Effects of barnyard management practices on groundwater quality in the central sands of Wisconsin. [DNR-009] 1992

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Madison, Wisconsin: Wisconsin Department of Natural Resources, 1992

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File #9

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May 1992

Project Final Report to Wisconsin DNR
Groundwater Management Section

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Introduction

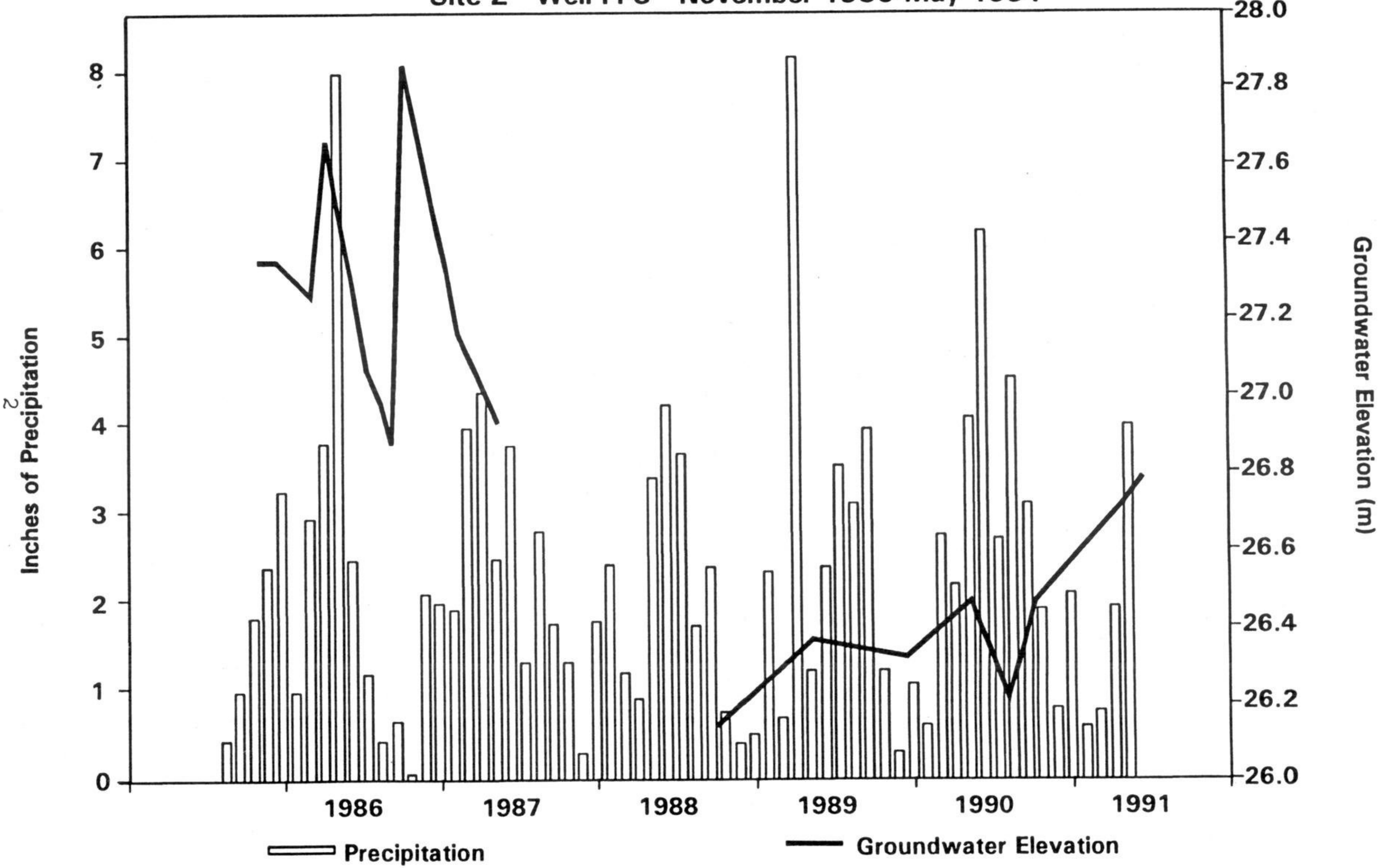
The following report is a summary of all data collected from 1985 through 1991 on a study of barnyard impacts on groundwater quality and the effects of installing state of the art manure handling systems in an attempt to improve water quality. This project was undertaken as a cooperative project between the University of Wisconsin-Stevens Point, Wisconsin Department of Natural Resources, Portage County Land Conservation Department, Wisconsin Department of Agriculture, Trade and Consumer Protection, United States Soil Conservation Service and the cooperating farmers.

Detailed results of the first two years of the project are available from the Master of Science thesis of Brian Bowen and Michael Travis. Complete chemical analysis is presented in the appendix. Four of the original five study sites are discussed in this report. The fifth site was found to be nonrepresentative of soil conditions to be evaluated by this project, and was not continued after the first two years.

Weather conditions throughout the project were extremely variable, and included two very dry years, 1988 and 1989. This is shown in figure 1, along with water table elevation data, which was effected by the varying rainfall amounts.

Figure 2 shows the location of the study sites in Portage County, located in the central part of Wisconsin.

Figure 1. Precipitation vs Groundwater Elevation
Site 2 Well FP3 November 1985-May 1991



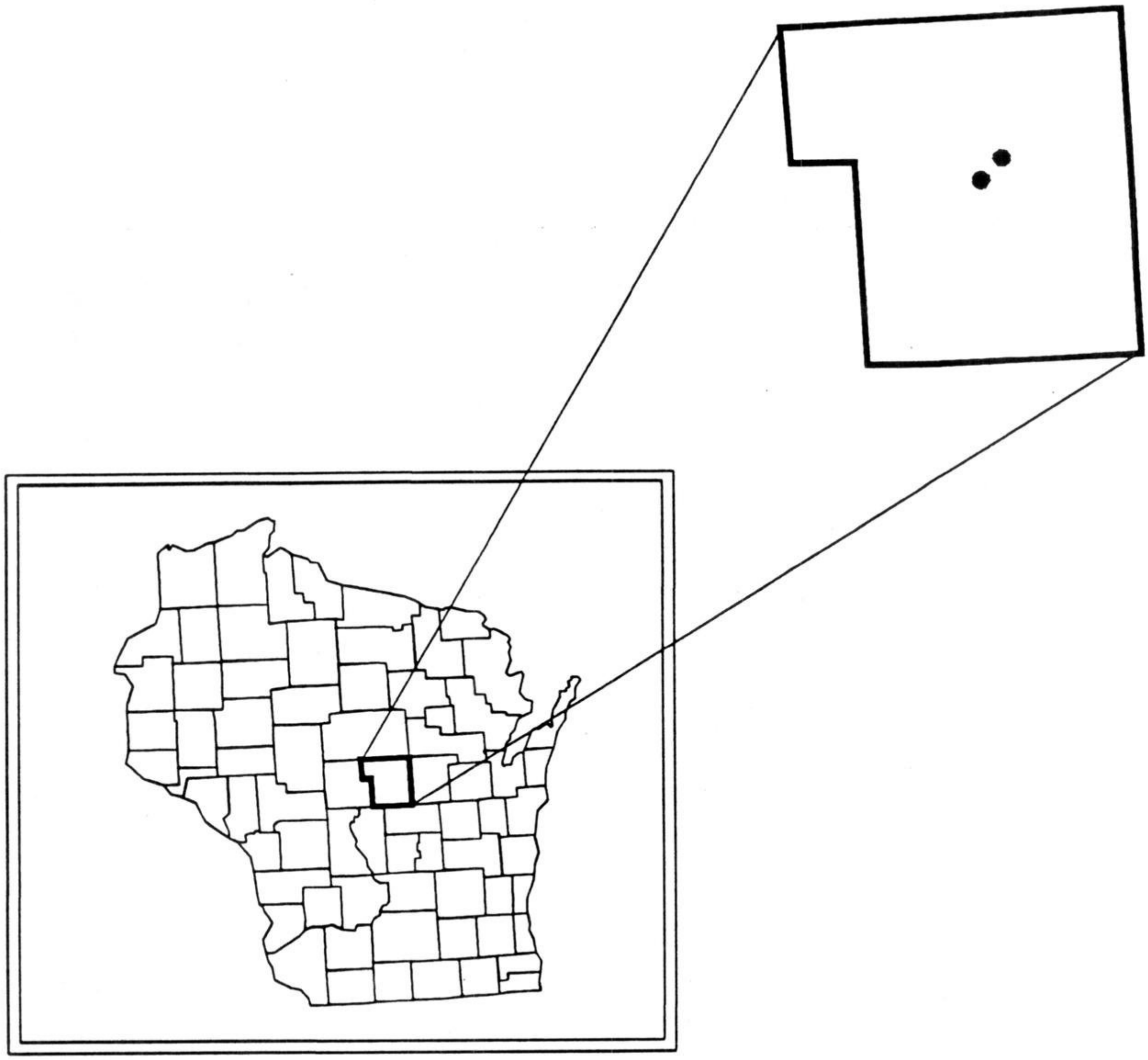


Figure 2. Location of the Barnyard Management study sites in the central sands of Portage County, Wisconsin.

LITERATURE REVIEW

Feedlot Potential for Groundwater Contamination

Feedlots present varying degrees of groundwater contamination potential as revealed by several studies in Canada and the United States over the past two decades. Stewart, et. al. (1967) reported findings of a Colorado feedlot study, investigating soil profiles and subsequent groundwater quality under the yards. They found a wide range of nitrate quantities in the soil profiles of the yards investigated, from negligible traces to as much as 4500 kg NO_3^-/hectare, enough to contaminate the aquifer under 20 hectares of the study area. They related the quantities found to the redox potential of the profile which in turn was found dependent on management, age and water content of the soil profile of each specific yard. Yet despite this high concentration of contaminant in the profile, little evidence of significant groundwater impact was found.

Gillham and Webber (1969) investigated the contamination potential presented by manure storage in a barnyard located in Ontario, Canada. Through construction of a flow net and approximately weekly analyses over a five month period, total nitrogen contribution to the watertable was determined to be 2.0 kg, mostly in the nitrate form. this represented a mere fraction of the potential in the stored manure. They attributed this low contamination to a lack of nitrate-producing nitrification, except at the perimeter of the manure pile, and adsorption of ammonium (NH_4^+) by the loam soil's cation exchange sites.

A twenty year old feedlot situated on silt loam to sandy loam soil above the sand

and gravel aquifer of the Platte River Valley was the subject of a study by Mielke et. al. (1970). Soil profile nitrogen content and groundwater quality were the focus of their investigation. Soil cores from the lot yielded low nitrate levels below the first foot, and ammonium only in moderate amounts below three feet. They attributed these observations to a high potential for denitrification in the profile, based on redox readings. Groundwater analyses indicated little evidence of water pollution from the yard (the aquifer ranged from 0.6 to 2.3 meters below the surface throughout the study period). They suggested that the manure pack created an effective barrier to infiltration. Runoff was considered a negligible factor; observation of free surface water for several weeks indicated evaporation as a key water removal agent.

Schuman and McCalla (1975), studying the chemical characteristics of the soil profile of the same lot as Mielke, substantiated his claims of a barrier to contaminant leaching. They found a dispersed, highly organic, virtually impermeable layer at the surface. They attributed this to the destruction of soil structure caused by high potassium levels and clogging of soil pores by organic molecules along with the contribution of physical compaction. While conceding that movement of potential groundwater contaminants may occur in early stages of feedlot development, they concluded that the formation of and subsequent maintenance of this layer provided an effective barrier to groundwater contamination.

Examining the potential for groundwater pollution by manure storage areas in a glacial till soil, Sowden and Hore (1976) concluded that there was indeed very little potential for a large amount of groundwater contamination under the facilities studied.

They observed favorable conditions for denitrification and cited the fine textured soils along with natural soil processes as a sufficient barrier to groundwater pollution in many cases. Overflow from the storage areas appeared to be the source of most of the nitrogen contamination observed.

Overcash et. al (1983) reviewed the information obtained from many studies which pertain to livestock waste management. According to this research data, an impermeable seal occurs under unsurfaced barnyards which restricts the movement of feedlot contaminants to the groundwater below. They believe this compaction occurs with a combination of "manure, moisture and animal traffic" and can be observed by drilling a hole into a feedlot surface. Many options for handling the waste are presented, but their focus is on contamination from the barnyards in the form of runoff, as opposed to feedlot contamination from direct infiltration into the groundwater. Management options presented include the use of alleys around the feedlot in combination with liquid holding ponds.

Crosby and others (1971) also investigating the pollution potentials of barnyards, analyzed soil borings in glacial outwash of the Spokane Valley in Washington. They attributed the presence of chloride and nitrate in the deeper profile to migration during the establishment of the profile and concluded that subsequent organic matte buildup on the surface made infiltration an insignificant factor.

Sweeten (1984) also recognizes the formation of the manure/compaction seal. He believes the seal occurs from hoof compaction in addition to the formation of polysaccharides (which result from the decomposition of organic matter). Once the feedlot is abandoned, this seal becomes ineffective in deterring the infiltration of contaminants to groundwater.

The capability of soil and manure to create an impermeable soil in a compacted barnyard varies with the characteristics of both the soil and the animal waste, as Krider (1987) notes. Although much of the existing research indicates that a good seal which resists the infiltration of contaminants is formed below a feedlot area, there is some research that indicates this seal is not formed, which must also be considered. Continued research is needed to determine if these seals are dependent upon soil and manure characteristics and what these characteristics are.

The fate of the nitrogen accumulation in feedlots after they are abandoned was investigated by Mielke and Ellis (1976) in Nebraska. This study compared soil cores from several abandoned and seasonally used feedlots with cores from active yards and others from cropland to determine groundwater threats posed by abandoned barnyards. They found an average of 3.9 times more nitrate in the profile of the inactive yards than in active yards, with as much as 18,200 kg/ha nitrates estimated in a 9.1 meter profile of one of the yards. The abandoned yards posed a serious potential for mineralization and nitrification of organic nitrogen or ammonium, due to drying and cracking of the surface, allowing less inhibited movement of oxygen and water. Nitrate content in groundwater under abandoned yards averaged 40.5 mg/l; six times greater than the active yards or the cornfields in the study.

Coote and Hore (1979) observed the movement and fate of nitrogen in groundwater under a feedlot on a loamy soil in Ontario, Canada. Sampling from single piezometers and several well nests, they characterized the contaminant plume from a feedlot serving approximately 100 head of beef cattle. Chloride and nitrogen (including total Kjeldahl nitrogen, ammonium and nitrate and nitrite) were the major focus of the investigation, and gave insight into the effects the barnyard was having on groundwater quality below and beyond the yard. The fate of nitrogen from infiltration at the feedlot to a distance of approximately 35 m down gradient was monitored. They concluded that much of the nitrogen was being leached in the organic form, mineralized to ammonium, then nitrified to nitrate within the first 10 to 20 meters from the yard. Beyond this, at 20 to 30 m, nitrates were found to decline more rapidly than chloride. They concluded that denitrification was an important process under the feedlot which rendered it a minimal threat to groundwater quality beyond 60 meters down gradient from the yard.

Though findings varied in the studies, most agreed that barnyards produce a small potential for nitrogen contamination of groundwater compared to irrigated farmland; however contamination of local water supplies was a concern. Direct leaching from the barnyards was considered insignificant in most cases. Several of the investigators found the greatest potential for contamination by a barnyard around the edges of the facility where aeration and unsealed surfaces yielded nitrate leaching. Abandoned or seasonally used yards presented a much greater risk that those yards which maintained a manure pack.

Contaminant Movement in Groundwater

Cherry et. al. (1975) noted three elements of a transport equation describing the movement of a contaminant through an aquifer: 1) movement of the solute resulting from dispersive effects, 2) movement resulting from convection or bulk flow, and 3) losses and additions of a solute due to chemical processes. Schwartz (1977) defined dispersion as "the non-steady, irreversible mixing of two miscible fluids displacing one another in a porous media." He identified two microscopic factors involved in this process to be molecular diffusion and microscopic variability in flow velocity. He also noted a macroscopic factor of "nonidealities" in the porous media responsible for changes in flow direction and velocity. He stated that generally, dispersivity decreases as conductivity contrast decreased and the medium structure is regularized. Cherry summarized his conclusions of the migration of conservative constituents as involving two aspects, groundwater velocity and dispersivity.

A landfill in Ontario, Canada was the site of a study of contaminant migration in groundwater. MacFarlane, et. al. (1983) described the physical conditions affecting groundwater movement at the site and proposed to relate these to the actual configuration of the plume. Several types of samplers were implemented in the study and installed throughout the area to view the groundwater in three dimensions.

Two important concepts of contamination were related to the study. Horizontal groundwater contours and vertical hydraulic head distributions identified localized recharge in certain areas of the site. This recharge led to groundwater mounding which imposed a vertical flow component, moving the contaminant plume downward much quicker than theoretically expected. The other unexpected phenomenon noted was very little vertical mixing between the contaminant plume and surrounding uncontaminated water. A much thinner downgradient plume was observed with a more distinct boundary than that predicted by generally theorized vertical dispersivities. These phenomenon yielded a deeper and more distinct contaminant plume than expected as a result of the landfill leachate.

In addition to the vertical hydraulic gradient, which appeared especially strong during spring and summer, a density gradient was also suggested as a result of the high solute concentrations in the contaminant plume. Though much weaker than the hydraulic vertical gradient during spring and summer, the density gradient was theorized to equal the hydraulic force during the low recharge of fall and winter and thus provide a significant additional factor to the plume's movement.

Contaminant plume movements have been the subject of many studies. Recently, and perhaps most extensive to date, was an experimental investigation at Borden, Ontario. MacKay et. al. (1986) addressed the plume movement portion of the study, which included over 5000 sampling points spread vertically and horizontally. The study utilized an injection of a solution containing inorganic and organic tracers in an attempt to thoroughly investigate the movement of a contaminant plume through an unconfined sand aquifer. Data collection at specific points in time for all sample points yielded snapshots of the plume location. A three year monitoring period yielded a vast bank of data useful for further analysis in the study of methods of contaminant movement.

Our study, though allowing for monitoring of some aspects of the groundwater flow components, does not provide for a thorough examination of this movement. These other studies indicate the comprehensive and expensive approach required to follow contaminant plume movement, but also lend insight into possible explanations of observations during this study.

Nitrogen in Groundwater

Nitrogen compounds occur in three ionic forms in natural water: ammonium, nitrate and nitrite; and may also be present as organic nitrogen from which the ions may be derived. Behnke (1975) suggested that the forms present in groundwater are dependent on local soil microorganisms, physical and chemical conditions present in the soil water matrix and interactions involving the groundwater as it moves from recharge to discharge areas. Nitrogen is a dynamic element involved in a complex biological and chemical cycle transferring it "to and from the lithosphere, atmosphere, hydrosphere and biosphere" (Hem 1983).

Many processes are involved in the nitrogen cycle which may be studied in detail in many soil and biological text books. Nitrification and denitrification will be discussed here because of their importance in groundwater contaminated by animal waste. The ionic nitrogen forms will also be handled as they relate to these processes and because of their significance in groundwater quality.

Ammonium (NH_4^+) is highly soluble in water. Its presence is pH dependent, in equilibrium with ammonia (NH_3). Under normal to low pH conditions, NH_4^+ takes precedence. Because of its net positive charge, it is subject to adsorption by cation exchange sites of the soil matrix. Nitrate (NO_3^-) is also highly soluble. Under aerobic conditions it is the stable end product of the nitrification process. With a net negative charge, it is not significantly adsorbed by the soils of this region. Nitrite (NO_2^-) is an unstable intermediary of both nitrification and denitrification.

Biological nitrification involves the conversion of NH_4^+ to NO_{3-} by bacteria through the equation:

$$NH_4^+ + 3/2\ O = NO_3^- + 2H^+ + H_2O$$

Nitrite which is unstable is quickly oxidized to NO_3^- in the presence of O_2. This entire process is dependent upon oxygen presence, suitable temperature and pH, and a carbon source for the bacterial population in the soil or water environment. The opposing reaction, denitrification occurs in the absence (or nearly so) of oxygen and the presence of a carbon source according to the equation:

$$5C_{ORGANIC} + 4NO_3^- + 4H^+ = 2N_2 + 5CO_2 + 2H_2O$$

Nitrate is reduced first to NO_2^-, then to nitrogen gas.

Gillham and Webber (1969) suggested that suitable conditions for nitrification and leaching occurred only at the edges of yards. Stewart (1967) on the other hand considered that denitrification was an important process under corrals. He noted that a high microbial count, an absence of nitrifying bacteria and the presence of nitrite pointed to active denitrification under the yards. Egboka (1984) observed leachate contamination from a barnyard but emphasized the role of biological transformation within the shallow aquifer under the yard. He suggested that as organic nitrogen was leached to the watertable, it was mineralized to NH_4^+ which was later oxidized to

NO_3^-. Coote and Hore (1979) also suggested this series of events and concluded that denitrification of the end product in the oxygen depleted water resulted in a lack of serious contamination greater than 60 m from the source. They based their conclusion on the feedlot size, soil type and permeability and groundwater flow.

Animal Waste Management

Several of the studies implied the important role management plays in the groundwater threat by animal waste. Stewart (1967) noted that a frequently cleaned corral exhibited NO_3^- accumulation, whereas an infrequently cleaned lot was low in leachable nitrate. Mielke, et. al. (1970) in their study of a heavily used feedlot found little evidence of pollution and noted the manure pack's effective barrier and the lack of runoff as determining factors. The greatest potential was found to be presented by abandoned lots. Drying and cracking of ammonium rich profiles led to nitrification and a subsequent leaching potential of large amounts of nitrate.

Conflicting results or conclusions may be attributed to the different soil and climatic environments represented by these studies. For this reason, careful consideration must be made in extrapolating findings to a particular situation.

Manure collection and handling varies with the type of animal housing and management implemented on a farm. The housing types used on the farms in this study are free stall (sites one and two) and loose housing (sites four and five). Overcash et. al. (1983) recommend manure removal by scraping in both free stall and loose housing situations. Daily manure removal is recommended with indoor feeding areas in free stall housing and weekly to monthly removal with outdoor feeding areas.

If loose housing is utilized, manure removal should be done bi-yearly to yearly with the feeding areas being scraped more frequently.

A study on alternatives for dairy manure management was conducted in the Conestoga Headwaters area of Lancaster County Pennsylvania by Young et. al. (1986). As a result of this study, they found the installation of long term structures for the control of barnyard contaminants unnecessary. Instead, the construction of a curb around the perimeter of a compacted barnyard, along with regular scraping to remove manure is recommended. This technique is utilized to control the effects from runoff. Daily spreading is recommended with the implementation of these techniques.

The relationships of the various studies to the sand plain barnyards investigated in this study may be difficult to interpret. However, many of the concepts reported give insight into the physical, chemical and biological factors involved in these and other animal waste facilities.

SITE DESCRIPTION

Portage County

Portage County lies in Central Wisconsin. Its area covers approximately 2120 square kilometers, of which approximately 36 square kilometers is open water (lakes and streams). Portage county's summers are generally warm and humid, yielding 60 percent of the year's precipitation during May through September. Fifteen to 25 cm of the 49 cm of precipitation falling as rainfall during these months are "lost" as runoff and recharge. The remainder of the rainfall budget is cycled through evapotranspiration. Snow cover averages 15 cm depth during 101 days each year. The total annual precipitation in this region is 80 cm. It is estimated that 90 percent of the runoff/infiltration water makes its way to groundwater recharge.

Portage county can be divided into three general geohydrologic provinces. The drift-crystalline rock province to the north and west of Stevens Point has thin glacial deposits over crystalline rock. The drift province, covering approximately the eastern one-third of the county, is an area of thick glacial till and glacio-fluvial deposit. The sand plain province, of interest in this study, consists primarily of thick sand and gravel deposits. These deposits can be found as deep as 75 m, but average 30 m in depth. Crystalline rock underlies these deposits in the north-central part of the county, while sandstone is beneath it in the southwest one-fourth of the county.

The sand plain province also known as the "Central Sand Plain" has a generally thick and uniform aquifer of well sorted sand capable of supplying large volumes of water. The aquifer drains west to the Wisconsin River; its groundwater divide is at approximately the eastern border of the province. The regional groundwater flow in the sand plain is west-southwest, but can be locally variable, flowing at a rate of up to a meter a day.

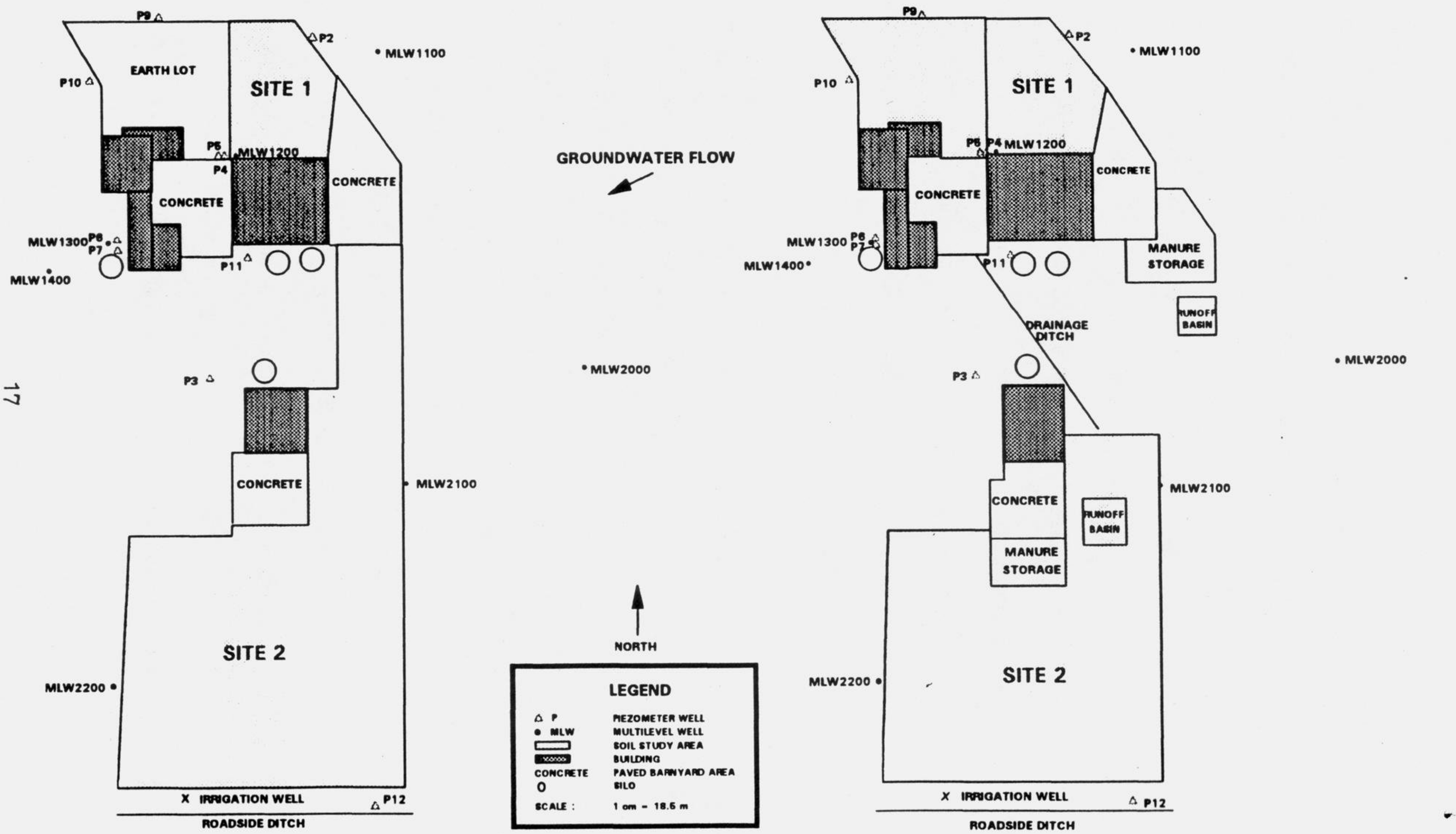
Sites for the study were chosen from Soil Conservation Service farmer-cooperators. Site criteria for the study included coarse textured soil, shallow depth to groundwater (generally four meters or less), accessibility for well placement and a general management/layout scheme conducive to the study objectives. Two farms were chosen for the study, with two earth barnyard areas each. The farms have dairy herds and raise dairy steer and heifers. In addition, they have irrigated cropland, growing feed and vegetable crops.

Site One

The George Feltz farm is located in the township of Plover, T.23N, R.8E, sec.12. This farm had the largest livestock operation in the study with 60 to 70 milking Holsteins, a steer herd of approximately 80 head, and housing for 40 to 45 heifers and 20 to 25 calves. Three separate barnyard schemes were employed; dairy cows, dairy young stock and steers. The cows were kept on a concrete loafing area the majority of the time with an earth lot used only during the driest conditions. The young stock and steers had constant access to earth lots (figure 3). All of the animals' nutritional needs are met through indoor provisions.

Site one was the earth yard used by the heifers, adjacent to the cow earth and concrete lots. The heifers were housed and fed in the opposite end of the same building as the cows. The heifers also had free access to an additional earth yard as

Figure 3. Plan view maps of Site 1 and 2 before and after the addition of the barnyard improvement system.



well as a concrete pad extending out from the feeding barn. These provisions allowed for 27 m^2/animal with a manure loading rate of 15,000 T/ha/yr.

The site one yard had been used for approximately 30 years. It was largely unmanaged without manure removal except in 1976, when 30 cm of topsoil/manure was removed and the yard was refilled with sand. Soils were loamy sand of the Plainfield series. Topography of the lot was fairly flat, however runoff did occur from the heifer lot, through an old waterway flowing along its north edge and into the field to the east. This area was pocketed from the cow hooves and remained blocky when the soils were dry.

Because of the farm layout in relation to groundwater flow, a cross section was chosen for the study which included the north heifer yard (1100 m^2) and the cows' concrete pad (720 m^2). An additional downgradient well nest was used to follow the dispersion of the contaminant plume. During the study, the water table fluctuated between 3 and 4.5 m from the ground's surface and flowed in a southwesterly direction.

Site Two

Site two was associated with the steer operation on the George Feltz farm. Located south of the dairy cattle complex is a 5800 m^2 area including a barn, concrete pad and the earthen lot. This site was used as a barnyard for 5 years prior to the study, which made it the youngest site to be examined. The previous use was row crop agriculture.

This operation housed about 80 holstein steers, with free access between the concrete floor barn with feed bunk, the concrete pad extension, and the unmanaged earth exercise area. The space allowed per animal was 78 m^2/animal with manure loading from this facility at a rate of 3,000 T/ha/yr. The manure was removed periodically from the concrete part of the facility, but had never been removed from the earthen lot. The estimated accumulation of manure at this site was about 1,200 T/ha.

The surface was roughly 1 m lower in elevation than site one, with the water table 1.5 to 2.5 m below the ground surface. The topography is fairly level, with a 1 to 2% slope in a southwesterly direction. There were two distinct soil types in this area. The majority of the yard is slightly higher and usually dry. It was generally used by the cattle only when the preferred area was wet. The smaller portion had heavier traffic and was more poorly drained. Mixing of the manure and organic matter occurred to the depth of 30 cm from the cattle hooves when the soil was wet. Water accumulated on the southern part of the site for periods up to two weeks during heavy rains and snow melt, indicating minimal infiltration to be occurring.

Addition of Manure Storage Facilities to Site One and Two

The addition of manure storage areas and runoff basins to sites one and two occurred in the spring of 1988. Both manure storage areas are adjacent to the cow or steer yards. The site one manure storage area was designed to contain the manure from 70 cows and 25 calves for 180 days. The site two manure storage area will accommodate the manure from 80 mature animals for 180 days. The manure storage areas consist of a concrete floor with three 1.2 m high retaining walls. The floor construction was a 15 cm deep sand-gravel bed with 13 cm of concrete overlay. Each manure storage area was connected to its own liquid runoff basin with a six inch diameter PVC pipe.

