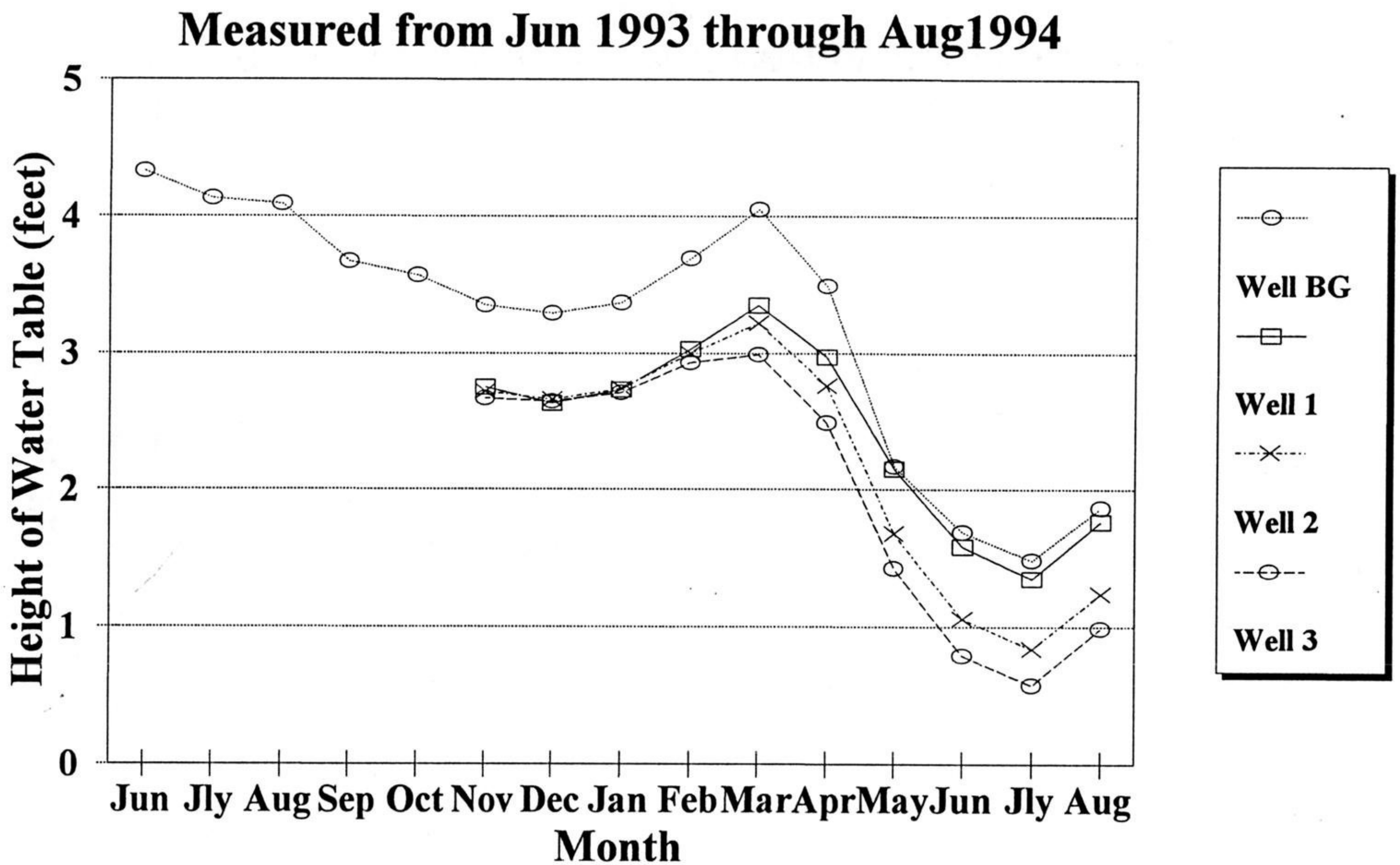


Figure 2.8. Monthly groundwater levels in four monitoring wells at Site 15 (mound system).

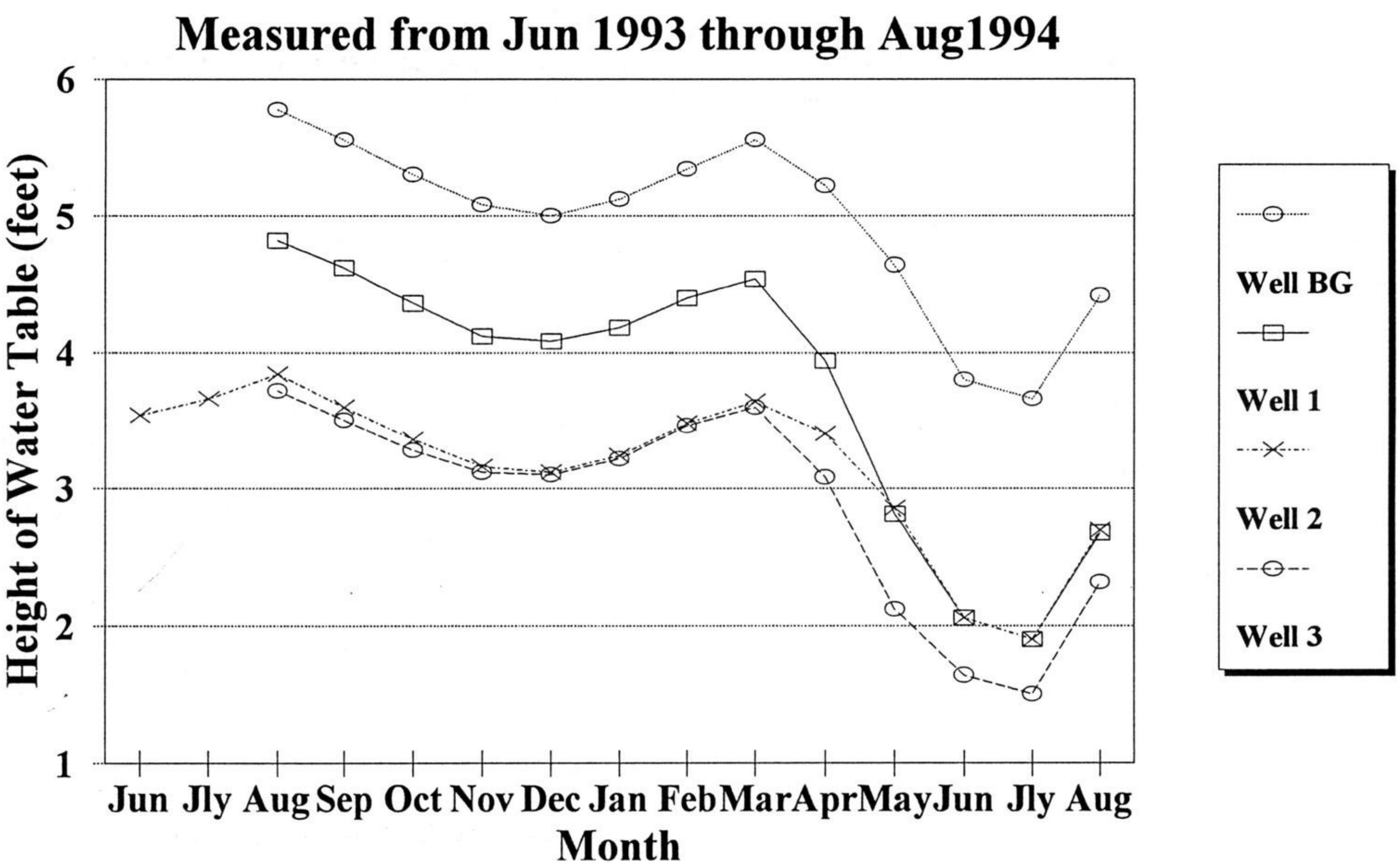


Figure 2.9. Monthly groundwater levels in four monitoring wells at Site 3-78 (mound system).

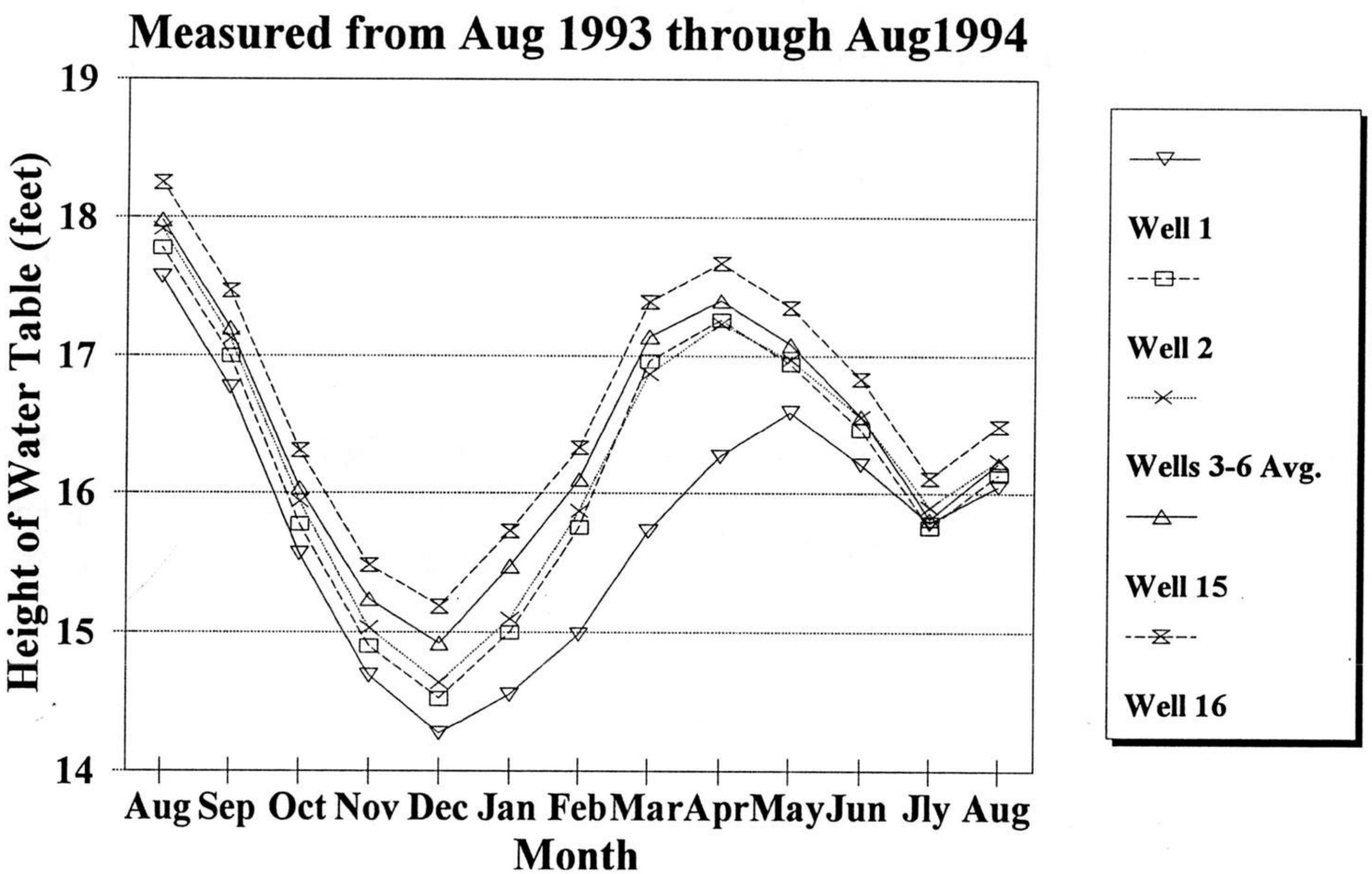


Figure 2.10. Monthly groundwater levels in representative monitoring wells at Wisconsin Heights High School (dosing system).

APPENDIX 3

MONTHLY AMMONIUM, NITRATE, AND TOTAL KJELDAHL NITROGEN LEVELS IN GROUNDWATER FROM MONITORING WELLS AT INDIVIDUAL SITES

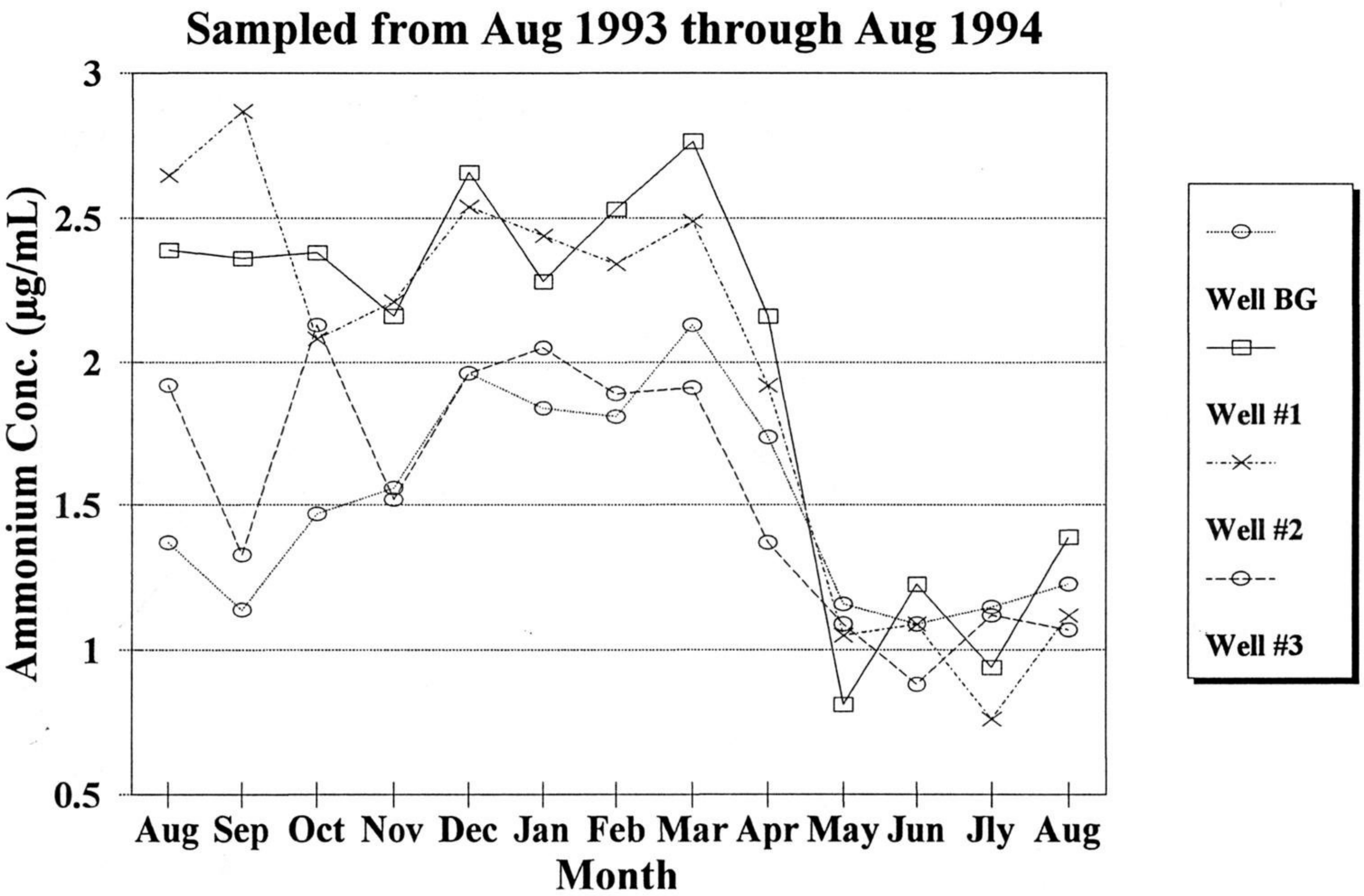


Figure 3.1. Monthly ammonium nitrogen levels in groundwater from four monitoring wells at Site 1 (mound system).

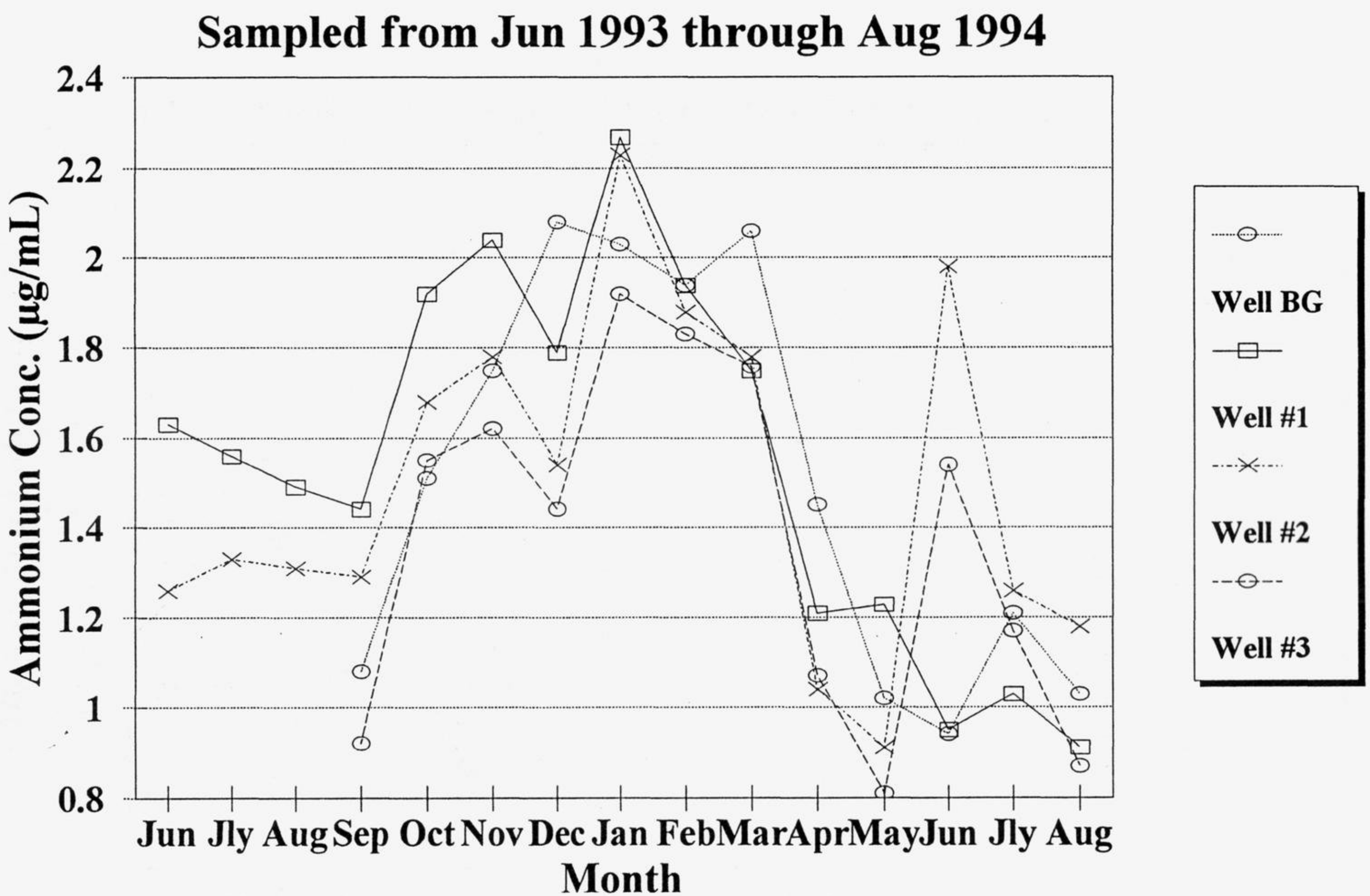


Figure 3.2. Monthly ammonium nitrogen levels in groundwater from four monitoring wells at Site 3 (dosing system).