The site one runoff basin is located south of the manure storage area that is adjacent to the cow yard/milk house. The site two runoff basin is located to the east of the manure storage area that is adjacent to the steer yard. Both liquid storage basins were designed to handle 18 cm of runoff from the manure storage area and 28 cm of runoff from the yards and lanes. This volume was estimated for the time period between December 1 and April 30. The bottom of these basins have 15 cm of sand-gravel below a 13 cm layer of concrete. The concrete side walls are 15 cm thick with waterstops in all joints.

The animal housing is a loose stall type, complete confinement system. Separate concrete yards are provided for the steers (Site two) and the cows and calves (Site one). All roof runoff was diverted by use of eve troughs. Excess runoff from the dairy yard was diverted to the south east through a trough ending up near our site two downgradient monitoring well (2100). Manure removal from the abandoned barnyard areas, especially at site two, were not completed due to a lack of cost sharing funds, although researchers repeatedly requested that they be a part of the total project.

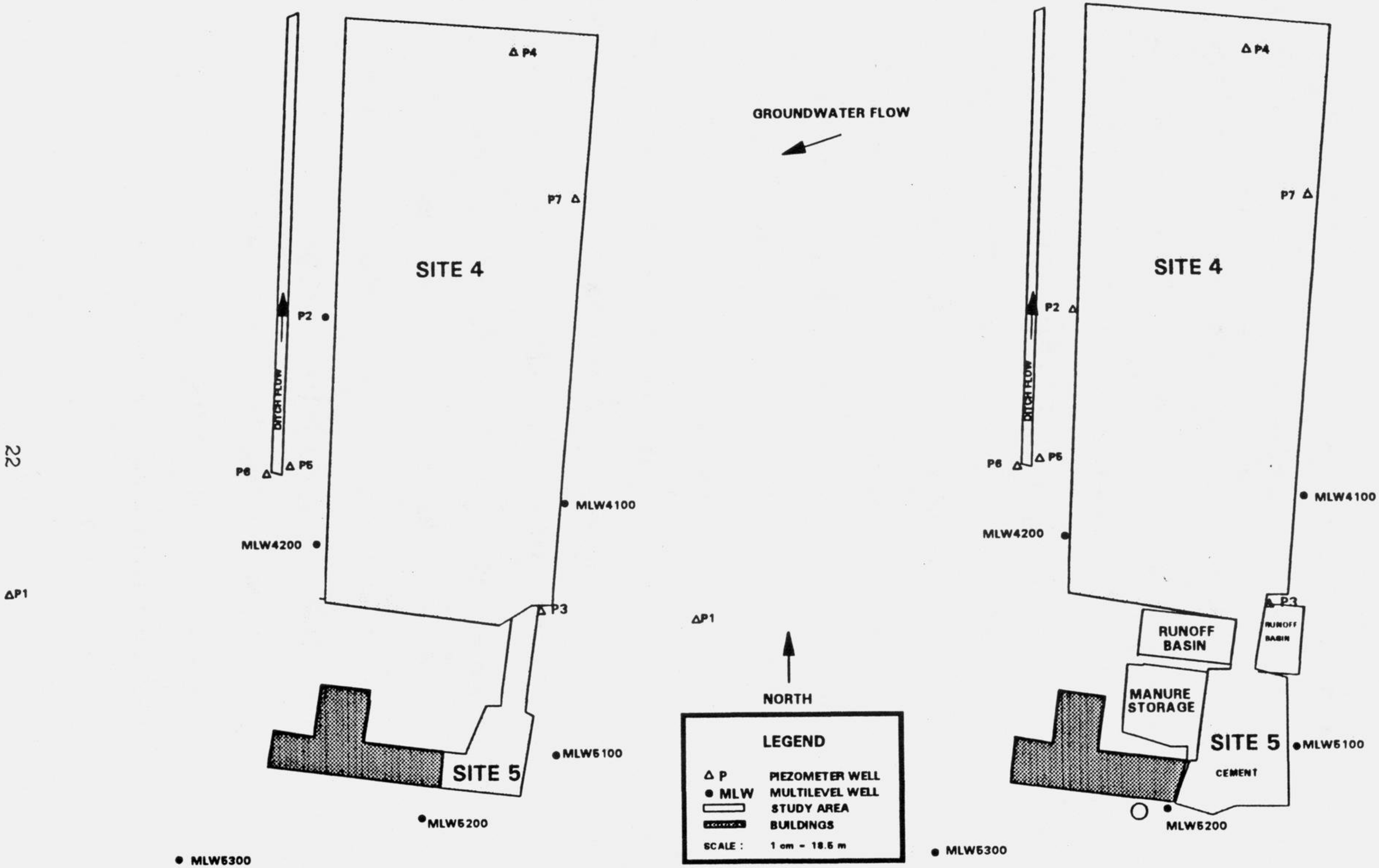
Sites Four and Five

Sites four and five are part of the dairy operation on the Jeff and Ben Klismith farm in the town of Stockton, Sec. 30, T.24N, R9E. When the 35 cow dairy herd is not in the milking barn, they have free access to both sites four and five between May and November (figure 4). Since both sites are utilized by the herd, the sites will be discussed together.

Site four is 9700 m^2 and serves as a loafing area for the dairy herd. The animal density on site four is fairly low (280 m^2/animal) which results in a manure loading rate of 4000 T/ha/yr. Cattle use is primarily heaviest at the south end, which is closest to the barn. Accumulation occurs as there is not manure removal in this area and the level topography shows little indication of surface runoff. This is the only vegetated site in the study. The low animal density and the fact that plants are allowed to establish themselves before the herd is reintroduced in May results in a pasture type area during much of the year. The south end is most heavily utilized as a result of the lane which connects site five. In addition, until 1986 a feed wagon was parked in this area, where the herd was fed between May and November. In the fall of 1985 a permanent concrete feed bunk was constructed within the perimeter of site five and in 1986 the feed wagon was removed from site four. Site five is 400 m^2. For approximately thirty years the yard was used for holding cattle before and after milking, as well as an exercise yard in the winter. This changed with the installation of the feed bunk in 1985. The yard was loaded with manure at a rate of 45,000 T/ha/yr, but accumulation did not occur to any extent because the area was scraped and the manure was removed biweekly. Each spring fill was laid down to maintain the grade of the yard.

For both sites four and five the depth from the yard surface to the groundwater was between 1.5 and 3 m. Groundwater flow was initially determined to be in a

Figure 4. Plan view maps of Site 4 and 5 before and after the addition of the barnyard improvement system.



southwesterly direction, however it was later determined to be affected during periods of high water table by a drainage ditch west of the site four yard. This alters the flow to the west. A corn/alfalfa rotation was used upgradient of the sites throughout the years of study. The crop types along with fertilizers that were applied upgradient of the sites are shown in table 1.

Addition of Manure Storage Facilities to Sites Four and Five

In the late spring and summer of 1989, a manure storage area and two liquid runoff basins were constructed between sites four and five. The concrete manure storage area was located adjacent to the west end of the feed bunk. This area provides 180 days of manure storage for 35 cows, 25 heifers and 25 calves. The pad is constructed with a 15 cm deep gravel bed covered with 13 cm of concrete. This pad is enclosed on three sides with 1.2 m high walls, which control runoff. This area is connected to the liquid runoff basins with a six inch diameter PVC pipe.

The two liquid runoff basins are located between sites four and five. The east pond is located north of site five. The west pond is located between the manure storage area and the east pond. The ponds are connected to one another with an eight inch diameter PVC pipe, allowing for a balanced distribution of the liquids. The bases of the ponds have a 15 cm deep gravel bed and 13 cm of concrete overlay. The side walls of the ponds have 15 cm of concrete, with waterstops in all joints.

These ponds are designed to handle 18 cm of runoff from the manure storage area and 28 cm of runoff from the yards and lanes. These quantities have been estimated for the period between December 1 to April 30.

The housing type utilized is a loose stall system with a non-concrete loafing area. All animals are housed in the same enclosure.

Table 1. Crop type and fertilizer applications in the fields upgradient of Sites 1, 2, 4 and 5.

Sites 1 and 2

1985	1986	1987	1988	1989	1990	1991
beans	corn	beans	corn	corn	peas/bean	corn

Fertilizer applications are as follows:

Corn crop	Bean crop
250 pounds/acre 9-23-30 starter	225 pounds/acre 9-23-30 starter
250 pounds/acre 30-0-0 side dress	250 pounds/acre side dress
37 pounds/acre manure input	37 pounds/acre manure input
Total addition of nitrogen 140 pounds/acre*	Total addition of nitrogen 135 pounds/acre*

Annual fertilizer application is accomplished in the spring.

Site 4 and 5

Field	1985	1986	1987	1988	1989	1990	1991
North	hay	hay	hay	corn	corn	corn	corn
South	corn	corn	corn	hay	hay	hay	hay

Annual fertilizer application is accomplished as follows:

Corn crop	Hay crop
200 pounds/acre/year potash	250 pounds/acre/year potash
250 pounds/acre 10-20-19 starter	Fall 1990:
200 pounds/acre 34% nitrogen	Irrigated with liquid waste from lagoon
15 pounds/acre manure	
Total addition of nitrogen 108 pounds/acre*	Total addition of nitrogen 0 pounds/acre*

* Total addition of nitrogen includes nitrogen obtained from manure application

MATERIALS AND METHODS

WATER

Initial Groundwater Investigation

Three single depth piezometer wells were initially installed at each farm. Triangulation of the groundwater elevations in the three wells yielded an approximate local groundwater flow direction. Multilevel monitoring wells were then installed along the determined flow path under each designated study area. An upgradient well at each site yielded assumed background samples from approximately the water table, to a depth of 3.7 m at sites one, four and five, and 5.5 m at site two. Downgradient wells were located at the edge of each yard and sampled from the water table surface to a 3.7 to 8.2 m depth into the aquifer, depending upon the site (Table 2). Site one had two downgradient multilevel wells, at 45 and 65 m from the barnyard.

Well Construction

Piezometer wells were constructed of 3.2 cm (1.25 inch) inside diameter (I.D.) PVC pipe with either a 0.31 m (1 foot) or 0.92 m (3 ft) slotted PVC well point. A 7.6 cm (3 in) auger was used to bore the holes to the desired depth, the bit removed, the well placed into the hole and back filled with clean sand. Bentonite was used for fill in the last 30 cm as a seal to prevent vertical water movement along the pipe and into the water table. In addition to the triangulation piezometers, two pairs of piezometers were installed at site one as a check for the presence of vertical gradients. One of each pair was placed shallow and the other deep with respect to the water table.

Multilevel wells were constructed with a backbone of 1.9 cm (3/4 in) I.D. PVC pipe with a 0.31 well point to serve as a water level piezometer. Sampling tubes of 0.32 cm (1/8 in) I.D. polyethylene were attached around the PVC pipe (Morrison, 1983). These tubes terminated beginning at approximately the water table (and at 0.31 m below the first one to accommodate fluctuations in the water table) then at 0.92 m intervals below this. Total depth monitored varied with site (see Table 2). Well ports were devised at the end of each tube by drilling 0.16 cm (1/16 in) holes over a 12.7 cm (5 in) section. The tube end was sealed with silicone and the sample port wrapped with a polyester filter cloth. Downgradient wells were generally constructed with two more ports than upgradient wells to reasonably assure sampling throughout and below the contaminant plume.

Table 2 lists individual well construction data. Piezometer and multilevel well ports were developed for sampling by repeated pumping or bailing. Multilevel sampler wells were installed with the cooperation of the Wisconsin Geologic and Natural History Survey (WGNHS) using a truck mounted hollow core drill rig. Wells were constructed in the lab for field assembly. Modification of depth (and consequently the number of sample ports) occurred at site two where depth to water and ease of drilling allowed installation of deeper wells.

Table 2. Total depth into the aquifer sampled by multilevel monitoring wells and groundwater depth for each sample port interval.

Multilevel Well	Number of Ports	Maximum Depth (m)
1100	6	3.7
1200	6	3.7
1300	8	5.5
1400	8	5.5
1500	8	5.5
2000	8	5.5
2100	8	5.5
2200	11	8.2
4100	6	3.7
4200	8	5.5
5100	6	5.5
5200	8	5.5
5300	8	5.5

Well Port	Depth (m) of Sample
1	0.0
2	0.3
3	0.9
4	1.8
5	2.7
6	3.7
7	4.6
8	5.5
9	6.4
10	7.3
11	8.2

Sampling Procedures

Groundwater elevations within the PVC pipes were determined throughout the study period with a fiberglass measuring tape to which a popper was attached at zero. The water table was measured according to the audible response of the popper hitting the water surface in the pipe. Elevations were recorded relative to an arbitrarily chosen bench mark and datum selected at each site.

Extraction of samples from the multilevel wells varied between two methods depending on the accessibility of the well with the equipment. Bottles were brought to the field filled with distilled water used to rinse equipment, then rinsed with the sample water prior to filling.

A peristaltic pump was used to acquire most samples. Water was pulled through the silicone pump tube and pumped directly into a 125 or 250 ml polyethylene bottle. Approximately three well volumes were pumped from the sample tubes before collection to assure an appropriate representation of the groundwater. Samples were then stored on ice and transported to the laboratory for analyses.

Sampling of wells followed approximately a monthly schedule until May 1987 at which time the schedule became quarterly. From November 1985 through May 1987, during spring snow melt and fall wet periods, biweekly sampling gave a closer look at changing water levels and contaminants. Each sample was analyzed for NO_2+NO_3-N, NH_4-N, K^+, Cl^-, electrical conductivity and pH. One spring and one fall sampling called for a more complete analysis including chemical oxygen demand, Kjeldahl-N, phosphorous, pH, hardness, alkalinity, SO_4 and Na^+. Dissolved oxygen and NO_2-N analyses were conducted on some of the samples during the summer and fall, respectively, of 1986.

Water Analysis

Analyses were conducted by the University of Wisconsin-Stevens Point Environmental Task Force Laboratory using standard techniques. Nitrogen and sulfate analyses were performed using the Technicon Autoanalyzer. NO_2+NO_3-N was determined using a Sulfanilamide Method read at 550nm (Industrial Method No. 158-71/WA). Total Kjeldahl nitrogen and ammonium nitrogen were determined using an ammonium-salicylate reagent read at 60nm (Industrial Method No. 329-74W/B). The sulfate analyses employed the Sulfate Industrial Method No. 118-71W/B which uses Methylthymol Blue color reagent read at 460 nm.

Phosphate determination followed EPA Methods for Chemical Analyses of Water and Wastes (1974). Potassium and sodium were analyzed using a Perkin-Elmer 51 Flame Photometer. Analyses for chemical oxygen demand, total hardness and alkalinity were conducted according to Standard Methods for the Examination of Water and Wastewater (APHA et. al. 1985). A Corning electrode/meter was used in the determination of pH, and a YSI conductivity cell was used in the determination of electrical conductivity.

Samples for dissolved oxygen analysis were drawn through a peristaltic pump into the bottom of a D.O. bottle and allowed to overflow 2 to 3 times the bottle volume in order to provide as fresh and non-oxygenated a sample as possible. The samples were fixed, then transported to the lab for titration by the Winkler method.

Precipitation data was recorded using a drum recording field rain gauge located at the George Feltz farm in 1986. For all other years, precipitation data was obtained from the Stevens Point Wastewater Treatment Facility.

SOILS

Field Assessment of Variability

The sampling positions were determined based upon the results of a preliminary investigation. Sites one and two had two sampling positions each. The two positions in site one were represented by: a) poor surface drainage, and b) moderate surface drainage with heavier manure loading. Site two sampling was represented by: a) poor surface drainage with heavier manure loading, and b) good surface drainage. Sites four and five were represented by one sampling position per site. Site four was a well drained barnyard with very little loading. Site five was a well drained heavily loaded barnyard with manure removal done biweekly. Two additional positions were added for comparison purposes, an irrigated field position and a fallow soil position.

The barnyard positions were sampled seven times between May 3 and September 2, 1986. All samples were analyzed for NH_4-N, NO_2+NO_3-N and water content. The sampling intervals were structured to account for sampling following precipitation events exceeding 2.5 cm as well as periods of no rainfall. This was done to determine what effects these conditions have on nitrogen movement and transformations in surface and subsurface soils. Samples were obtained using a 7.5 cm diameter bucket auger. Depth increments of 0-15 cm and 15-30 cm were taken at the surface with the remainder of the cores sampled in 30 cm increments down to the water table surface.

Incremental samples obtained within the barnyards were composites of five single cores combined at similar depths. The five single cores per composite core were taken along a straight transect, with cores spaced one meter apart. Repetitive transects for composite sampling throughout the season were placed within a 1.5 m x 6.0 m area in an attempt to sample similar barnyard conditions over time. All bucket auger holes were back filled, returning the soil to its respective depth in the profile. The top 30 cm of the holes were filled with bentonite clay to prevent preferential infiltration.

Laboratory Analysis

All soil samples for nitrogen analysis were stored in an ice chest while in the field and maintained at 4°C until laboratory testing could be conducted. Prior to nitrogen analysis, moist samples were passed through a 10 mm sieve to remove coarse fragments. Kjeldahl-N was determined on the single May 3 sample set for the barnyards and the June 13 samples for the field profile adjacent to site one. The remaining soil from these same samples were air dried and had the following chemistry measured: exchangeable K^+, Na^+, Mg^{2+}, Ca^{2+}, pH, organic carbon, and percent sand, silt and clay. In addition, distilled water, extractable Cl^- analysis was run on a set of mid-season samples for all sites.

Inorganic N was determined by steam distillation as described by Keeney and Nelson (1982) to $\pm$ 1.6 mg/kg for NH_4-N and $\pm$ 1.9 mg/kg for NO_3-N of reported values at the 95% confidence level. Amounts of NO_3-N in the soil solution were based on soil moisture content at the time of sampling, which was near field moisture capacity for all except surface samples and samples at or near groundwater level in the capillary fringe. The method by Bremner and Mulvaney (1982) was employed to measure organic N. This method was found to be accurate to $\pm$ 70 mg/kg of reported values. Soil moisture content for all N soil samples were determined by drying at 105°C for 24 to 48 hours.

Exchangeable cations were extracted using the ammonium acetate method of Thomas (1982). The filtered extract was analyzed for Na^+ and K^+ using a Perkin-Elmer 51 flame photometer, and for Ca^{2+} and Mg^{2+} on a Varian AA-475 atomic absorption spectrophotometer. Extractable P was determined colorimetrically (Olsen and Sommers, 1982). Measure of pH was made using a Corning glass indicating electrode linked to a Corning model 12 research pH meter. The procedure used is as described by McLean (1982), except a 1:5 soil/water ratio was used due to excessive water absorption by high organic matter samples. Organic carbon determinations were made with the Wakley Black method (Nelson and Sommers, 1982) and the hydrometer method (Day, 1965) was used to determine the percent sand, silt, and clay fractions of samples. Prior to the particle size analysis, combustion of organic carbon in surface samples was accomplished using a muffle furnace to eliminate any organic matter influence. This was done because hydrogen peroxide was not found to be adequate in removing the organic matter influence for the hydrometer method. The sand fraction of each sample was further separated into two categories: percent very coarse to medium sand (2.00 mm - 0.25 mm), and percent fine to very fine sand (0.25 mm - 0.05 mm) by wet sieving.

The results of the K^+, Na^+, Mg^{2+}, Ca^{2+} and P analyses were found to be within the range $\pm$ 20 mg/kg at the 95% level of confidence (based on five replicate samples). Organic carbon, clay, and pH resulted in ranges of 0.09%, 0.5%, and 0.24%, respectively of reported data.

At each barnyard position and the field at site one, a small soil pit was excavated to a depth of 54 cm. Bulk density samples were taken at 6 cm intervals with a double cylinder, hammer-driven core sampler (Blake, 1965) to a depth of 54 cm. Organic carbon analysis was also run on these samples. Corresponding to each 6 cm depth, a mean of seven pocket pentrometer readings (P.R.) was recorded from the vertical profile face at 6 cm depth increments. A profile description including horizon depth, soil color, structure, grade, and consistence was also conducted according to Soil Conservation Service guidelines (U.S.D.A., 1981).

An estimation of surface infiltration rates at the six barnyard positions and one field position was made using a 15 cm diameter cylinder driven to a 15 cm depth. A modified falling head method (Klute, 1965) was adopted with an initial head of 15 cm. At sites where infiltration was measurable, the test was run for three hours. The cylinder was monitored over a twelve hour period at sites showing little or no infiltration.

Field Moisture Capacity (FMC) values were established for the surface soils of each sampling position using undisturbed cores taken from the center of the 0-15 cm and 15-30 cm depths. These cores were installed in porous plate pressure cells and maintained at 1/3 bar until equilibrium was established (Klute, 1965). FMC was determined by oven-drying.

RESULTS

Barnyard Soil Studies

Bowen (1987) established several important findings in the soil profile investigation portion of this study, separating them according to physical and chemical properties. These properties are summarized in Tables 3 and 4.

Physical Properties

Organic carbon accumulation, soil compaction and field moisture capacity (F.M.C.) were significant factors which affect the groundwater contamination potential by direct leaching from the yards. Organic carbon (O.C.) content in the upper 15 cm ranged from 3.0 to 7.5% in the two yards with high manure accumulation. Site four's surface organic carbon content may reflect live vegetation present in the sample in addition to manure as suggested by a sharp decrease in the second 15 cm as compared to sites one and two. Manure loading of site four was approximately one-third that of other yards.

Field moisture capacity for surface samples (upper 15 cm) ranged from 27 to 45% at sites one and two, while F.M.C. of approximately 7% was found in the two yards with lowest O.C. accumulation. Water infiltration rates were found to be immeasurable at the two sites of greatest O.C. content and high animal density.

At site four, the lightly used barnyard or heavily used pasture, the infiltration rate was 1.9 cm/hour compared to <.1 at sites 1 and 2 and 2.8 at the adjacent field. The nitrate-N and ammonia-N concentrations with depth under the barnyard presented in table 4 provides further evidence of the minimal nitrate-N leaching under sites 1 and 2 compared to sites 4 and 5.

The physical data suggests that hoof compaction along with organic matter accumulation in high use barnyards, leads to a high water holding capacity and an effective seal, thereby greatly reducing the opportunity for leaching.

Table 3. Summary of soil physical properties at sites 1, 2, 4, and 5 (Bowen).

Site	1*	2*	4	5	Field
Barnyard Age (years)	30	5	30	30	
Area (hectares)	0.1	0.6	1.0	0.04	
Stocking density (m^2/animal)	30	80	300	10	
Manure Loading (T/hectare)#	15,000	3,000	4,000	45,000~	
Organic Carbon (%)					
0 - 15 cm	7	3	3	0.4~	1
15 - 30 cm	3	1	0.2	0.2	0.6
F.M.C. (%)					
0 - 15 cm	45	27	7	7	10
15 - 30 cm	9	8	5	5	6
Infiltration (cm/hr)	<0.1	<0.1	1.9	0.7	2.8
sand (%)^	91	84	84	85	94
silt (%)^	2	8	7	6	2
clay (%)^	7	8	9	9	4

* analyses reflect weighted average of two sample positions.
\# wet manure loading calculated over lifetime of barnyard.
~ active removal program implemented.
^ mean profile values.

Chemical Properties

Analysis of the chemical properties of the soil profile concentrated on NH_4-N, NO_3-N and K^+. This data provided further evidence that where a surface seal formed in the barnyards, a minimum opportunity for direct leaching of nitrate to occur. Table 4 summarizes the soil chemistry data.

Total nitrogen occurred in greatest concentration in the first 30 cm. Ammonium accumulated most in sites with a combination of high loading and poor drainage (sites one and two). The two yards in which highest O.C. accumulation, highest F.M.C. and undetectable infiltration were found, yielded the smallest amounts of NO_3- in the subsurface layers. Subsurface nitrate occurred in highest concentrations in the two profiles that had well drained surfaces and lacked a tight organic seal; conditions conducive to nitrification and leaching.

Potassium concentrations of three times those found under upgradient irrigated fields were considered indicative of significant animal waste influence. The depth at which these levels of accumulation were found, seemed most influenced by the presence or absence of a surface seal and the age of the barnyard.

Table 4. Summary of soil chemical properties at sites 1, 2, 4, and 5. (Bowen, 1987)

Site	1*	2*	4	5	Field	Fence Line‘	Field Depression‘
Surface $NH_4^{\#}$ (mg/kg)	50	36	3.6	6.3	2.5	3.7	1.6
Subsurface $NH_4^{\sim}$ (mg/kg)	30	9.7	1.9	3.3	1.5	1.2	0.8
Surface $NO_3^{\#}$ (mg/kg)	15	13	18	18	12	7.4	18.5
Subsurface $NO_3^{\sim}$ (mg/kg)	1.4	1.2	9.9	6.6	6.9	3.4	6.8
pH (0 - 15 cm)	8.2	7.7	6.7	6.9	5.8	6.1	5.9
Potassium leaching^	270	60	150	150	0		

Unless otherwise noted, these values are the average of seven sampling dates.

* analyses reflect weighted averages of two sample positions.

\# average of the surface 30 cm.

~ average of all sample depths from 30 cm to the watertable.

^ maximum soil depth where potassium concentrations exceed 300 mg/kg (3 times maximum field profile concentration

‘ average of corresponding depth for one sampling.

Soil buildup of NH_4^+ and K^+ occurred in relationship to lifetime loading over a long period of time under a sealed surface. This surface seal is believed to prevent nitrification and/or induce denitrification, thereby greatly reducing the potential for nitrate accumulation and leaching. Nitrate leaching was evident in the soil profile under yards where hoof compaction was minimal. These sites also had lower amounts of manure accumulation due to lower animal density or manure removal. Prevention of nitrate contamination of groundwater by the barnyards appeared most effective from a soil profile standpoint through maintenance of a hoof compacted organic physical barrier, provided runoff from the site is controlled.

Table 5 shows the accumulation of organic-N for the unpaved barnyards ranged from 1,316 to 15,841 kg/Ha. With the highest accumulations at sites 1 and 2, there is obviously significant fertilizer value in the accumulated manure even after volatilization, denitrification and runoff losses. This large reservoir of organic-N poses a significant hazard to groundwater if the barnyards are abandoned.

Table 5. Organic nitrogen concentration (mg/kg) in soil underlying four barnyards and adjacent fields.

	Site number/Description					
Depth (cm)	1	2	4	5	Fallow	Upgradient Ag. Field
0 - 30	3528	1816	1630	293	313	630
30 - 60	399	155	178	164	115	89
60 - 90	115	77	177	93	32	65
90 -120	82	103	68	41	20	34
120-150	61	133	47	37	15	46
	kg Nitrogen/ Ha (upper 30 cm)					
	15,841	8,154	7,319	1,316	1,405	2,829

Barnyard Study Water Quality Results

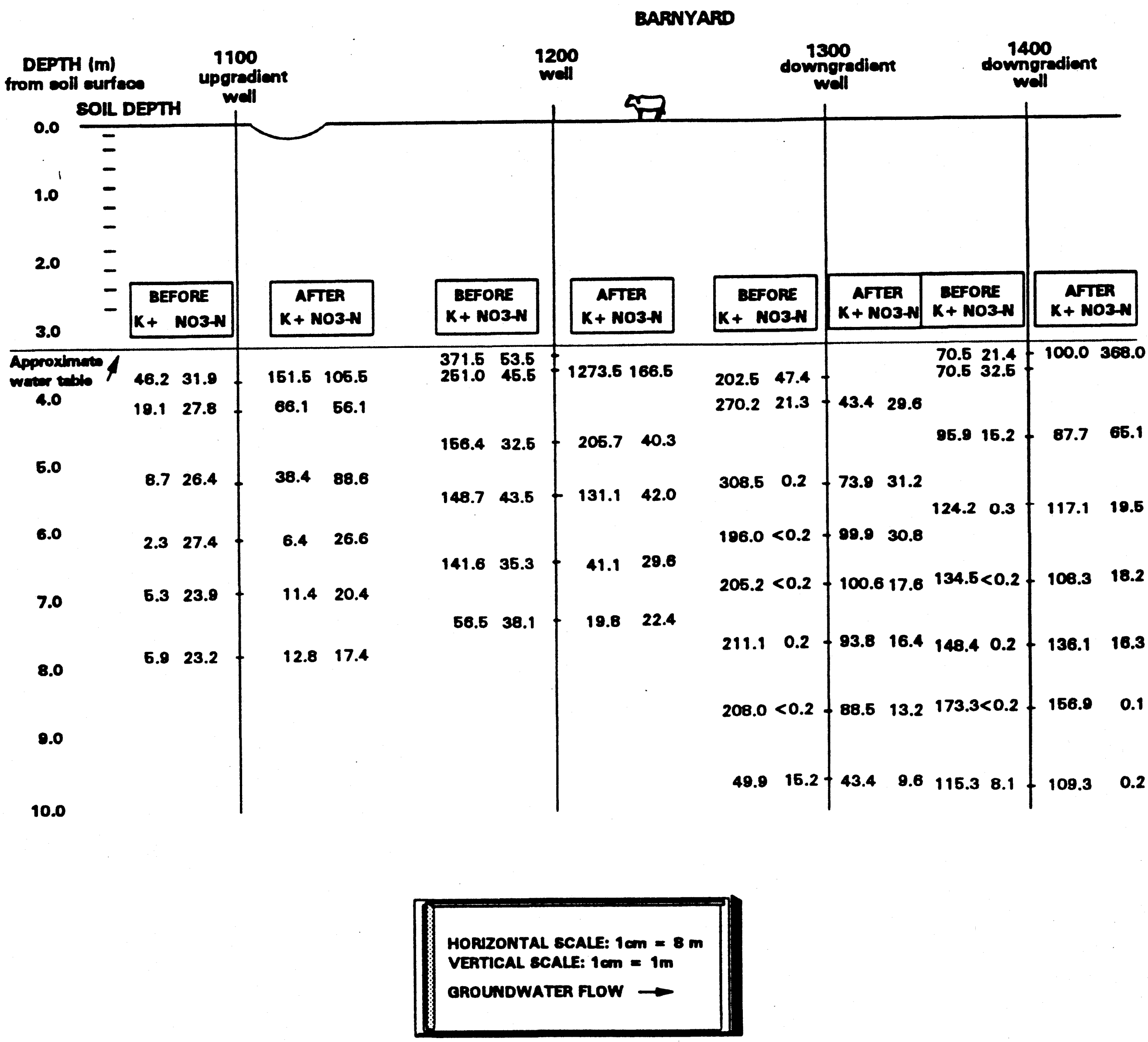
The results of groundwater monitoring associated with the barnyard project are organized into the following sections. Initial results from 1986 to 1989 representing data from earthen barnyards (preconstruction), results since 1989 to document the changes that have occurred as a result of installation of barnyard improvements (post construction) and results from upgradient wells related to cropping practices up flow of barnyard sites. This later data is not directly related to barnyards but generated some very useful information. Data will be presented by study site.

Site One Preconstruction Results

This site had the second highest animal density (30 m^2/animal) and the second greatest lifetime loading of manure (15,000 ton/Hectare) of the four study areas. The barnyard was 30 years old. The site map (figure 3) shows the series of four multiport monitoring wells installed to monitor this site. In addition to wells immediately upgradient (1100) and downgradient (1200) of the earthen yard there was a well nest installed 45 m downgradient (1300) with a paved barnyard and milking barn between wells 1200 and 1300 and a fourth well nest 65 m downgradient of the unpaved barnyard (1400).

Figure 5 presents the average nitrate-N and potassium data for the multiport wells with depth for the time period preceding installation of pavement and manure storage and for the years 1990-91 following improvements. This data clearly shows impacted groundwater with most well ports exceeding 10 mg/l nitrate-N. Separating upgradient land use impacts from barnyard impacts was greatly facilitated by the

Figure 5. Average concentrations (mg/l) of potassium and nitrate-N at site 1 before and after installation of manure storage facilities. Cross section of the aquifer perpendicular to the flow.



presence of elevated potassium levels where leaching from barnyards occurred. Leaching of potassium from fields resulted in potassium values less than 10 mg/l, even though nitrate-N was often between 20 and 30 mg/l. Potassium was used as a tracer to identify which well ports were impacted by animal waste and used in the following analyses to identify the contaminant plume wherever plume averages are presented.

Site One was found to have nitrate-N values ranging from 30 to 55 mg/l immediately downgradient of the barnyard (well 1200) even though soil analysis clearly showed minimal leaching directly under the barnyard. It is believed that the majority of the leaching occurred at the edges of this barnyard and under the fence line, where hoof compaction was not sufficient to produce an effective seal. The soil data presented in table 4 shows elevated sub-surface nitrate-N under the fence line compared to the barnyard. Yearly average data for potassium, nitrate-N and chloride in the contaminant plume is presented in table 6 and figures 6A, 6B and 6D. This data for well 1200 shows a distinct contaminant plume with elevated concentrations of nitrate-N, chloride and potassium.

Moving downgradient from well nest 1200 to 1300 shows some dynamic changes in groundwater quality as chloride increases, potassium remains very high (>200 mg/l) yet nitrate-N decreases to generally less than 10 mg/l. Figure 6F shows elevated C.O.D. levels beginning at well 1200 while figure 6C and 6E show increases in ammonia and phosphorous beginning at well 1300 with very low concentrations at well 1200. The occurrence of a crack and depression in the paved barnyard between

Table 6. Summary of average annual chloride, potassium and nitrate-N for sites 1 and 2. 1985-1991

AVERAGE CHLORIDE (mg/l) values for Sites 1 and 2 in the contaminant plume (downgradient) or the upper 4.6 m of the aquifer (upgradient).

WELL NUMBER	1985	1986	1987	1988	1989	1990	1991
MLW1100 upgradient	30.2	24.9	32.3	31.9	35.9	60.3	55.5
MLW1200 downgradient	97.7	66.1	94.3	51.7	61.2	71.0	146.7
MLW1300 45 m downgradient	162.3	97.8	114.3	58.3	33.0	38.4	40.4
MLW1400 65 m downgradient	105.7	57.4	65.3	65.1	59.8	55.0	66.5
MLW1500 45 m downgradient		15.1	9.6				
MLW2000 upgradient		21.9	17.8	17.6	16.0	28.0	27.6
MLW2100 downgradient of field depression	55.3	77.8	62.1	54.1	44.9	87.0	82.9
MLW2200 downgradient of barnyard	53.3	69.8	91.2	43.6	66.7	162.3	81.2

AVERAGE POTASSIUM (mg/l) values for Sites 1 and 2 in the contaminant plume (downgradient) or the upper 4.6 m of the aquifer (upgradient).

WELL NUMBER	1985	1986	1987	1988	1989	1990	1991
MLW1100 upgradient	19.5	15.5	14.1	12.0	10.7	44.4	32.9
MLW1200 downgradient	279.2	229.4	194.4	95.9	89.7	90.9	205.7
MLW1300 45 m downgradient	275.4	215.3	178.1	143.7	91.1	60.7	73.1
MLW1400 65 m downgradient	94.5	142.3	120.5	114.5	141.7	98.6	130.3
MLW1500 45 m downgradient		174.1	141.8				
MLW2000 upgradient		7.4	5.6	7.1	5.9	7.8	4.4
MLW2100 downgradient of field depression	74.4	132.3	154.6	77.8	92.6	86.6	279.7
MLW2200 downgradient of barnyard	13.7	24.0	46.5	16.7	26.9	38.0	61.5

AVERAGE NITRATE-N (mg/l) values for Sites 1 and 2 in the contaminant plume (downgradient) or the upper 4.6 m of the aquifer (upgradient).

WELL NUMBER	1985	1986	1987	1988	1989	1990	1991
MLW1100 upgradient	27	28.5	24.6	27.8	34.8	58.9	66.4
MLW1200 downgradient	59.7	42.2	33	25.9	33.6	50.7	70.2
MLW1300 45 m downgradient	8	6.3	13.4	16.2	24.8	17.2	21.6
MLW1400 65 m downgradient	4.7	10.6	10.6	3.3	7.5	18.2	26.1
MLW1500 45 m downgradient							
MLW2000 upgradient		12.8	10.4	9.4	14.5	31.2	24.9
MLW2100 downgradient of field depression	13.7	19.8	41.3	21.2	29.9	44.4	43.3
MLW2200 downgradient of barnyard	7.8	12	13.7	9.4	5.6	50.6	96.3

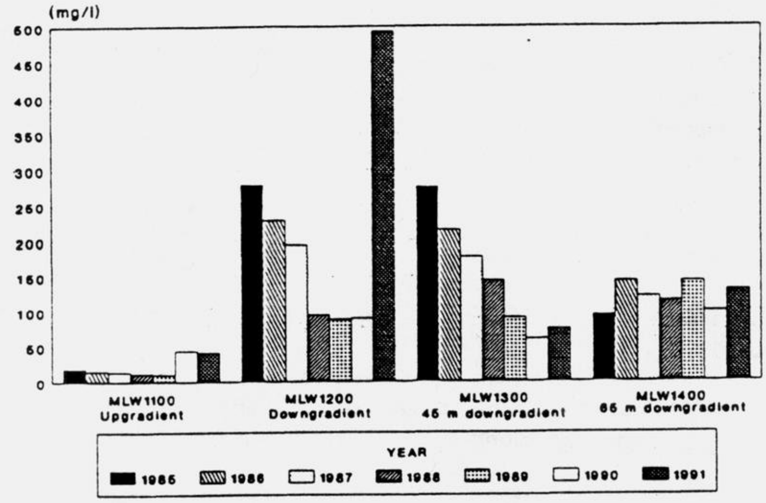
**Shaded area represents values obtained after the installation of the manure facility.

The average thickness of the contaminant plumes in downgradient wells (based on potassium concentrations) is as follows:

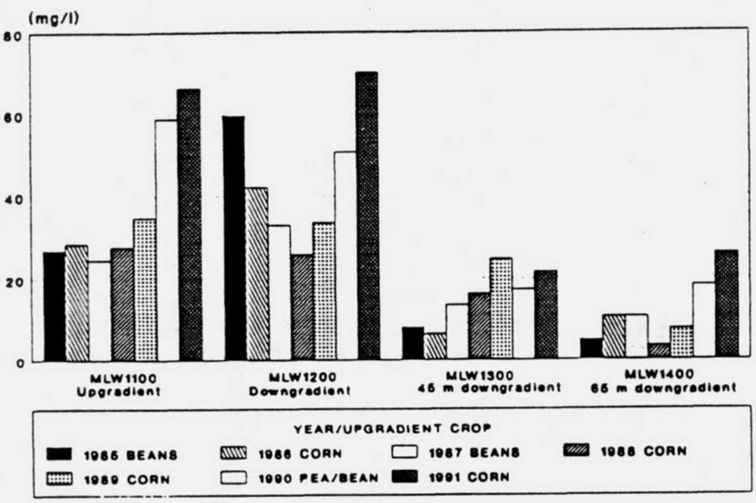
MLW1200	3.1 m	MLW2100	4.3 m
MLW1300	4.0 m	MLW2200	4.4 m
MLW1400	4.8 m		

ammonia, chloride, phosphorous, and COD in upgradient wells and
contaminant plumes of downgradient wells at site 1.

(A) AVERAGE POTASSIUM (mg/l)
Site 1 Contaminant Plume or
Upper 4.6 m of Aquifer (Upgradient)



(B) AVERAGE NITRATE-N (mg/l)
Site 1 Contaminant Plume or
Upper 4.6 m of Aquifer (Upgradient)



(C) AVERAGE AMMONIA-N (mg/l)
Site 1 Contaminant Plume or
Upper 4.6 m of Aquifer (Upgradient)

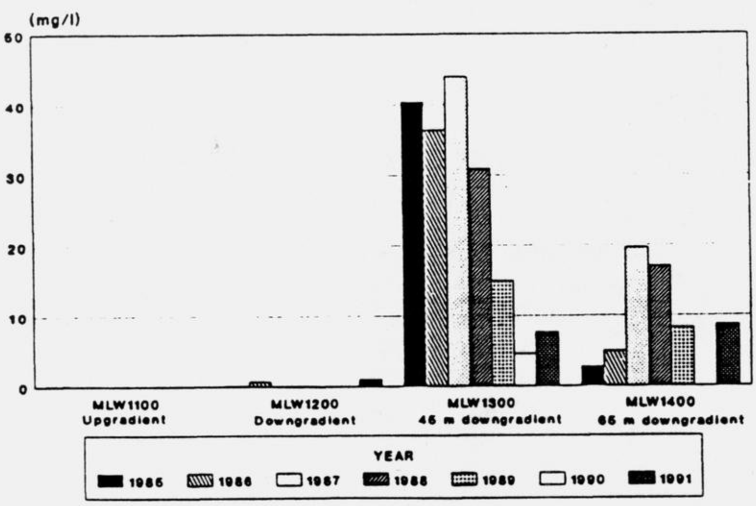
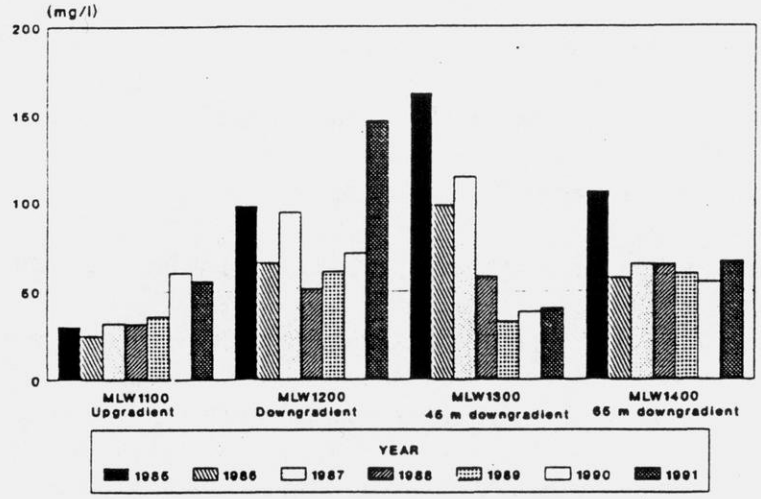
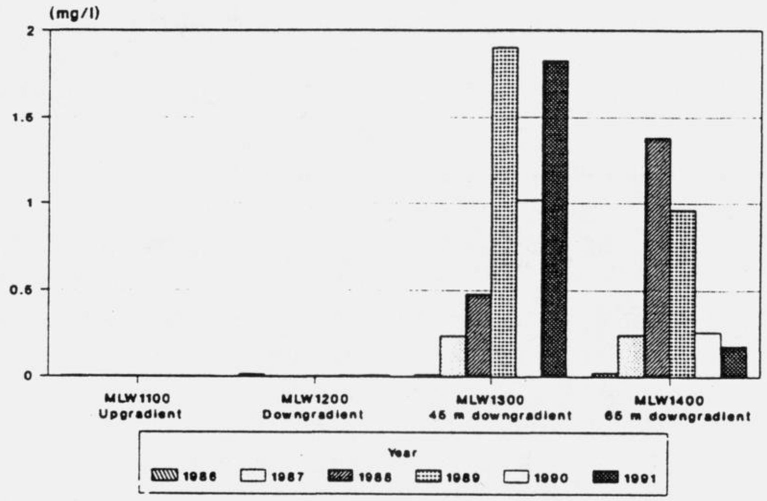


Figure 6. (cont.)

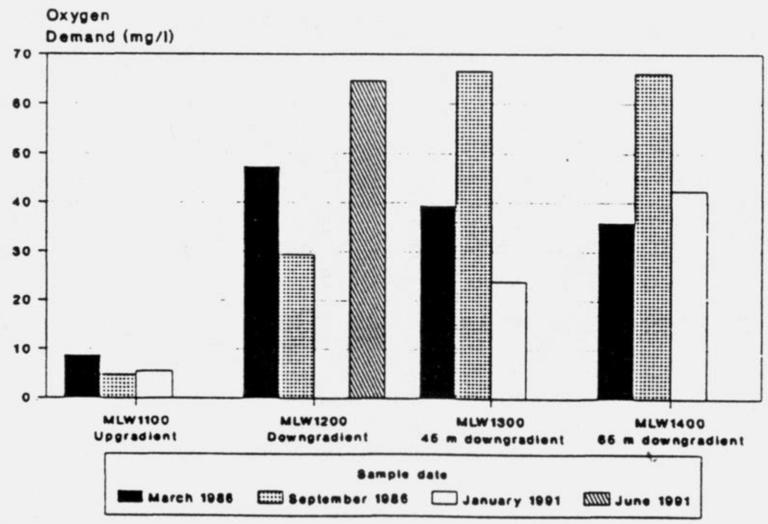
(D) AVERAGE CHLORIDE (mg/l)
Site 1 Contaminant Plume or
Upper 4.6 m of Aquifer (Upgradient)



(E) AVERAGE REACTIVE PHOSPHOROUS (mg/l PO4-)
Site 1 Contaminant Plume or
Upper 4.6 m of Aquifer (Upgradient)



(F) CHEMICAL OXYGEN DEMAND (mg/l)
Site 1 Contaminant Plume or
Upper 4.6 m of Aquifer (Upgradient)



wells 1200 and 1300 is believed to be the source of the elevated concentration of ammonia-N and phosphorous, not the unpaved barnyard. The reduction in nitrate-N is believed to be a result of denitrification in the groundwater between sites 1200 and 1300. Further reductions in nitrogen between sites 1300 and 1400 was also observed in the part of the plume containing high C.O.D. values. Dissolved oxygen tests indicated a lack of oxygen in the contaminant plume making conditions suitable for denitrification to occur. These nitrogen transformations were not observed at other sites. While these differences in concentrations with distance from the barnyard are interesting and illustrate the transformation that can occur in groundwater, we do not believe they represent effects from leaching associated with the unpaved barnyard. This data does closely show the impact a crack in a paved barnyard can have on groundwater quality and emphasizes the importance of proper construction and maintenance of paved areas to prevent groundwater contamination. This data also illustrates that animal waste can result in elevated phosphorous and dissolved organic matter concentrations in groundwater.

Post Construction Results at Site 1

In the summer of 1989, the barnyard at site one was paved along with repaving the barnyard between wells 1200 and 1300. Manure storage was provided with runoff from the paved yards diverted to cement lagoons or diverted to the field to the east via a cement drainage way as illustrated in figure 3.

Figure 5 shows the concentration of nitrate-N and potassium before and after the installation of the above practices. The "after" column is an average for 1989-91.

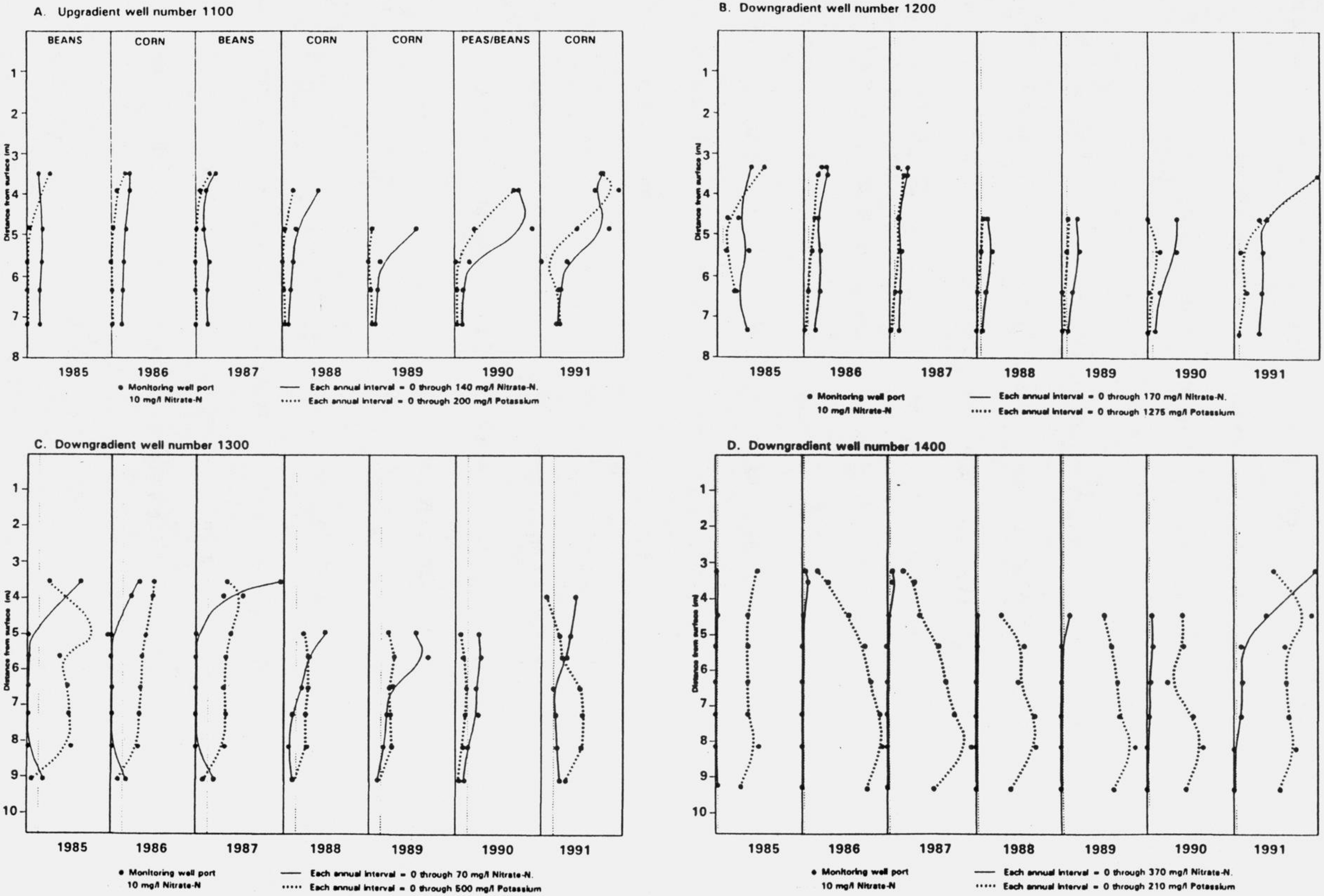
Table 5 presents yearly average concentrations for the contaminant plume for nitrate-N, potassium and chloride through 1991, as do the bar graphs on figure 6a, 6b and 6d. Average annual nitrate and potassium concentrations are presented in figures 7a-d.

These data show generally worse groundwater quality conditions after the installation of pavement and manure storage. Nitrate-N concentrations have increase at all wells even though downgradient wells 1300 and 1400 were previously low in nitrogen. There appears to be a reduction in potassium concentrations (figure 6a) at wells 1200 and 1300 and some reduction in chloride (figure 6d) at well 1300.

The reduction in potassium and chloride are somewhat encouraging in that the reduced amount of manure available for leaching is apparently beginning to result in some reduced chemical concentrations in groundwater. It is hoped that nitrate values will also decline over time, however, as most nitrogen buildup in soils from manure is as organic-N or ammonia-N it needs to first be converted to nitrate-N before it is leached and removed from the areas. Similar conversions are not necessary for potassium and chloride, which may account for the more rapid decreases in these concentrations compared to nitrogen.

The increased concentrations of nitrate-N observed at each well nest have different causes. Well 1100, the upgradient well nest, experienced increases in nitrate-N and potassium (Figures 6a, 6b and 7a) following the installation of manure storage. The haul road from the manure storage area goes past this well nest. Spillage of manure from the spreaders has been observed near this well which we

Figure 7. Profile of the average annual nitrate-N and potassium concentrationsfor upgradient and downgradient wells at site 1.



believe has resulted in the increased concentrations at well site 1100.

The observed increases in nitrate-N at well 1200 are believed to be due to both residual manure from the abandoned earthen barnyard and from stacking a bank of snow with some manure that was plowed off of the newly paved barnyard during the winter of 1990-91. This contained significant manure and actually covered well 1200. Data from sites two and four also emphasize the impact of abandoned barnyards on groundwater quality. Much of the residual manure was removed from this site, yet nitrate-N concentrations increased to over 100 mg/l in 1991. This data emphasizes the need for careful management of manure to prevent it from getting off pavement areas where it can quickly convert to nitrate-N and leach from these sandy soils.

Increases in nitrate-N at well 1300 are believed to be largely due to a decrease in denitrification once the cracked barnyard pavement was replaced, plus increased concentrations of nitrate-N moving downgradient from well 1200. Similar increases occurred at well 1400 for the same reasons plus a chicken pen was installed around well 1400 in 1990, which probably accounts for the large (>300 mg/l) nitrate-N concentration seen in the upper well ports of well 1400 in 1991 (figure 7d).

The above data illustrates the complexity of monitoring barnyard impacts to groundwater and emphasizes that a variety of sources and reactions need to be considered when designing systems to minimize impacts. The installation of state of the art manure storage at this site has obviously only resulted in degrading groundwater quality relative to nitrate-N concentrations. Handling of abandoned barnyards and the increased manure that must be moved and spread needs careful attention if the improvements in water quality are to be obtained from the installation of barnyard paving and manure storage.

Site Two Water Quality

Site two, located just south of site one on the same farm, is not nearly as complex as site one. It contained one large earthen barnyard used to contain 80 holstein steer. Figure 3 shows the layout before and after barnyard improvements. The field depression upgradient of this barnyard received runoff from site one and two prior to 1989. It currently still receives some runoff from site one via the concrete channel shown in figure 3.

Figure 8 shows the average nitrate-N and potassium concentrations with depth in each multiport well before and after the installation of barnyard pavement and manure holding structures. Table 6 provides average annual concentrations of chloride, potassium and nitrate in the contaminant plume for well 2000 upgradient of the field depression, well 2100 located between the field depression and the barnyard, and well 2200 downgradient of the barnyard. Figures 9a-d present annual plume averages for the same wells using bar graphs. From these data it is obvious that prior to 1989 the major groundwater impact at this site was from the field depression which is measured at well 2100. Well 2200, downgradient of the earthen barnyard, was found to average 11 mg/l nitrate-N compared to 25 mg/l. During the same time period, the upgradient well 2100 in the middle of the irrigated field, averaged 11.6 mg/l nitrate-N. Potassium values were also highest at site 2100 occurring at 12 mg/l compared to 6 mg/l upgradient and 25 mg/l downgradient to the barnyard. These data indicates

Figure 8. Average concentrations (mg/l) of Potassium and Nitrate-N at Site 2 before and after installation of manure storage facilities. Cross section of the aquifer perpendicular to the flow.

DEPTH (m) from soil surface: 0.0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0

SOIL DEPTH — Approximate water table

2000 upgradient

BEFORE K+	BEFORE NO3-N	AFTER K+	AFTER NO3-N
7.1	11.1	7.1	22.8
7.1	11.5	7.2	21.0
6.2	12.3	6.8	21.0
6.2	10.7	6.5	15.1
5.9	12.5	5.1	15.2
3.6	19.9	2.4	17.0
0.8	23.8	2.8	17.3
0.8	24.7	2.8	15.9

Field Depression — 2100 — BARNYARD

BEFORE K+	BEFORE NO3-N	AFTER K+	AFTER NO3-N
267.5	68.8		
253.1	66.8	355.0	52.7
239.8	36.3	275.7	76.2
127.3	0.3	171.8	10.7
26.3	4.5	33.7	27.1
9.9	8.3	17.4	37.8
13.2	7.4	15.0	28.4
11.2	8.7	18.1	27.6

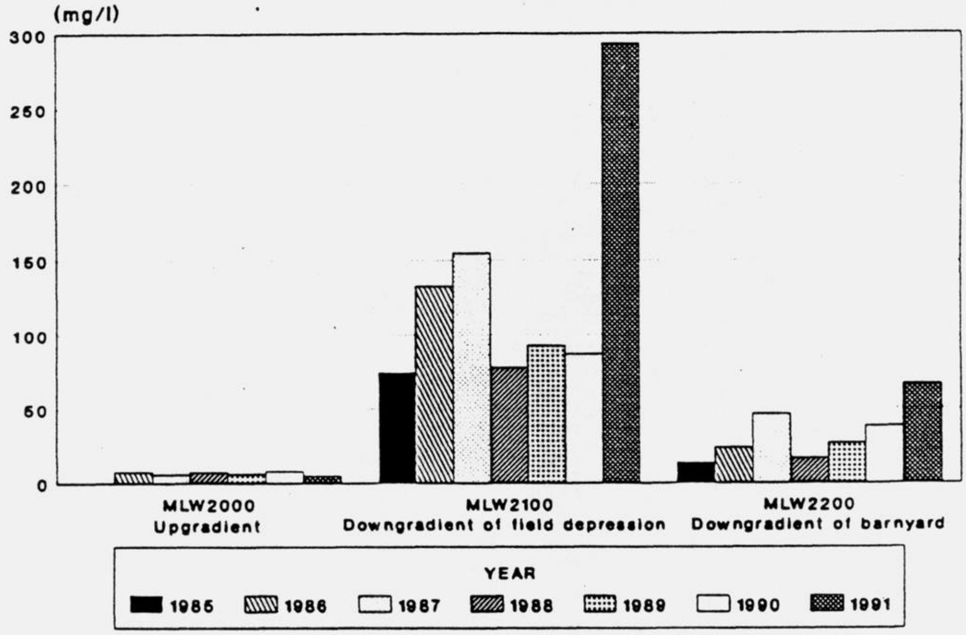
2200 downgradient

BEFORE K+	BEFORE NO3-N	AFTER K+	AFTER NO3-N
60.9	10.4		
55.4	12.6		
24.5	10.1	56.1	70.0
23.7	15.9	31.4	50.6
12.5	14.9	23.8	40.6
8.3	14.1	20.2	33.8
28.7	2.1	52.4	10.1
26.9	4.4	38.1	10.2
4.4	14.2	6.5	17.8
1.8	14.5	2.9	15.5
2.9	12.5	5.5	19.3

VERTICLE SCALE: 1cm = 1m
HORIZONTAL SCALE: 1cm = 8m
GROUNDWATER FLOW →

Figure 9. Bar graphs of average annual concentrations of potassium, nitrate-N, chloride and phosphorous in upgradient wells and contaminant plumes of downgradient wells at site 2.

(A) AVERAGE POTASSIUM (mg/l)
Site 2 Contaminant Plume or
Upper 4.6 m of Aquifer (Upgradient)



(B) AVERAGE NITRATE-N (mg/l)
Site 2 Contaminant Plume or
Upper 4.6 m of Aquifer (Upgradient)

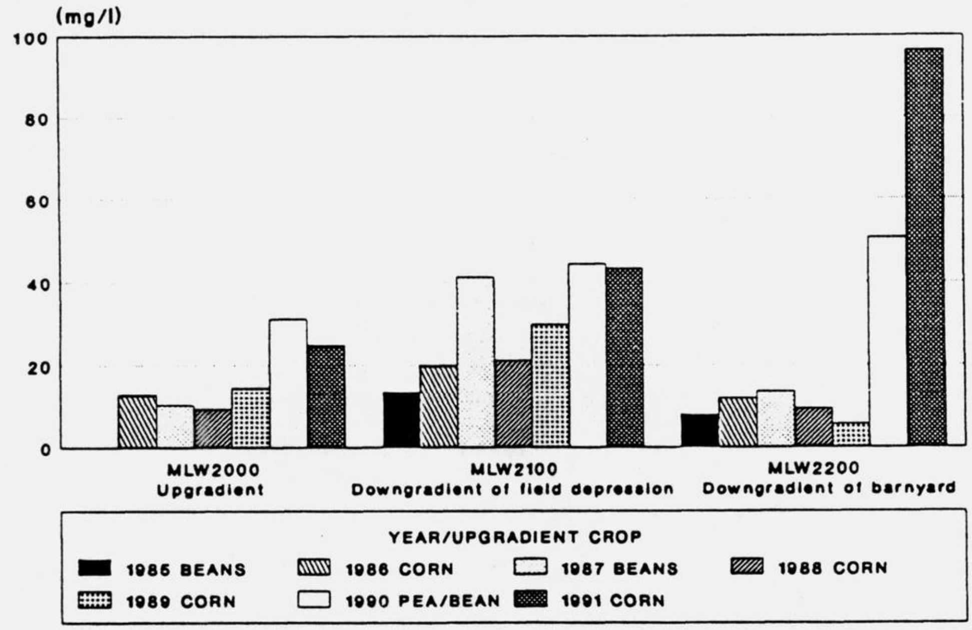
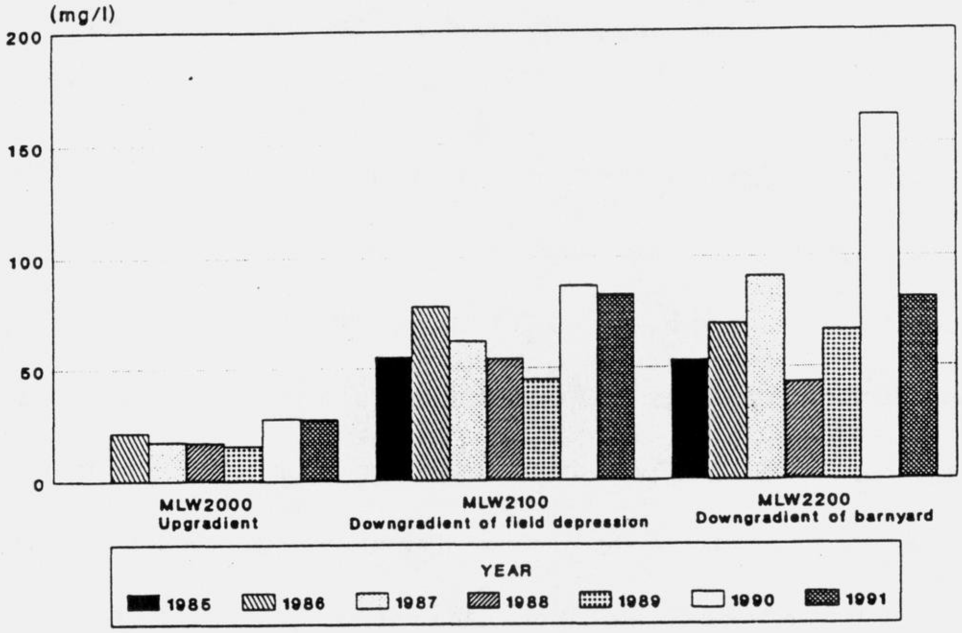
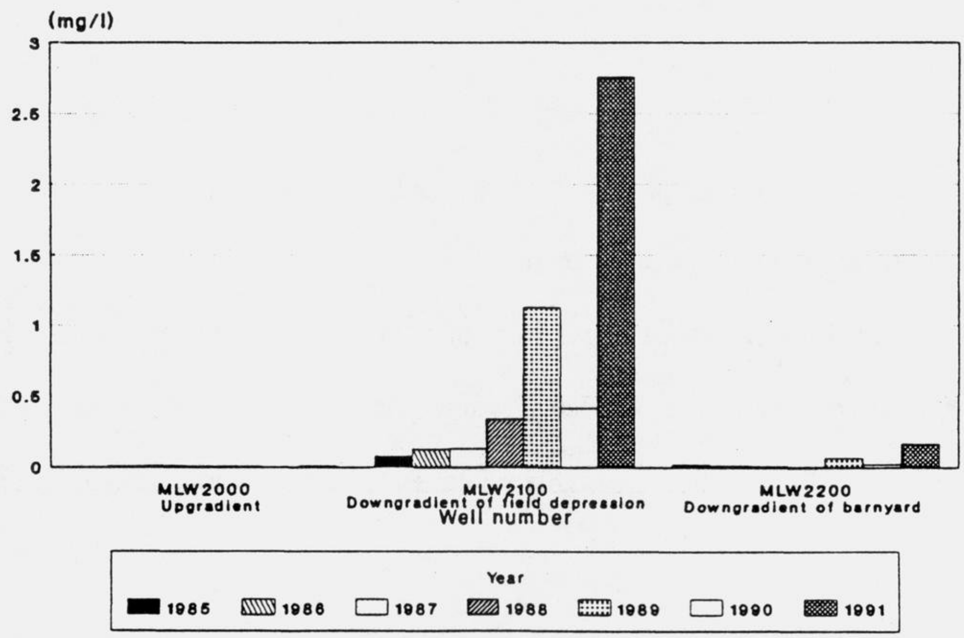


Figure 9. (cont.)