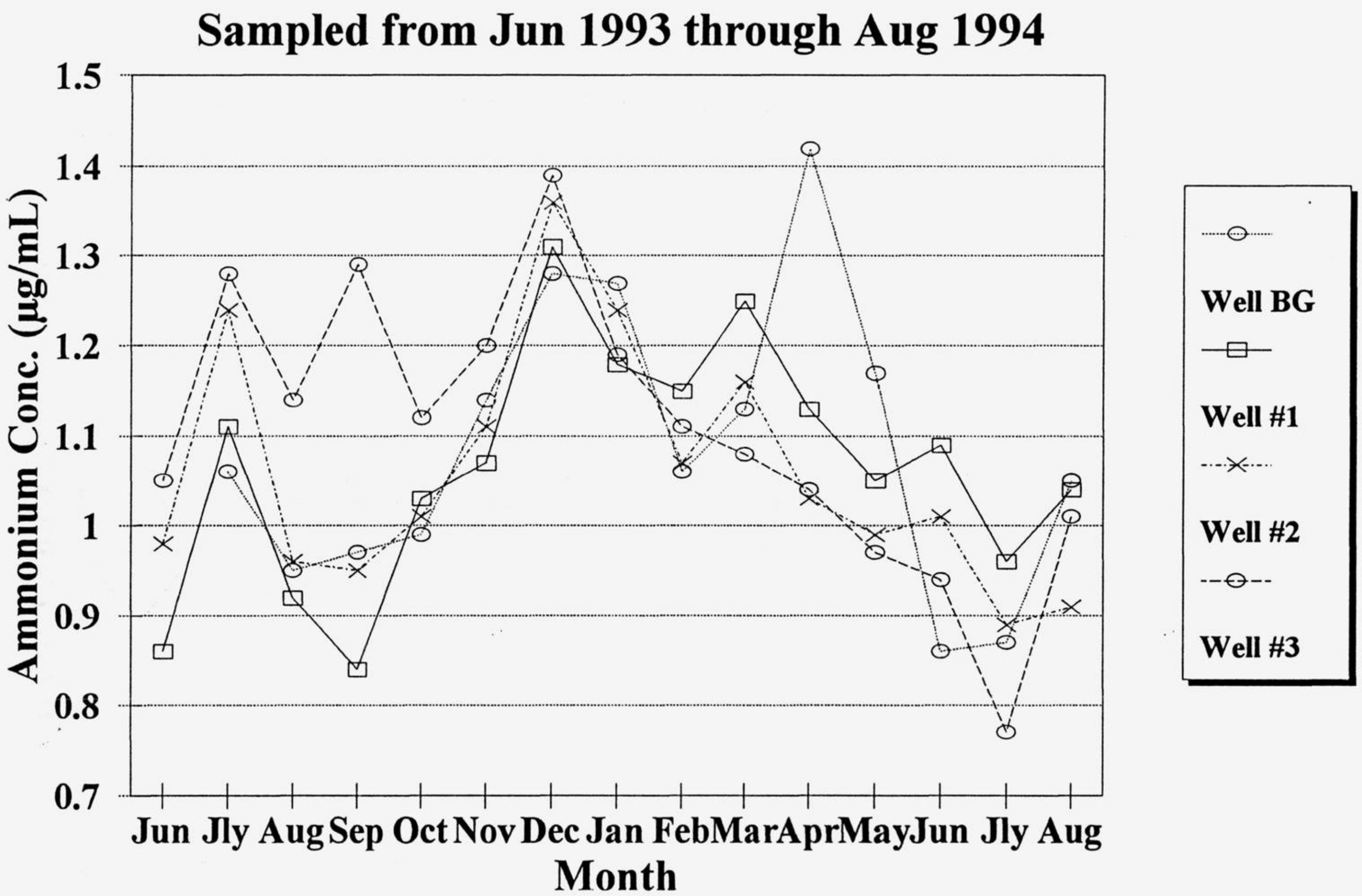


Figure 3.3. Monthly ammonium nitrogen levels in groundwater from four monitoring wells at Site 6 (conventional system).

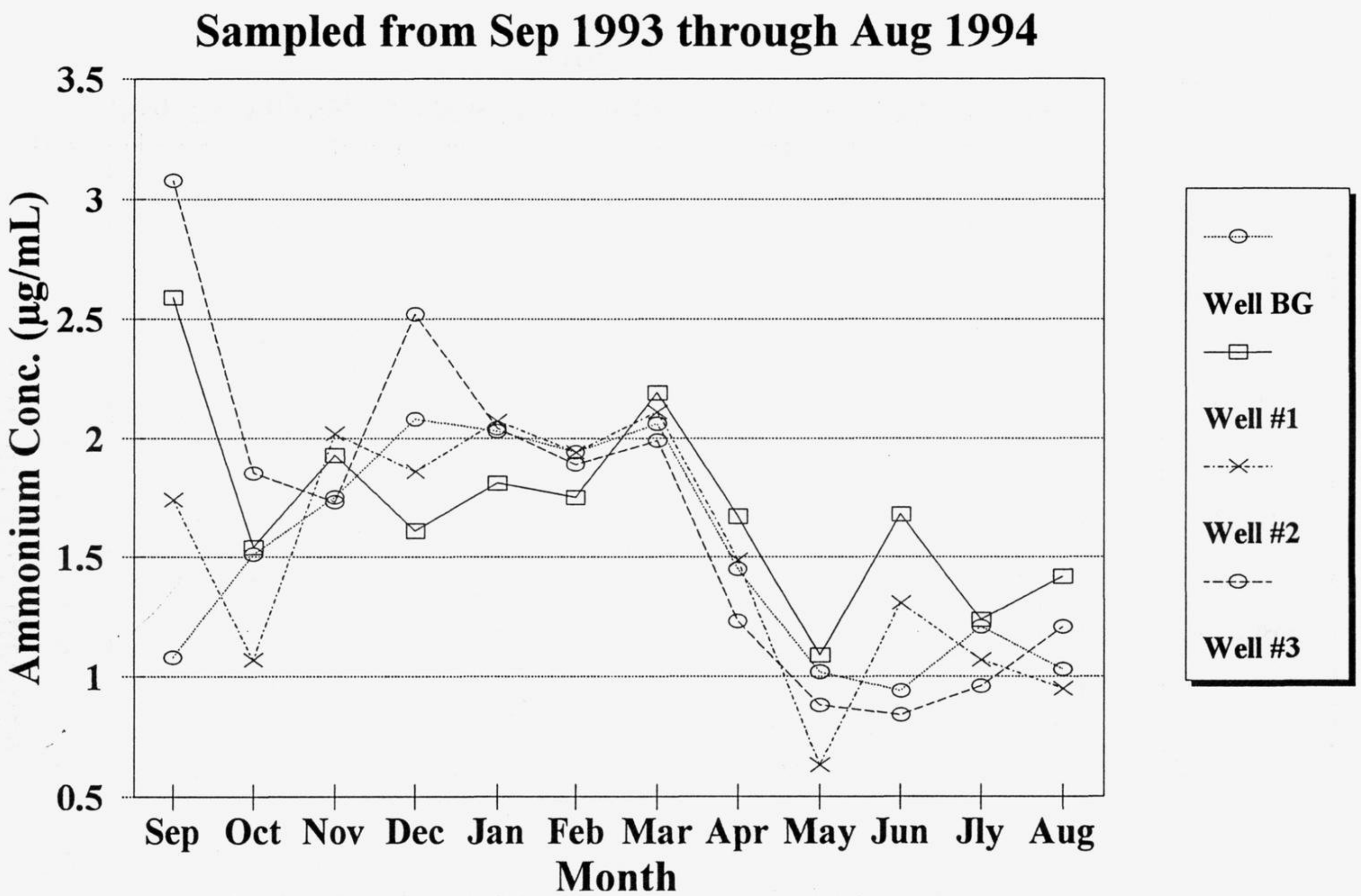


Figure 3.4. Monthly ammonium nitrogen levels in groundwater from four monitoring wells at Site 8 (conventional system).

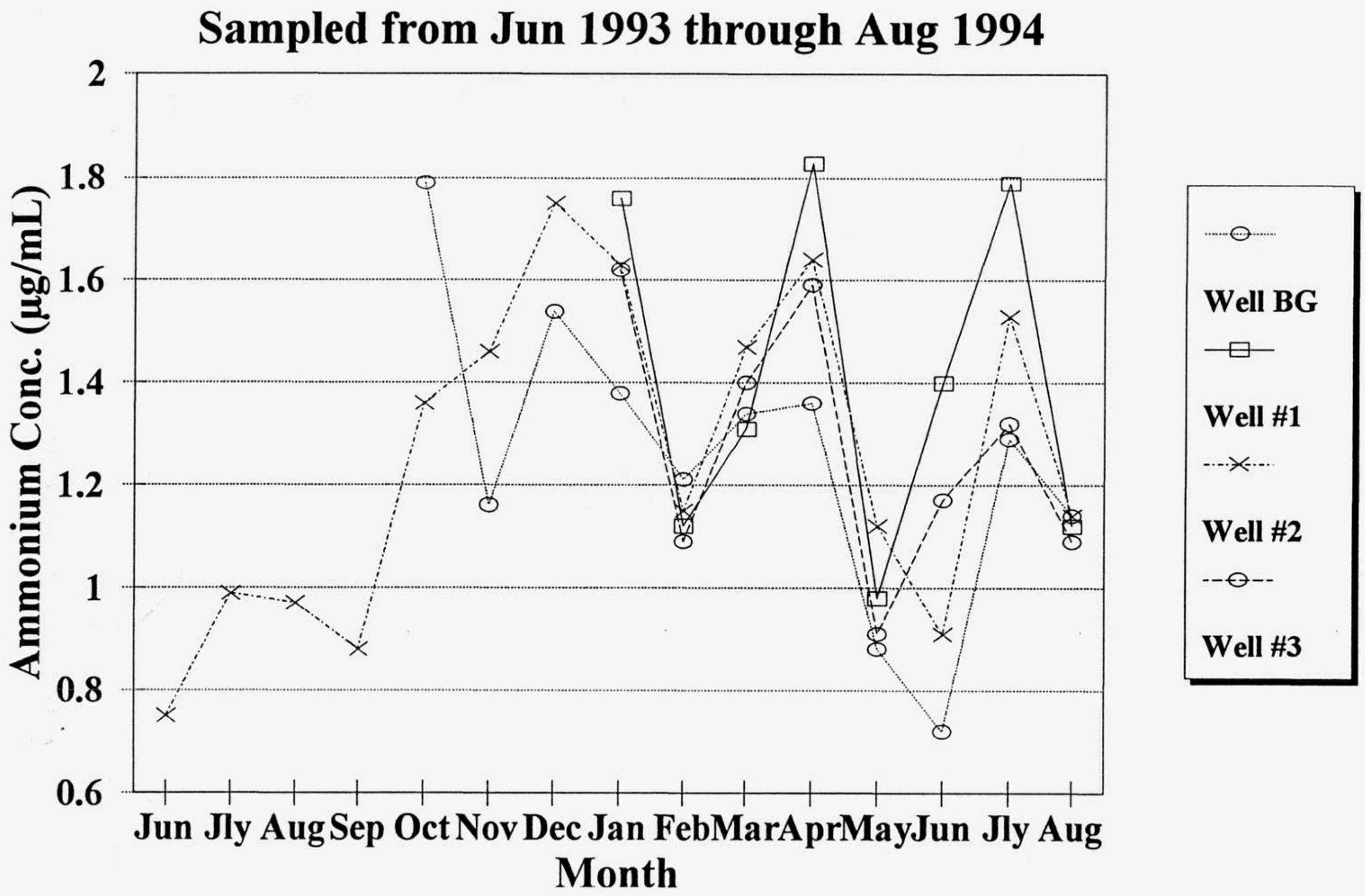


Figure 3.5. Monthly ammonium nitrogen levels in groundwater from four monitoring wells at Site 9 (dosing system).

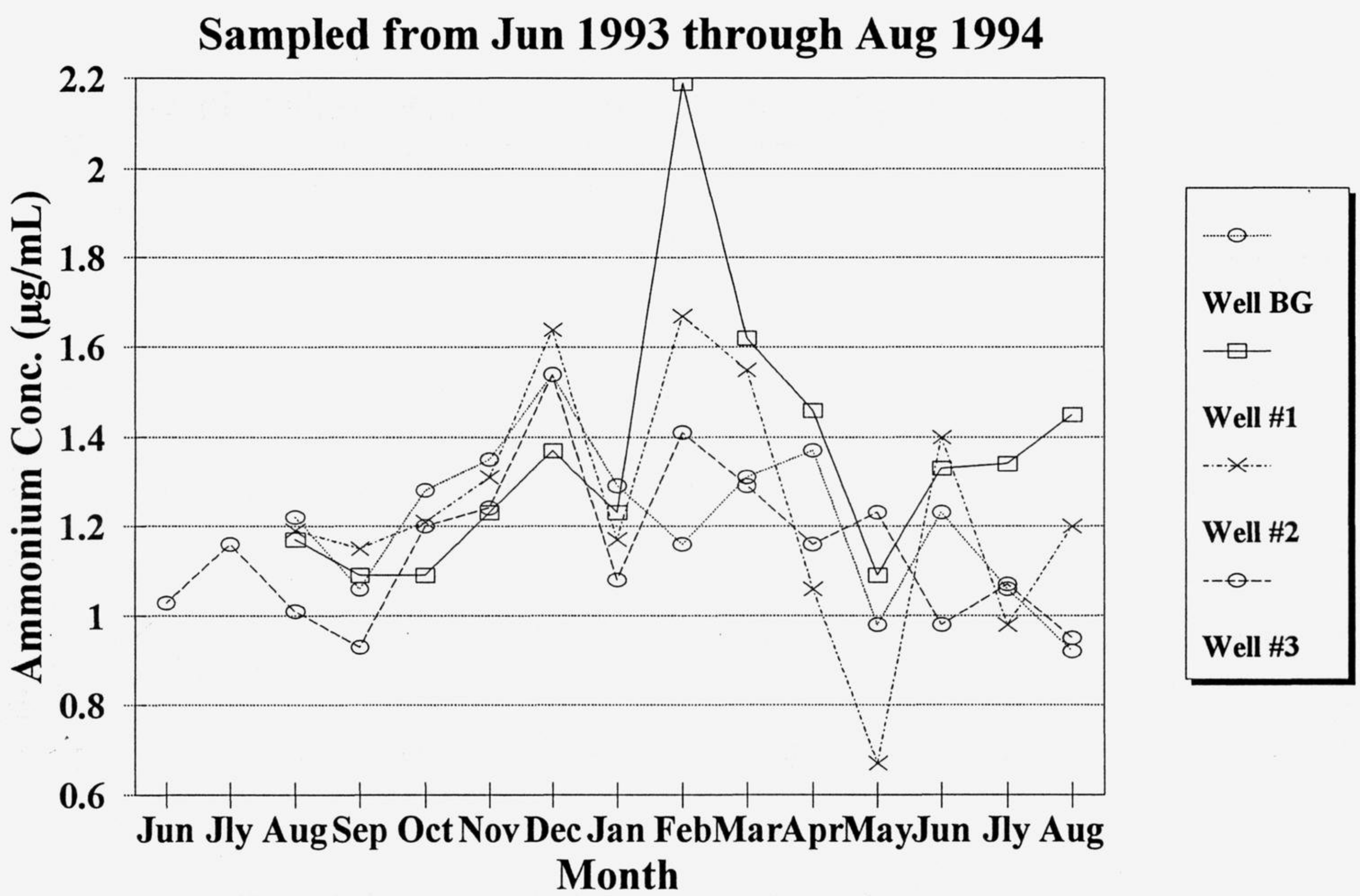


Figure 3.6. Monthly ammonium nitrogen levels in groundwater from four monitoring wells at Site 10 (mound system).

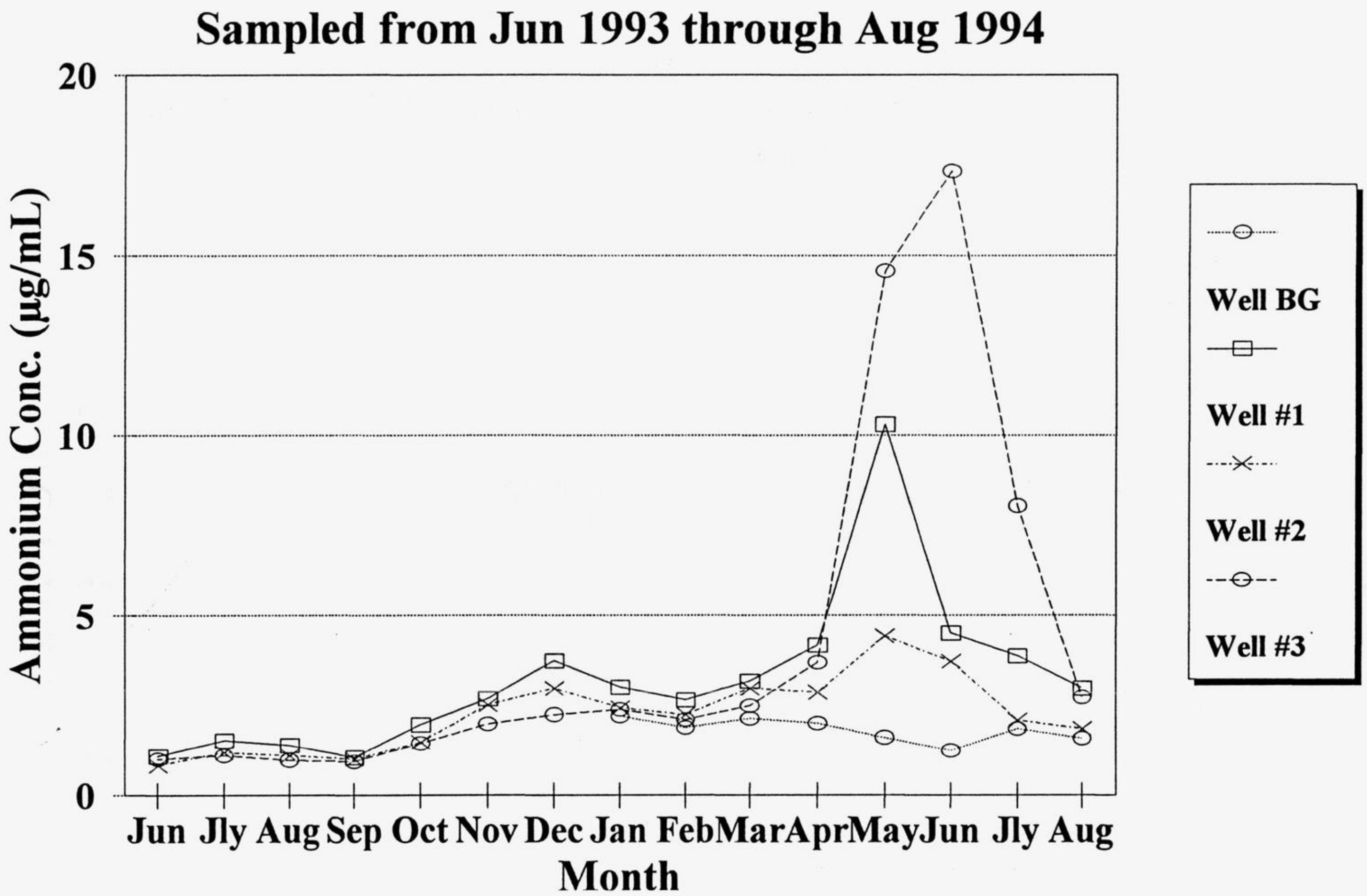


Figure 3.7. Monthly ammonium nitrogen levels in groundwater from four monitoring wells at Site 12 (dosing system).