(C) AVERAGE CHLORIDE (mg/l)
Site 2 Contaminant Plume or
Upper 4.6 m of Aquifer (Upgradient)



(D) AVERAGE REACTIVE PHOSPHOROUS (mg/l PO4-)
Site 2 Contaminant Plume or
Upper 4.6 m of Aquifer (Upgradient)

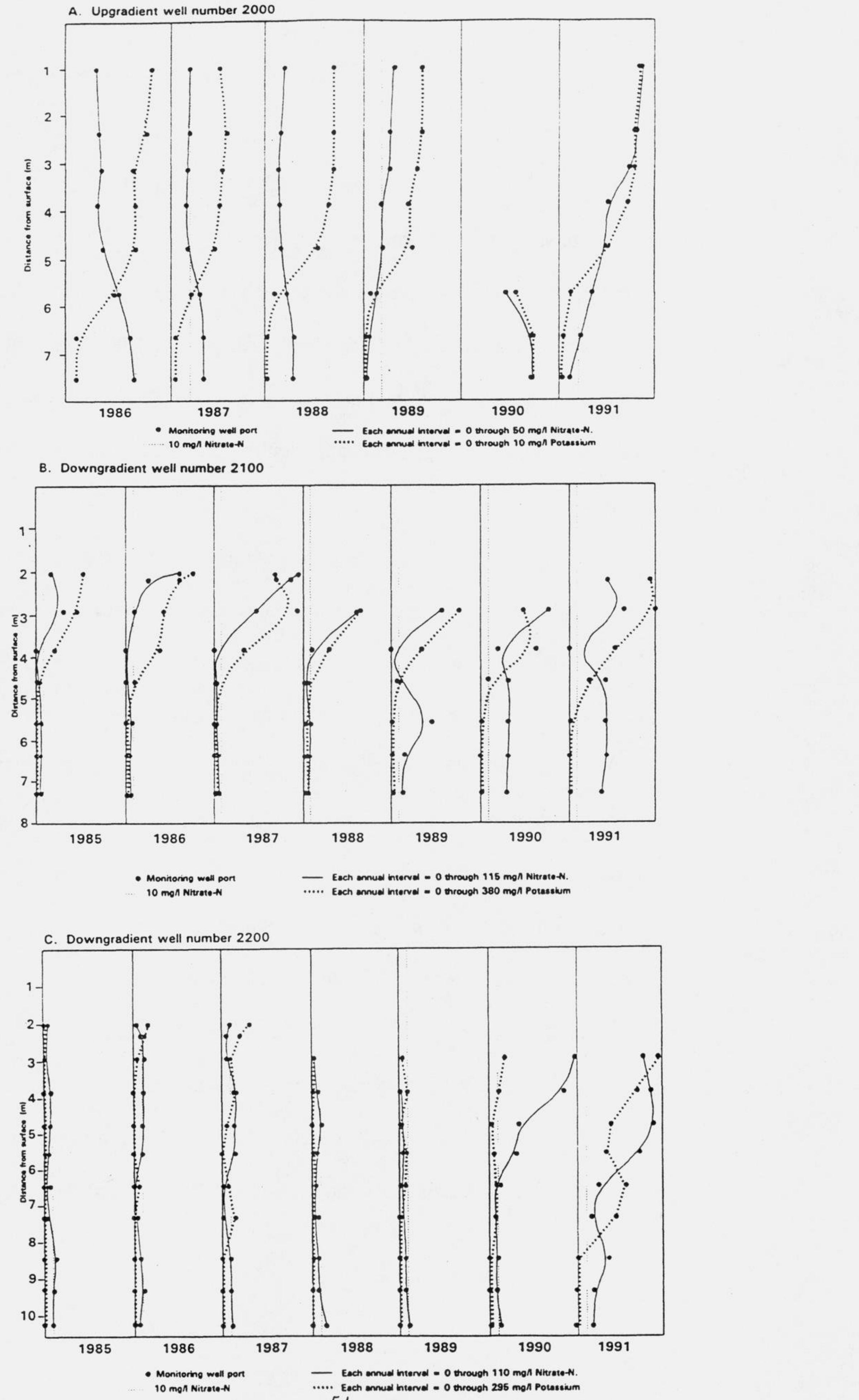


that hoof compaction at site two fairly effectively prevented much leaching through the earthen barnyard. We feel the impacts observed prior to 1989 at the 2200 well were largely from leaching along the edge of the yard, where hoof compaction was not sufficient.

The field depression received runoff from site one and two, especially during spring snow melt and other very heavy rainfall periods. While it is difficult to estimate total manure loading to this site, a several mm thick layer of organic debris was often observed after the spring ponding subsided. The well 2100 was obviously impacted with elevated potassium, nitrate-N, chloride and phosphorous as shown in figures 9a-d and 10. Figure 10 shows that nitrate-N values in the shallow well ports at well 2100 often exceeded 50 mg/l and in excess of 100 mg/l on several samplings. These data clearly shows that areas receiving runoff from both earthen barnyards and paved barnyards pose serious threats to groundwater quality. The water quality condition at well 2100 did not improve after installation of manure storage facilities largely due to the diversion of runoff from the paved site one area to the same depression.

In 1989 the barnyard at site two was reduced in size and paved, with solid and liquid manure storage provided. This resulted in the abandonment of a large part of the earthen barnyard as seen in figure 3. No cost sharing was provided to remove and spread the residual manure from this site. Several requests were made to have the manure removed, as we felt it would pose a severe groundwater problem. Such removal did not fit into allowable practices for cost sharing. The data presented in

Figure 10. Profile of the average annual nitrate-N and potassium concentrations for upgradient and downgradient wells at site



Figures 9a-d clearly illustrate the result of abandoning the barnyard without removing the old manure.

Site Four Water Quality

The study area designated as site four is shown on Figure 4 before and after the installation of barnyard concrete and manure storage. Site four was and still is used as an exercise area for the dairy cows. The fact that the cattle spend much of their time at the southern end of this area results in the south third being largely devoid of vegetation and showing significant manure accumulation as discussed in the previous soil section.

The data on Figure 11 shows the average annual nitrate-N and potassium concentrations of this area, upgradient and downgradient, before and after the installation of manure storage. These results show the contaminant plume for the downgradient well to extend about 1.5 m into the aquifer. Figure 12 shows the nitrate-N and potassium profiles each year from 1986 through 1991, both upgradient and downgradient from the barnyard. The upgradient data will be discussed later, as it relates to upgradient land use. These data along with the average annual concentration data for the contaminant plume shown in Table 7 and Figure 13b, show this site to have resulted in nitrate-N contamination of greater than 20 mg/l prior to the installation of manure storage. The site was cultivated in 1989 in an attempt to reseed it, which for a variety of climatic reasons, failed to result in vigorous vegetative growth. The result of cultivation actually facilitated the conversion of residual manure nitrogen to nitrate-N and resulted in increased leaching to

Figure 11. Average concentrations (mg/l) of Potassium and Nitrate-N at Site 4 before and after installation of manure storage facilities. Cross section of the aquifer perpendicular to the flow.

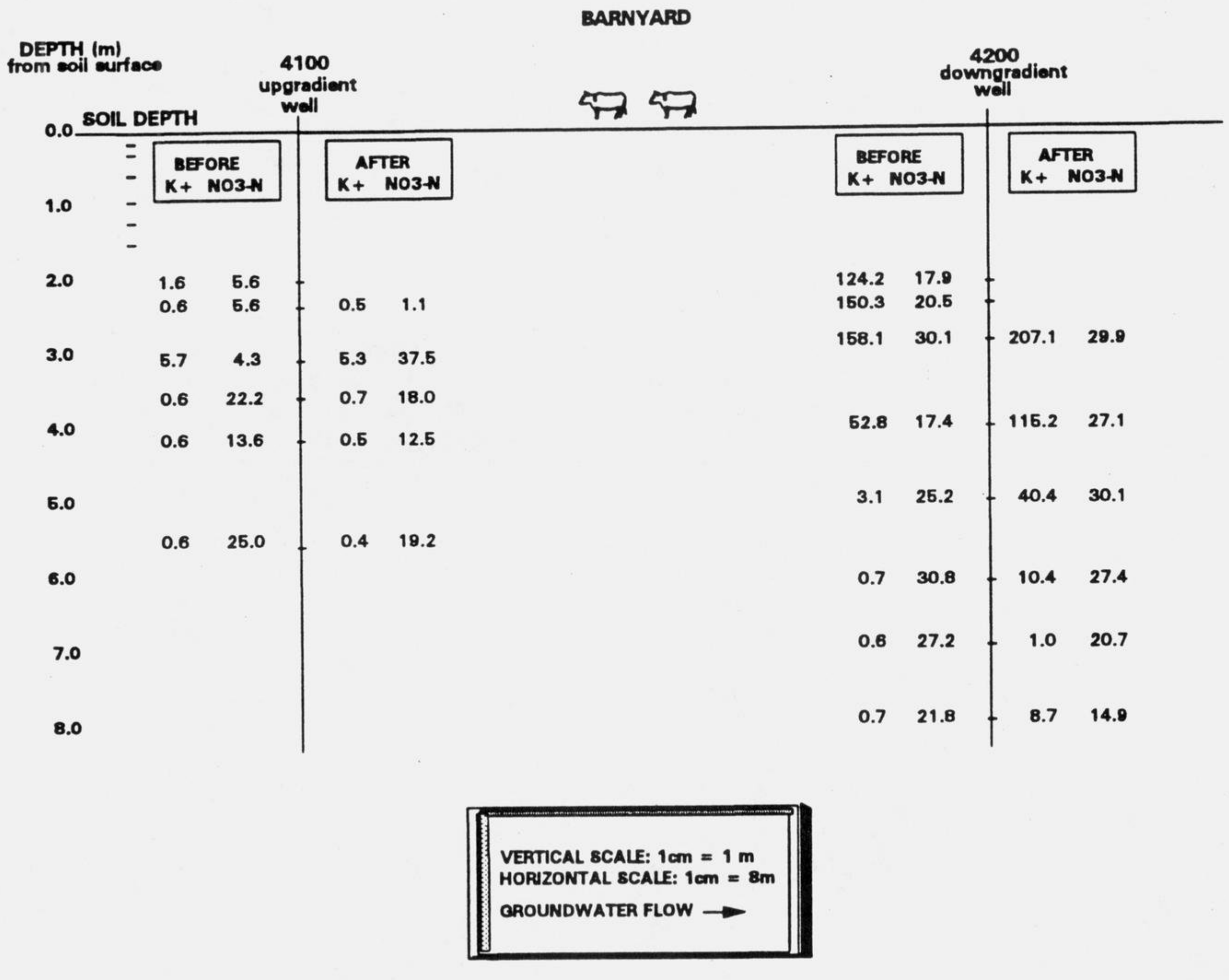
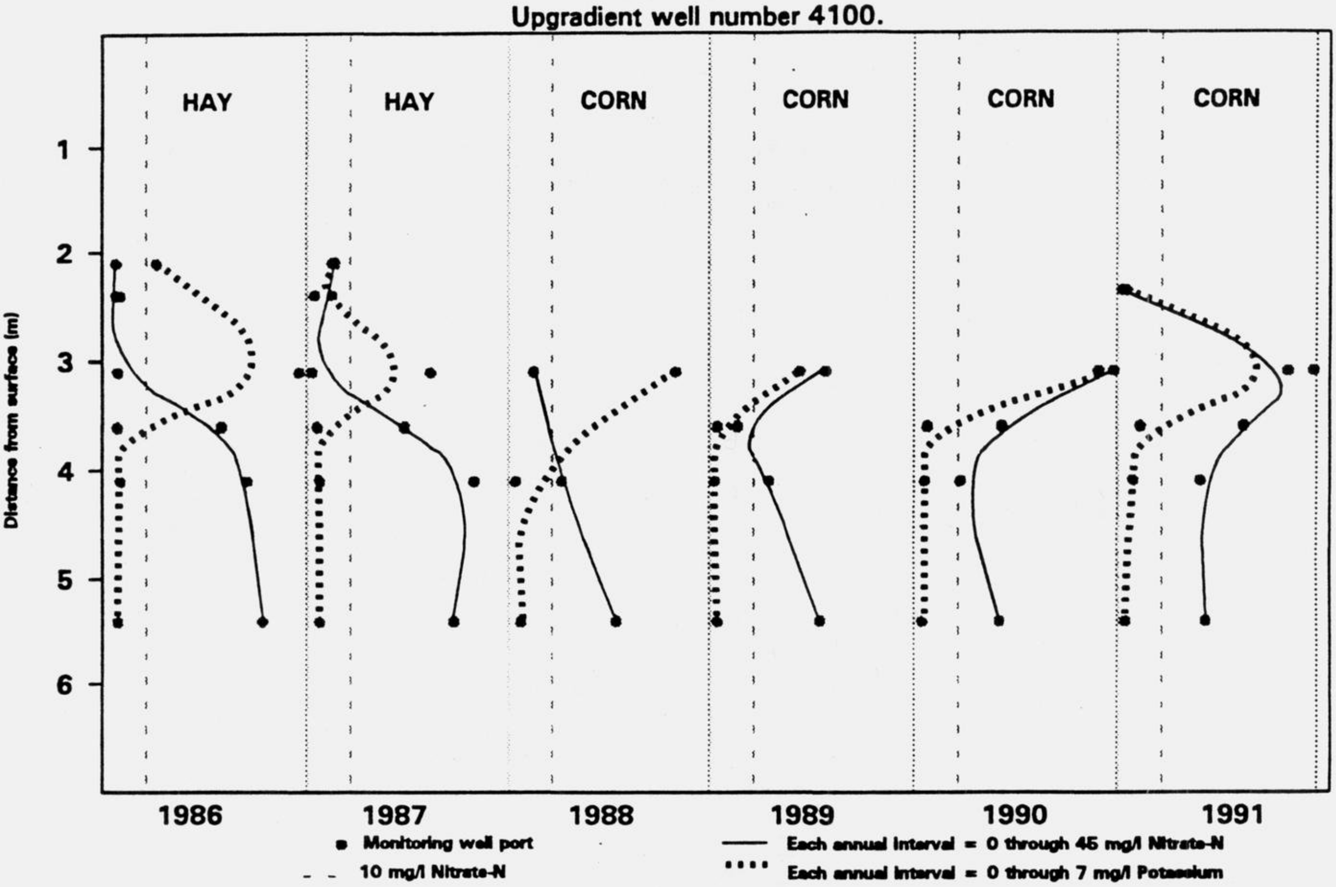


Figure 12. Profile of the average annual nitrate-N and potassium concentrations for upgradient and downgradient wells at site 4.



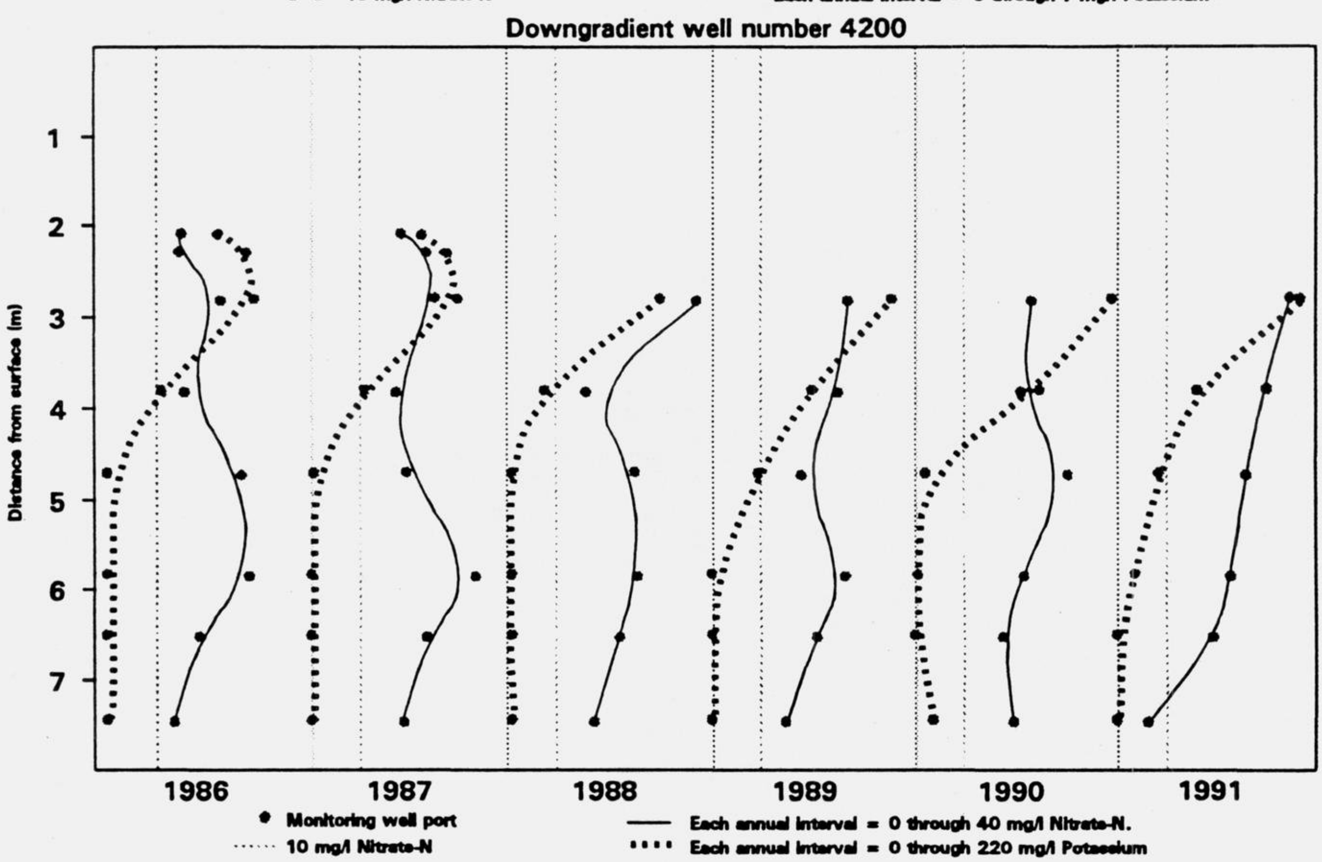


Table 7. Summary of chloride, potassium and nitrate-N for sites 4 and 5. 1985-1991

AVERAGE CHLORIDE (mg/l) values for Sites 4 and 5 in the contaminant plume (downgradient) or the upper 3.0 m of the aquifer (upgradient).

Well Number	1985	1986	1987	1988	1989	1990	1991
MLW4100 upgradient		34.3	34.9	24.9	27.2	44.5	38.2
MLW4200 downgradient		50.1	43.4	44.2	55.0	82.4	52.9
MLW5100 upgradient	31.5	37.7	32.5	36.7	40.4	33.4	38.5
MLW5200 downgradient	8.0	8.8	4.7	81.1	49.4	40.0	47.5
MLW5300 65 m downgradient	15.8	24.5	25.5	49.6	57.3	52.0	46.4

AVERAGE POTASSIUM (mg/l) values for Sites 4 and 5 in the contaminant plume (downgradient) or the upper 3.0 m of the aquifer (upgradient).

Well Number	1985	1986	1987	1988	1989	1990	1991
MLW4100 upgradient		2.2	1.4	2.3	1.1	5.5	2.1
MLW4200 downgradient		127.0	116.4	70.5	122.6	133.3	115.4
MLW5100 upgradient	1.1	1.1	0.7	0.5	0.5	0.3	0.6
MLW5200 downgradient	9.0	22.5	6.5	94.7	35.0	36.3	48.4
MLW5300 65 m downgradient	18.8	15.7	9.9	21.9	34.5	80.2	71.7

AVERAGE NITRATE-N (mg/l) values for Sites 4 and 5 in the contaminant plume (downgradient) or the upper 3.0 m of the aquifer (upgradient).

Well Number	1985	1986	1987	1988	1989	1990	1991
MLW4100 upgradient		14.4	12.1	13.1	16.9	22.6	23.2
MLW4200 downgradient		18.2	22.3	28.2	24.9	42.8	29.5
MLW5100 upgradient	22.2	16.5	16.7	17.5	8.3	8.6	9.9
MLW5200 downgradient	5.5	3.9	4.4	8.2	7.9	10.7	11.7
MLW5300 65 m downgradient	20.6	21.3	20.7	11.6	9.9	7.8	6.5

****Shaded area represents values obtained after the installation of the manure facility.**

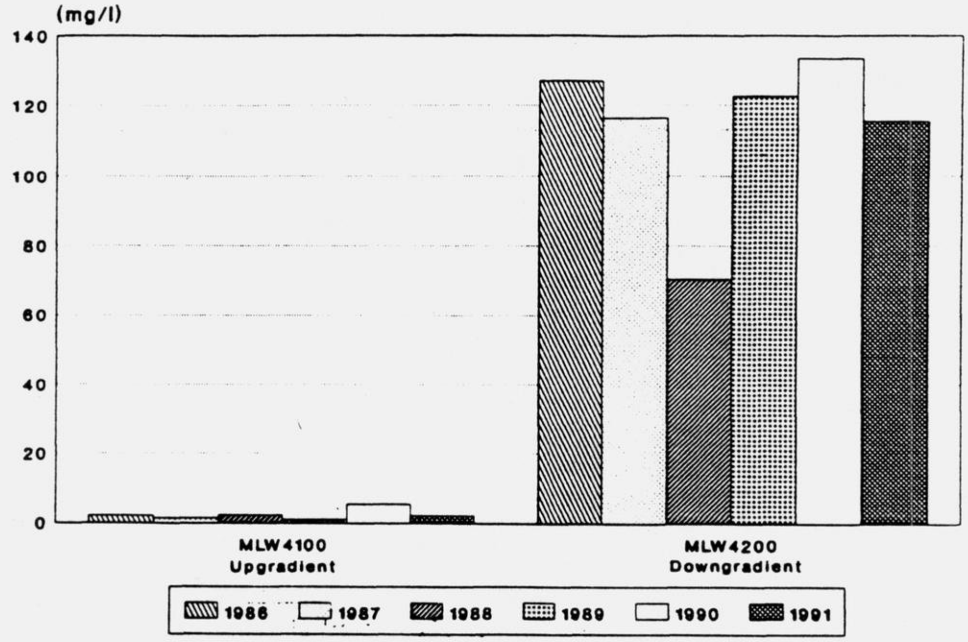
The average thickness of the contaminant plumes in downgradient wells (based on potassium concentrations) is as follows:

MLW4200 1.9 m

MLW5200 3.5 m
MLW5300 3.7 m

Figure 13. Bar graphs of average annual concentrations of potassium, nitrate-N, chloride and phosphorous in upgradient wells and contaminant plumes of downgradient wells at site 4.

(A) AVERAGE POTASSIUM (mg/l)
Site 4 Contaminant Plume or
Upper 3.0 m of Aquifer (Upgradient)



(B) AVERAGE NITRATE-N (mg/l)
Site 4 Contaminant Plume or
Upper 3.0 m of Aquifer (Upgradient)

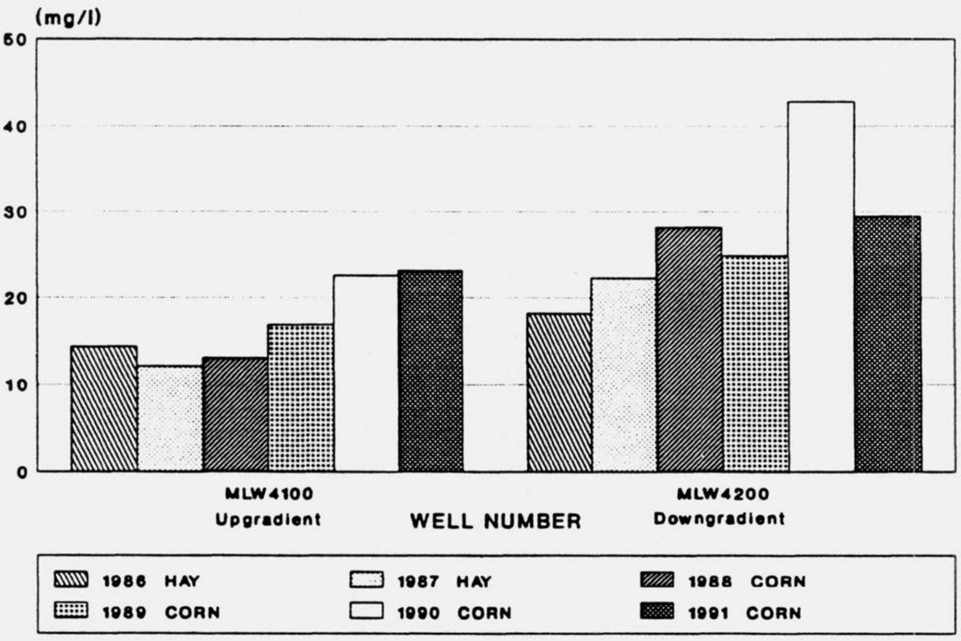
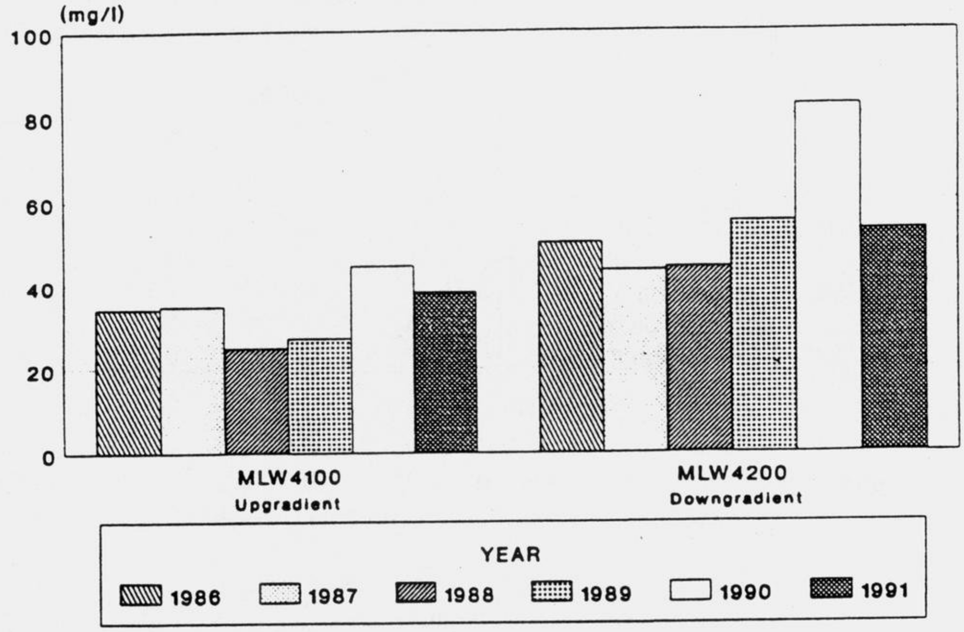


Figure 13. (cont.)

(C) AVERAGE CHLORIDE (mg/l)
Site 4 Contaminant Plume or
Upper 3.0 m of Aquifer (Upgradient)



(D) AVERAGE REACTIVE PHOSPHOROUS (mg/l PO4-)
Site 4 Contaminant Plume or
Upper 3.0 m of Aquifer (Upgradient)

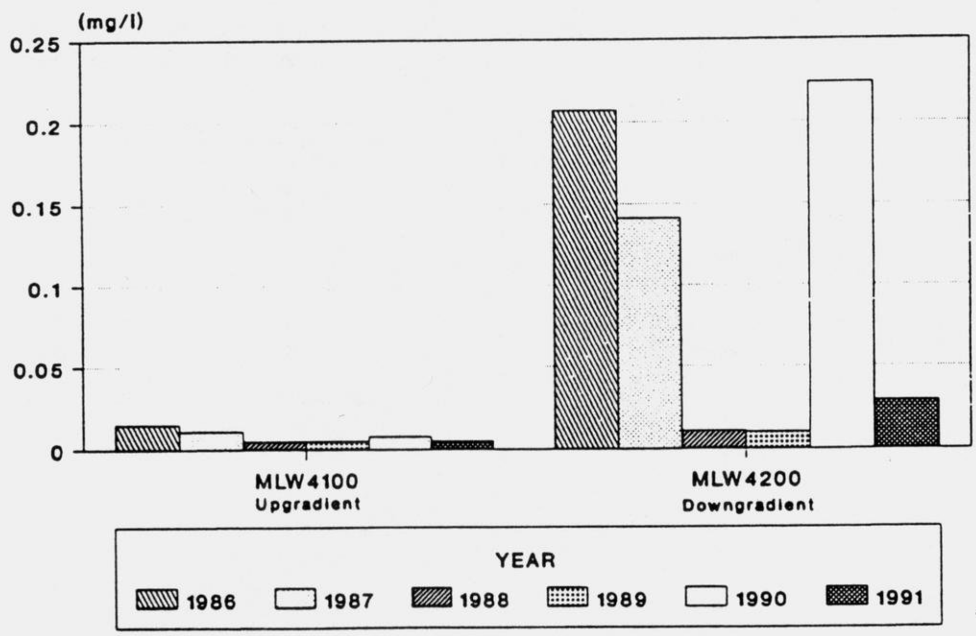


Table 8. Summary of chloride, potassium and nitrate-N before and after the installation of the manure storage facility.

AVERAGE CHLORIDE (mg/l) values in the contaminant plume (downgradient) or the upper 3.0 m of the aquifer (upgradient) for Sites 4 and 5 before and after the installation of the manure facility.

	BEFORE			AFTER		
Well Number	Average	Low	High	Average	Low	High
MLW4100 upgradient	23.1	24.9	34.9	36.6	27.2	44.5
MLW4200 downgradient	45.9	43.4	50.1	63.4	52.9	82.4
MLW5100 upgradient	34.6	31.5	37.7	37.4	33.4	40.4
MLW5200 downgradient	25.6	4.1	81.1	45.6	40	49.4
MLW5300 65 m downgradient	28.8	15.8	49.6	51.9	46.4	57.3

AVERAGE POTASSIUM (mg/l) values in the contaminant plume (downgradient) or the upper 3.0 m of the aquifer (upgradient) for Sites 4 and 5 before and after the installation of the manure facility.

	BEFORE			AFTER		
Well Number	Average	Low	High	Average	Low	High
MLW4100 upgradient	1.9	1.4	2.3	2.9	1.1	5.5
MLW4200 downgradient	104.6	70.5	127	123.8	115.4	133.3
MLW5100 upgradient	0.9	0.5	1.1	0.5	0.3	0.6
MLW5200 downgradient	33.2	6.5	94.7	39.9	48.4	36.3
MLW5300 65 m downgradient	16.6	9.9	21.9	61.9	34.5	80.2

AVERAGE NITRATE-N (mg/l) values in the contaminant plume (downgradient) or the upper 3.0 m of the aquifer (upgradient) for Sites 4 and 5 before and after the installation of the manure facility.

Well Number	BEFORE			AFTER		
	Average	Low	High	Average	Low	High
MLW4100 upgradient	13.2	12.1	14.4	20.9	16.9	23.2
MLW4200 downgradient	22.9	18.2	28.2	32.4	24.9	42.8
MLW5100 upgradient	18.2	16.5	22.2	8.9	8.3	9.9
MLW5200 downgradient	5.5	3.9	8.2	10.1	7.9	11.7
MLW5300 65 m downgradient	18.5	11.6	21.3	8.1	6.5	9.9

groundwater. Figures 13b and 12 show nitrate-N concentration to exceed 40 mg/l in 1990 following cultivation of this site. Conditions did not improve in 1991, as this site was again being used as an exercise area for cattle with no vegetation in the southern third of the area.