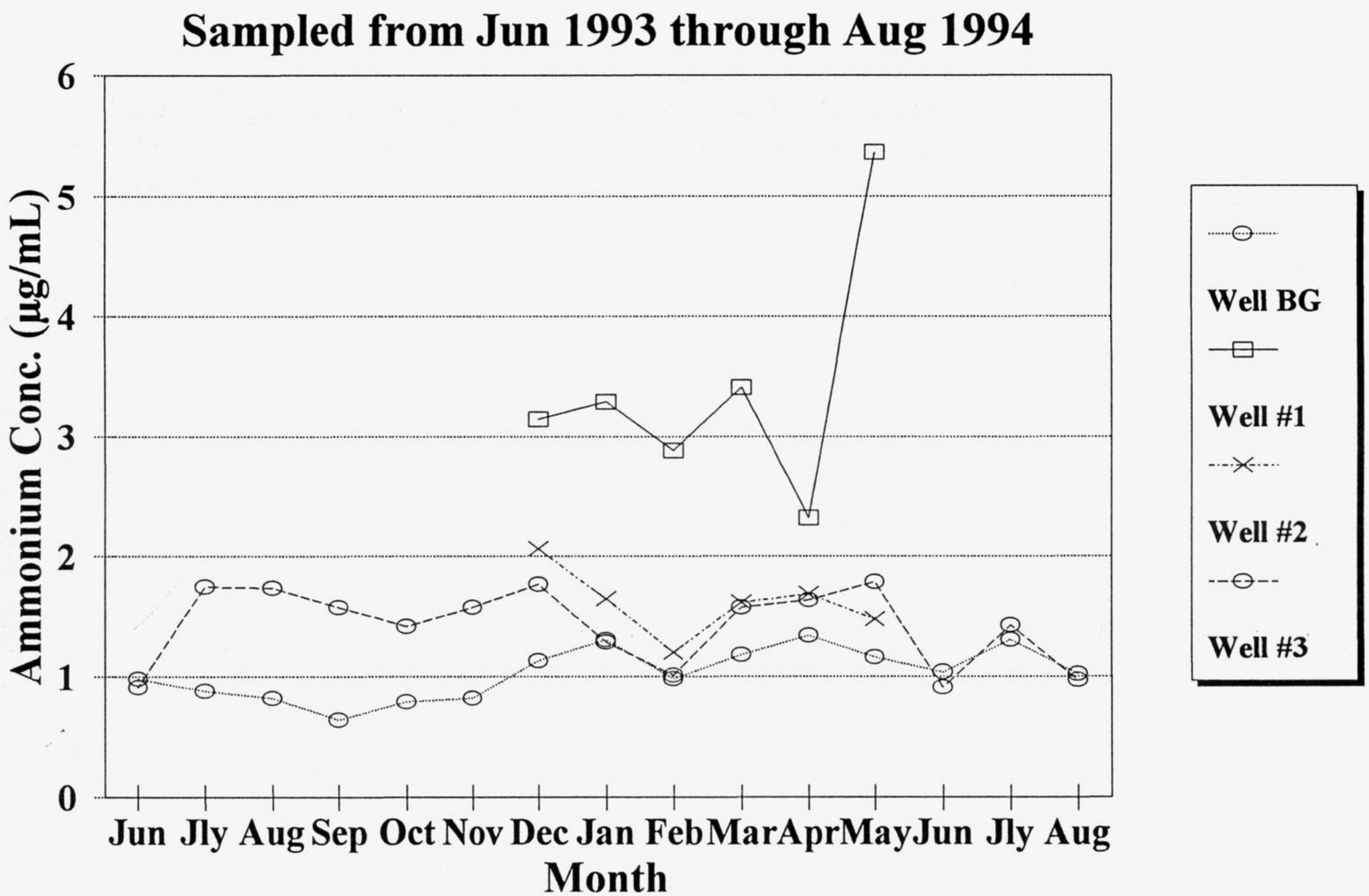


Figure 3.8. Monthly ammonium nitrogen levels in groundwater from four monitoring wells at Site 13 (conventional system).

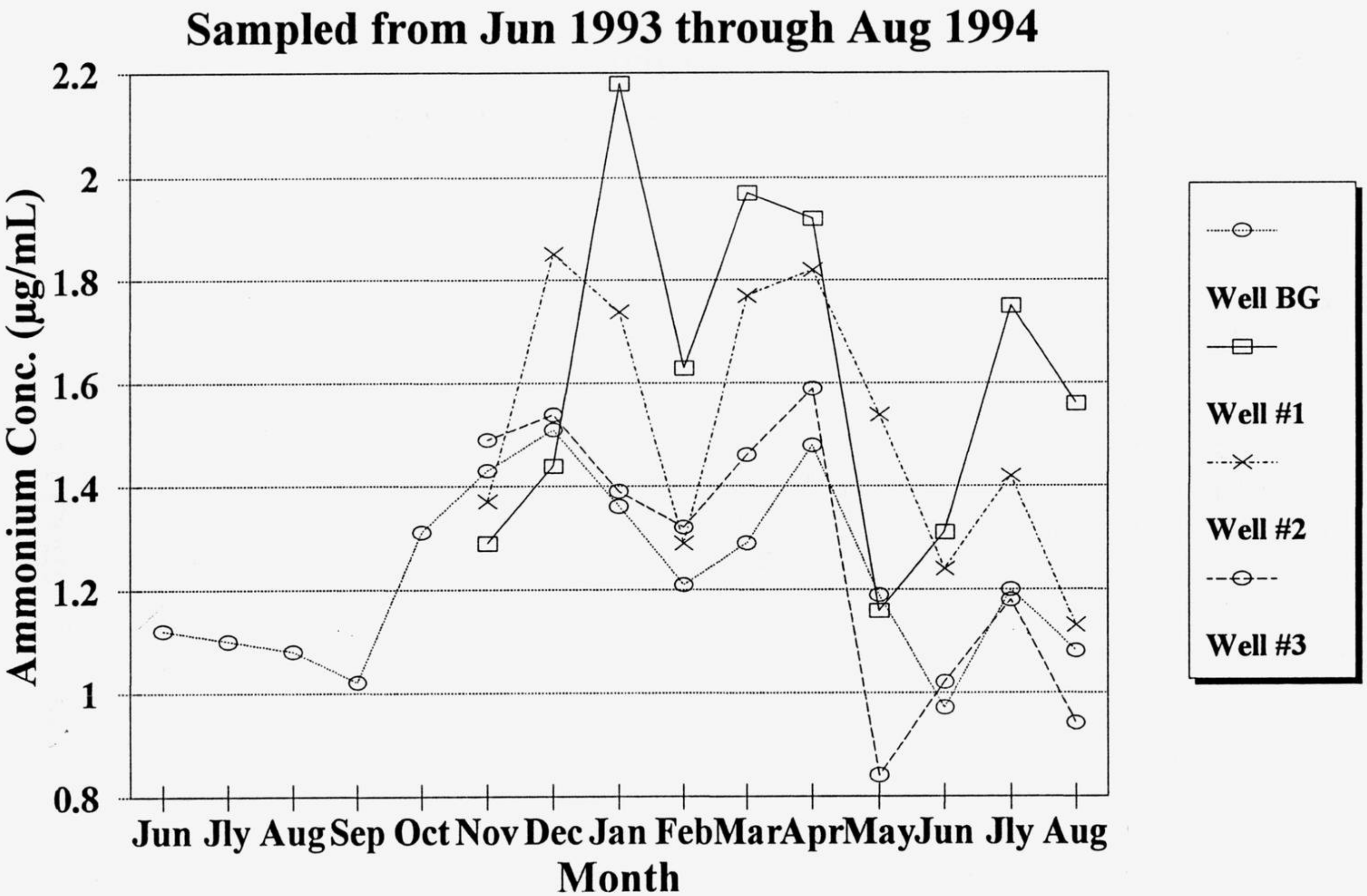


Figure 3.9. Monthly ammonium nitrogen levels in groundwater from four monitoring wells at Site 14 (mound system).

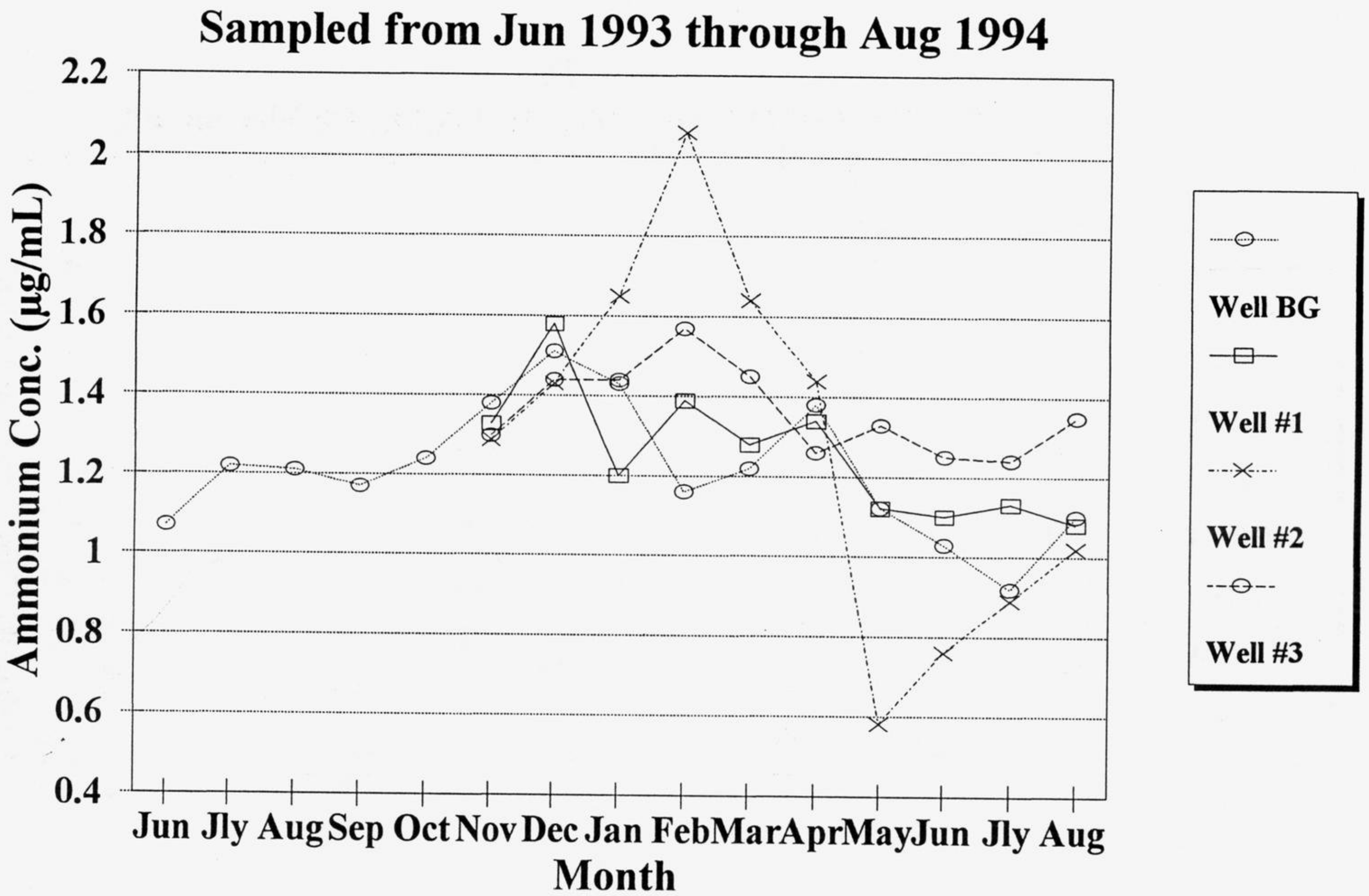


Figure 3.10. Monthly ammonium nitrogen levels in groundwater from four monitoring wells at Site 15 (mound system).

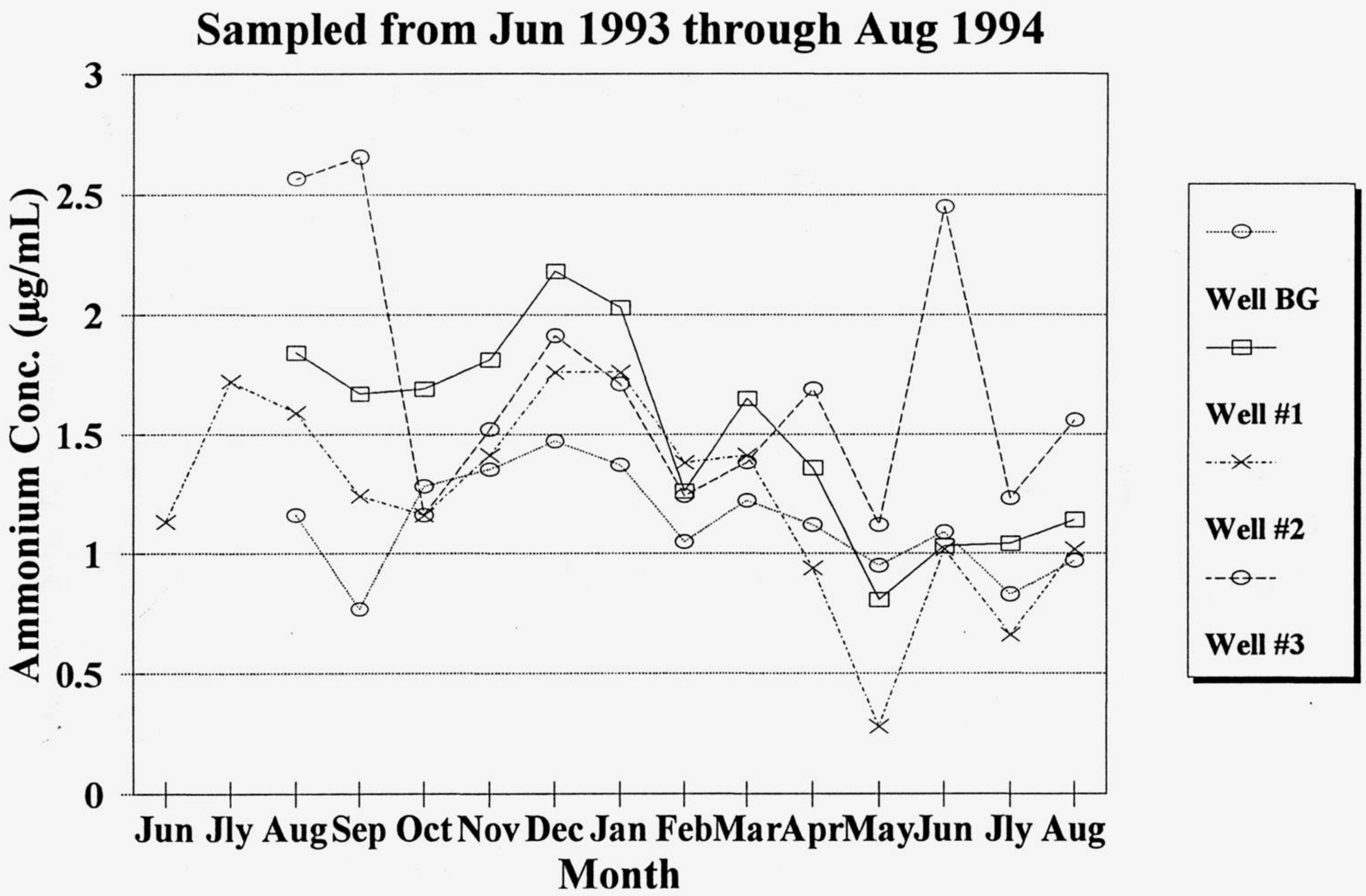


Figure 3.11. Monthly ammonium nitrogen levels in groundwater from four monitoring wells at Site 3-78 (mound system).

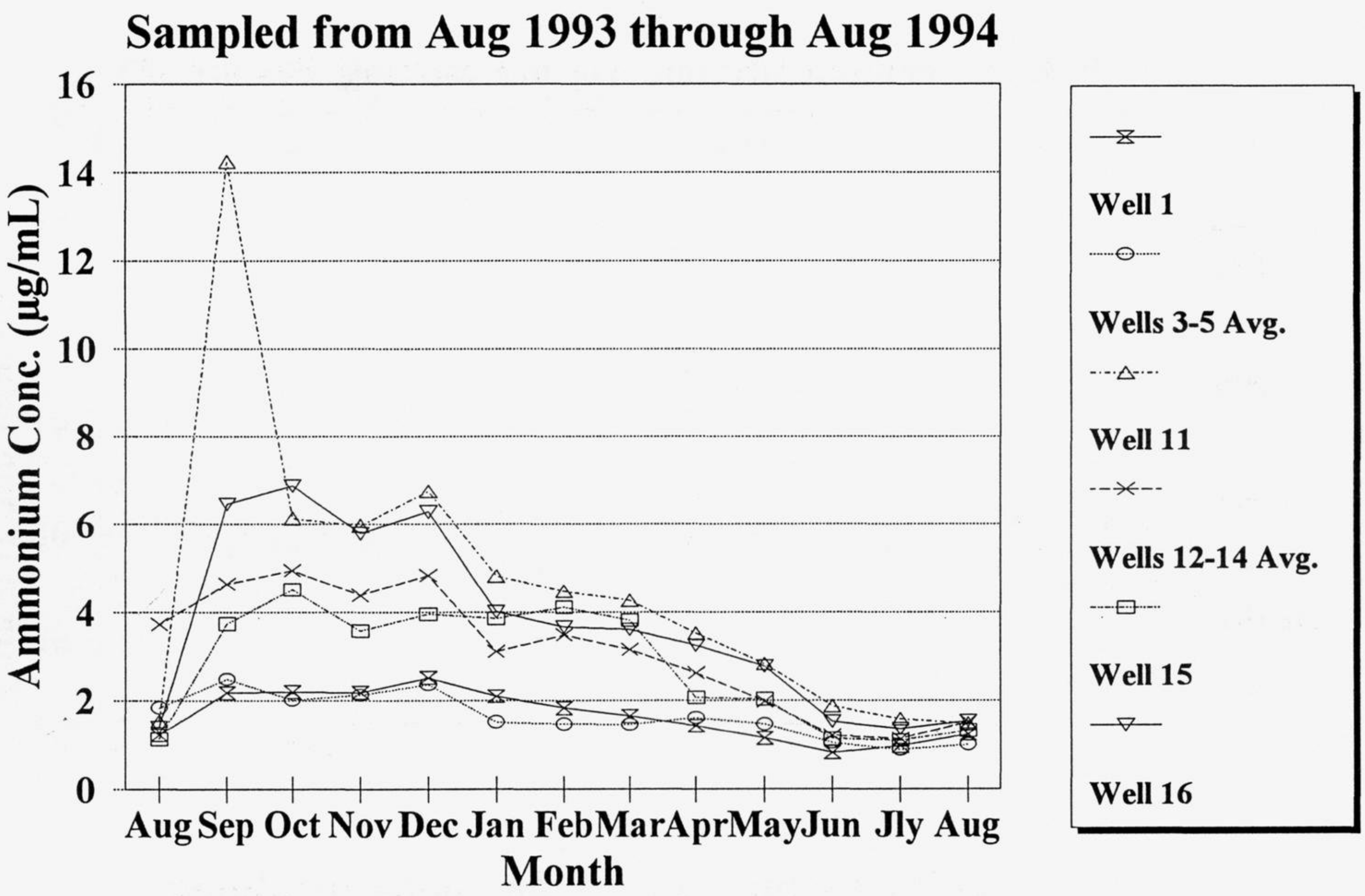


Figure 3.12 Monthly ammonium nitrogen levels in groundwater from representative monitoring wells at Wisconsin Height High School (dosing system).

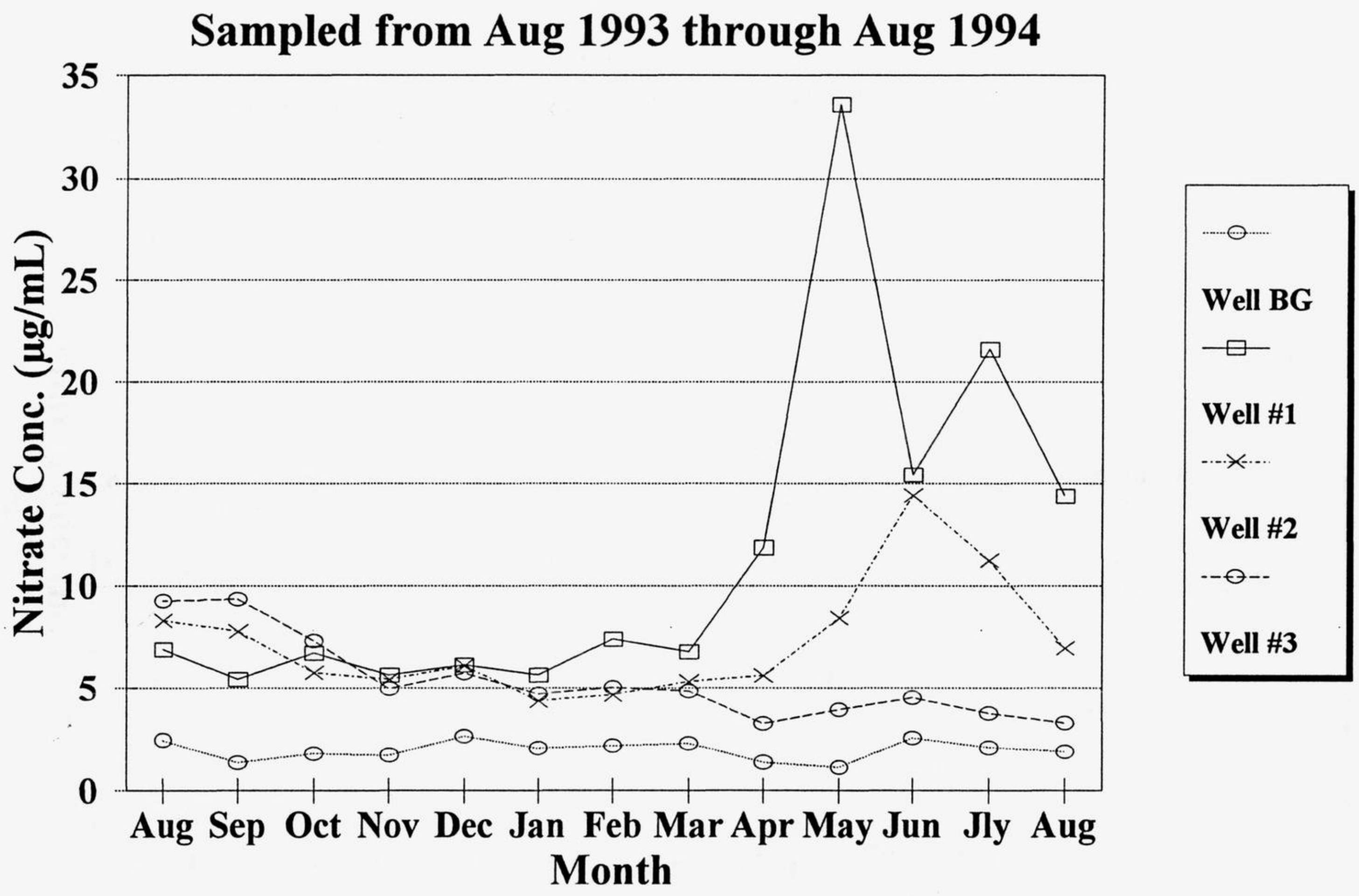


Figure 3.13. Monthly nitrate nitrogen levels in groundwater from four monitoring wells at Site 1 (mound system).

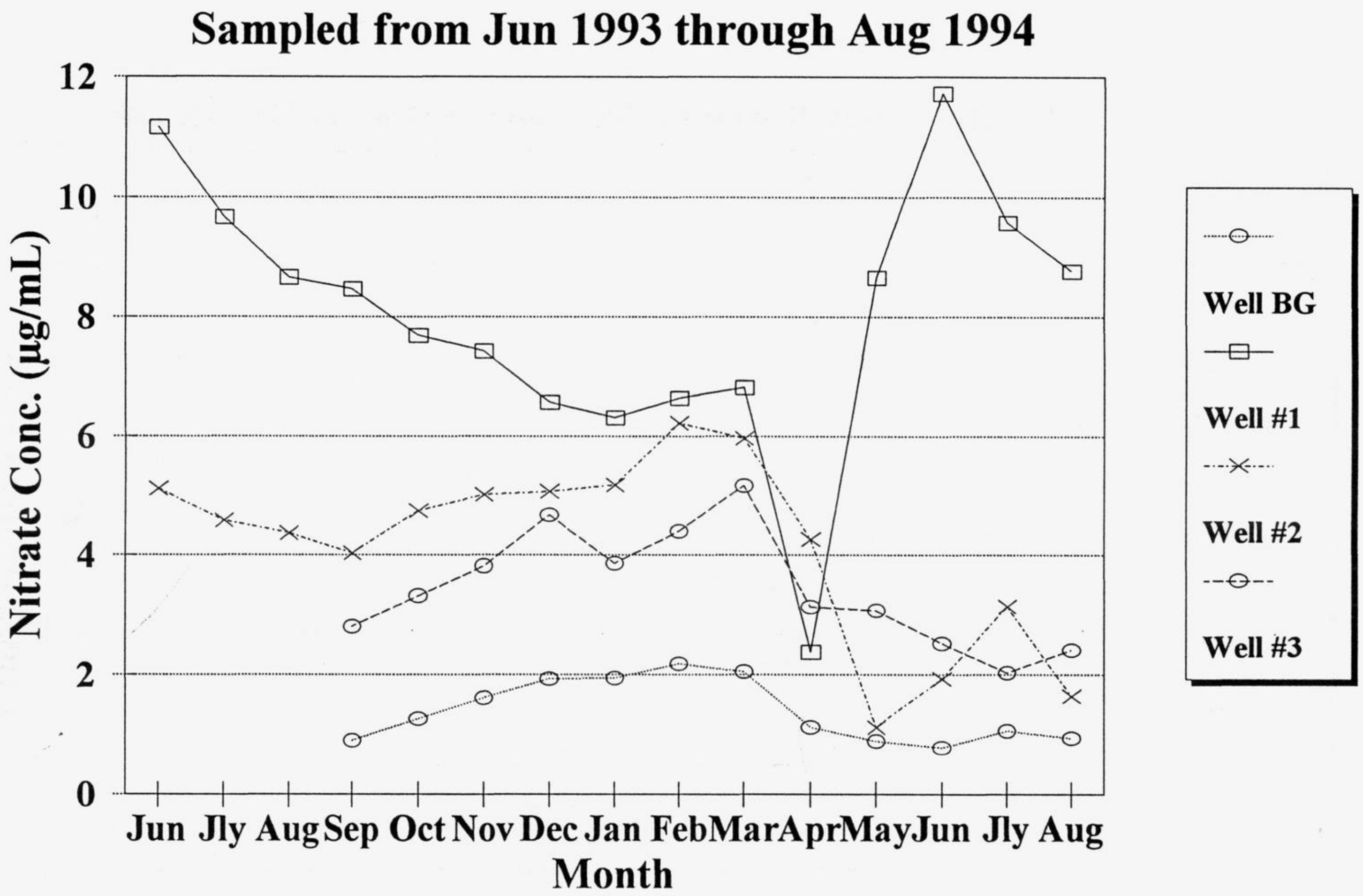


Figure 3.14. Monthly nitrate nitrogen levels in groundwater from four monitoring wells at Site 3 (dosing system).

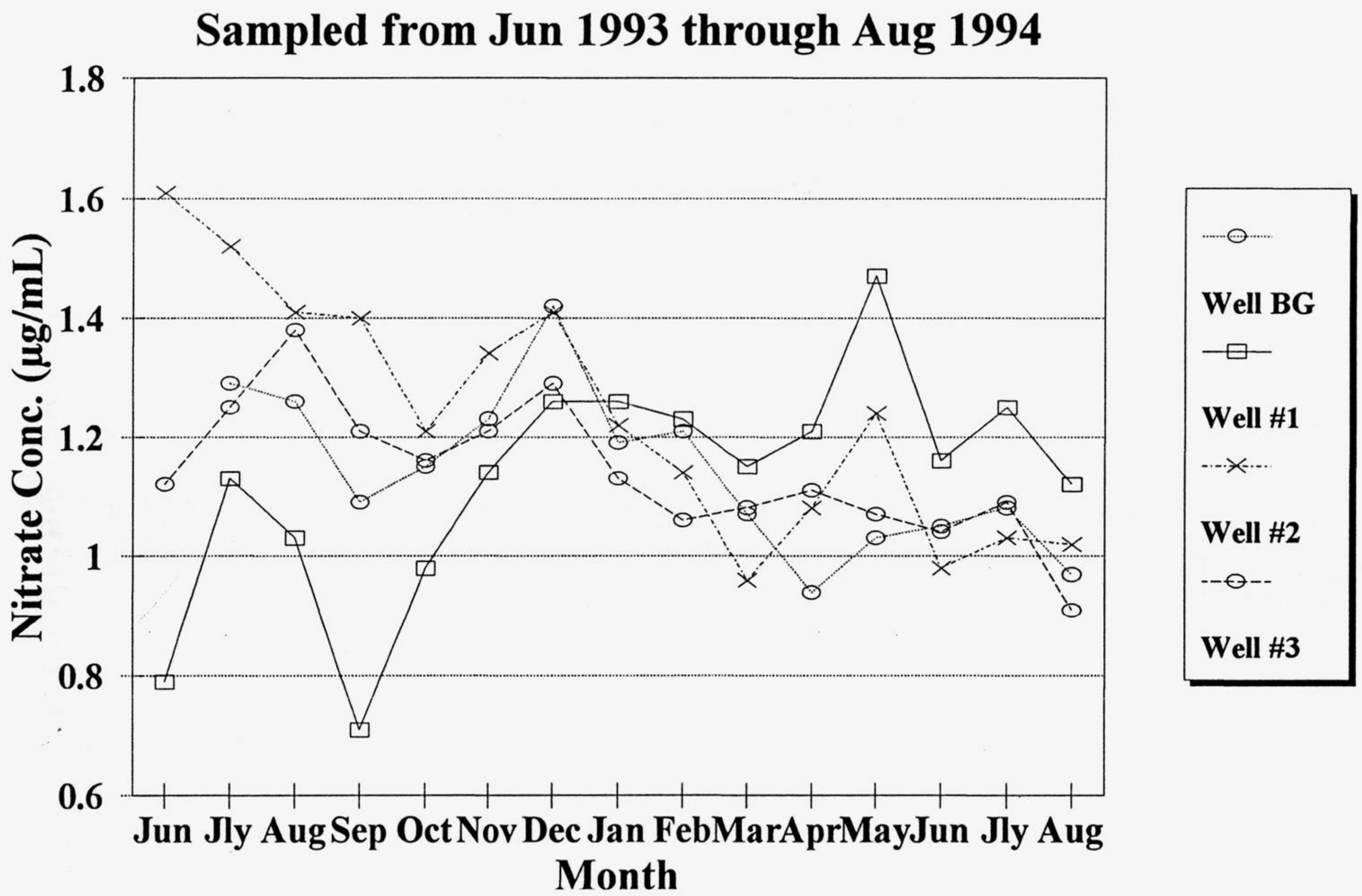


Figure 3.15. Monthly nitrate nitrogen levels in groundwater from four monitoring wells at Site 6 (conventional system).

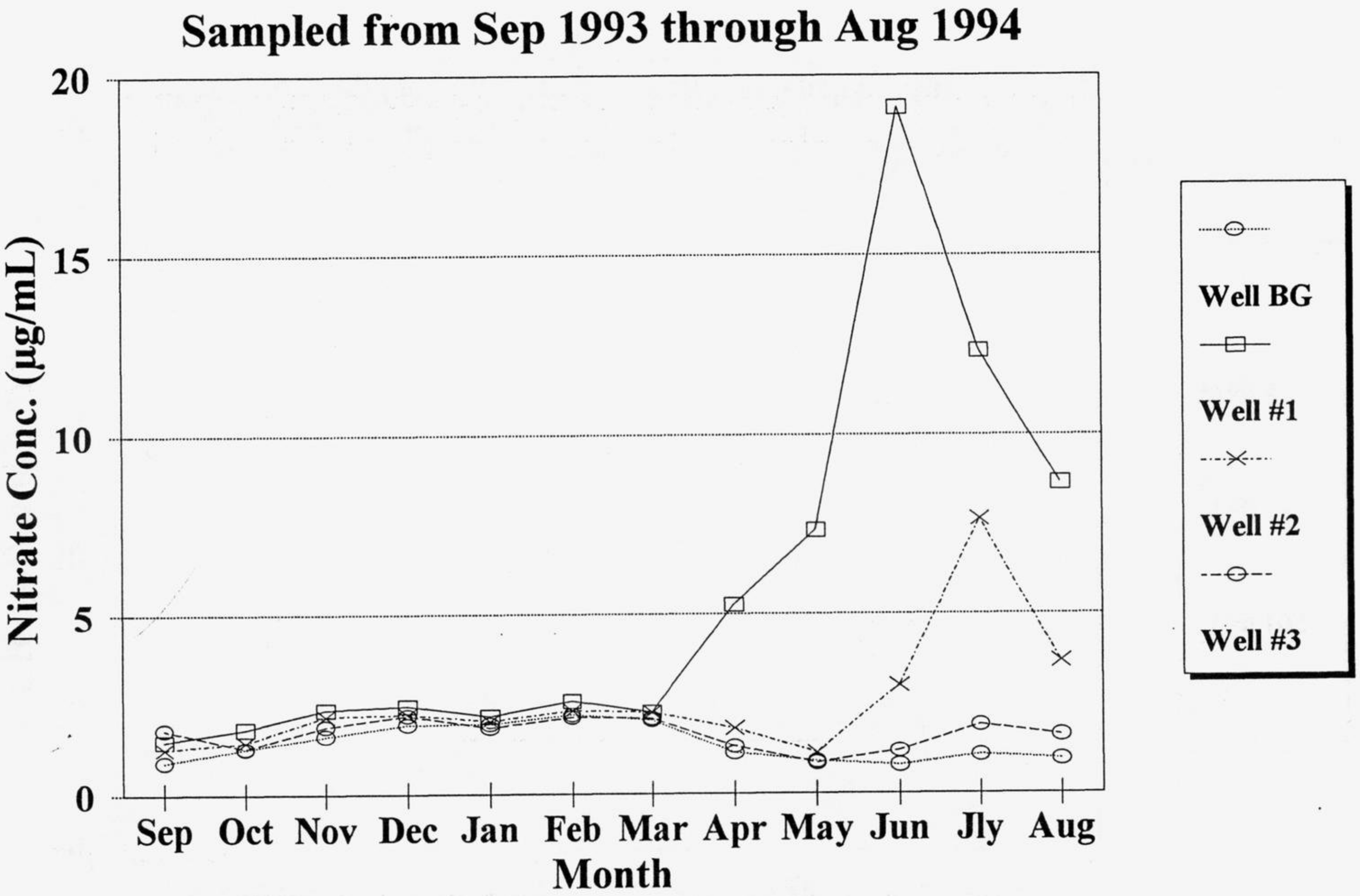


Figure 3.16. Monthly nitrate nitrogen levels in groundwater from four monitoring wells at Site 8 (conventional system).

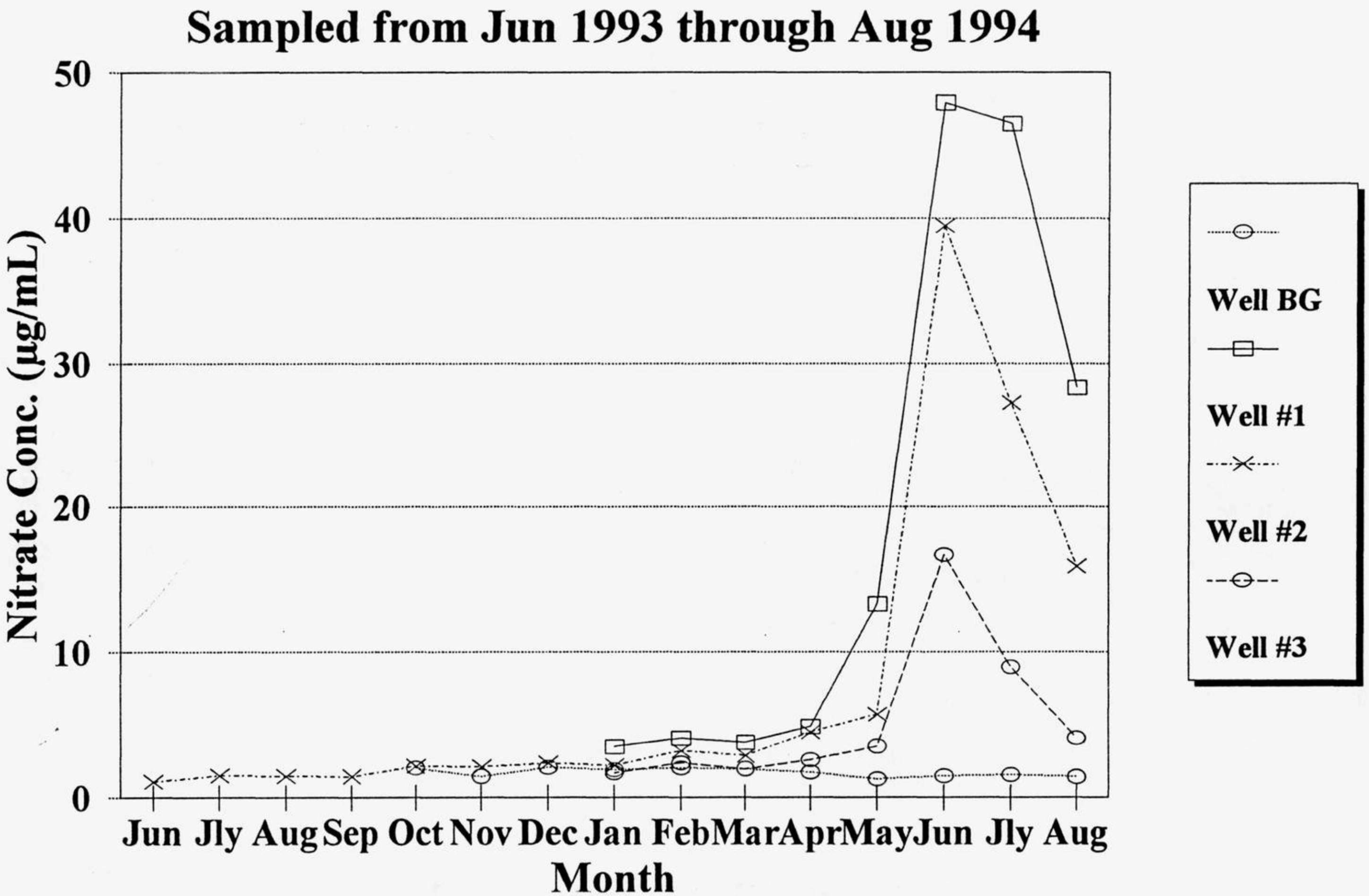


Figure 3.17. Monthly nitrate nitrogen levels in groundwater from four monitoring wells at Site 9 (dosing system).