These data clearly show groundwater contamination at four times the drinking water standard, as a result of what could be considered a heavily used pasture or lightly used barnyard. There was actually more leaching occurring from under this site than from the heavily used earthen barnyard, where hoof compaction was adequate to prevent leaching.

The management plan which was recommended to the farmer was to decrease the size of this site and to establish and maintain permanent vegetation. This was obviously not accomplished by 1992.

The farmer wanted to provide a dry enclosure lot for his cattle for health and humanitarian reasons. It has been difficult to accomplish this without localized heavy use near the barn, which results in significant leaching. It may be necessary to use a rotational pasture arrangement to protect groundwater while still meeting the needs of the farmer in this type of situation.

The above data indicates significant potassium leaching along with nitrate-N and chloride for this site. This further indicates the potential usefulness of potassium as a tracer for groundwater impacts resulting from dairy manure. Potassium values increased in 1989-91 (figure 13a), which indicates increased leaching after the cultivation of the site and no reduction in animal use. The cultivation of the site may have actually enhanced the leaching of contaminants. Figure 13d shows the phosphorous concentration found in the contaminant plume downgradient of this site. These values are not as high as found downgradient of sites one or two, but show significant leaching during several time periods.

Site Five Water Quality

Site five represented a small farm barnyard where manure was regularly scraped and removed about every two weeks. The site included a feed bunk and provided space for the herd between milking, as well as a winter exercise area. Figure 4 shows the site and monitoring wells used for this site. The soil data indicated a lack of a hoof compaction layer, and showed nitrate occurrence under the site (table 4).

This site included two downgradient monitoring well nests, the 5200 well immediately downgradient of the yard, and the 5300 an additional 65 m downgradient of the yard. Average results of nitrate-N and potassium from before and after installation of the pavement and manure storage are presented in figure 14. This figure shows a contaminant plume (as indicated by potassium values) to occur in the upper 2 m of the aquifer at site 5200, and to occur at between 1 and 5 m below the water table at site 5300. This figure, along with figures 15a, 15b 15c and figures 16a-c show that prior to installation of the manure holding facilities, while nitrate-N leaching did occur from this site, it was generally below the 10 mg/l standard at site 5200 and averaged about 20 mg/l at site 5300. This data indicate that well nest 5300 was located more directly in the contaminant plume than the 5200 well nest.

There is a significant decrease in nitrate-N since 1987 at site 5300 (figure 15b),

Figure 14. Average concentrations (mg/l) of Potassium and Nitrate-N at Site 5 before and after installation of manure storage facilities. Cross section of the aquifer perpendicular to the flow.

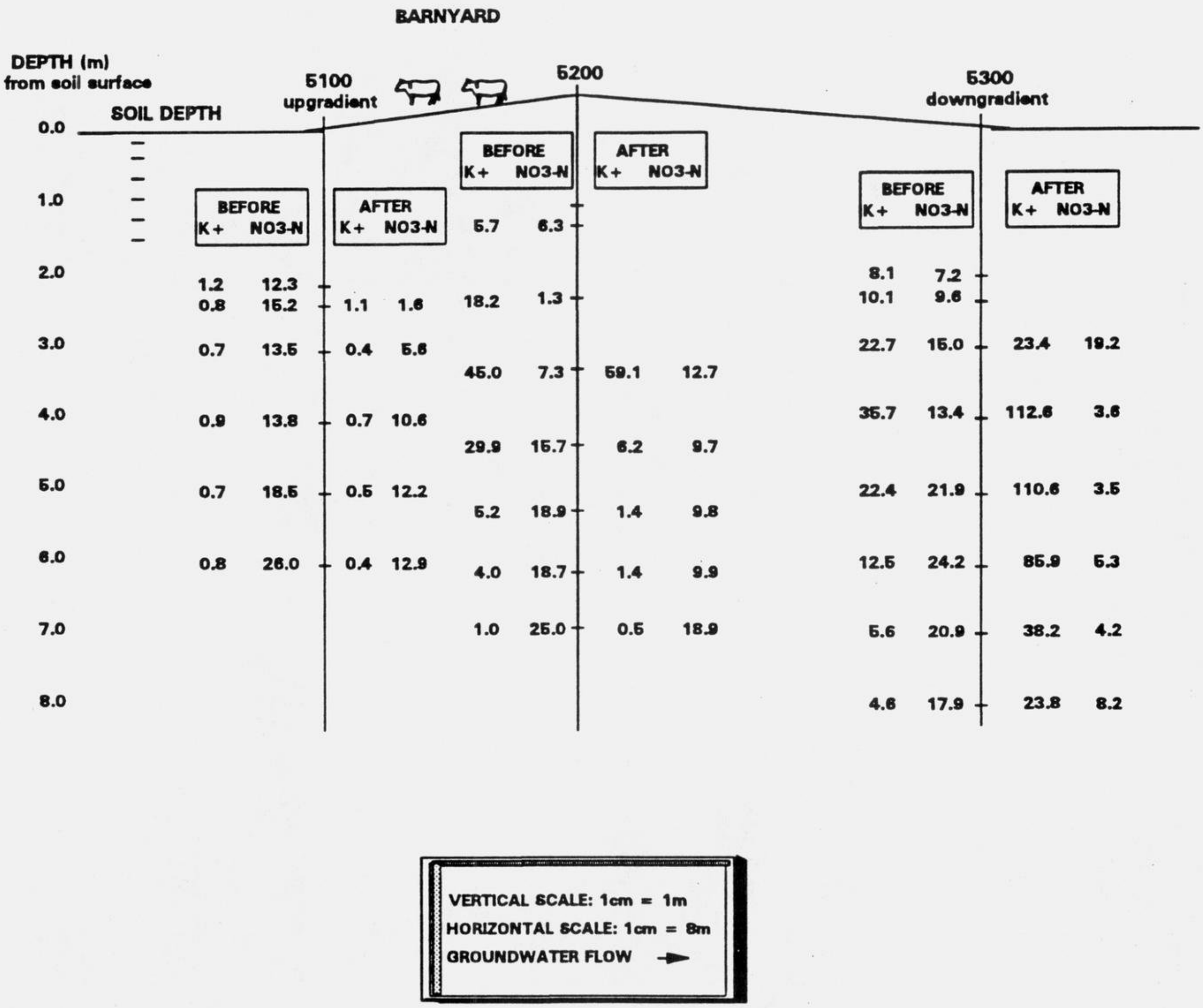
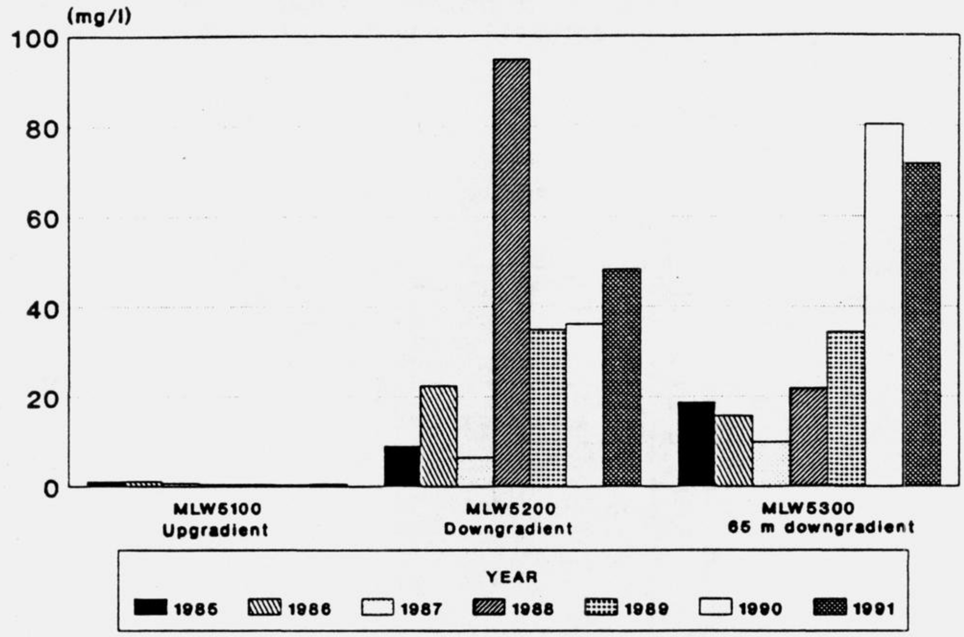


Figure 15. Bar graphs of average annual concentrations of potassium, nitrate-N, chloride and phosphorous in upgradient wells and contaminant plumes of downgradient wells at site 5.

(A) AVERAGE POTASSIUM (mg/l)
Site 5 Contaminant Plume or
Upper 3.0 m of Aquifer (Upgradient)



(B) AVERAGE NITRATE-N (mg/l)
Site 5 Contaminant Plume or
Upper 3.0 m of Aquifer (Upgradient)

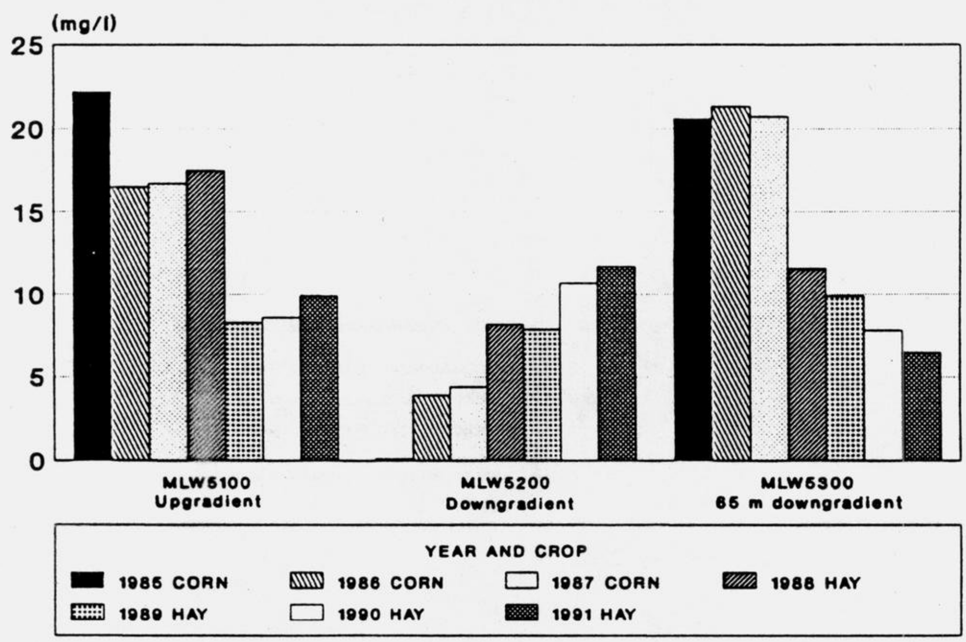
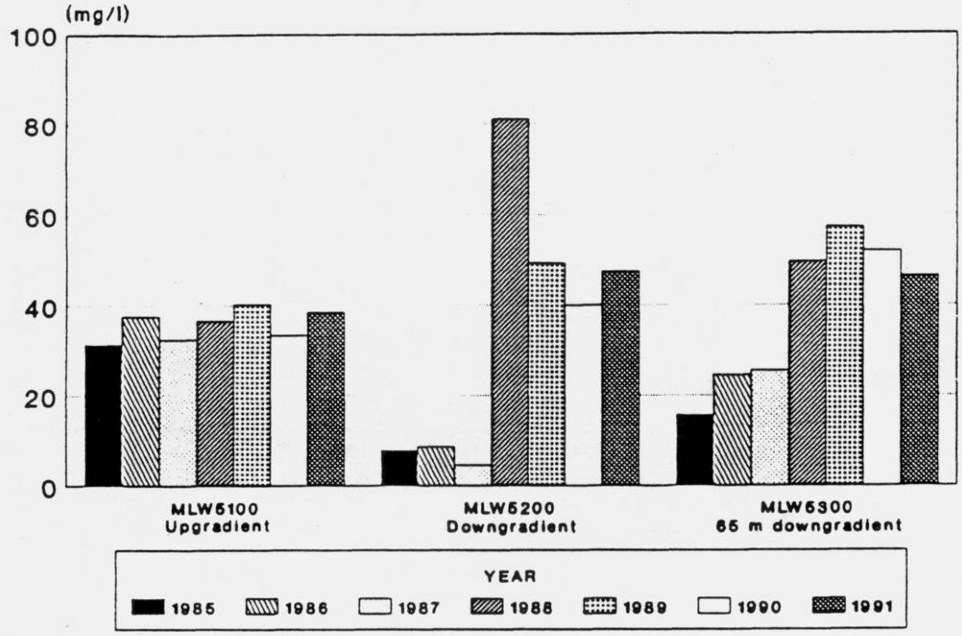


Figure 15. (cont.)

(C) AVERAGE CHLORIDE (mg/l)
Site 5 Contaminant Plume or
Upper 3.0 m of Aquifer (Upgradient)



(D) AVERAGE REACTIVE PHOSPHOROUS (mg/l PO4-)
Site 5 Contaminant Plume or
Upper 3.0 m of Aquifer (Upgradient)

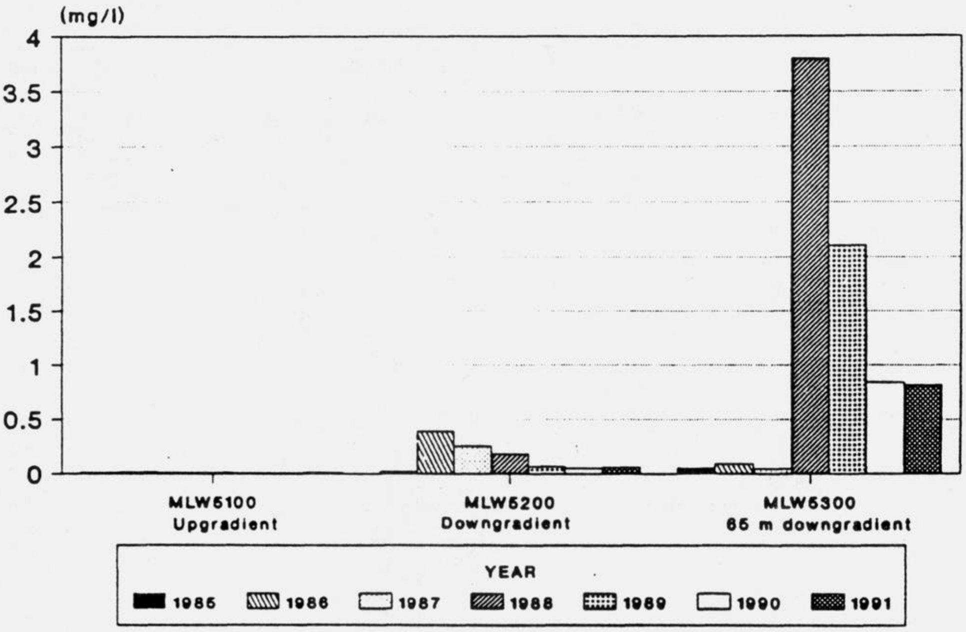
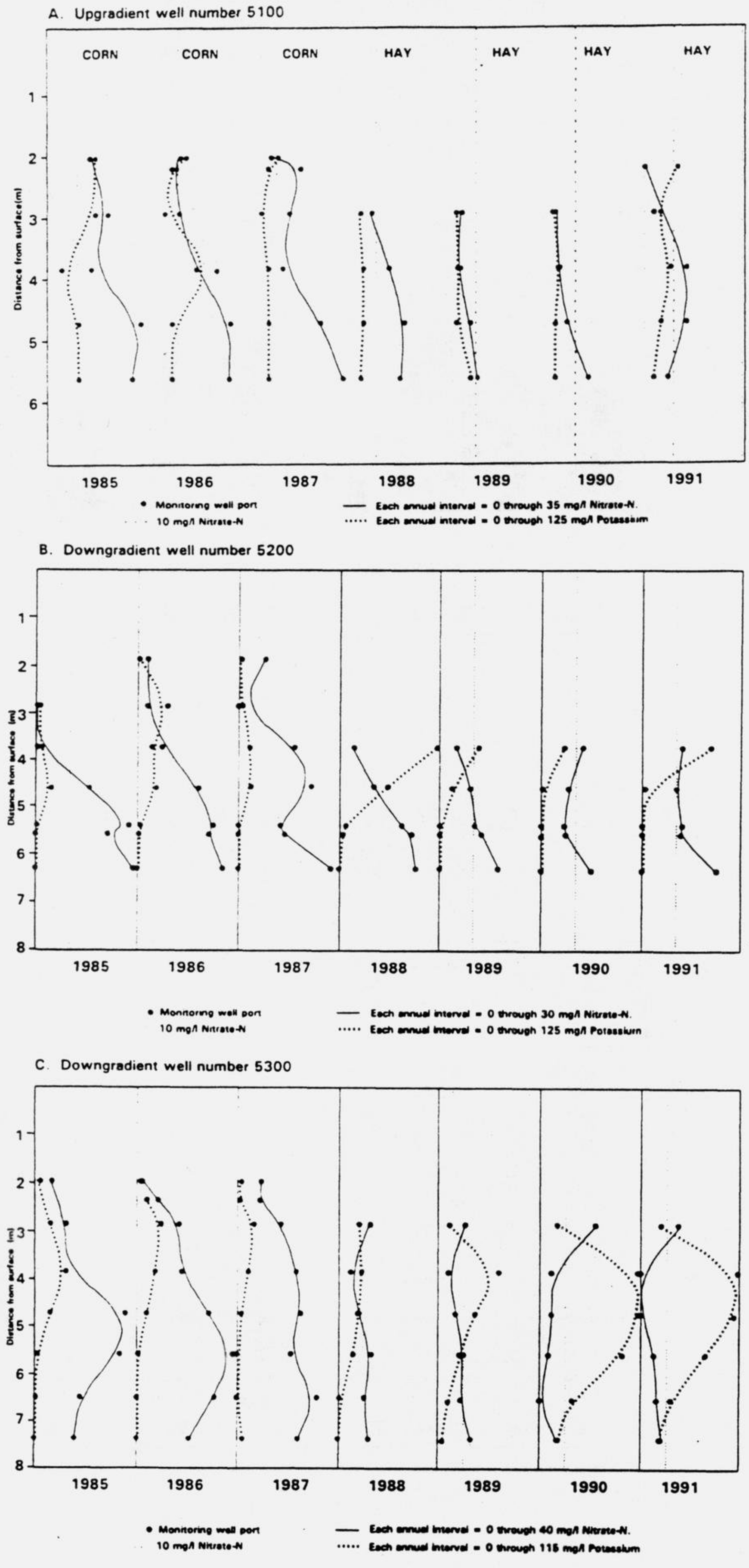


Figure 16. Profile of the average annual nitrate-N and potassium concentrations for upgradient and downgradient wells at site 5



which can be attributed to the installation of the concrete barnyard and manure storage. Potassium, chloride and phosphorous levels at site 5200 and 5300 had increased somewhat over the same time period, which may indicate residual effects of contaminants leached prior to the installation of the practices. The increase in nitrate-N and potassium observed for site 5200 since installation of practices is difficult to explain, but may relate to increased leaching associated with the construction activities. Nitrate-N values occasionally exceeded 10 mg/l at well 5200, but were generally lower than other sites and lower than concentrations found in upgradient wells.

In general, it appears that water quality is improving downgradient of this site as a result of paving the site. The data however, point out that for even a small site such as this, the improvement in groundwater quality occurs over a number of years after installation of practices to reduce leaching. It would have been desirable to monitor this site for several more years to more clearly observe ultimate changes in groundwater quality.

The paving of small earthen barnyards near a feed bunk where manure is removed may be of the most cost effective practice for farms on sandy soils to aid in the protection of groundwater. These sites are susceptible to continued leaching and receive sufficient manure loading to impact groundwater quality. Within 65 m of the barnyard groundwater nitrate-N levels have run between 10 and 20 mg/l.

Upgradient Land Use Effects on Water Quality

The nested wells placed upgradient of the barnyards monitored the impacts of varying cropping practices on groundwater over a seven year period. The average annual data for nitrate-N and potassium for these sites are presented in figures 17 for sites one and two and 18 for sites four and five. Land use data including crop type and fertilizer application are presented in table 1.

Results for each well port are presented in this data, as it is otherwise difficult to establish what depths into the aquifer are impacted by the land use immediately upgradient of the monitoring wells. Potassium data is plotted with nitrate-N to allow for evaluation of whether animal waste associated with the barnyard is impacting this upgradient water quality.

The data for well nest 1100 at site one, (figure 17) show little impact of animal waste until 1990, when manure hauling operations apparently effected both nitrate-N and potassium results. Cropping practices upgradient of both wells 1100 and 2000 were the same and are listed on figure 17 and table 1. The fertilization practices used for these crops resulted in the nitrate-N concentration consistently exceeding 10 mg/l in the upper 2 m of the aquifer, and generally ranging between 15 and 40 mg/l nitrate-N at site 1100. Site 2000, downgradient of the same field, shows significantly less nitrate-N contamination of groundwater. Fertilizer rates were similar for both sites. The major potential explanation for the variability is the fact that well 2000 is further from the barn and apparently received less manure than the field area upgradient of the 1100 well. The sharp increase in nitrate-N levels at both sites 1100 and 2000 in 1990 and 1991 may be due to both increased leaching from greater precipitation compared to the dry year of 1988-89. The additional manure available for spreading due to the addition of manure storage may also account for greater leaching in 1990-91 since appropriate nitrogen credits from the manure were not considered in the determination of the amount of nitrogen fertilizer being applied. These data further emphasize the susceptibility of these soils to nitrogen leaching and indicates the variability of water quality with depth into the aquifer that is often observed. Variations in upgradient land use and groundwater recharge account for the variability observed. The fertilizer amounts reported to be used by this farmer are similar to what is currently recommended for these crops as Best Management Practices. These levels of fertilizer use are apparently high enough to cause nitrate levels in groundwater to exceed the 10 mg/l standard.

Site four and five upgradient well data show very clear differences between corn and alfalfa impacts on groundwater quality. The field east of site four and five are rotated between field corn and alfalfa with the well 4100 and 5100 (figure 19) adjacent and downgradient of each half of the field. Figures 17 and 18 explicitly show the impact of these two crops on groundwater quality. The year when alfalfa hay was the adjacent crop, nitrate-N levels remained well below 10 mg/l, and often fell into the 2-5 mg/l range. After conversion to corn, nitrate-N concentration in the impacted part of the aquifer rose to between 20 and 45 mg/l at site four and 10 to 20 mg/l at site five. Fertilizer use by the farmer as shown in table 1 are not greater than current recommendations, however alfalfa and manure credits were not taken, which should reduce fertilizer use and nitrate leaching.

Figure 17. Profile of the average annual nitrate-N and potassium concentrations for upgradient wells at sites 1 and 2.

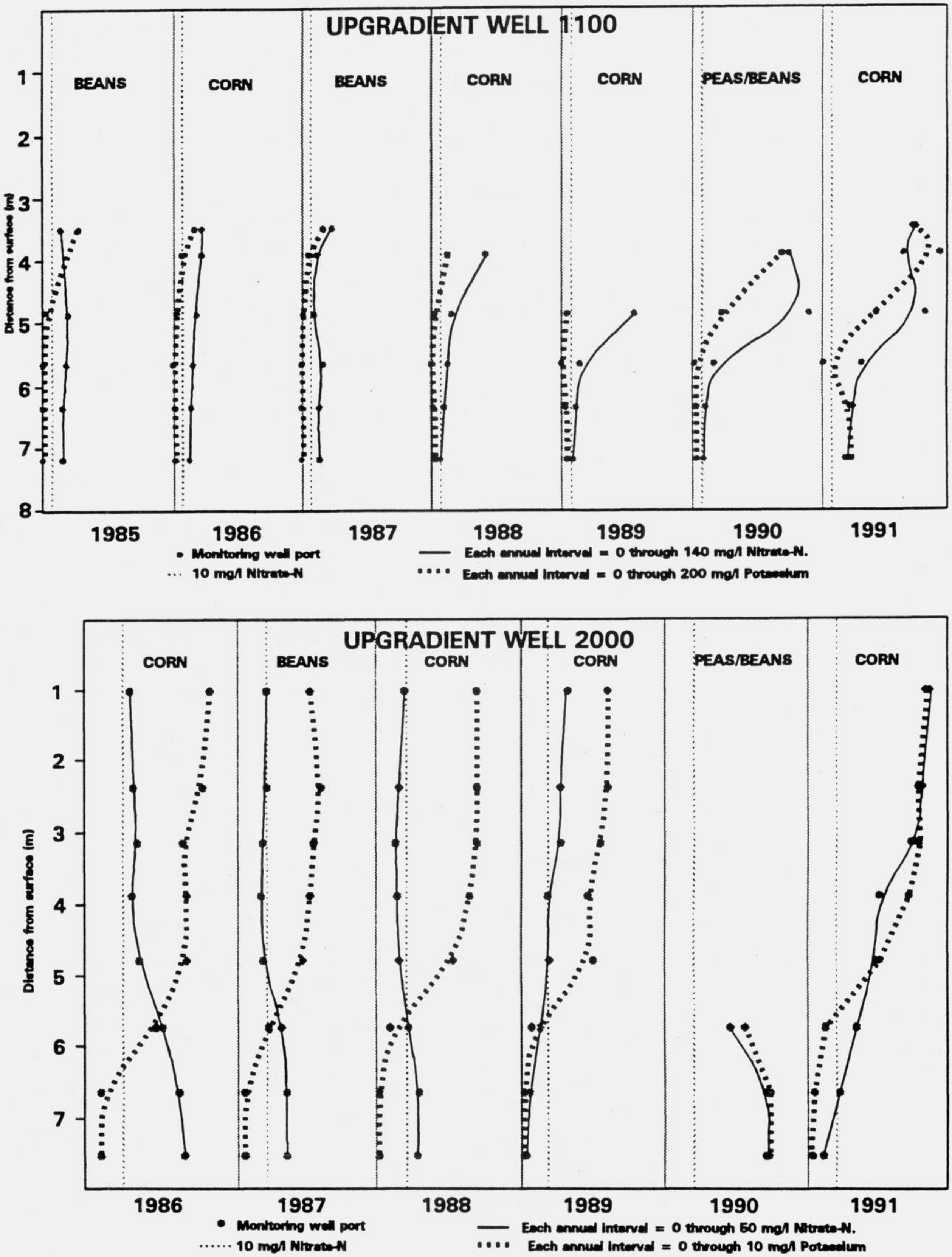
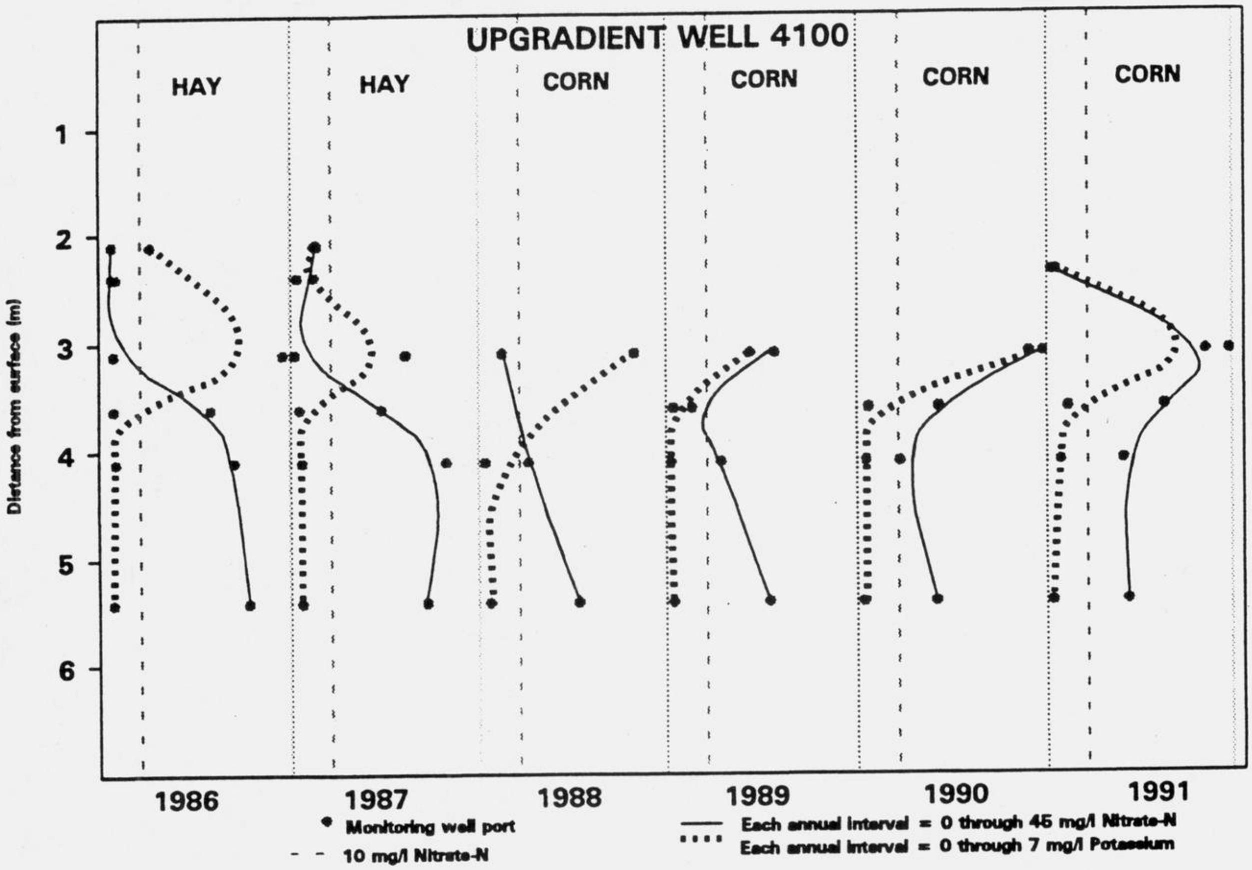


Figure 18. Profile of the average annual nitrate-N and potassium concentrations for upgradient wells at sites 4 and 5.