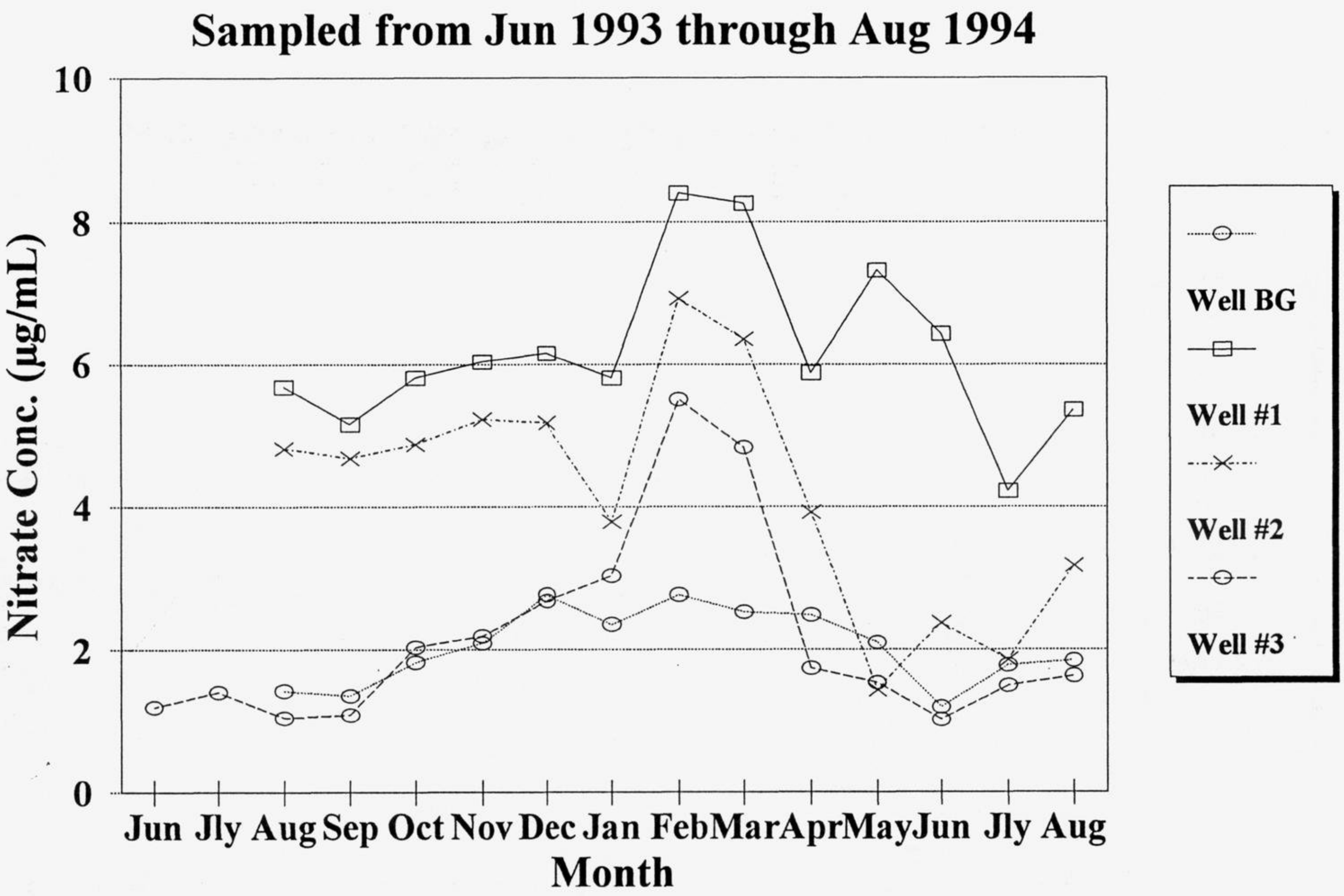


Figure 3.18. Monthly nitrate nitrogen levels in groundwater from four monitoring wells at Site 10 (mound system).

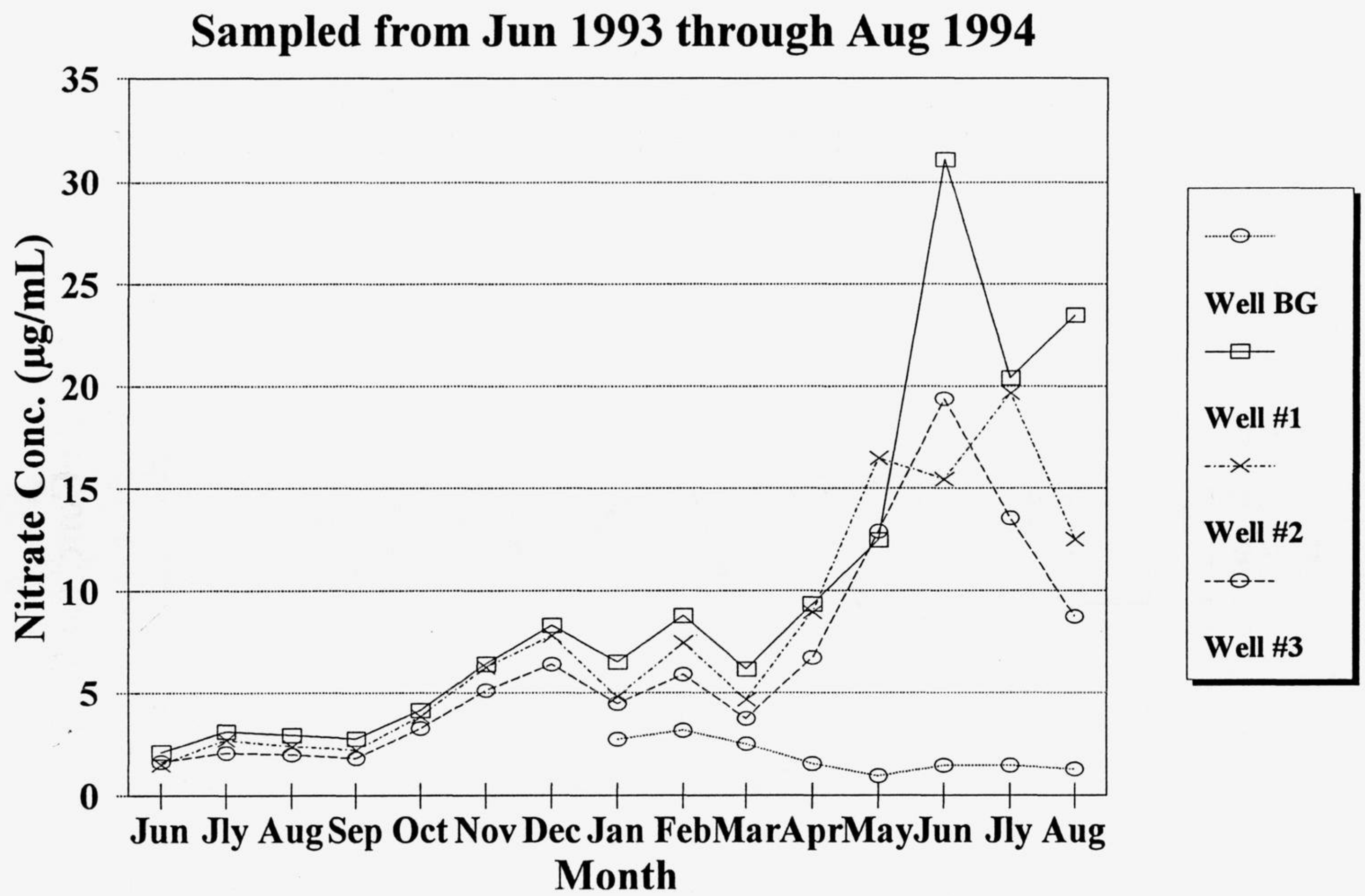


Figure 3.19. Monthly nitrate nitrogen levels in groundwater from four monitoring wells at Site 12 (dosing system).

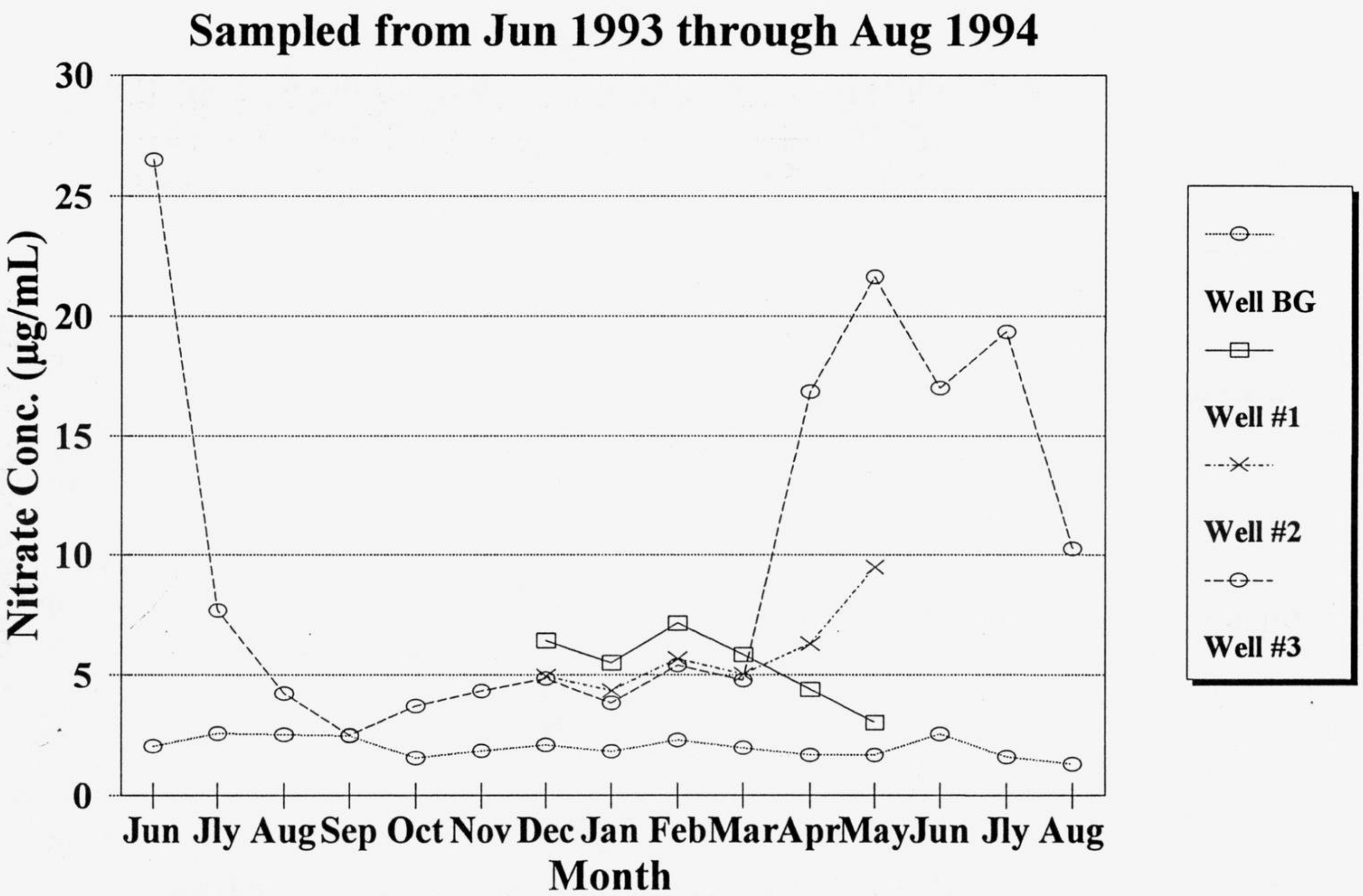


Figure 3.20. Monthly nitrate nitrogen levels in groundwater from four monitoring wells at Site 13 (conventional system).

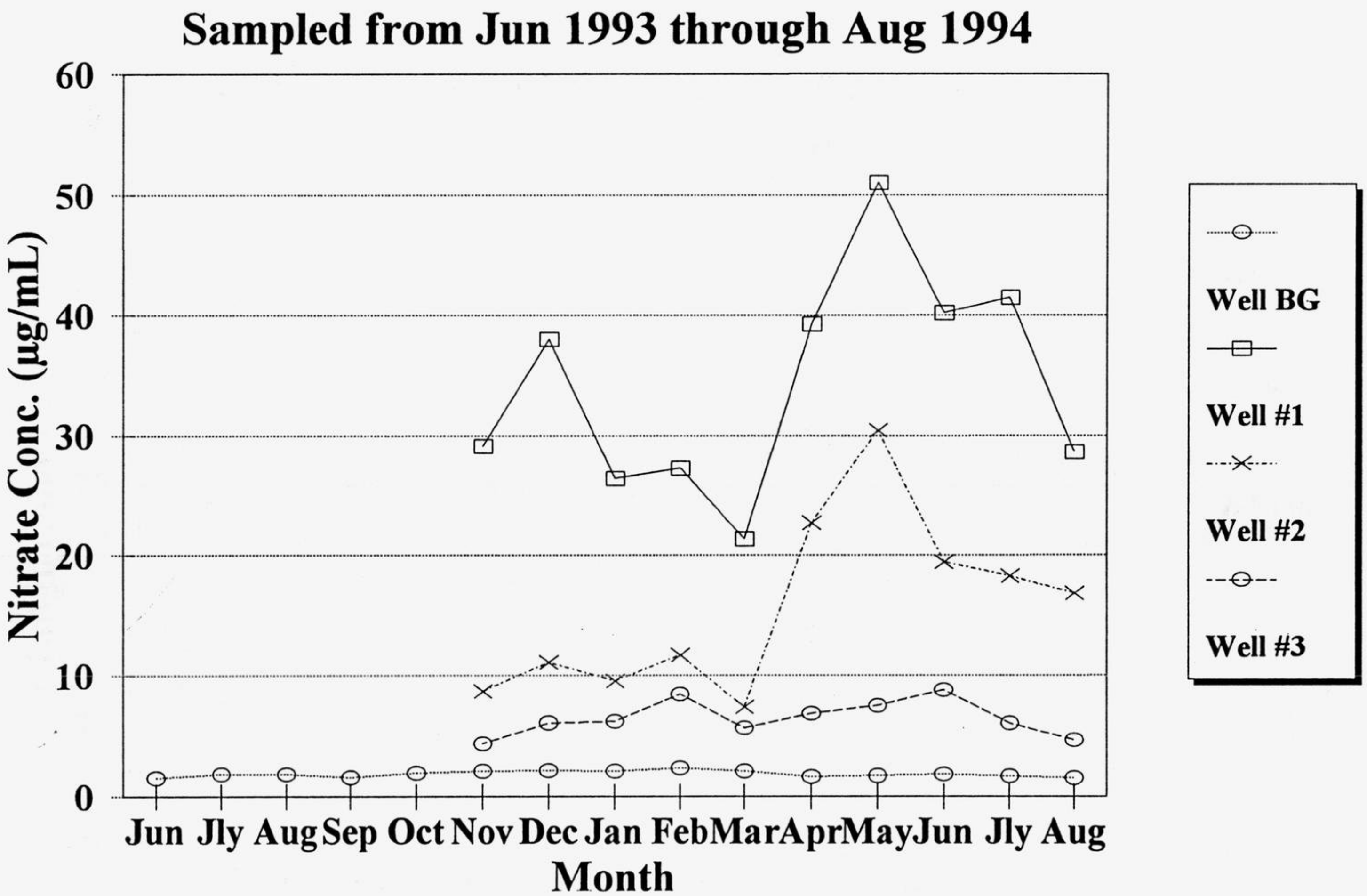


Figure 3.21. Monthly nitrate nitrogen levels in groundwater from four monitoring wells at Site 14 (mound system).

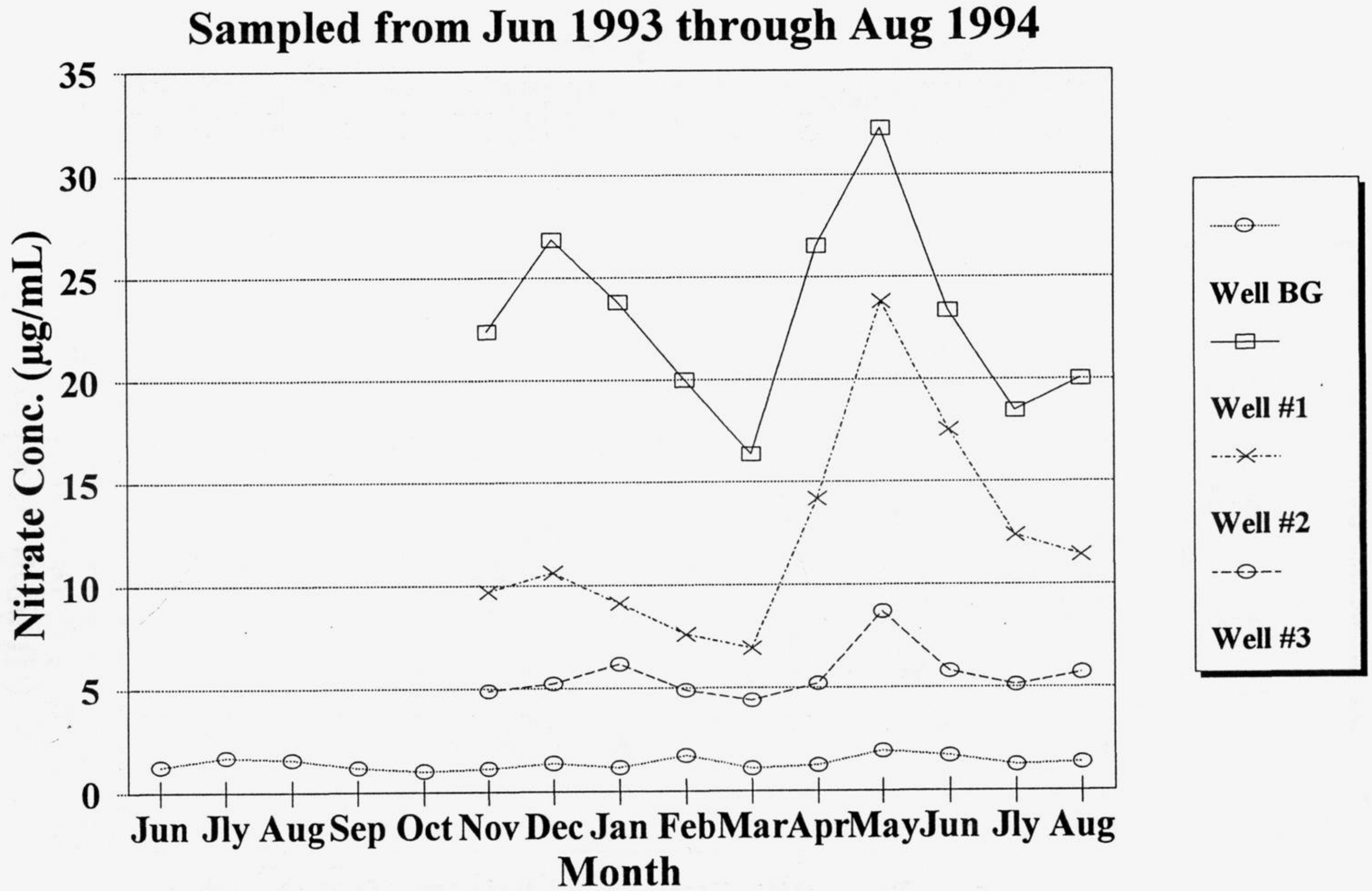


Figure 3.22. Monthly nitrate nitrogen levels in groundwater from four monitoring wells at Site 15 (mound system).

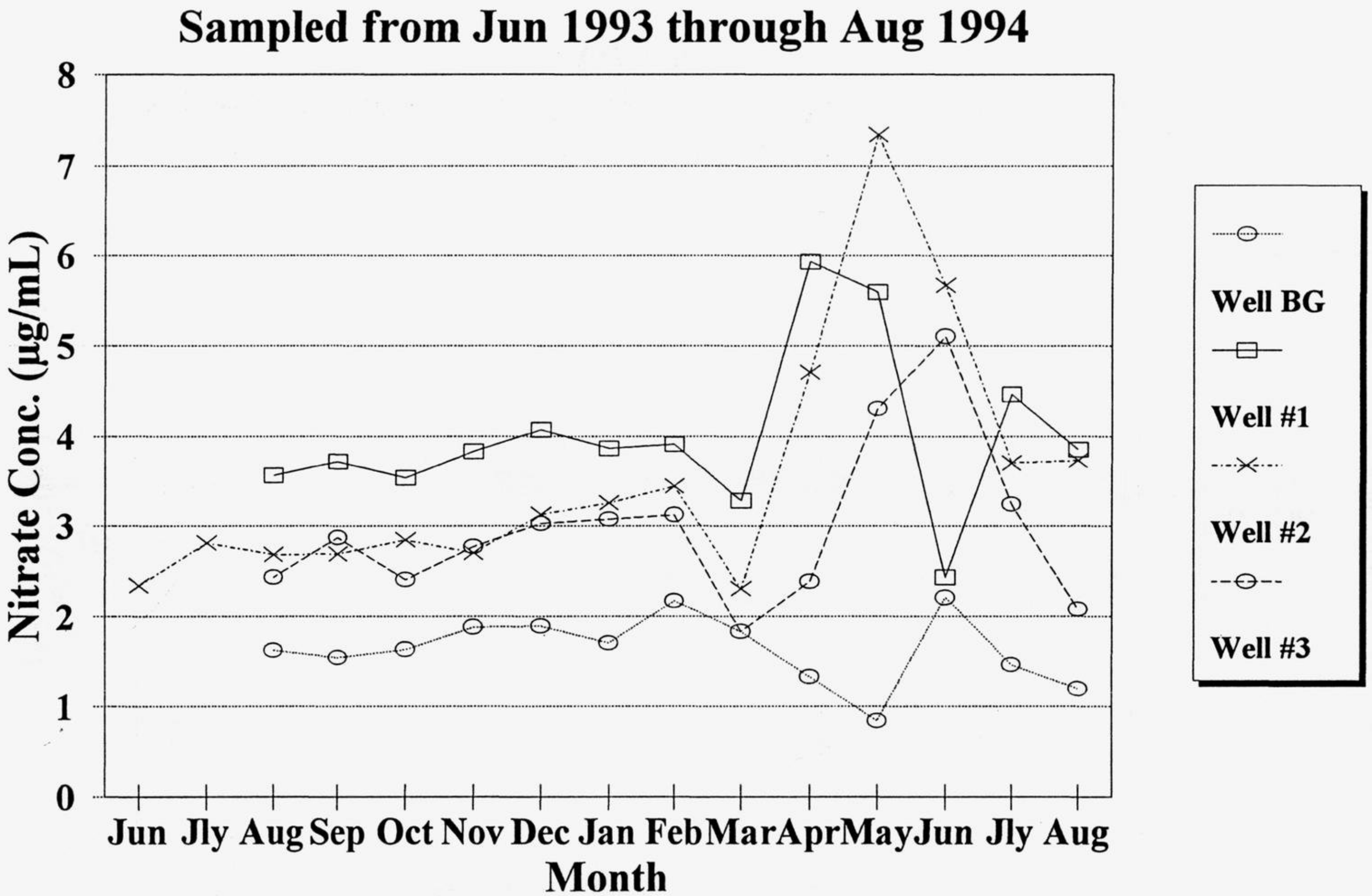


Figure 3.23. Monthly nitrate nitrogen levels in groundwater from four monitoring wells at Site 3-78 (mound system).

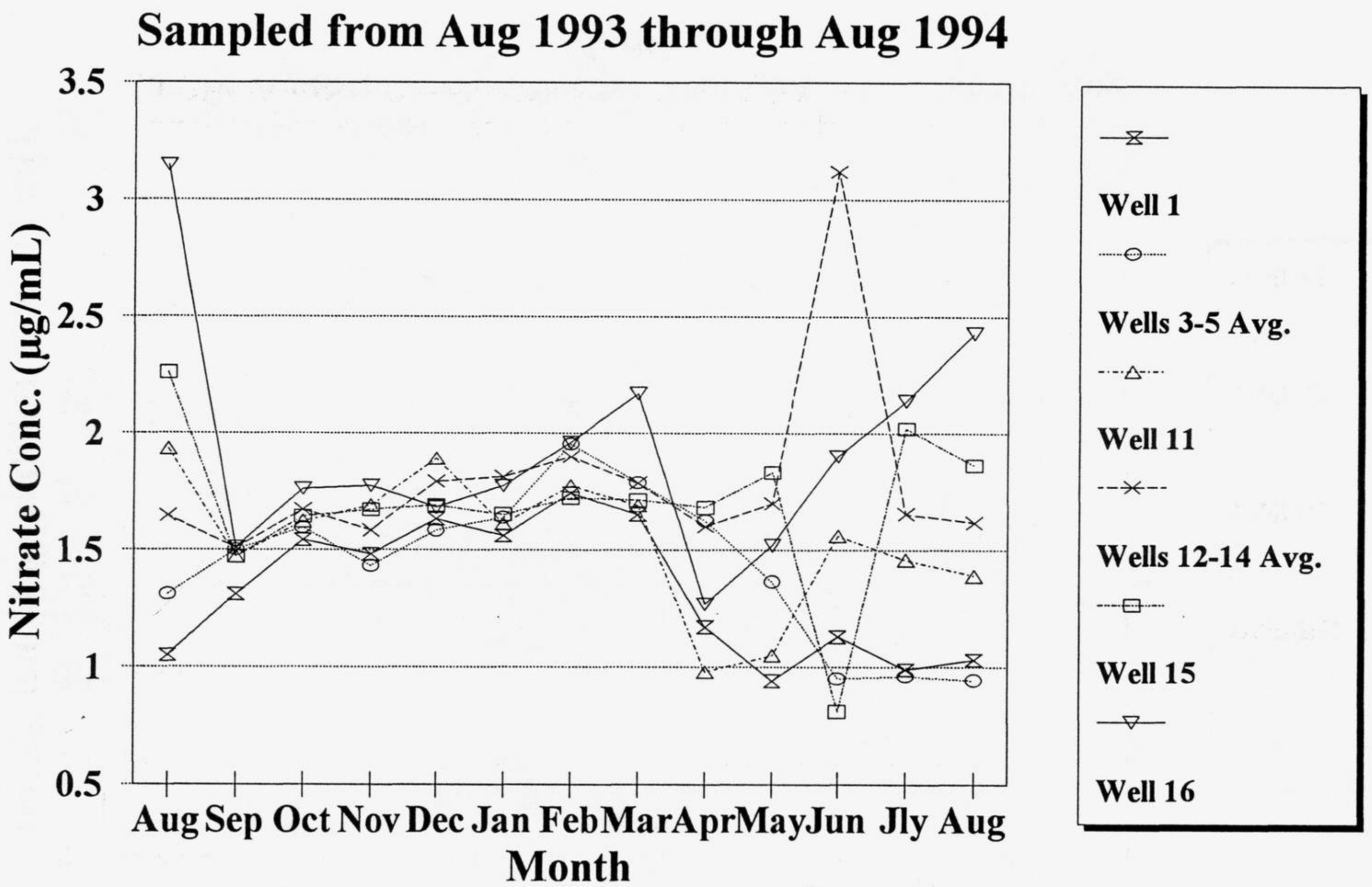


Figure 3.24. Monthly nitrate nitrogen levels in groundwater from representative monitoring wells at Wisconsin Height High School (dosing system).

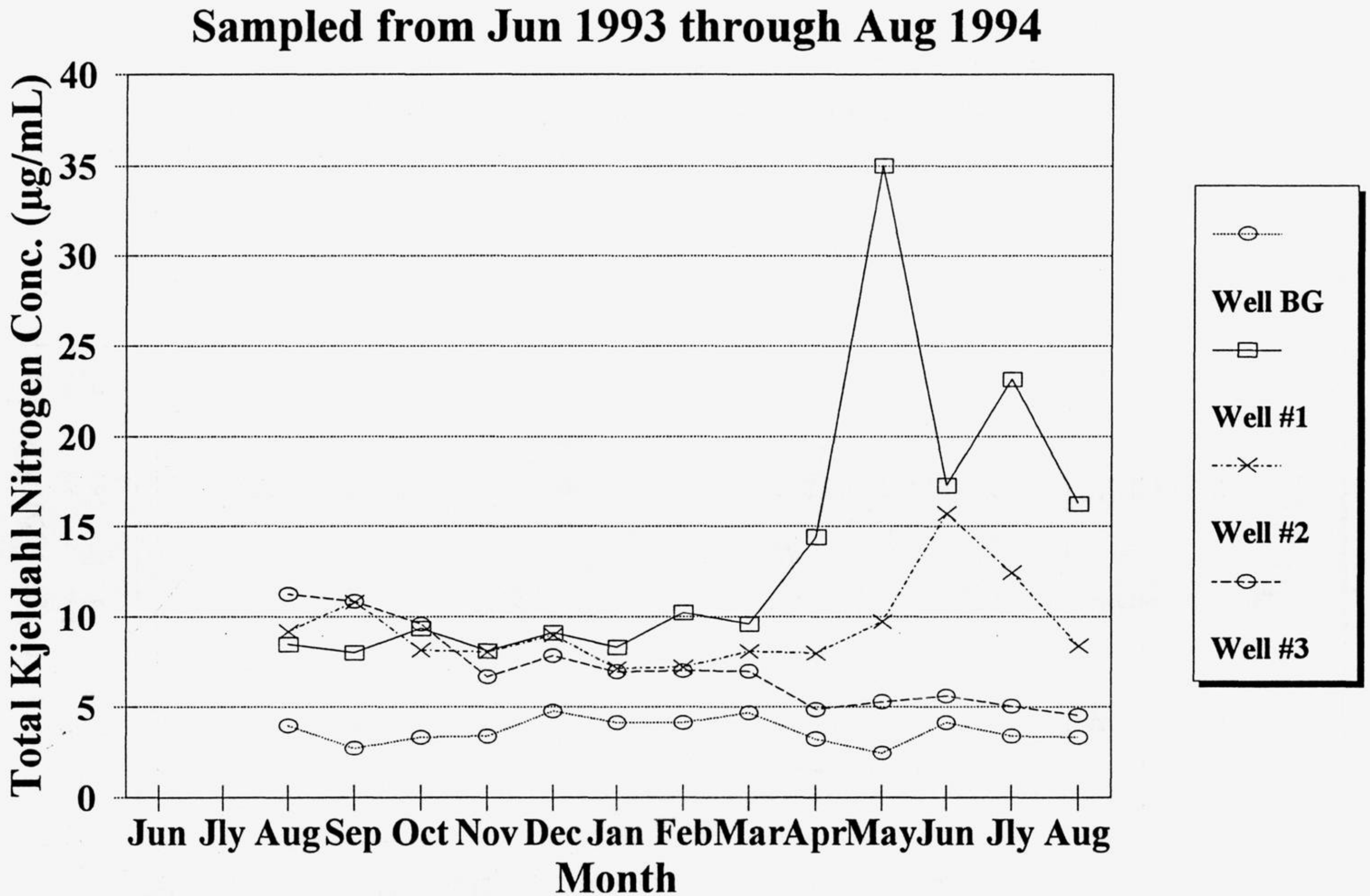


Figure 3.25. Monthly total Kjeldahl nitrogen levels in groundwater from four monitoring wells at Site 1 (mound system).

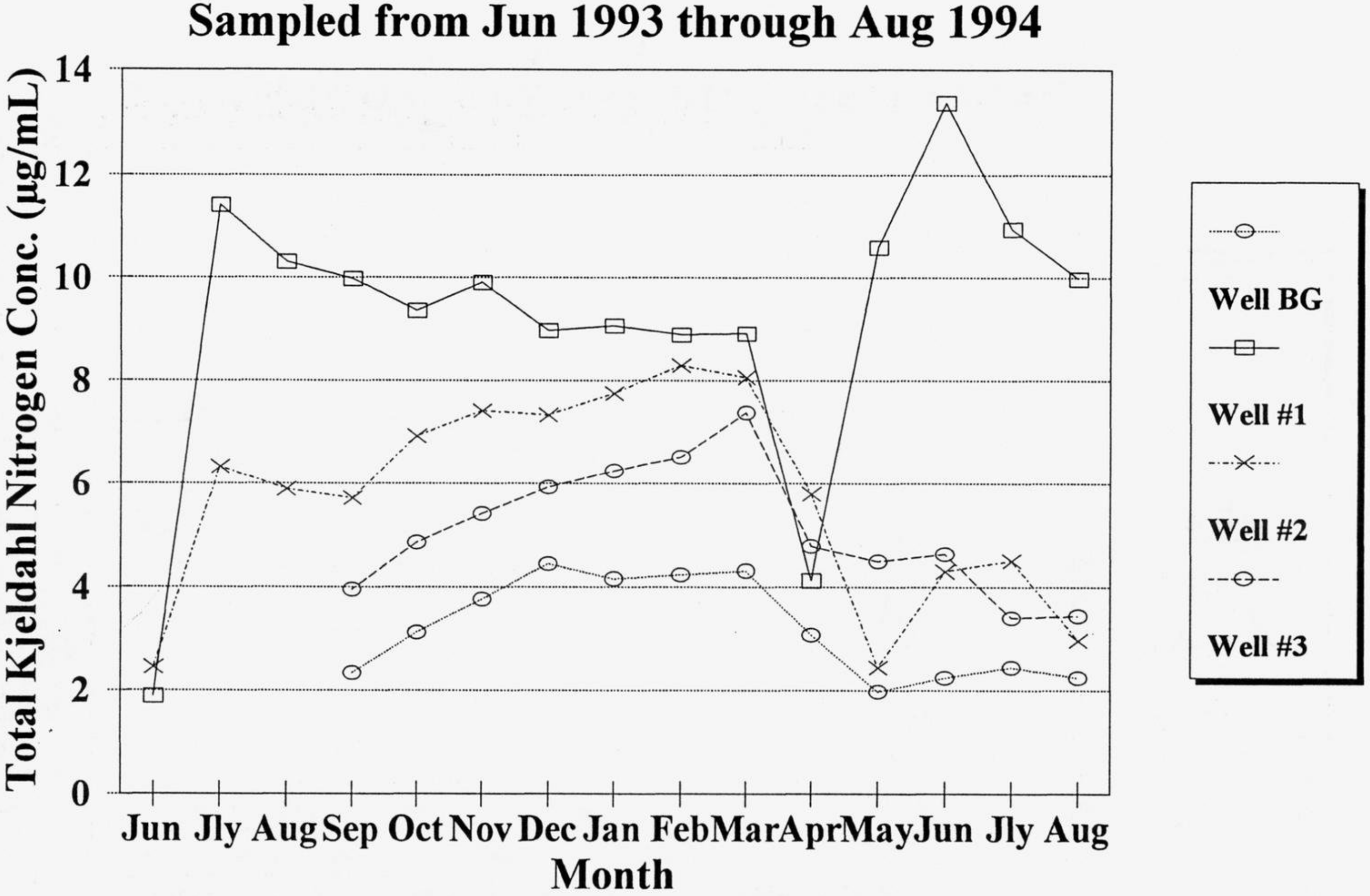


Figure 3.26. Monthly total Kjeldahl nitrogen levels in groundwater from four monitoring wells at Site 3 (dosing system).