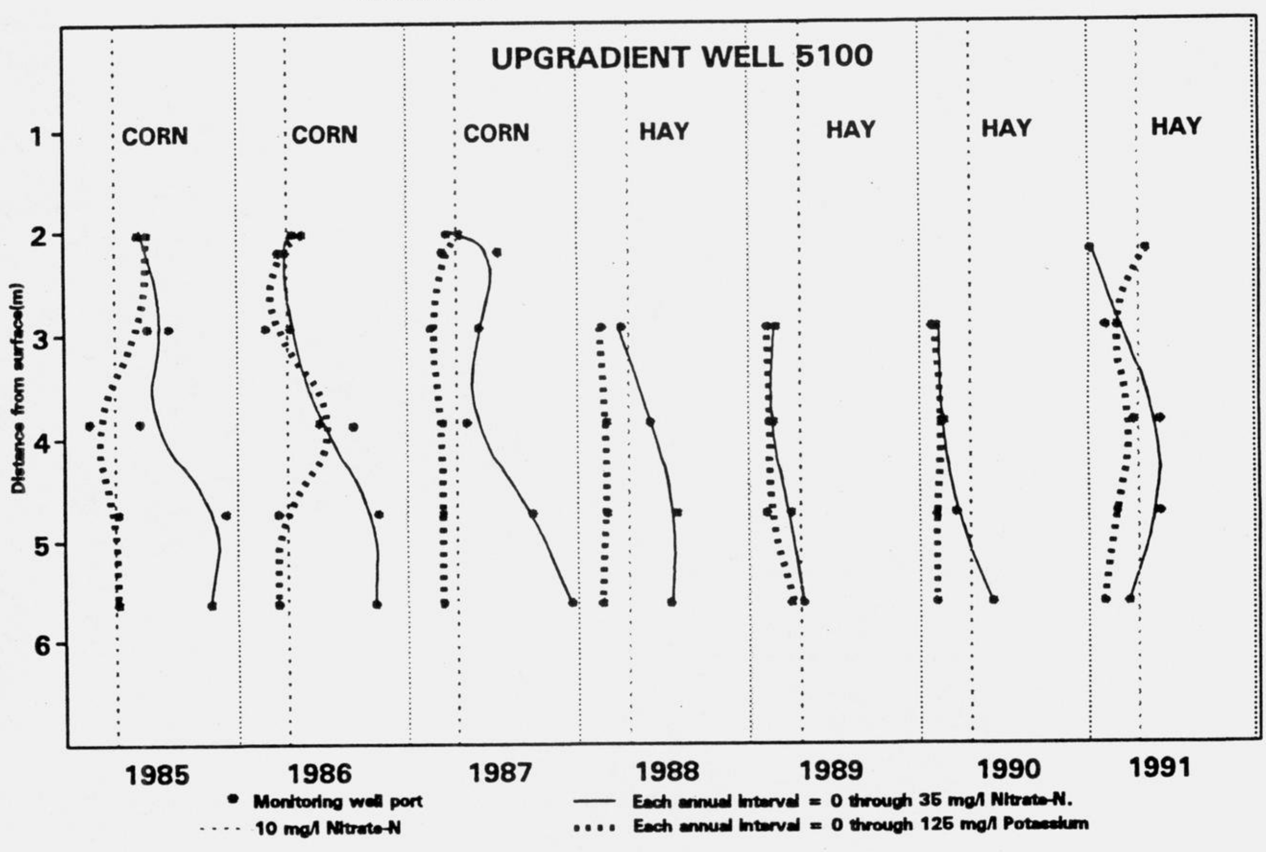


Figure 19. Plan view map of Sites Four and Five with Agricultural Field Designations Upgradient from the Barnyard Study Areas.

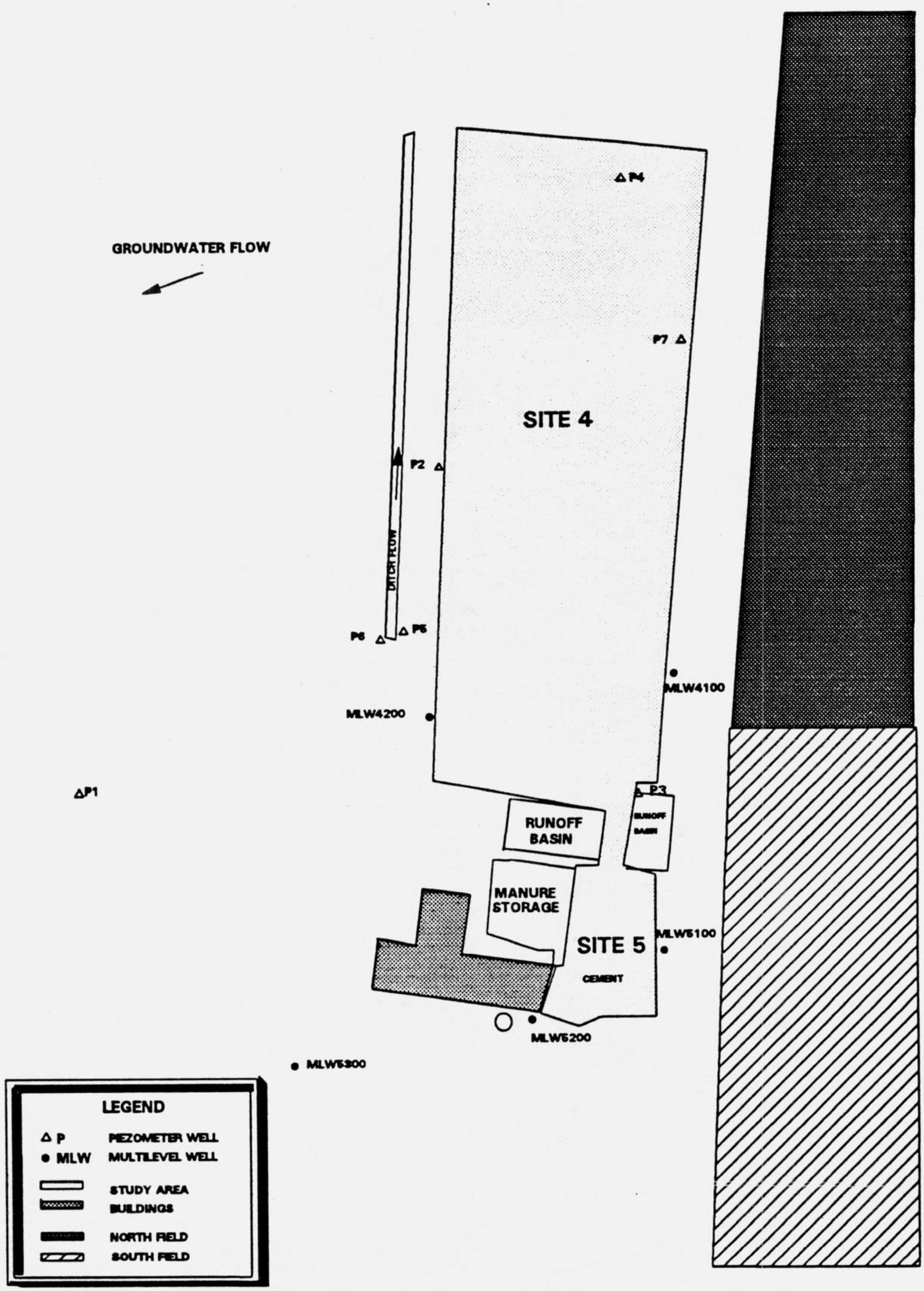
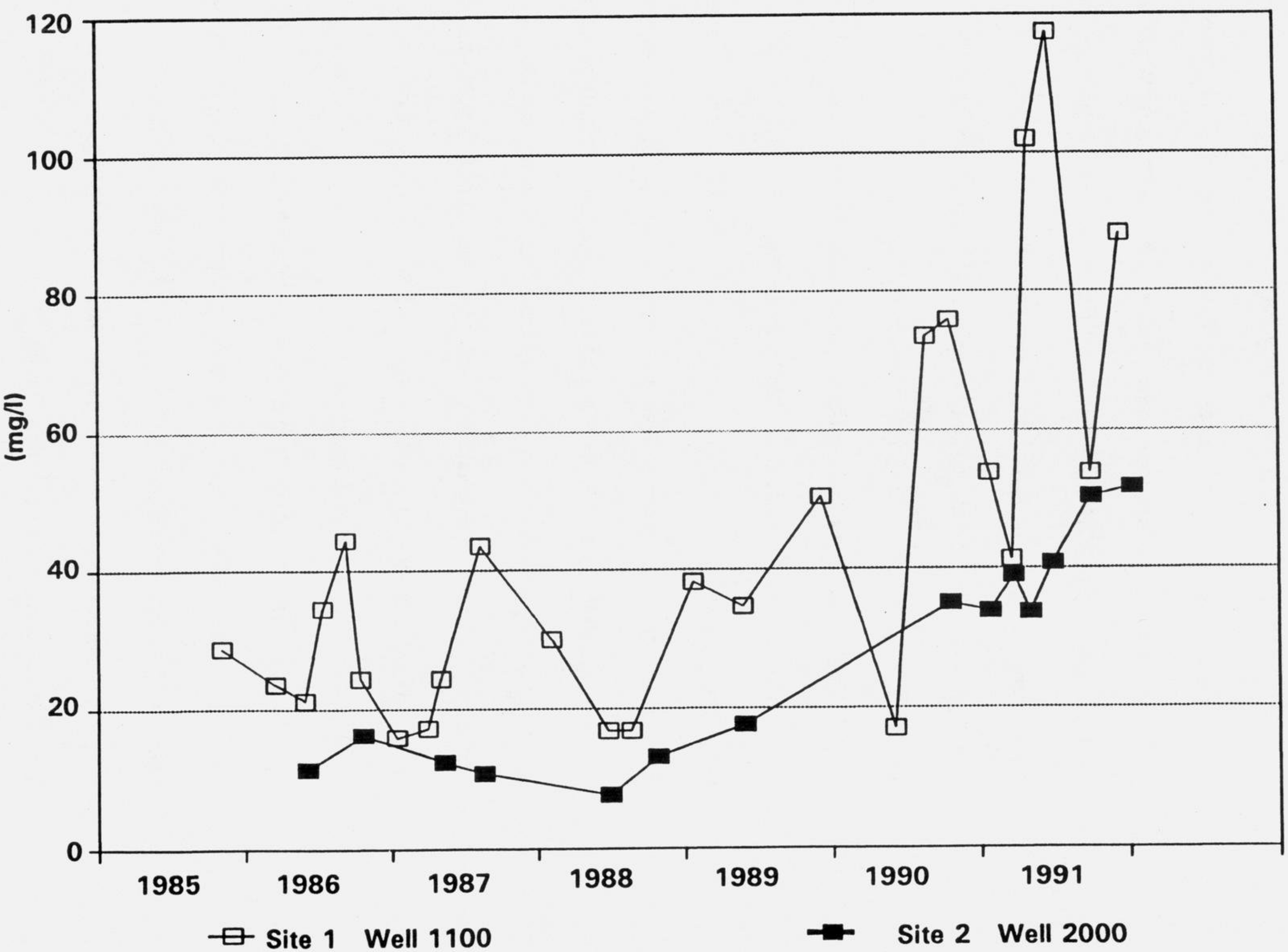


Figure 20. Average concentration of nitrate-N in the top 3 yielding ports of the upgradient multiport wells at sites 1 and 2. 1985-1991



SUMMARY AND CONCLUSIONS

Sandy Barnyards

Barnyards on sandy soils in central Wisconsin were found to vary widely in the extent of their impacts to groundwater quality. Nitrogen in downgradient wells ranged from 12.9 to 37.6 mg/l prior to the installation of improvements. Chloride ranged from 25 to 82 mg/l and potassium from 80 to 212 mg/l.

Barnyard management, animal density and areas receiving runoff from barnyards are major factors determining groundwater impacts.

At animal densities greater than 1 animal per 80 m^2, there is sufficient hoof compaction to effectively seal the barnyard proper from leaking. This decreased infiltration can lead to increased runoff carrying manure to nearby depressions, ditches, and fence lines where leaching and groundwater impacts may occur.

Lower animal densities may not result in decreased infiltration and may cause greater leaching than high animal densities. Sites with more than 300 m^2 per animal resulted in higher nitrate concentrations than sites with higher animal densities. This density is high enough to overload soils with nitrogen, yet does not permit sufficient hoof compaction to prevent leaching.

Regular scraping of sandy barnyards reduced manure buildup and made use of the manure, but did not prevent leaching, as hoof compaction did not develop to prevent leaching.

Field depressions receiving manure laden runoff were found to be sites of high leaching and groundwater contamination.

Non compacted fence lines along barnyard edges are sites of higher leaching than central parts of the barnyards.

Based on the above information the following recommendations are presented. Barnyards on sandy soils where animal densities exceed 80 m^2 per animal do not need paving in the barnyard proper. Paving or curbing along the edges and fence lines could prevent leaching in the non compacted areas and allow for directing runoff water to the most suitable disposal point.

Runoff from paved or improved barnyards can be a significant impact to groundwater and should be controlled to the extent possible. All roof runoff and upgradient runoff should be diverted from the barnyard. Collecting barnyard runoff and application to fields is the optimal system. However, if this is not possible, dispersing the runoff onto as large an area of permanent vegetation to maximize nutrient use is far better than allowing it to runoff to a field depression, especially if they do not contain permanent vegetation.

Results of Paving Barnyards and Installing Manure Holding Facilities

Barnyards were reduced in size to 6.9-9 m^2 per animal and paved in 1989 with both solid manure storage and lagoons for holding liquid runoff. Results as of spring of 1992 have shown improvement in groundwater nitrate-N at site five. When nitrate-N has been reduced from 21 to 6.5 mg/l, no residual manure had been left at this site. The other three sites have actually increased in nitrate-N concentrations with most of the impact attributed to residual manure from abandoned barnyards which increased leaching once active hoof compaction was eliminated. One of the sites (Site one) had increases primarily from manure accidently stacked off the edge of the paved barnyard. Nitrate contamination even increased downgradient of Site four after this heavily used pasture was tilled and replanted. This activity allowed for more rapid leaching of the accumulated manure after tillage. This data indicates that even the best designed manure management systems will not solve groundwater contamination problems unless careful management and handling of manure is practiced by the farmer and residual manure in abandoned barnyards is removed and spread on fields.

Abandoned Barnyards

When abandoned, barnyards loose the hoof compacted layer quickly and begin to leach very high amounts of nitrogen. We observed values in excess of 100 mg/l nitrate-N after site two was abandoned. There was in excess of 7.9 metric tons/hectare of organic-N in the upper foot of soil for this site, much of which could leach upon the site being abandoned. It is still unclear as to how long it will take for decomposition and leaching of the manure left on the abandoned site. I recommend this site be monitored on a quarterly basis until improvement in groundwater quality is observed.

These data lead to the obvious conclusion that barnyards to be abandoned need to have the residual upper foot of manure/soil mixture removed and spread on land, with appropriate nutrient credit used.

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APPENDIX

Table 1. Site 1 Potassium concentrations (mg/l)

Sample Date	1101	1102	1103	1104	1105	1106	1201	1202	1203	1204	1205	1206	1301	1302	1303	1304	1305	1306	1307	1308	1401	1402	1403	1404	1405	1406	1407	1408
11/06/85	60.0		10.5	2.5	5.0	6.0	645.0		107.5	85.0	207.0		147.0		500.0	210.0	255.0	265.0	275.0	38.0	107.5		85.0	65.0	65.0	85.0	110.0	67.5
02/03/86																												
03/18/86	6.3	9.3	6.0	2.0	5.0	5.8	312.0	308.0	180.0	170.0	116.0	50.0			200.0	164.0		190.0				48.0	120.0	150.0	180.0	212.0	185.0	123.0
03/31/86																												
04/17/86							265.0	240.0	165.0	145.0	90.0	65.0																
05/07/86							275.0	215.0	155.0	200.0	105.0	60.0																
05/27/86																												
05/28/86																												
06/18/86																												
07/14/86	73.0	22.5	10.0	2.5	7.0	7.5	315.0	275.0	205.0	140.0	120.0	60.0	415.0	450.0	375.0	25.0	26.0	27.0	26.0	73.0		44.5	135.0	185.0	185.0	235.0	240.0	150.0
08/11/86							450.0	275.0	175.0	125.0	250.0	63.0																
09/09/86	49.0	29.2	10.4	2.0	5.8	6.2	375.0	320.0	198.0	198.0	138.0	57.6																
09/17/86																						195.0	124.0	98.0	164.0	166.0	169.0	189.0
09/22/86													160.0	208.0	229.0	260.0	202.0	208.0	169.0	49.0								
10/02/86							236.0	242.0	236.0	178.0	68.0	96.6	164.0	274.0	208.0	214.0	250.0	155.0	128.0	35.0								
10/15/86	31.8	20.5	9.7	1.5	6.0	6.1	250.0	235.0	197.0	142.0	54.0	40.0	121.0	156.0	239.0	201.0	222.0	225.0	236.0	46.5	61.0	63.5	104.0	200.0	156.0	164.0	218.0	190.0
10/28/86							241.0	213.0	175.0	175.0	74.0	72.0	119.0	124.0	138.0	245.0	247.0	243.0	234.0	55.0								
11/11/86							250.0	210.0	173.0	148.0	65.0	35.2	215.0	134.0	136.0	190.0	197.0	205.0	183.0	55.0								
12/09/86							385.0	320.0	235.0	170.0	92.5	42.5	650.0	450.0	180.0	238.5	170.0		225.0	67.5								
01/12/87	34.1	12.0	6.8	2.1	5.0	6.0	10.0	236.0	237.0	188.0	167.0	87.0	35.7	495.0	318.0	172.0	188.0		180.0	55.0	36.4	70.0	93.0	161.0	195.0	190.0	207.0	92.0
02/10/87							245.0	247.0	180.0	235.0	110.0	50.0		335.0	150.0	200.0	163.0		190.0									
03/31/87	29.0	15.6	6.7	2.3	5.2	5.4	239.0	200.0	128.0	210.0	108.0	46.5	265.0	190.0	156.0	165.0	192.0	186.0	184.0	57.5	58.0	64.5	87.5	136.0	164.0	171.0	218.0	102.0
05/04/87	31.0	17.5	6.2	2.2	5.3	5.0							291.0	256.0	398.0	192.0	171.0	182.0	164.0	62.0	34.2	75.0	88.0	140.0	148.0	162.0	217.0	88.0
06/10/87	60.0	26.0	7.0	3.0	4.5	5.0		290.0	140.0	160.0	60.0	35.0		145.0	40.0	200.0	150.0	200.0	170.0	55.0			60.0	80.0	80.0	140.0	185.0	180.0
02/02/88															175.0	299.0	180.0	130.0	145.0	62.0			86.0	153.0	75.0	156.0	202.0	54.0
02/03/88		23.0	8.5		7.0				145.0	105.0		32.5																
02/04/88																												
02/05/88																												
06/20/88		33.5	9.5	3.0	8.5	9.0			130.0	60.0	28.0	24.0			80.0	85.0	140.0	137.5	120.0	65.0			47.5	97.5	112.5	140.0	60.0	85.0
08/17/88		31.2		5.0	10.0	10.0			162.0	148.0	47.1	27.0			111.0	91.0	142.0	146.0	172.0	55.0				115.0	139.0	150.0	190.0	131.0
10/17/88																												
01/19/89			17.5	4.5	10.0				162.5	102.5	19.5	16.0			117.5	152.5	112.5	87.5	65.0	57.5			105.0	135.0	147.5	162.5	200.0	
02/15/89																												
05/22/89			12.0	3.5	9.0				107.5	70.0	32.0	9.5			45.5	75.0	82.5	90.0	82.5	65.0			115.0	122.5	137.5	132.5	172.5	135.0
12/01/89				5.0	13.0	13.0			112.0	166.0	35.5	12.5																
05/31/90				11.0	5.6	10.4					98.0	7.2			54.4	62.8	61.2	61.2	40.9	41.4								
06/15/90			52.5	6.5	12.0	12.9																	100.0	100.0	12.5	125.0	150.0	110.0
10/12/90		142.0	46.0	8.5	12.5	12.5			12.0	204.0	15.5	12.5			28.0	52.0	90.0	82.0	74.0	38.0			80.0	82.0	100.0	108.0	128.0	90.0
10/20/90									12.0	204.0	15.5	12.5																
01/16/91			36.6	6.8	16.0	15.9									75.5	81.5	72.0	68.0	67.0	42.2			77.0	127.0	129.0	139.0	162.0	107.0
03/14/91			43.2	8.0	15.0	17.5									36.2	56.0	72.0	75.0	72.0	46.0			125.0	140.0	132.0	130.0	164.0	108.0
03/15/91																												
04/25/91																												
04/26/91	142.0	20.9	97.0	8.2	17.4	14.1		1447.0	516.0	100.0	62.0	9.5			36.5	80.0	87.0	90.0	95.0	95.0			52.0	134.0	114.0	129.0	129.0	110.0
06/19/91	161.0	33.5	146.0	9.1	17.2	19.6		1100.0	560.0	107.0	48.1	46.4		43.4	55.0	63.0	70.0	74.0	75.0	48.0	100.0		82.0	107.0	127.0	129.0	151.0	124.0
09/23/91																												
12/10/91		526.0	138.5	11.7	180.0	199.0			407.0	150.0	500.0	236.0			375.0	374.0	672.0	952.0	901.0	526.0			616.0	124.6	139.5	145.0	145.7	118.3

Table 2. Site 1 Nitrate-N concentrations (mg/l)

Sample Date	1101	1102	1103	1104	1105	1106	1201	1202	1203	1204	1205	1206
11/06/85	24.0		31.0	29.5	25.5	25.0	70.0		44.0	65.0	42.5	62.5
02/03/86							62.0	62.0	29.0	32.4	20.4	16.0
03/18/86	31.8	19.5	19.2	24.0	22.5	21.6	57.3	72.0	42.6	37.8	37.2	23.4
03/31/86							60.0	65.0	44.5	42.2	31.8	22.5
04/17/86							62.5	60.0	38.2	49.5	48.5	25.0
05/07/86							47.0	48.5	36.0	61.0	51.0	32.0
05/27/86							42.7	48.7	34.2	57.5	43.0	53.5
05/28/86	20.2	21.7	22.0	20.5	22.0	22.5						
06/18/86							32.8	43.5	32.8	42.5		30.5
07/14/86	66.0	60.0	31.5	28.2	21.2	16.7	39.0	43.0	41.0	42.5	41.5	25.0
08/11/86							40.5	44.5	47.2	45.0	68.8	29.0
09/09/86	44.5	42.5	46.0	29.0	25.0	25.0	41.0	44.0	43.2	52.5	42.2	38.0
09/17/86												
09/22/86												
10/02/86							55.0	55.0	50.5	39.5	19.2	31.5
10/15/86	14.0	27.0	32.0	28.0	26.0	24.2	49.5	42.5	5.5	20.5	36.8	18.0
10/28/86							46.0	39.0	10.0	17.6	30.2	30.0
11/11/86							50.4	34.2	12.2	10.5	33.6	30.0
12/09/86							46.5	47.0	16.0	16.0	27.0	21.5
01/12/87	23.8	9.0	15.0	26.5	24.0	23.0	48.0	48.8	21.5	25.0	34.0	18.5
02/10/87							43.0	45.5	22.0	30.0	28.0	27.5
03/31/87	21.5	15.0	15.5	26.8	21.5	21.0	34.5	34.5	23.8	33.8	16.5	27.2
05/04/87	29.2	26.0	18.0	25.5	21.5	21.0						
06/10/87	72.0	35.5	23.4	26.0	24.4	23.5		36.0	18.0	21.7	24.2	19.8
02/02/88												
02/03/88		33.8	26.0		20.2				20.0	26.5		19.2
02/04/88												
02/05/88												
06/20/88		60.0	25.5	19.2	14.8	12.0			26.0	26.0	13.5	14.5
08/17/88		90.0		22.8	16.5	14.5			30.5	50.5	35.5	24.5
10/17/88												
01/19/89			81.2	18.5	15.0				30.0	27.0	12.0	10.0
02/15/89												
05/22/89			72.5	18.0	13.5				26.0	23.5	15.0	12.0
12/01/89			88.0	31.0	32.5	15.8			49.5	68.0	51.0	26.2
05/31/90				13.2	22.0	15.8					44.5	23.0
08/15/90			177.0	27.2	15.2	15.0						
10/12/90		106.0	79.4	42.2	14.7	15.0			60.4	60.3	18.5	15.9
10/20/90									60.4	60.3	18.5	15.9
01/16/91			101.0	39.3	21.0	18.9						
03/14/91			104.0	20.0	17.9	20.5						
03/15/91												
04/25/91												
04/26/91	99.0	81.0	126.0	41.1	28.6	17.7		200.0	37.6	23.6	26.4	26.1
06/19/91	112.0	92.0	148.0	41.5	37.6	43.4		133.0	42.2	44.3	54.8	45.6
09/23/91			120.0	75.0	74.0	40.1			64.0	96.0	69.0	72.0
12/10/91		100.0	96.0	69.0	38.9	42.1			59.0	76.0	78.0	65.0

Sample Date	1301	1302	1303	1304	1305	1306	1307	1308	1401	1402	1403	1404	1405	1406	1407	1408
11/06/85	47.0		0.5	<0.2	<0.2	0.5	<0.2	15.0	11.0		16.5	<0.2	<0.2	0.5	<0.2	16.5
02/03/86			<0.2	<0.2		<0.2	<0.2			39.2	18.2	<0.2	<0.2	<0.2	<0.2	6.8
03/18/86			<0.2	<0.2		<0.2				49.5	29.4	<0.2	<0.2	<0.2	<0.2	5.4
03/31/86																
04/17/86																
05/07/86																
05/27/86	21.5	45.2	<0.2	<0.2	<0.2	<0.2	0.2	14.0	16.5	34.5	8.7	0.7	0.2	<0.2	<0.2	3.0
05/28/86																
06/18/86																
07/14/86	50.0	30.0	<0.2	<0.2	<0.2	<0.2	<0.2	13.5		43.0	23.0	0.5	<0.2	<0.2	<0.2	1.5
08/11/86																
09/09/86																
09/17/86									<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
09/22/86	32.0	20.0	<0.2	<0.2	<0.2	<0.2	<0.2	18.0								
10/02/86	36.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	19.8								
10/15/86	25.2	17.5	<0.2	0.5	<0.2	<0.2	<0.2	13.5	51.0	42.0	21.0	0.5	0.2	<0.2	<0.2	0.2
10/28/86	8.8	15.0	<0.5	<0.5	<0.5	<0.5	<0.5	11.5								
11/11/86	14.0	1.2	<0.2	<0.2	<0.2	<0.2	<0.2	10.6								
12/09/86	13.5	22.0	<0.2	<0.2	<0.2		<0.2	11.5								
01/12/87	<0.2	<0.2	<0.2	<0.2	<0.2		<0.2	13.6	25.2	26.5	2.5	<0.2	<0.2	<0.2	<0.2	6.8
02/10/87		<0.2	<0.2	<0.2	<0.2		<0.2									
03/31/87	80.0	12.0	<0.2	<0.2	<0.2	<0.2	<0.2	15.6	35.2	16.5	11.6	<0.2	<0.2	<0.2	<0.2	5.0
05/04/87	130.0	55.0	<0.2	<0.2	<0.2	<0.2	<0.2	18.0	31.6	45.6	2.5	<0.2	<0.2	<0.2	<0.2	7.0
06/10/87		52.0	0.6	<0.2	<0.2	<0.2	<0.2	18.7			33.0	2.0	<0.2	<0.2	<0.2	0.8
02/02/88			37.5	50.0	<0.5	<0.5	<0.5	7.2			1.0	<0.5	<0.5	<0.5	<0.5	<0.5
02/03/88																
02/04/88																
02/05/88																
06/20/88			31.0	13.0	49.5	25.0	16.5	10.6			20.2	5.5	2.0	<0.2	<0.2	0.6
08/17/88			37.5	1.0	0.5	0.5	0.5	9.2				15.6	0.5	0.5	0.5	0.5
10/17/88																
01/19/89			60.0	83.6	1.8	4.5	0.5	9.5			55.0	1.0	0.2	0.2	0.2	
02/15/89																
05/22/89			20.5	17.0	35.5	29.0	27.5	7.0			33.5	<0.2	<0.2	<0.2	<0.2	<0.2
12/01/89																
05/31/90			32.6	39.5	34.0	38.5	23.0	6.5								
08/15/90											44.5	30.6	29.9	18.0	0.2	<0.2
10/12/90			9.1	6.5	2.6	2.1	0.9	9.4			19.0	34.6	16.1	25.6	<0.2	<0.2
10/20/90																
01/16/91			53.6	37.6	4.3	6.9	9.1	11.0			19.4	22.9	40.8	22.2	<0.2	0.2
03/14/91			17.6	24.0	8.9	11.8	10.7	11.2			274.0	30.9	43.7	41.5	<0.2	
03/15/91																
04/25/91																
04/26/91			11.3	21.9	19.8	34.8	40.8	12.2			186.0	45.5	50.4	50.6		
06/19/91		29.6	30.8	30.9	34.2	26.4	24.1	14.3	366.0		213.0	51.9	61.0	59.0	<0.2	0.4
09/23/91			21.8	2.7	<0.2	<0.2	<0.2	22.1				36.8	34.9	37.2	<0.2	3.4
12/10/91			16.5	16.7	1.3	0.4	<0.2	30.0			36.6	66.0	55.2	55.7	<0.2	2.0

Table 3. Site 1 Ammonia concentrations (mg/l)

Sample Date	1101	1102	1103	1104	1105	1106	1201	1202	1203	1204	1205	1206	1301	1302	1303	1304	1305	1306	1307	1308	1401	1402	1403	1404	1405	1406	1407	1408
11/06/85	<0.20		<0.20	<0.20	<0.20	<0.20	<0.20		<0.20	<0.20	<0.20	<0.20	2.50		45.50	37.00	43.00	52.50	63.60	0.50	3.00		1.20	3.00	1.20	0.20	7.50	3.50
02/03/86							0.10	0.08	0.20	0.20	0.05	0.10			54.00	43.50		37.50	27.50			0.10	0.10	4.75	10.00	1.88	8.00	<0.02
03/18/86	0.08	0.02	<0.02	0.04	0.04	0.06	0.34	0.04	0.02	0.04	0.04	0.02			54.50	45.00		36.00				0.44	0.80	2.76	1.88	4.20	6.10	0.36
03/31/86							0.04	0.04	0.02	<0.02	<0.02	0.02																
04/17/86							0.28	0.28	0.02	<0.02	0.04	<0.02																
05/07/86							<0.05	0.05	<0.05	<0.05	<0.05	<0.05																
05/27/86							0.04	0.04	0.02	0.08	0.04	0.02	15.00	18.00	80.00	74.50	50.50	54.50	48.80	2.80	0.36	0.12	0.96	2.04	2.48	5.50	5.50	2.66
05/28/86	<0.02	<0.02	0.02	0.02	<0.02	<0.02																						
06/18/86							1.24	0.06	0.02	<0.02		0.04																
07/14/86	<0.02	0.02	0.04	<0.02	<0.02	<0.02	0.08	<0.02	0.02	<0.02	0.04	0.08	17.60	26.40	67.60	54.40	45.60	50.00	49.60	0.12		<0.02	0.88	2.40	3.24	5.40	6.20	0.60
08/11/86							0.04	<0.02	<0.02	<0.02	0.02	<0.02																
09/09/86	0.08	<0.02	<0.02	<0.02	0.02	<0.02	0.02	0.04	0.04	0.02	0.02	0.04																
09/17/86																					12.00	14.40	4.80	8.80	8.80	4.80	13.60	11.20
09/22/86													3.60	15.50	52.80	50.80	51.20	40.00	52.00	0.20								
10/02/86							0.04	0.04	<0.02	<0.02	<0.02	<0.02	11.60	37.60	36.00	48.80	67.20	42.80	28.80	0.04								
10/15/86	0.04	<0.02	0.04	<0.02	<0.02	<0.02	0.30	0.24	0.02	0.04	0.02	<0.02	0.06	42.00	56.50	28.00	54.00	54.50	57.50	0.18	<0.02	0.04	4.00	13.50	6.00	7.50	18.00	9.20
10/28/86							0.04	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	24.00	77.60	48.80	66.40	58.40	53.60	0.06								
11/11/86							0.12	0.10	<0.02	<0.02	<0.02	<0.02	0.14	15.20	72.80	51.60	48.00	48.80	56.80	<0.02								
12/09/86							0.14	0.12	<0.02	<0.02	<0.02	<0.02	12.40	16.40	55.60	41.60	51.60		60.00	0.04								
01/12/87	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	17.60	22.00	62.80	60.00	53.60		58.40	0.02	<0.02	<0.02	3.28	32.80	32.80	22.00	14.40	1.00
02/10/87							0.02	<0.02	<0.02	<0.02	0.68	<0.02		29.60	65.60	56.00	64.00		62.00									
03/31/87	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02	0.20	0.02	21.60	44.80	64.40	59.20	54.40	56.00	60.80	0.06	0.02	0.12	13.20	32.00	29.60	16.00	15.20	1.20
05/04/87	0.04	0.02	0.02	<0.02	<0.02	0.04							3.20	36.80	94.00	64.40	57.20	54.40	61.60	0.02	<0.02	0.04	20.00	36.80	35.60	16.40	16.80	0.20
06/10/87	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04		<0.04	<0.04	1.20	<0.04	<0.04		5.20	70.00	70.00	58.00	64.00	64.00	0.04			0.52	18.40	20.00	19.20	14.00	16.00
02/02/88															14.20	66.80	61.90	56.20	57.00	0.06			8.80	19.80	16.60	19.50	21.80	7.50
02/03/88		<0.01	<0.01		<0.01				<0.01	<0.01		<0.01																
02/04/88																												
02/05/88																												
06/20/88		0.06	0.02	0.02	0.02	0.02			0.02	0.02	0.02	0.04			6.40	16.00	22.80	25.60	26.80	0.16			1.36	11.20	14.40	16.40	18.40	1.20
08/17/88		<0.02		<0.02	<0.02	<0.02			0.55	0.05	<0.02	<0.02			2.40	56.20	49.40	48.80	43.10	0.05				4.65	17.50	21.20	35.00	31.20
10/17/88																												
01/19/89			0.03	0.06	<0.02				0.07	0.10	0.03	0.04			0.06	4.65	47.20	45.00	45.20	0.06			0.01	0.05	7.80	9.90	31.80	
02/15/89																												
05/22/89			<0.02	<0.02	<0.02				<0.02	<0.02	<0.02	<0.02			<0.02	3.32	17.50	12.00	5.02	<0.02			0.10	5.16	4.75	3.66	26.00	4.10
12/01/89			0.02	0.10	0.05	<0.02			0.02	0.10	0.05	0.05																
05/31/90				0.02	<0.02	<0.02					<0.02	<0.02			13.80	9.00	0.06	3.62	1.25	0.02								
08/15/90			0.02	0.10	0.20	0.02																	0.02	0.10	0.36	0.72	11.00	5.50
10/12/90		0.05	0.05	0.10	0.02	<0.02			0.05	0.05	0.02	0.02			0.05	0.26	25.00	24.50	24.50	0.10			0.05	0.55	0.25	0.88	38.00	3.85
10/20/90									0.05	0.05		0.02																
01/18/91			0.05	0.02	<0.02	0.06									0.05	0.12	16.80	17.50	16.20				<0.02	<0.02	3.50	3.55	21.20	3.20
03/14/91			0.12	<0.02	<0.02	0.20									0.05	0.60	12.00	8.00	7.00	0.06			0.16	1.15	2.00	1.45	42.50	5.50
03/15/91																												
04/25/91																												
04/26/91		0.02	0.06	0.05	0.10	0.06		0.10	8.80	0.05						3.48	11.20	2.50	1.25				0.05	1.30	1.56	3.10	37.50	5.50
06/19/91	<0.02	<0.02	0.02	<0.02	<0.02	<0.02		0.72	5.20	<0.02	<0.02	<0.02		<0.02	<0.02	0.88	3.75	3.75	2.50	<0.02	0.02		<0.02	1.62	1.60	1.60	40.50	6.20
09/23/91			0.02	0.02	0.05	<0.02			1.18	0.05	<0.02	<0.02			<0.02	2.32	39.50	35.20	26.00	0.02				0.65	2.00	2.45	35.00	0.86
12/10/91		<0.02	<0.02	<0.02	<0.02	<0.02			<0.02	<0.02	<0.02	<0.02			<0.02	2.62	11.50	13.00	12.80	<0.02			<0.02	<0.02	0.18	0.40	37.00	6.60