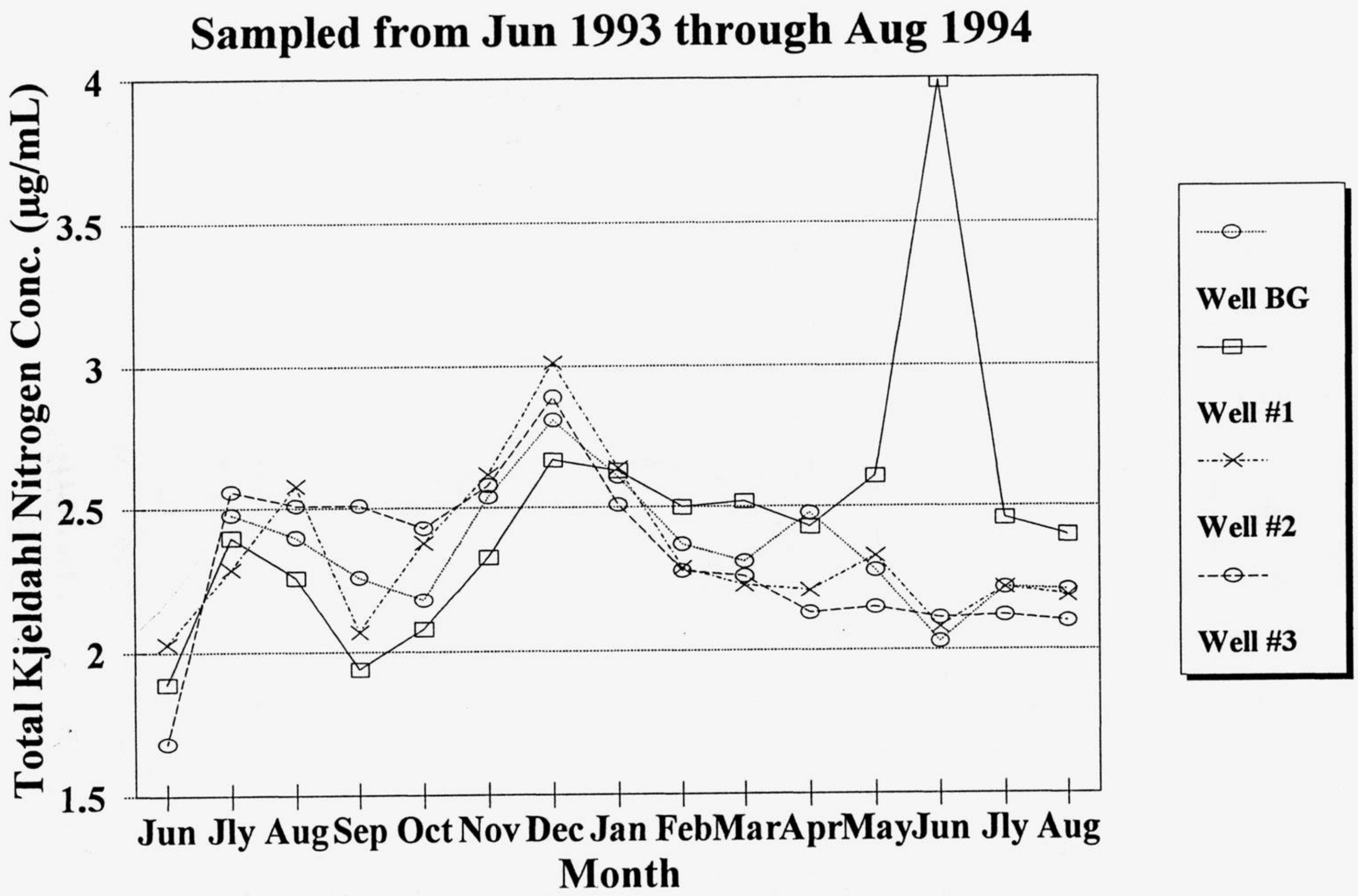


Figure 3.27. Monthly total Kjeldahl nitrogen levels in groundwater from four monitoring wells at Site 6 (conventional system).

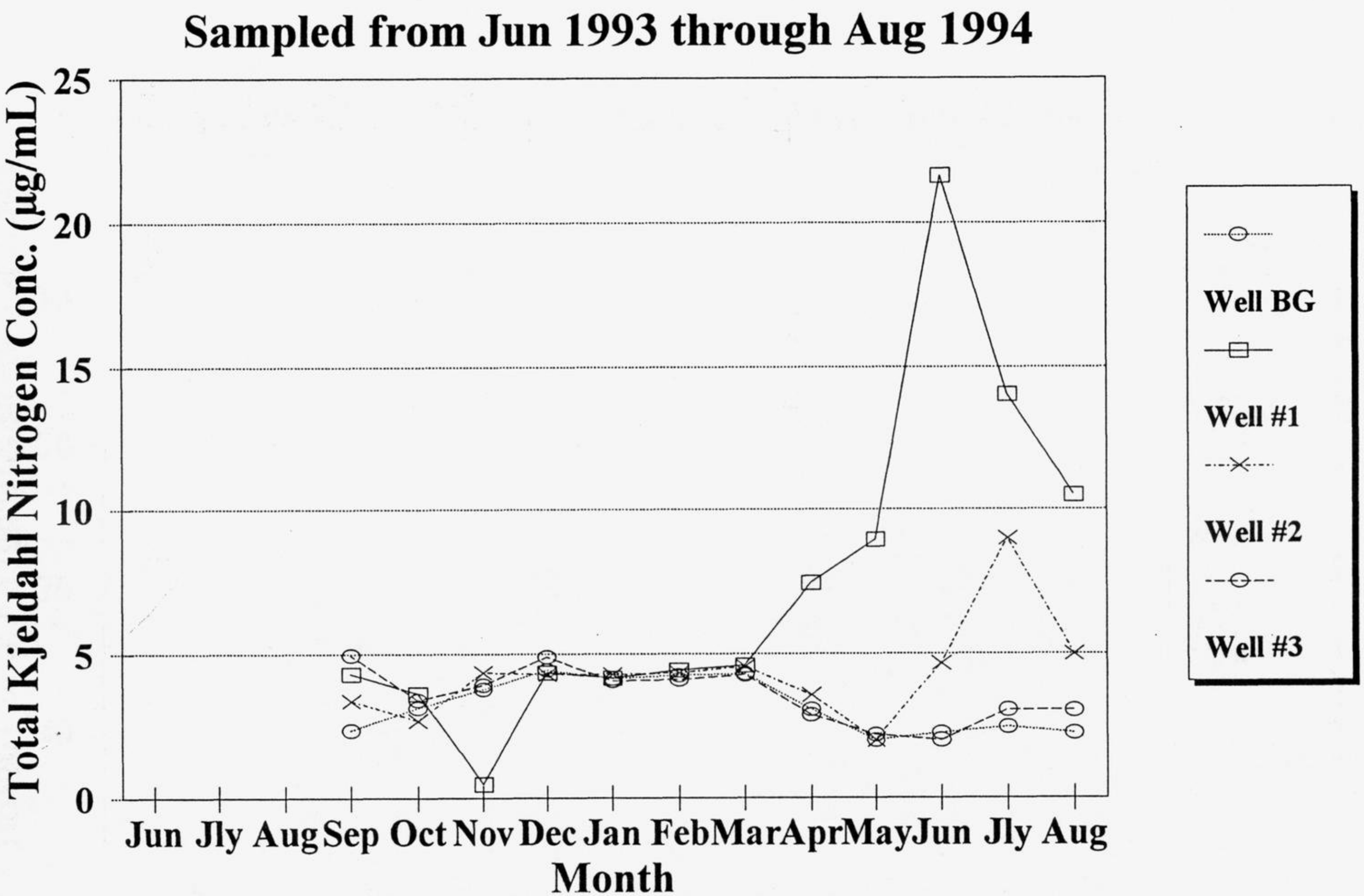


Figure 3.28. Monthly total Kjeldahl nitrogen levels in groundwater from four monitoring wells at Site 8 (conventional system).

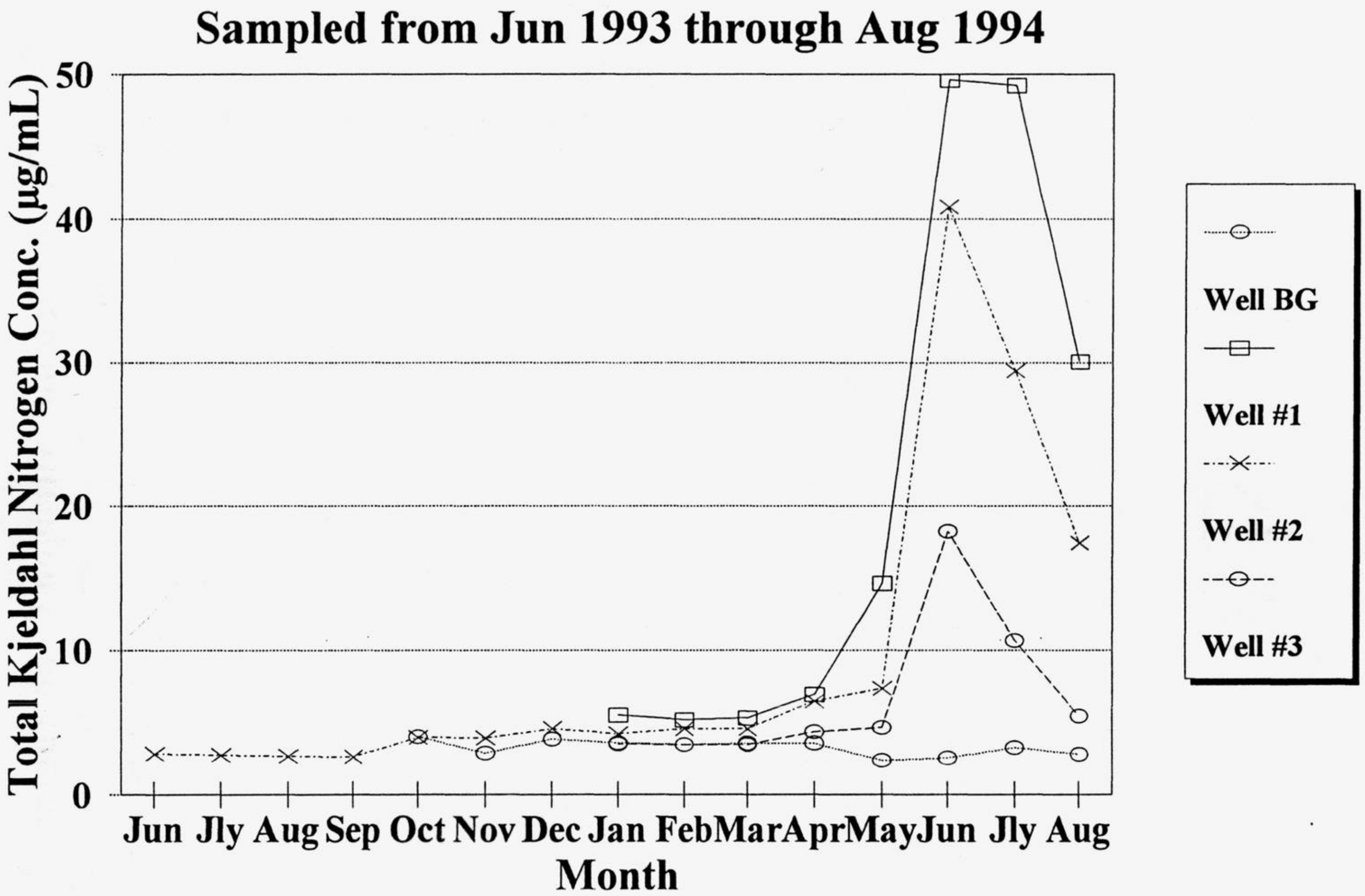


Figure 3.29. Monthly total Kjeldahl nitrogen levels in groundwater from four monitoring wells at Site 9 (dosing system).

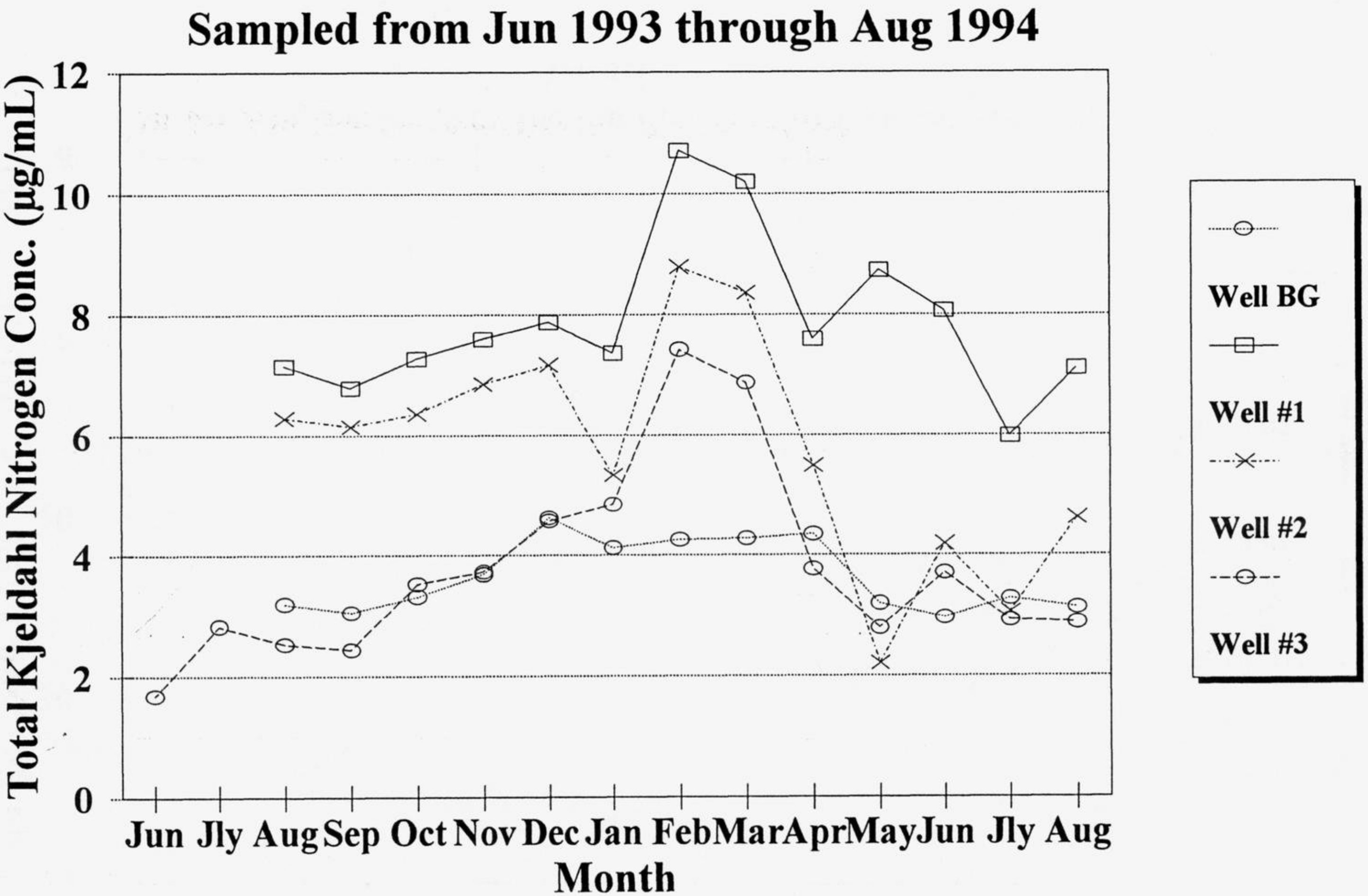


Figure 3.30. Monthly total Kjeldahl nitrogen levels in groundwater from four monitoring wells at Site 10 (mound system).

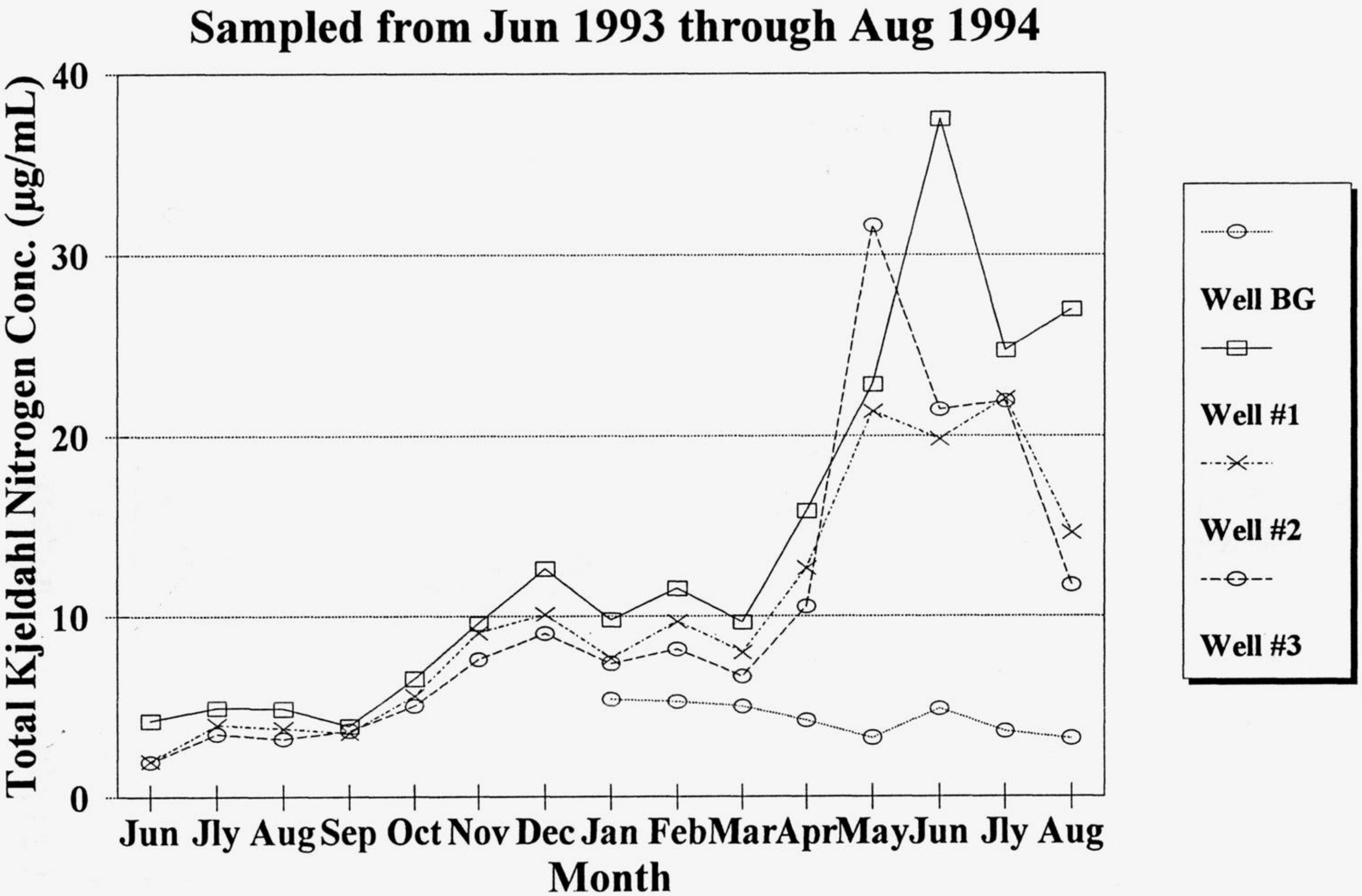


Figure 3.31. Monthly total Kjeldahl nitrogen levels in groundwater from four monitoring wells at Site 12 (dosing system).

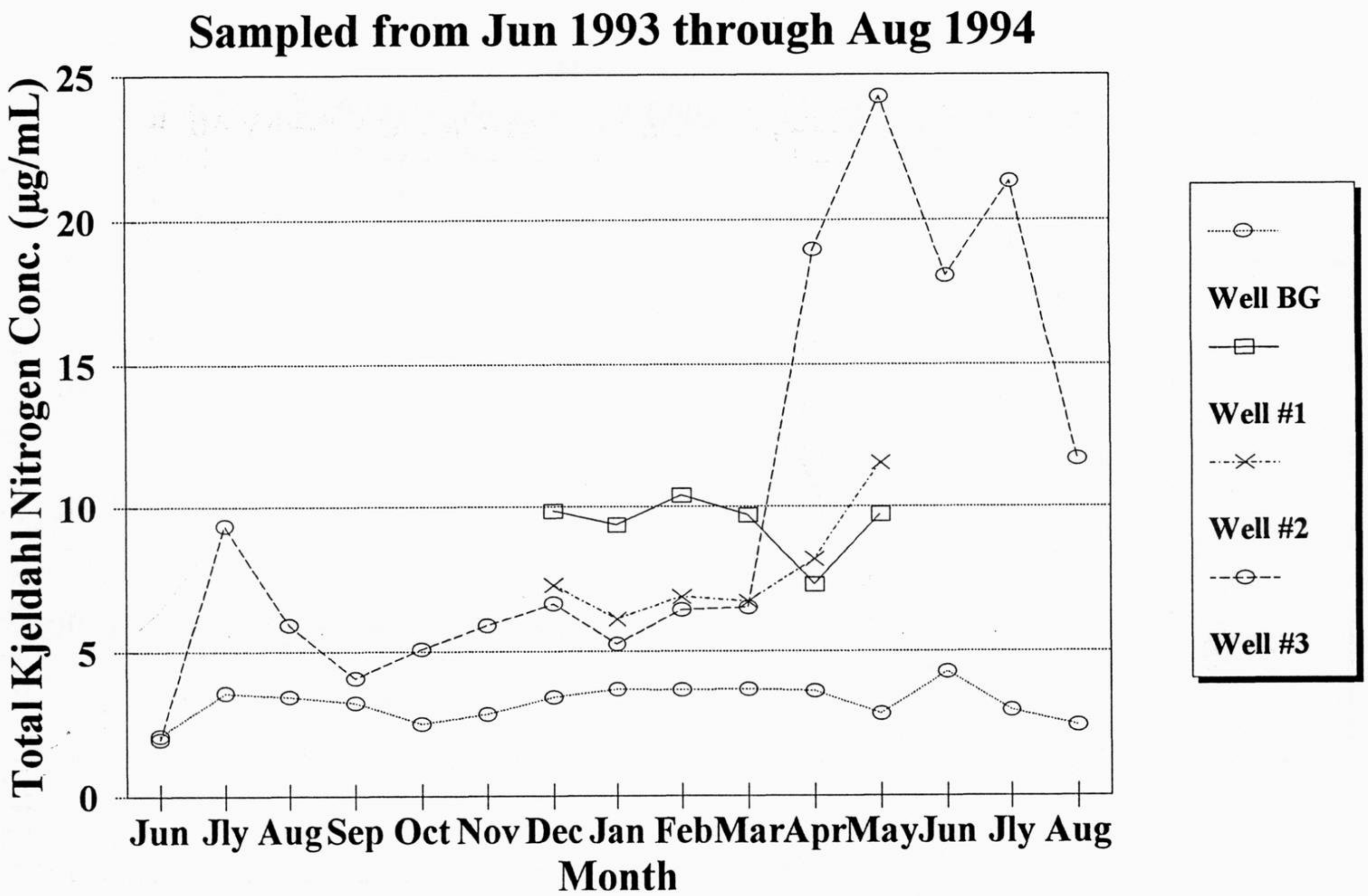


Figure 3.32. Monthly total Kjeldahl nitrogen levels in groundwater from four monitoring wells at Site 13 (conventional system).

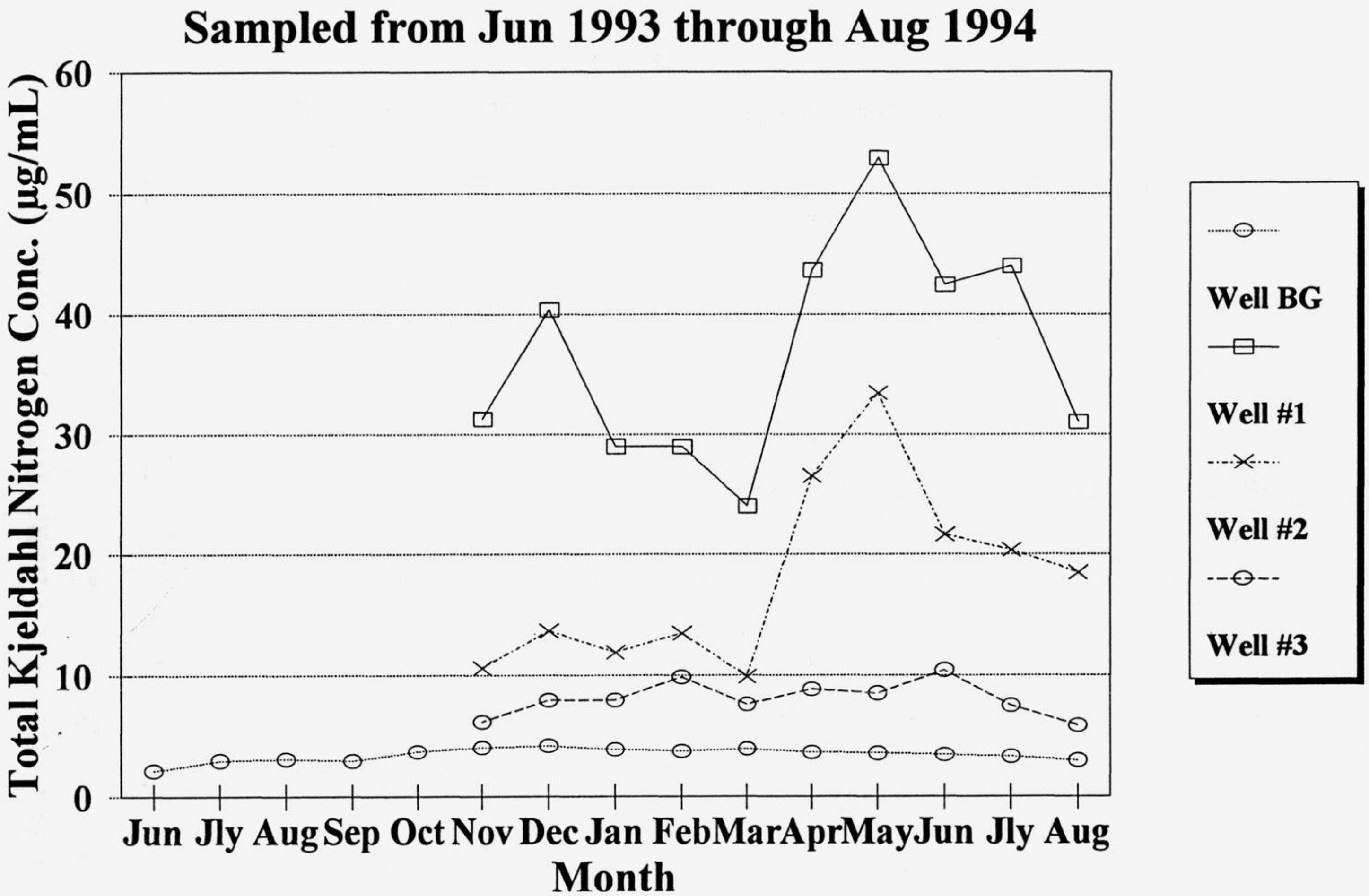


Figure 3.33. Monthly total Kjeldahl nitrogen levels in groundwater from four monitoring wells at Site 14 (mound system).

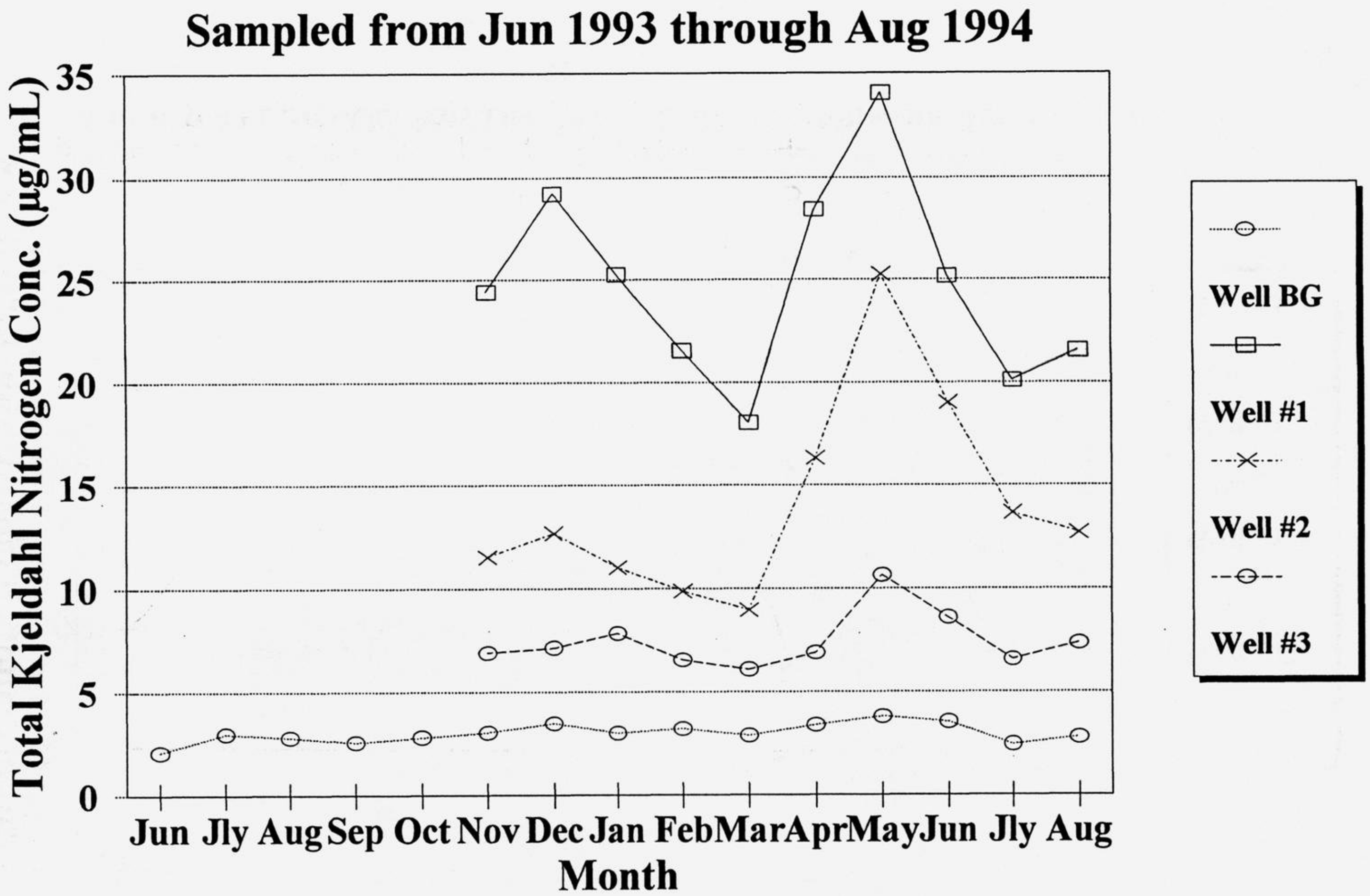


Figure 3.34. Monthly total Kjeldahl nitrogen levels in groundwater from four monitoring wells at Site 15 (mound system).

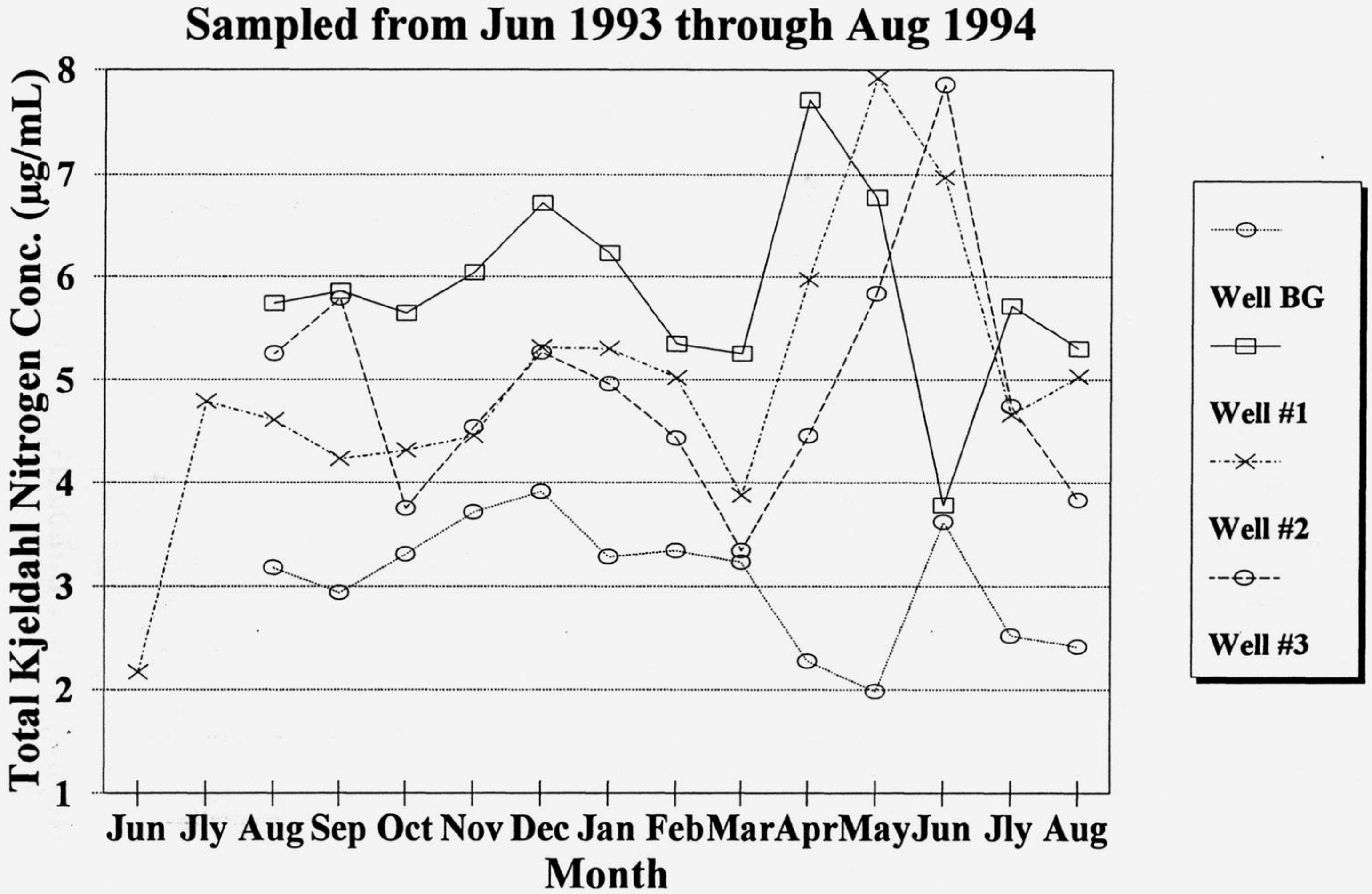


Figure 3.35. Monthly total Kjeldahl nitrogen levels in groundwater from four monitoring wells at Site 3-78 (mound system).

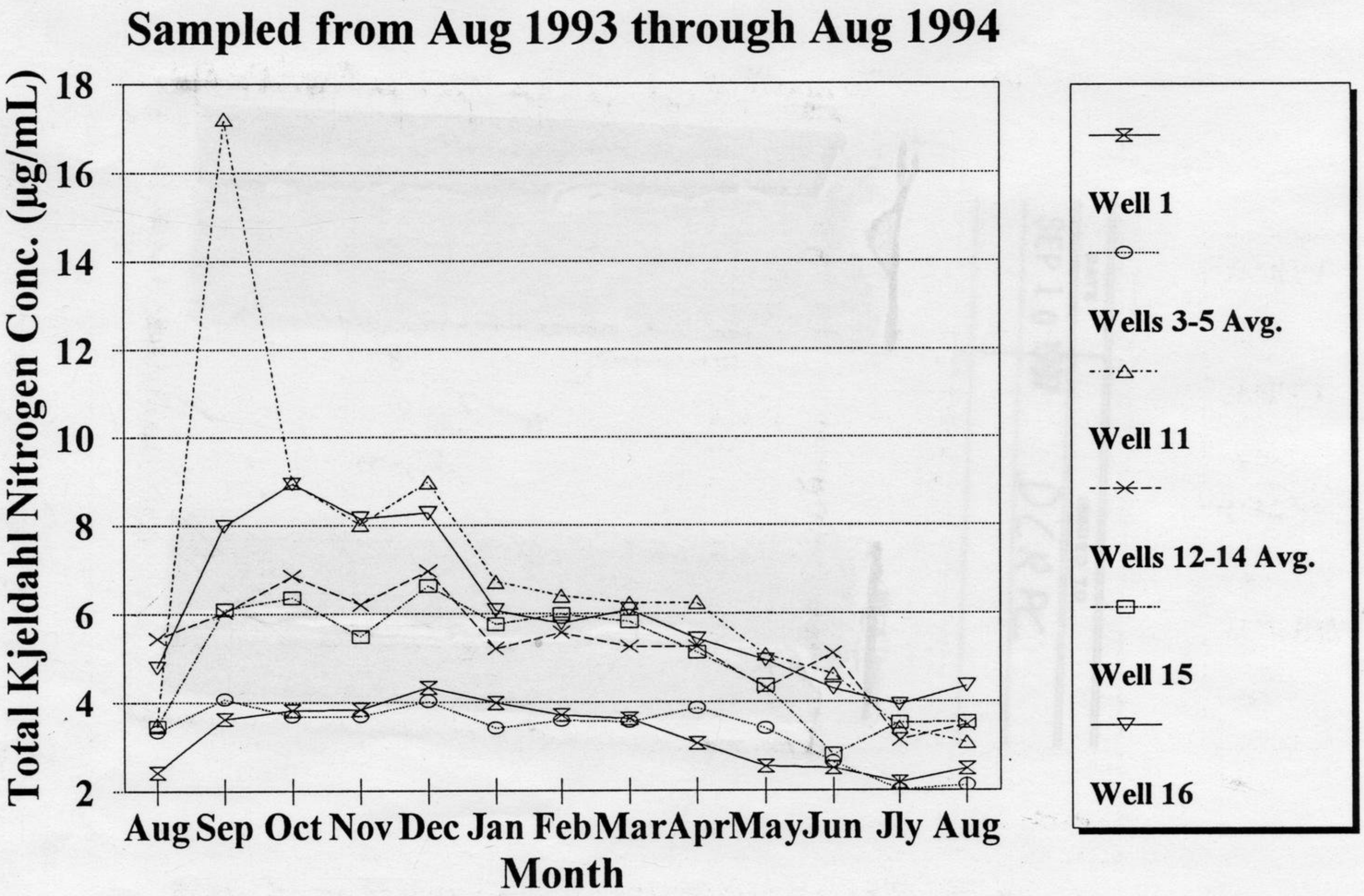


Figure 3.36. Monthly total Kjeldahl nitrogen levels in groundwater from representative monitoring wells at Wisconsin Height High School (dosing system).

Long-term Transformation
and Fate of Nitrogen in
Mound-Type Soil
Absorption Systems for
Septic Tank Effluent

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