Table 4. Site 1 Chloride concentrations (mg/l)

Sample Date	1100	1102	1103	1104	1105	1106	1201	1202	1203	1204	1205	1206	1301	1302	1303	1304	1305	1306	1307	1308	1401	1402	1403	1404	1405	1406	1407	1408
11/06/85	11.0		21.0	43.0	34.0	42.0			64.0	24.0	12.0	20.0	19.0		145.0	130.0	230.0	210.0	240.0	64.0	67.0		87.0	90.0	115.0	120.0	135.0	72.0
02/03/86							120.0	110.0	17.0	80.0	64.0	36.0			91.0	85.0		90.0	110.0			20.0	19.0	40.0	79.0	47.0	89.0	20.0
03/18/86	18.0	13.0	10.0	24.0	26.0	24.0	94.0	78.0	28.0	17.0	39.0	80.0			69.0	72.0		63.0				10.0	18.0	54.0	70.0	83.0		
03/31/86							86.2	98.8	42.1	33.3	31.7	24.2																
04/17/86							71.0	68.0	23.0	38.0	60.0	18.0																
05/07/86							64.0	65.0	28.0	68.0	67.0	46.0																
05/27/86							52.0	60.0	19.0	91.0	29.0	44.0	120.0	155.0	230.0	190.0	112.0	160.0	90.0	30.0	9.3	22.0	42.0	80.0	115.0	160.0	120.0	77.0
05/28/86	10.0	12.0	14.0	24.0	24.0	25.0																						
06/18/86							137.0	57.0	23.0	45.0		19.0																
07/14/86	38.0	39.0	21.0	25.0	21.0	20.0	98.0	47.0	32.0	36.0	26.0	19.0	147.0	190.0	125.0	93.0	95.0	101.0	100.0	22.0		22.0	34.0	44.0	46.0	99.0	106.0	74.0
08/11/86							124.0	64.0	49.0	49.0	101.0	24.0																
09/09/86	40.6	38.9	40.6	25.3	26.5	26.4	55.2	51.1	52.6	67.0	32.0	25.0																
09/17/86																					70.0	78.0	78.0	103.0	103.0	19.0	19.0	16.0
09/22/86													55.0	66.0	109.0	109.0	95.0	102.0	95.0	81.0								
10/02/86							62.0	66.0	93.0	67.0	61.0	36.0	61.0	98.0	100.0	103.0	124.0	59.0	34.0	24.0								
10/15/86	12.0	27.2	30.2	31.1	31.1	28.6	80.5	75.0	83.3	62.9	35.6	53.9	14.4	55.8	22.4	102.5	110.5	22.7	27.1	28.9	27.3	23.6	43.3	20.9	90.7	95.3	28.8	105.8
10/28/86							67.0	64.0	74.0	83.0	52.0	32.0	37.0	30.0	87.0	95.0	115.0	115.0	110.0	29.0								
11/11/86							72.0	65.0	66.0	69.0	32.0	32.0	92.0	65.0	93.0	90.0	100.0	98.0	100.0	26.0								
12/09/86							140.0	87.0	88.0	64.0	34.0	30.0	165.0	153.0	106.0	107.0	108.0		118.0	32.0								
01/12/87	36.0	16.0	20.0	37.0	29.0	27.0	82.0	80.0	84.0	61.0	36.0	25.0	165.0	120.0	94.0	98.0	95.0		92.0	28.0	21.0	29.0	46.0	90.0	88.0	97.0	106.0	32.0
02/10/87							94.0	91.0	93.0	106.0	57.0	29.0		118.0	100.0	103.0	102.0		100.0									
03/31/87	39.0	29.0	26.0	33.0	26.0	27.0	107.0	91.0	75.0	179.0	31.0	65.0	183.0	111.0	138.0	103.0	113.0	109.0	103.0	33.0	31.0	29.0	42.0	63.0	80.0	109.0	159.0	49.0
05/04/87	43.0	43.0	31.0	26.0	26.0	26.0							120.0	100.0	210.0	110.0	88.0	90.0	87.0	32.0	20.0	26.0	55.0	65.0	86.0	97.0	110.0	37.0
06/10/87	60.0	40.0	42.0	32.0	26.0	28.0		140.0	84.0	48.0	19.0	24.0		24.0	170.0	110.0	90.0	105.0	102.0	21.0			38.0	40.0	38.0	77.0	130.0	82.0
02/02/88															71.0	143.0	101.0	79.0	86.0	27.0			42.0	77.0	65.0	90.0	118.0	106.0
02/03/88		43.0	39.0		30.0				66.0	33.0																		
02/04/88																												
02/05/88																												
06/20/88		46.0	33.0	26.0	21.0	16.0			48.0	26.0	18.0	20.0			12.0	12.0	50.0	40.0	35.0	29.0			7.0	35.0	53.0	75.0	93.0	34.0
08/17/88		41.0		32.0	31.0	28.0			73.0	95.0	65.0	34.0			26.0	55.0	63.0	65.0	87.0	26.0				27.0	73.0	75.0	99.0	56.0
10/17/88																												
01/19/89			71.0	31.0	29.0				89.0	47.0	22.0	22.0			16.0	34.0	60.0	44.0	36.0	44.0			26.0	44.0	63.0	71.0	97.0	
02/15/89																												
05/22/89			62.0	24.0	17.0				53.0	53.0	18.0	17.0			7.0	11.0	40.0	30.0	32.0	42.0			18.0	56.0	68.0	68.0	86.0	59.0
12/01/89			68.0	31.0	25.0	24.0			86.0	97.0	84.0	45.0																
05/31/90				19.0	25.0	22.0					61.0	23.0			25.0	26.0	5.0	34.0	13.0	30.0								
06/15/90			128.0	30.0	23.0	23.0																	36.0	36.0	57.0	65.0	83.0	63.0
10/12/90		130.0	70.0	34.0	21.0	21.0			105.0	67.0	31.0	22.0			8.0	47.0	82.0	80.0	81.0	30.0			11.0	35.0	65.0	63.0	86.0	60.0
10/20/90									105.0	67.0	31.0	22.0																
01/16/91			68.0	34.0	26.0	25.0									46.0	63.0	54.0	44.0	36.0	37.0			52.0	70.0	68.0	72.0	92.0	65.0
03/14/91			72.0	26.0	23.0	24.0									11.0	31.0	38.0	26.0	20.0	38.0			201.0	67.0	56.0	47.0	91.0	55.0
03/15/91																												
04/25/91																												
04/26/91	90.0	58.0	94.0	38.0	31.0	24.0		596.0	102.0	26.0	27.0	29.0			6.0	26.0	33.0	37.0	46.0	43.0			75.0	46.0	56.0	63.0	79.0	59.0
06/19/91	90.0	68.0	112.0	39.0	39.0	44.0		197.0	110.0	55.0	61.0	39.0		6.0	25.0	26.0	42.0	58.0	63.0	46.0	310.0		106.0	48.0	74.0	73.0	83.0	63.0
09/23/91			75.0	63.0	63.0	40.0			85.0	152.0	88.0	70.0			9.0	33.0	137.0	140.0	109.0	51.0				22.0	79.0	72.0	82.0	58.0
12/10/91		67.0	50.0	64.0	35.0	39.0			78.0	127.0	89.0	100.0			3.0	10.0	112.0	126.0	136.0	81.0			20.0	59.0	80.0	81.0	82.0	77.0

Table 5. Site 1 Reactive Phosphorous concentration (mg/l PO4)

Sample Date	1101	1102	1103	1104	1105	1106	1201	1202	1203	1204	1205	1206	1301	1302	1303	1304	1305	1306	1307	1308	1401	1402	1403	1404	1405	1406	1407	1408
03/19/86	0.008	0.002	0.002	0.005	0.002	0.005	0.015	0.015	0.014	0.008	0.005	0.040			0.015	0.108		0.036				0.036	0.030	0.215	0.036	1.500	0.065	0.032
03/31/86							0.015	0.015	0.005	0.005	0.005	0.040																
09/09/86	0.012	<0.002	<0.002	<0.002	0.005	0.006	0.024	0.020	0.010	0.010	0.010	0.020																
03/31/87	<0.002	0.002	0.008	0.005	0.002	<0.002	<0.002	0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.036	0.032	0.180	0.250	<0.002	0.200	<0.002	<0.002
05/04/87																												
08/10/87	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		0.010	<0.005	<0.005	0.035	0.010		0.010	<0.005	0.130	3.000	0.025	0.120	0.005			0.190	0.140	1.500	1.250	<0.005	<0.005
02/02/88															<0.005	<0.005	<0.005	1.440	0.125	0.002			0.242	0.175	1.500	2.750	0.025	<0.005
02/03/88		<0.002	<0.002		<0.002				<0.002	<0.002		<0.002																
08/17/88		<0.002		<0.002	0.002	0.005			<0.002	0.008	0.005	0.005			0.015	2.560	0.085	0.270	0.315	0.002				0.495	2.370	8.750	0.030	0.005
10/17/88																												
01/19/89			0.002	<0.002	<0.002				<0.002	<0.002	<0.002	0.008			0.005	0.250	4.440	8.000	8.120	<0.002			0.188	0.600	2.050	5.000	<0.002	
02/15/89																												
05/22/89			<0.002	<0.002	<0.002				<0.002	<0.002	<0.002	<0.002			<0.002	0.112	0.010	0.075	<0.002	<0.002			0.205	0.390	1.880	1.250	0.005	<0.002
12/01/89			0.005	0.015	<0.002	<0.002			<0.002	<0.002	0.010	<0.002																
05/31/90				0.008	<0.002	0.002					0.005	0.005			0.100	0.082	0.010	0.040	0.082	<0.002								
08/15/90			0.002	0.002	0.002	0.002																	0.370	0.470	0.418	0.250	0.038	<0.002
10/12/90		0.005	<0.002	<0.002	<0.002	0.002			0.005	0.005	0.002	0.002			0.020	0.065	5.800	5.750	0.250	<0.002			0.380	0.462	0.448	0.212	0.038	0.002
10/20/90									0.005	0.005	0.002	<0.002																
01/16/91			<0.002	0.002	<0.002	<0.002									0.005	0.050	4.380	6.880	2.500	<0.002			0.280	0.125	0.385	0.215	0.040	0.002
03/14/91			<0.002	<0.002	<0.002	<0.002									0.008	0.055	5.200	3.380	2.380	0.002			0.160	0.435	0.352	0.205	<0.002	
04/26/91			0.020	0.005	0.002	0.002		0.010	0.010							0.050	4.200	1.800	1.250	0.002			0.145	0.342	0.265	0.165	0.025	0.002
06/19/91	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002		0.025	0.008	<0.002	<0.002	<0.002		0.008	<0.002	0.042	1.750	1.500	1.120	<0.002	0.032		0.130	0.360	0.270	0.270	0.032	0.002
08/23/91			0.002	0.002	<0.002	<0.002			0.010	0.005	0.002	<0.002			0.002	0.090	21.500	14.200	8.400	0.005				0.502	0.370	0.250	0.062	0.002
12/10/91		<0.002	<0.002	<0.002	<0.002	<0.002			<0.002	<0.002	<0.002	<0.002			<0.002	0.272	1.320	1.620	1.420	<0.002			0.292	0.340	0.290	0.190	<0.002	<0.002

Table 6, Site 1 pH

Sample Date	1101	1102	1103	1104	1105	1106	1201	1202	1203	1204	1205	1206	1301	1302	1303	1304	1305	1306	1307	1308	1401	1402	1403	1404	1405	1406	1407	1408
11/06/85	7.55		7.26	7.62	7.60	7.58	6.48		6.84	7.07	7.62	7.58	6.96		7.07	7.17	6.76	6.97	6.92	7.30	6.63		6.64	7.06	6.61	6.65	6.94	7.00
02/03/86																												
03/18/86	7.14	6.75	7.16	7.57	7.55	7.62	6.74	6.52	6.78	7.04	7.45	7.57			6.92	6.97		6.95				6.70	6.68	6.78	6.69	6.72	6.92	7.29
09/09/86	7.14	6.93	7.17	7.36	7.49	7.50	6.44	6.51	6.68	6.54	7.00	7.35																
06/10/87	6.06	7.14	7.35	7.70	7.71	7.72		6.70	7.09	7.34	7.55	7.63		7.36	7.59	7.15	7.37	7.70	7.44	7.68			6.24	7.03	7.05	7.18	7.01	7.22
02/02/88															6.82	7.03	6.91	6.86	6.88	7.44			6.70	6.61	6.66	6.71	6.94	7.15
02/03/88		7.00	7.00		7.45				6.77	7.11		7.66																
06/20/88		6.22	6.78	7.30	7.38	7.44			6.55	7.12	7.16	7.23			6.94	7.01	6.79	6.84	6.65	7.21			6.66	6.81	6.84	6.71	6.67	7.03
08/17/88		6.67		7.45	7.46	7.48			6.28	6.41	7.25	7.44			6.77	6.90	6.81	6.82	6.93	7.32				6.95	6.76	6.92	6.83	7.04
10/17/88																												
01/19/89			7.31	7.45	6.92				6.49	6.62	7.24	7.34			6.83	6.55	6.82	6.87	6.99	7.20			6.95	7.07	6.93	7.05	6.66	
02/15/89																												
05/22/89			7.01	7.30	7.37				6.37	6.65	7.23	7.26			6.61	6.56	6.61	6.58	6.55	7.14			6.90	6.70	6.52	6.55	6.86	7.02
12/01/89			6.91	7.50	7.52	7.53			6.47	6.45	6.97	6.88																
05/31/90				7.32	7.33	7.42					7.03	7.29			6.64	6.53	6.82	6.57	6.74	7.19								
06/15/90			6.70	7.47	7.48	7.44																	6.96	6.66	6.65	6.62	6.97	7.20
10/12/90		6.92	7.07	7.10	7.55	7.65			6.74	6.97	7.41	7.57			6.94	6.62	6.77	6.84	6.86	7.21			7.06	7.06	7.06	6.93	7.05	7.34
10/20/90									6.74	6.97	7.41	7.57																
01/16/91			7.03	7.44	7.47	7.39									6.39	6.43	6.61	6.60	6.61	7.13			6.93	6.65	6.55	6.58	6.80	7.06
03/14/91			7.14	7.50	7.54	7.49									6.74	6.57	6.64	6.55	6.75	7.17			6.63	6.65	6.76	6.24	6.62	7.12
03/15/91																												
04/25/91																												
04/26/91	6.70	7.35	6.61	7.44	7.47	7.56		7.66	7.75	7.37	7.62	7.33			6.92	6.77	7.53	6.66	6.63	7.26			6.62	6.55	6.41	6.45	6.85	7.49
06/19/91	6.65	7.04	6.46	7.27	7.37	7.40		7.23	7.03	6.95	6.96	7.26		6.95	6.27	6.42	6.55	6.44	6.43	7.06	6.35		6.61	6.49	6.36	6.42	6.62	6.94
09/23/91			6.96	7.39	7.37	7.46			6.64	6.32	6.93	7.09			6.73	6.61	6.78	6.64	6.64	7.17				6.78	6.46	6.54	6.62	7.02
12/10/91		7.07	6.97	7.51	7.27	7.58			6.65	6.50	7.01	7.00			6.62	6.60	6.54	6.59	6.53	6.95			6.66	6.42	6.46	6.45	7.07	7.27

Table 7. Site 1 Conductivity (umho)

Sample Date	1101	1102	1103	1104	1105	1106	1201	1202	1203	1204	1205	1206	1301	1302	1303	1304	1305	1306	1307	1308	1401	1402	1403	1404	1405	1406	1407	1408
11/06/85	450		520	583	560	551	1718		963	908	683	817	820		1775	1447	2090	2100	2270	765	962		972	1391	1537	1579	1604	860
02/03/86							1811	1699	743	751	596	552			1723	1506		1688	1604			903	940	1376	1526	1545	1834	786
03/18/86	610	433	460	638	591	577	1901	1637	1017	850	972	625			1681	1466		1520				886	1049	1443	1536	1699	1841	1132
03/31/86							1376	1481	995	840	771	599																
04/17/86							1364	1184	736	852	851	511																
05/07/86							1105	1055	733	1032	952	725																
05/27/86							1177	1225	702	1204	850	1018	1976	2840	3260	2440	1890	2110	1620	662	492	697	1153	1467	1592	1639	1786	1121
05/28/86	433	397	443	483	487	476																						
06/18/86							1719	1148	710	882		678																
07/14/86	773	664	529	586	530	512	1295	1049	816	775	764	578	1966	2220	2150	1660	1597	1739	1757	611		717	1032	1208	1258	1467	1594	1095
08/11/86							1835	1231	940	905	1340	668																
09/09/86	730	621	664	635	630	626	1334	1207	927	1115	874	758																
09/17/86																					1505	1798	1634	1535	1553	1685	1811	1561
09/22/86													1084	1384	1799	1993	1518	1611	1548	669								
10/02/86							1260	1340	1380	1150	1133	804	1329	1965	1580	1558	1950	1103	896	650								
10/15/86	439	506	626	662	654	634	1294	1195	1007	961	812	869	760	1532	1943	1410	1553	1630	1863	686	1052	921	1114	1727	1605	1662	1856	1513
10/28/86							1212	1063	880	1048	714	712	733	919	1844	1823	1828	1809	1849	683								
11/11/86							1332	1137	910	953	788	756	1735	1189	1859	2010	1878	1878	1821	723								
12/09/86							1574	1268	900	642	705	830	1000	1851	1958	1550	1753		1595	684								
01/12/87	550	326	407	625	603	586	1264	1253	982	886	765	633	2630	1918	1717	1591	1581		1480	669	694	754	766	1398	1467	1476	1764	1744
02/10/87							1207	1220	968	1183	859	696		2050	1572	1605	1494		1515									
03/31/87	498	385	444	654	590	586	1226	1141	919	1387	673	908	1924	1837	1929	1697	1724	1707	1708	698	808	788	865	1162	1345	1522	1808	891
05/04/87																												
06/10/87	412	532	516	615	532	584		1415	927	805	576	544		1038	2430	1956	1722	1670	1741	648			791	928	923	1476	1720	1305
02/02/88															1405	2200	1783	1619	1672	665			914	1238	1418	1487	1858	1391
02/03/88		551	599		630				821	787		650																
02/04/88																												
02/05/88																												
06/20/88		972	646	678	692	657			882	778	625	618			668	750	1273	1108	1052	742			494	731	862	1129	1724	808
08/17/88		1175		646	630	621			1029	1255	1015	768			973	1312	1240	1254	1236	633				680	1035	1078	1598	949
10/17/88																												
01/19/89			1156	626	612				1094	831	602	606			870	1212	1319	1099	939	759			963	761	1018	1071	1663	
02/15/89																												
05/22/89			1114	634	611				975	928	662	590			542	574	1165	956	632	835			768	826	924	915	1734	959
12/01/89			1147	654	610	624			1168	1316	1193	1152																
05/31/90				567	662	584					1092	657			868	879	567	909	566	716								
08/15/90			1558	578	526	521																	902	888	809	772	1267	932
10/12/90		1766	1216	584	564	530			1551	1557	614	566			319	639	1307	1241	1238	768			843	768	752	926	1435	1062
10/20/90									1551	1557	614	566																
01/16/91			1232	778	616	608									812	879	955	894	871	777			721	887	1002	945	1429	970
03/14/91			1324	626	592	613									416	719	920	813	764	674			3000	1012	899	813	1408	857
03/15/91																												
04/25/91																												
04/26/91	1329	1051	1431	784	674	530		5780	1855	494	507	647			288	597	794	942	1026	800			1703	847	944	1017	1313	742
06/19/91	1500	1134	1702	765	749	806		4150	2370	928	1009	823		626	525	649	919	894	888	772	3630		2070	823	992	1007	1275	880
09/23/91			1388	980	977	704			2050	1632	1262	1152			546	548	1545	1412	1466	855				592	949	899	1161	867
12/10/91		1324	1331	1062	541	785			1676	1557	1432	1499			384	474	1240	1327	1341	1042			677	1059	1103	1148	1060	1006
03/16/92		1534	1196	631	550	534			1512	1331	719	786			503	853	678	690	684	1016			837	782	872	906	1176	916

Table 8. Site 1 Chemical Oxygen Demand (mg/l oxygen demand)

Sample Date	1101	1102	1103	1104	1105	1106	1201	1202	1203	1204	1205	1206	1301	1302	1303	1304	1305	1306	1307	1308	1401	1402	1403	1404	1405	1406	1407	1408
11/06/85	18.0		2.6	3.8	3.8	3.8	43.5		51.2	30.7	17.9	15.4	28.2		74.2	78.1	160.	134.	139.	24.3	35.8		30.7	56.3	53.8	51.2	65.3	23.0
03/18/86	10.0	9.3	11.6	10.0	10.0	10.8	67.2	42.5	49.4	41.7	36.3	17.8			89.5	55.6		76.4				14.7	24.7	51.7	57.1	57.1		
09/17/86																					85.1	74.6	84.2	57.3	52.9	67.2	58.4	68.8
09/22/86													40.3	46.4	88.9	77.5	96.5	73.7	90.4	19.0								
01/17/91			10.7	6.0	5	6									13.1	18.6	32.3	25.7	22.7	30.7			19.2	27.2	22.2	35.8	78.1	38.8
06/19/91								87.6	122.3	25.7	23.0	16.7																
12/10/91		10.6	20.4	6.2	10.6	10.2			42.6	51.9	36.4	43.5			12.6	13.1	33.1	39.6	44.0	41.9			16.6	22.7	27	27.5	66.3	44.5

Table 9. Site 1 Sodium (mg/l)

Sample Date	1101	1102	1103	1104	1105	1106	1201	1202	1203	1204	1205	1206	1301	1302	1303	1304	1305	1306	1307	1308	1401	1402	1403	1404	1405	1406	1407	1408
11/06/85	2.0		2.5	6.0	6.5	2.5	63.0		19.0	19.0	1.5		19.0		58.5	21.5	36.0	49.0	61.5	19.0	38.5		71.0	97.5	76.0	67.0	55.0	19.0
03/18/86	2.7	3.3	3.3	4.2	3.8	3.8	40.0	38.0	14.0	3.6	3.8	3.0			91.0	38.0		42.0				26.0	30.0	97.0	73.0	40.0		
09/09/86	3.0	2.5	3.0	3.0	3.5	3.5	18.0	17.0	7.0	11.0	6.0	3.5																
09/17/86																						36.8	47.2	97.5	92.5	50.0	37.8	45.0
09/22/86													35.8	95.0	61.5	48.6	26.0	37.6	19.4	6.0								
01/12/87													90.0	100.	130.													
08/10/87	4.0	2.0	2.0	6.0	6.0	6.0		22.5	11.0	5.5	2.5	2.5		34.5	100.	100.	120.	120.	100.	8.5			31.5	50.0	250.	280.	30.0	1.5
02/02/88															14.0	11.8	12.8	13.6	13.6	4.0			19.7	25.0	30.5	21.0	6.4	29.0
02/03/88		3.0	2.9		3.3				6.5	4.4		3.3																

Table 10. Site 1 Alkalinity (mg/l)

Date	1101	1102	1103	1104	1105	1106	1201	1202	1203	1204	1205	1206	1301	1302	1303	1304	1305	1306	1307	1308	1401	1402	1403	1404	1405	1406	1407	1408
03/18/86	84	60	88	168	144	144	416	264	188	160	200	160			660	556		580				172	324	628	632	680	776	416
09/09/86	88	56	72	160	156	156	334	280	156	196	180	176																
09/17/86																					672	816	744	712	696	752	808	664
09/22/86													292	520	724	808	568	612	560	176								
10/02/86								236	232	240					570			316										
02/02/88															448	628	728	680	684	216			344	460	528	580	812	544
02/03/88		44	114		192				204	186		194																
01/19/89			116	180	204				248	200	208	228			128	160	532	384	332	260			136	240	368	372	732	
05/22/89			124	164	200				232	232	212	192			148	152	400	232	260	268			156	228	276	268	712	316
12/01/89			136	160	208	220			244	212	292	276																
12/10/91		120	128	140	44	152			396	232	232	348			100	144	440	464	480	276			136	100	136	140	424	376

Table 11. Site 1 Total Hardness (mg/l)

Sample Date	1101	1102	1103	1104	1105	1106	1201	1202	1203	1204	1205	1206	1301	1302	1303	1304	1305	1306	1307	1308	1401	1402	1403	1404	1405	1406	1407	1408
03/18/86	190	190	206	268	255	260	268	268	165	130	297	243			140	177		210				280	235	210	297	364	332	240
09/09/86	264	240	276	308	304	296	184	204	200	292	248	292																
09/17/86																					444	588	640	352	336	580	552	432
09/22/86													224	168	272	332	220	240	236	276								
10/02/86								220	216	224					292			144										
02/02/88															116	80	136	108	120	240			240	316	364	440	496	400
02/03/88		110	282		310				184	214		278																
01/19/89			520	308	308				284	264	284	300			220	224	96	80	68	312			300	196	260	272	372	
05/22/89			272	308	292				308	360	276	280			168	116	184	172	220	320			196	180	220	232	364	276
12/01/89			508	332	316	316			400	372	532	424																
12/10/91		552	404	704	256	356			208	528	616	744			120	160	272	288	308	456			232	284	324	320	204	324

Table 12. Site 2 Potassium concentrations (mg/l)

Sample Date	2001	2002	2003	2004	2005	2006	2007	2008	2101	2102	2103	2104	2105	2106	2107	2108	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211
11/21/85									210.0		185.0	90.0	14.0	9.5	12.0	5.5	13.5		13.0	8.0	6.5	12.0	29.0	3.0	3.0	1.0	3.0
02/03/86																											
03/18/86									170.0		176.0	82.0	24.0	16.0	19.0	15.5		7.7	16.0	7.6	5.2	6.2	16.5	17.0	2.8	1.8	3.0
03/31/86																											
04/17/86																	12.5	11.0	22.0	8.5	5.0	5.5	25.0	28.5	2.8	4.0	2.5
05/07/86																	14.0	12.0	21.0	8.5	5.5	5.5	35.0	22.0	2.5	2.0	2.5
05/27/86																											
05/28/86																											
06/18/86																											
07/14/86	9.0	8.5	7.5	8.0	7.0	6.5	< 1.0	< 1.0	445.0	240.0	145.0		26.0	9.5	11.0	16.0		29.5	23.5	9.5	7.5	8.0	24.0	19.5	3.5	2.0	3.5
08/11/86																		24.0	17.0	8.5	6.0	6.0	18.0	21.0	2.5	2.0	3.0
09/17/86									368.0	285.0	148.0	225.0	30.0	9.2	17.5	18.0		31.8	19.2	9.2	7.2	7.2	21.5	13.6	3.5	2.5	3.2
09/22/86	7.8	7.6	7.2	7.8	7.8	5.6	1.0																				
10/15/86	9.0	8.0	5.0	5.0	6.0	2.0	1.0	1.0	270.0	180.0	240.0	150.0	126.0	14.0	19.0	15.0	21.0	55.0	25.0	14.0	5.0	5.0	30.0	30.0	4.0	2.0	3.0
10/26/86									224.0		135.0	154.0	25.0	10.0	13.0	9.0	223.0	71.0	28.0	12.0	6.0	8.0	28.0	30.0		2.0	
11/11/86																	34.0	65.0	29.0	10.0	6.0	6.0	36.0	34.0	3.0		
12/09/86																	55.0	65.0	23.0	9.0	11.0	11.0	23.0	21.0	3.0		
01/12/87									280.0	229.0	198.0	82.0	18.0	10.0	12.0	13.0	73.0	40.0	15.0	7.0	6.0	6.0	20.0	16.0	3.0	2.0	3.0
02/10/87									262.0	255.0	225.0	90.0					75.0	33.0	19.0				30.0	22.0			
03/16/87									268.0	234.0	865.0	286.0	15.2	10.4	14.1	13.0											
03/31/87																	57.0	20.0	17.0	9.0	5.0	6.0	52.0	142.0	16.0		
05/04/87	5.0	6.3	5.4	5.0	4.8	1.4	0.8	0.9	258.0	298.0	260.0	68.0	22.0	8.2	10.7	13.0	232.0	201.0	130.0	175.0	80.0		49.0	36.2	2.5	2.0	2.5
06/10/87	6.0	6.0	6.0	6.0	5.0	3.5	0.5	0.5		340.0	280.0	170.0	20.0	5.0	10.0	15.0			10.0	23.0	7.0	6.0	6.5				
02/03/88											275.0	7.0		12.5	12.5	18.0			17.0	18.0		19.5	6.5	46.0	35.0	8.0	3.0
06/20/88	7.0	7.5	7.0	6.5	6.0	2.5	0.5	0.5			31.5	70.0	22.5	24.0	18.0	20.0				10.5	7.0	7.0	39.0	26.0	2.5	2.0	2.5
08/17/88											458.0	293.0	39.0	20.5	25.9	22.8				12.2	9.0	8.9	16.7	14.7	3.2	2.5	2.7
10/19/88	7.9	7.5	8.0	7.5	5.8	<0.1																					
01/19/89											180.0	112.5			19.9	20.0					97.5	23.5	28.6	19.5	2.5	2.0	1.5
05/22/89	6.5	6.5	6.0	5.0	5.5	1.0	0.5	0.5			400.0	175.0	33.5	17.0	16.0	19.5				10.5	8.0	6.5	50.0	47.5	3.0	2.0	2.5
12/01/89											325.5	142.0	45.0	20.0	17.5	19.5				30.0	13.0	10.5	20.0	18.0		2.5	2.0
05/31/90											366.4	300.8	34.3	17.0	11.6	16.1			26.7	37.0	14.9	37.0	37.6	2.2	2.8	2.2	2.8
08/15/90																				50.0		28.0	60.0	50.0	3.4	2.5	29.0
10/12/90						6.0	7.5	7.5			12.0	186.0	45.0	19.5	13.5	16.5			96.0	38.0	19.5	17.0	48.0	37.0	2.5	2.0	1.5
01/16/91		7.0	6.6	7.0	1.0	1.0	0.4	0.4			470.0	154.0	26.1	15.5	12.4	17.8			67.5	57.1	43.6	40.8	166.0	85.8	11.1		9.6
03/14/91	7.2	7.0	7.0	6.5		1.4		0.4			204.0	195.0	22.8	14.8	11.6	16.6				37.0	23.0	19.6	64.0	36.4	4.6		4.5
04/26/91		8.4	7.4	8.6	7.0	2.1	0.8	0.8		355.0	397.0	183.0	26.2	11.8	8.7	14.0			108.0	58.0	24.7	24.0	92.0	72.0	4.8	3.3	4.3
06/19/91	10.1	10.0	9.3	8.3	7.9	1.8	1.0	0.9		358.0	394.0	223.0	29.8	11.9		13.5			207.0	78.0	35.9	38.6	84.0	79.0	5.9	4.5	6.6
09/23/91																											
12/10/91	8.7	6.5	8.2	7.4	5.7	1.6	0.9				437.0	278.0	363.0	12.1	10.2				797.0	880.0	530.0	431.0	506.0	464.0	5.6	3.9	4.7

Table 13. Site 2 Nitrate-N concentrations (mg/l)

Sample Date	2001	2002	2003	2004	2005	2006	2007	2008	2101	2102	2103	2104	2105	2106	2107	2108	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211
11/21/85									23.5		38.0	0.2	7.0	7.5	6.0	9.0	9.5		4.5	12.0	11.2	9.2	0.6	7.2	17.4	15.2	13.0
02/03/86																		0.4	22.8	13.6	12.8	16.4	<0.2	2.0	3.6	7.0	5.6
03/18/86									29.4	47.4	42.0	<0.2	1.2	4.2	4.2	4.2	7.2	3.6	27.0	21.0	17.6	19.2	<0.2	0.8	4.8	16.2	10.2
03/31/86																	4.2	1.5	14.2	11.8	15.5	8.0	0.5	<0.2	6.6	16.0	9.8
04/17/86																	7.0	2.8	19.5	11.5	14.5	14.0	0.2	1.0	10.0	17.2	10.0
05/07/86																	4.0	1.0	15.2	8.0	13.0	10.2	0.7	0.5	10.2	17.8	9.0
05/27/86	8.5	8.5	14.2	15.7	19.0	25.2											2.2	1.0	13.2	11.0	11.5	11.0	0.7	1.5	12.2	18.2	8.5
05/28/86									92.5	32.2	9.0	<0.2	1.5	11.0	8.5	11.0											
06/18/86																	8.6	5.0	11.5	11.0	12.5	12.0	0.5	<0.2	14.0	17.0	8.5
07/14/86	11.0	11.2	13.7	13.0	13.5	20.0	31.2	33.7	135.0	28.0	27.7		0.5	8.5	8.0	7.5		31.0	10.7	14.7	15.0	13.5	1.0	2.7	15.5	16.0	15.5
08/11/86																		60.0	14.0	15.0	15.0	15.0	3.5	3.5	15.8	17.0	12.5
09/17/86									49.2	23.5	1.0	<0.2	<0.2	10.2	7.5	9.0		42.0	13.8	12.8	13.2	13.0	3.8	1.8	13.5	8.0	10.5
09/22/86	11.2	15.0	12.6	8.0	10.8	21.5	27.0																				
10/15/86	15.0	14.5	16.0	11.0	14.2	24.5	26.8	26.2	70.0	28.2	0.5	<0.2	7.5	22.2	10.8	11.0	6.0	60.0	<0.2	18.8	15.5	10.0	5.0	5.5	11.5	10.8	7.5
10/28/86									51.5		0.8	<0.2	6.0	11.0	10.2	10.5	3.5	10.5	28.2	17.0	15.5	14.5	3.0	2.5		10.5	
11/11/86																	18.0	7.5	19.6	16.2	18.0	17.6	3.2	3.4	12.0		
12/09/86																	15.2	1.0	12.0	19.0	17.8	17.5	1.2	1.2	10.8		
01/12/87									140.0	115.0	12.0	<0.2	4.5	6.2	5.0	7.2	7.2	1.0	10.2	21.0	19.6	20.8	2.0	2.2	11.6	11.4	.12 0
02/10/87									120.0	132.0	39.0	0.2					8.0	1.0	6.5				3.6	4.0			
03/16/87									130.0	146.0	49.5	2.2	3.5	<0.2	8.5	6.5											
03/31/87																	9.2	1.0	8.8	21.0	20.0	20.8	2.5	5.0	15.2		
05/04/87	11.5	11.5	11.2	9.5	10.2	22.0	18.2	18.8	56.5	75.0	97.5	0.5	2.8	11.8	10.5	10.0	31.5	32.5	23.0	24.8	19.2	19.0	4.2	5.5	16.5	16.5	17.2
06/10/87	9.8	9.8	9.6	9.5	10.9	11.9	20.2	20.0		40.0	89.0	0.5	3.5	6.8	9.4	9.0			1.0	17.8	16.8	16.7	7.2				
02/03/88											70.0	19.0		12.0	3.2	4.8			5.0	12.0		0.5	11.2	4.5	8.0	20.5	19.0
06/20/88	6.0	6.8	7.0	7.5	9.5	9.0	15.5	15.5			92.5	24.0	0.2	10.2	17.0	18.5				15.5	20.0	18.5	5.0	8.2	10.8	8.0	21.0
08/17/88											52.5	<0.2	9.0	15.0	15.5	14.0				8.0	9.5	10.0	8.0	8.5	11.0	2.0	18.5
10/19/88	16.0	11.2	9.5	9.5	10.5	15.5																					
01/19/89											77.5	0.8			15.8	15.5					10.5	12.0	7.5	11.0	12.5	12.2	13.0
05/22/89	18.0	16.0	16.0	11.0	11.5	8.5	4.5	3.0			38.0	0.8	12.2	20.5	20.8	18.8				2.2	1.0	1.8	2.5	4.0	10.0	14.5	16.5
12/01/89											90.0	<0.2	21.0	90.0	27.2	24.5				6.5	7.2	7.2	2.0	3.5		6.5	14.2
05/31/90											95.0	50.0	34.0	34.2	37.2	36.0			60.0	49.8	16.2	4.5	6.2	16.8	15.5	17.2	18.8
08/15/90																				123.0		50.9	11.7	9.1	11.9	7.2	15.7
10/12/90						24.9	39.1	38.7			85.2	<0.2	42.1	42.5	39.7	36.3			138.0	110.0	64.3	57.8	17.4	6.2	14.2	12.4	18.0
01/16/91		36.1	36.8	26.2	17.6	17.6	13.9	7.5			109.0	<0.2	37.1	36.0	37.7	34.8			138.0	137.0	115.0	128.0	9.4	8.6	25.5		26.4
03/14/91	37.6	38.1	38.8	27.2		17.2		3.6			2.0	0.6	43.0	45.0	41.4	42.2				107.0	139.0	91.0	11.4	14.8	38.6		20.3
04/26/91		38.0	37.2	23.1	26.7	17.4	6.4	5.2		59.0	106.0	0.9	60.5	50.8	46.3	45.3			65.0	46.8	73.0	40.3	18.0	12.7	39.1	23.3	24.0
06/19/91	41.0	40.3	38.7	26.3	27.4	18.1	9.3	8.8		46.3	81.0	9.3	55.0	47.8		45.5			85.0	77.0	77.0	63.0	27.3	31.0	40.2	33.0	30.9
09/23/91	51.0	51.5	46.7	29.4	28.3	20.5	15.9	10.3			21.0	<0.2	42.2	52.2	74.0	56.0				96.0	86.0	79.0	79.0	15.3	49.7	15.8	3.9
12/10/91	51.8	50.9	50.3	34.2	31.4	25.2	20.1				116.0	<0.2	58.0	58.0	58.0				49.8	90.0	90.0	71.0	33.4	35.6	58.0	16.3	24.0

Table 14. Site 2 Ammonia-N concentrations (mg/l)

Sample Date	2001	2002	2003	2004	2005	2006	2007	2008	2101	2102	2103	2104	2105	2106	2107	2108	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211
11/21/85									1.03		1.70	1.54	0.23	0.17	0.28	0.05	0.26		0.24	0.20	0.12	0.58	3.00	0.04	0.04	0.06	0.01
02/03/86																		<0.02	<0.02	<0.02	<0.02	<0.02	0.95	1.35	<0.02	<0.02	<0.02
03/18/86									0.76	0.34	2.04	3.44	0.14	0.04	0.16	0.06	0.06	0.04	0.04	<0.01	<0.01	<0.01	1.92	1.74	0.06	<0.01	0.04
03/31/86																	<0.02	0.02	0.06	0.02	<0.02	0.02	3.02	2.66	0.16	0.02	<0.02
04/17/86																	0.02	0.06	0.02	<0.02	<0.02	<0.02	2.86	2.72	<0.02	<0.02	<0.02
05/07/86																	0.10	0.50	0.05	0.05	<0.05	<0.05	2.90	2.40	<0.05	<0.05	<0.05
05/27/86	0.14	0.08	<0.02	0.02	0.04	<0.02											1.32	1.90	0.26	0.06	<0.02	<0.02	2.56	2.28	0.14	0.04	0.02
05/28/86									2.78	0.44	1.12	1.48	0.02	0.06	<0.02	<0.02											
06/18/86																	10.40	3.38	0.34	0.06	0.20	0.02	2.24	2.92	0.04	<0.02	<0.02
07/14/86	0.04	0.02	<0.02	<0.02	<0.02	0.10	0.02	<0.02	21.60	0.76	0.80		0.04	<0.02	0.06	0.04		4.40	0.06	0.04	0.02	0.02	1.68	1.10	0.02	<0.02	0.02
08/11/86																		0.14	0.02	0.02	0.04	<0.02	1.66	2.14	0.08	<0.02	<0.02
09/17/86									0.38	0.20	0.20	1.28	0.10	0.02	<0.02	<0.02		0.02	0.06	<0.02	0.04	<0.02	2.12	0.70	0.02	0.04	<0.02
09/22/86	0.04	0.04	0.04	<0.02	<0.02	0.04	0.06																				
10/15/86	<0.02	<0.02	<0.02	<0.02	0.02	<0.02	<0.02	<0.02	0.12	0.22	2.28	0.96	<0.02	<0.02	<0.02	<0.02	0.04	0.22	<0.02	0.02	<0.02	0.12	3.36	3.02	0.04	0.04	0.02
10/28/86									0.16		2.00	0.88	0.02	<0.02	<0.02	<0.02	<0.02	0.30	0.06	<0.02	<0.02	<0.02	3.32	3.02		<0.02	
11/11/86																	0.20	0.38	0.12	<0.02	0.04	<0.02	3.54	3.18	0.04		
12/09/86																	1.06	0.38	0.06	<0.02	<0.02	<0.02	1.82	1.52	<0.02		
01/12/87									0.06	0.12	1.16	0.20	<0.02	<0.02	<0.02	<0.02	2.00	0.52	0.04	<0.02	<0.02	<0.02	1.84	1.24	<0.02	<0.02	<0.02
02/10/87									0.06	0.16	0.98	0.28					1.80	0.40	0.12				2.98	2.16			
03/16/87									0.16	0.20	0.86	0.18	0.04	<0.02	0.04	<0.02											
03/31/87																	0.18	0.20	0.06	<0.02	0.04	<0.02	3.14	1.98	<0.02		
05/04/87	0.02	0.04	0.04	0.04	0.02	<0.02	0.04	0.04	0.04	0.12	0.04	0.20	0.04	0.06	0.04	0.04	0.02	<0.02	0.30	0.25	0.20	<0.02	3.56	2.92	0.04	<0.02	0.04
08/10/87	<0.04	<0.04	<0.04	<0.04	0.04	<0.04	<0.04	<0.04		0.06	<0.04	0.32	<0.04	<0.04	<0.04	<0.04			0.04	<0.04	<0.04	<0.04	2.08				
02/03/88											<0.01	<0.01		<0.01	<0.01	<0.01			<0.01	<0.01		0.26	<0.01	2.06	1.56	<0.01	<0.01
06/20/88	0.04	0.02	0.02	<0.02	<0.02	0.04	0.02	0.04			0.04	0.06	0.04	0.04	0.02	0.04				0.04	0.02	0.04	2.56	1.42	0.04	0.04	0.02
08/17/88											0.25	0.12	<0.02	<0.02	<0.02	0.05				<0.02	<0.02	<0.02	0.22	0.15	<0.02	<0.02	<0.02
10/19/88	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02																					
01/19/89											0.09	0.21			<0.02	0.03					0.07	0.03	1.50	0.50	0.03	<0.02	<0.02
05/22/89	0.02	0.12	<0.02	<0.02	<0.02	<0.02	<0.02	0.10			0.26	0.10	0.05	0.05	<0.02	<0.02				<0.02	0.10	0.02	1.25	1.10	0.22	<0.02	0.05
12/01/89											0.02	0.06	0.05	0.02	0.02	<0.02				0.06	0.06	0.10	0.10	0.30		0.06	0.02
05/31/90											0.05	0.05	0.05	0.05	<0.02	0.02			0.10	1.02	0.45	0.55	0.30	0.05	0.02	0.02	0.02
08/15/90																				0.15		0.50	0.05	0.38	0.10	<0.02	0.05
10/12/90						0.02		0.02			0.02	0.05	<0.02	<0.02	<0.02	<0.02			0.02	0.05	0.15	0.06	0.02	0.60	<0.02	<0.02	<0.02
01/16/91		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02			0.18	0.06	0.02	0.02		0.05			0.02	0.28	1.02	0.30	0.05	0.40	0.12		<0.02
03/14/91	0.10	0.08	0.10	0.45		<0.02		<0.02			0.10	0.10	0.05	0.15	0.02	0.05				0.12	0.40	0.25	0.05	0.30	0.10		<0.02
04/26/91		0.05	0.02	1.28	0.05	0.10	0.05	0.10				0.15	0.05	0.05	0.02	0.05			0.12	1.62	1.45	1.55	0.55	0.35	0.05	0.05	0.02
06/19/91	0.02	<0.02	<0.02	0.85	<0.02	<0.02	<0.02	<0.02		<0.02	<0.02	0.05	<0.02	<0.02		<0.02			0.05	4.62	3.00	3.42	0.45	0.15	<0.02	<0.02	
09/23/91	0.02	<0.02	0.05	0.55	<0.02	0.05	<0.02	<0.02			<0.02	0.12	<0.02	<0.02	0.02	<0.02				0.25	1.30	0.95	0.05	0.10	0.02	0.02	<0.02
12/10/91	<0.02	<0.02	<0.02	0.12	<0.02	<0.02	<0.02				<0.02	0.15	<0.02	<0.02	<0.02				<0.02	<0.02	1.10	0.85	0.12	0.02	<0.02	0.05	<0.02

Table 15. Site 2 Chloride concentrations (mg/l)

Sample Date	2001	2002	2003	2004	2005	2006	2007	2008	2101	2102	2103	2104	2105	2106	2107	2108	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211
11/21/85									66.0		102.0	69.0	30.0	32.0	33.0	36.0	49.0		88.0	46.0	38.0	46.0	53.0	53.0	22.0	26.0	20.0
02/03/86																		50.0	56.0	54.0	37.0	41.0	22.0	50.0	16.0	10.0	11.0
03/18/86									136.0		25.0	54.0	32.0	29.0	39.0	34.0	202.0	140.0	99.0	50.0	46.0	46.0	58.0	61.0	68.0	34.0	21.0
03/31/86																	172.0	105.0	86.0	44.0	33.0	38.0	30.0	30.0	26.0	19.0	15.0
04/17/86																	10.0	50.0	89.0	40.0	35.0	37.0	37.0	39.0	39.0	20.0	15.0
05/07/86																	239.0	293.0	117.0	71.0	35.0	29.0	42.0	44.0	41.0	28.0	19.0
05/27/86	20.0	22.0	23.0	23.0	22.0	34.0											63.0	31.0	29.0	36.0	42.0	29.0	43.0	43.0	45.0	28.0	18.0
05/28/86									116.0	148.0	110.0	58.0	22.0	22.0	22.0	23.0											
06/18/86																	242.0	207.0	108.0	29.0	23.0	21.0	22.0	32.0	31.0	29.0	18.0
07/14/86	21.0	21.0	22.0	20.0	20.0	23.0	24.0	25.0	170.0	107.0	68.0		22.0	19.0	18.0	18.0		117.0	89.0	20.0	23.0	28.0	34.0	37.0	31.0	22.0	19.0
08/11/86																		253.0	57.0	27.0	27.0	25.0	43.0	42.0	35.0	28.0	23.0
09/17/86									459.0	309.0	43.0	23.0	17.0	16.0	17.0	17.0		72.0	104.0	25.0	19.0	20.0	36.0	37.0	30.0	22.0	20.0
09/22/86	19.0	20.0	20.0	17.0	17.0	19.0	21.0																				
10/15/86	22.0	22.0	23.0	20.0	19.0	22.0	24.0	24.0	160.0	96.0	76.0	46.0	28.0	34.0	40.0	30.0	30.0	111.0	82.0	52.0	34.0	35.0	37.0	35.0	25.0	23.0	17.0
10/28/86									90.0		66.0	46.0	36.0	38.0	34.0	30.0	36.0	115.0	60.0	52.0	33.0	34.0	40.0	38.0		24.0	
11/11/86																	90.0	108.0	84.0	54.0	40.0	41.0	47.0	42.0	26.0		
12/09/86																	224.0	126.0	91.0	55.0	45.0	45.0	43.0	42.0	28.0		
01/12/87									77.0	146.0	198.0	32.0	21.0	24.0	17.0	23.0	240.0	165.0	64.0	48.0	41.0	44.0	35.0	36.0	24.0	24.0	22.0
02/10/87									85.0	71.0	106.0	37.0					250.0	195.0	105.0				39.0	36.0			
03/16/87									102.0	87.0	110.0	29.0	18.0	18.0	18.0	23.0											
03/31/87																	157.0	208.0	98.0	51.0	45.0	46.0	67.0	45.0	34.0		
05/04/87	18.0	18.0	18.0	17.0	16.0	20.0	20.0	20.0	110.0	110.0	98.0	48.0	19.0	17.0	17.0	19.0	99.0	111.0	70.0	114.0	27.0	27.0	21.0	63.0	56.0	35.0	28.0
06/10/87	16.0	16.0	15.0	15.0	17.0	17.0	21.0	21.0		130.0	130.0	110.0	16.0	12.0	14.0	15.0			180.0	45.0	30.0	31.0	44.0				
02/03/88											110.0	22.0		41.0	16.0	18.0			18.0	75.0		70.0	32.0	68.0	60.0	41.0	22.0
06/20/88	16.0	18.0	17.0	16.0	16.0	15.0	17.0	18.0			250.0	88.0	14.0	18.0	21.0	21.0				51.0	36.0	35.0	47.0	48.0	27.0	17.0	24.0
08/17/88											160.0	93.0	20.0	19.0	23.0	22.0				59.0	43.0	45.0	42.0	41.0	27.0	17.0	23.0
10/19/88	20.0	18.0	17.0	20.0	19.0	19.0																					
01/19/89											160.0	68.0			20.0	22.0					125.0	83.0	65.0	48.0	29.0	25.0	25.0
05/22/89	19.0	18.0	18.0	16.0	16.0	16.0	13.0	12.0			160.0	73.0	19.0	20.0	20.0	20.0				9.0	20.0	23.0	64.0	57.0	30.0	188.0	24.0
12/01/89											55.0	45.0	23.0	24.0	22.0	23.0				116.0	140.0	110.0	35.0	43.0		23.0	22.0
05/31/90											150.0	190.0	57.0	39.0	38.0	37.0			190.0	180.0	130.0	72.0	120.0	39.0	33.0	39.0	32.0
08/15/90																				467.0		202.0	138.0	128.0	38.0	33.0	21.0
10/12/90						25.0	33.0	33.0			177.0	110.0	87.0	63.0	53.0	43.0			172.0	190.0	172.0	158.0	104.0	127.0	60.0	40.0	34.0
01/16/91		33.0	34.0	27.0	24.0	25.0	22.0	18.0			181.0	86.0	58.0	50.0	48.0	47.0			82.0	85.0	113.0	120.0	87.0	107.0	95.0		45.0
03/14/91	32.0	35.0	34.0	32.0		24.0		16.0			110.0	104.0	60.0	59.0	45.0	55.0				66.0	93.0	113.0	93.0	120.0	102.0		35.0
04/26/91		34.0	33.0	29.0	30.0	23.0	17.0	17.0		38.0	60.0	89.0	68.0	62.0	51.0	50.0			21.0	82.0	104.0	86.0	81.0	84.0	91.0	38.0	36.0
06/19/91	35.0	35.0	34.0	32.0	32.0	24.0	19.0	19.0		52.0	81.0	104.0	61.0	54.0		52.0			29.0	48.0	71.0	70.0	74.0	96.0	93.0	54.0	46.0
09/23/91	36.0	38.0	37.0	33.0	32.0	27.0	24.0	20.0			80.0	118.0	80.0	66.0	82.0	62.0				35.0	64.0	97.0	65.0	91.0	112.0	69.0	77.0
12/10/91	36.0	35.0	35.0	33.0	31.0	30.0	25.0				36.0	131.0	57.0	56.0	52.0				14.0	33.0	48.0	62.0	59.0	84.0	79.0	65.0	38.0

Table 16. Site 2 Reactive Phosphorous concentrations (mg/l PO4)

Sample Date	2001	2002	2003	2004	2005	2006	2007	2008	2101	2102	2103	2104	2105	2106	2107	2108	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211
11/21/85									0.175		0.045	0.032	0.005	0.120	0.010	0.010	0.025		0.015	0.025	0.030	0.040	0.180	0.028	0.950	0.073	0.040
02/03/86																											
03/18/86									0.080	0.032	0.125	0.040	0.015	0.008	0.020	0.008	0.020	0.010	0.008	0.005	0.010	0.012	0.015	0.008	0.005	0.002	0.010
03/31/86																	0.010	0.008	0.010	0.008	0.005	0.010	0.020	0.015	0.008	0.008	0.010
09/17/86									0.232	0.335	0.160	0.022	0.005	0.004	0.005	0.002		0.005	0.010	0.005	0.002	<0.002	0.005	<0.002	0.002	0.020	0.010
09/22/86	<0.002	<0.002	<0.002	<0.002	<0.002	0.005	0.015																				
03/16/87																											
03/31/87																	0.015	0.005	0.020	0.005	0.005	<0.002	<0.002	<0.002	<0.002		
05/04/87																		<0.002	<0.002	<0.002	<0.002	<0.002					
08/10/87	<0.005	0.005	<0.005	<0.005	0.010	0.010	0.010	0.010		0.220	0.160	0.010	<0.005	<0.005	<0.005	<0.005			0.025	0.005	<0.005	<0.005	<0.005				
02/03/88											0.350	<0.002		0.005	<0.002	<0.002			<0.002	0.002		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
06/20/88																											
08/17/88											1.000	<0.002	<0.002	0.002	0.005	0.005				<0.002	0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
10/19/88	<0.002	<0.002	<0.002	<0.002	0.015	0.012																					
01/19/89											0.695	0.002			0.002	<0.002					0.575	0.055	0.005	0.002	<0.002	<0.002	<0.002
05/22/89	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002			0.680	<0.002	0.002	<0.002	<0.002	<0.002				0.122	0.025	0.005	<0.002	<0.002	<0.002	<0.002	<0.002
12/01/89											5.380	<0.002	<0.002	<0.002	<0.002	0.020				0.088	0.025	0.010	<0.002	0.015		0.008	0.002
05/31/90											4.180	0.010	0.002	0.002	0.005	0.005			0.072	0.052	0.005	<0.002	<0.002	<0.002	<0.002	<0.002	0.002
08/15/90																				0.022		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
10/12/90											0.750	0.005	0.002	<0.002	0.002	<0.002			0.108	0.042	0.002	<0.002	0.002	<0.002	<0.002	<0.002	<0.002
01/16/91		<0.002	<0.002	<0.002	0.010	<0.002	0.005	0.005			0.675	<0.002	<0.002	<0.002	<0.002	<0.002			0.270	0.018	0.005	<0.002	<0.002	<0.002	<0.002		<0.002
03/14/91	0.005	0.002	<0.002	0.005		0.015		0.020			<0.002	<0.002	<0.002	0.002	0.005	0.002				0.040	0.012	0.010	0.005	<0.002	<0.002		<0.002
04/26/91		0.002			0.005	0.008		0.002		5.700	2.450	0.005	0.002						1.250	0.020			0.002			0.005	
06/19/91	<0.002	<0.002	<0.002	0.052	<0.002	0.008	0.010	0.010		8.120	2.280	0.005	<0.002	<0.002		<0.002			1.300	0.080	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
09/23/91	<0.002	0.002	0.002	0.042	0.005	0.008	0.015	0.015			2.580	0.002	<0.002	<0.002	<0.002	<0.002				0.140	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
12/10/91	<0.002	<0.002	<0.002	0.028	<0.002	0.008	0.010				0.180	<0.002	<0.002	<0.002	<0.002				0.825	0.062	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002

Table 17. Site 2 pH

Sample Date	2001	2002	2003	2004	2005	2006	2007	2008	2101	2102	2103	2104	2105	2106	2107	2108
11/21/85									7.42		7.16	7.20	7.46	7.38	7.35	7.23
02/03/86																
03/18/86									6.50	6.37	6.65	6.93	6.87	6.69	6.91	7.15
09/17/86									6.04	6.03	6.29	6.49	6.55	6.48	6.44	6.69
08/10/87	7.11	7.19	4.36	6.95	7.27	7.70	8.02	8.33		7.21	6.86	7.11	6.99	7.04	7.07	7.27
02/03/88											6.40	7.09		6.28	6.73	6.65
06/20/88	6.22	6.24	6.28	6.34	6.93	7.31	7.82	7.78			6.33	6.48	6.59	6.54	6.49	6.65
08/17/88											6.38	6.60	6.61	6.65	6.65	6.97
10/19/88	6.62	6.52	6.50	6.60	7.19	7.83										
01/19/89											6.32	6.60			6.77	6.90
05/22/89	6.36	6.21	6.32	6.58	6.91	7.73	7.84	7.87			6.26	6.48	6.61	6.62	6.63	6.86
12/01/89											6.52	6.63	6.75	7.05	7.04	7.28
05/31/90											6.45	6.31	6.60	6.78	6.89	6.94
08/15/90																
10/12/90						6.88	6.78	6.98			6.52	6.43	6.56	6.92	7.02	7.03
01/16/91		6.54	6.45	6.56	7.83	7.74	7.85	7.86			6.50	6.23	6.74	6.86	6.93	6.94
03/14/91	6.22	6.22	6.22	6.48		7.77		7.93			6.20	6.18	6.59	6.87	6.96	6.97
04/26/91		6.32	6.42	6.56	7.15	7.71	7.91	7.91		6.37	6.34	6.28	6.66	6.77	6.95	7.07
06/19/91	6.23	6.21	6.26	6.64	6.96	7.70	7.84	7.88		6.47	6.36	6.29	6.56	6.74		6.92
09/23/91	6.07	6.20	6.20	6.61	7.18	7.64	7.82	7.87			6.38	6.26	6.52	6.74	6.66	6.84
12/10/91	6.36	6.25	6.33	6.46	7.04	7.70	7.84				6.78	6.35	6.75	7.03	7.11	

Sample Date	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211
11/21/85	7.29		6.76	7.23	7.57	7.53	7.30	7.11	7.53	7.44	7.66
02/03/86											
03/18/86	6.94	6.45	6.38	6.96	6.85	6.74	6.64	7.06	7.17	6.94	7.30
09/17/86		6.50	6.03	6.29	6.31	6.33	6.40	6.48	6.88	6.83	6.95
08/10/87			6.41	6.72	6.80	6.85	7.05				
02/03/88			7.05	5.94		6.52	6.44	6.95	6.68	7.23	6.77
06/20/88				6.06	6.19	6.19	6.49	6.44	6.93	6.69	6.88
08/17/88				6.14	6.22	6.27	6.44	6.48	7.10	7.32	7.20
10/19/88											
01/19/89					6.41	6.28	6.48	6.53	7.02	7.01	7.14
05/22/89				6.37	6.19	6.22	6.35	6.42	6.75	6.44	7.19
12/01/89				6.31	6.34	6.49	6.72	6.76		7.38	7.43
05/31/90			6.50	6.31	6.30	6.69	6.46	6.54	6.84	6.51	7.35
08/15/90				6.35		6.28	6.46	6.36	6.87	7.19	7.21
10/12/90			6.74	6.36	6.40	6.34	6.53	6.59	6.99	7.22	7.17
01/16/91			7.14	6.48	6.41	6.26	6.61	6.46	6.66		7.28
03/14/91				6.39	6.31	6.27	6.55	6.46	6.62		7.18
04/26/91			6.91	6.37	6.36	6.46	6.60	6.49	6.66	6.72	6.56
06/19/91			6.72	6.29	6.30	6.29	6.52	6.40	6.61	6.52	7.18
09/23/91				6.80	6.60	6.52	6.61	6.60	6.67	6.97	7.24
12/10/91			7.00	6.77	6.42	6.41	6.48	6.31	6.91	7.06	7.12

Table 18. Site 2 Conductivity (umho)

Sample Date	2001	2002	2003	2004	2005	2006	2007	2008	2101	2102	2103	2104	2105	2106	2107	2108
11/21/85									848		1122	892	539	535	557	604
02/03/86																
03/18/86									1215	1476	1265	692	491	473	464	532
03/31/86																
04/17/86																
05/07/86																
05/27/86	412	517	547	529	540	531										
05/28/86									1550	1106	948	969	390	407	379	456
06/18/86																
07/14/86	390	443	475	469	505	578	518	518	2780	1120	771		462	422	413	495
08/11/86																
09/17/86									224	165	807	1238	475	461	438	523
09/22/86	393	428	437	420	461	524	486									
10/15/86	412	445	482	474	495	530	502	483	1604	1180	783	751	545	516	509	553
10/28/86									1268		745	736	491	491	460	527
11/11/86																
12/09/86																
01/12/87									1697	1554	1061	507	402	402	323	457
02/10/87									1619	1629	1255	511				
03/16/87									1814	1874	1326	460	365	372	341	467
03/31/87																
05/04/87																
06/10/87	323	333	368	341	454	527	436	396		1559	1790	1107	437	364	394	464
02/03/88											1720	486		512	380	389
06/20/88	318	328	334	347	469	515	433	430			2010	1569	405	460	503	578
08/17/88											1884	1409	450	469	478	518
10/19/88	423	389	404	384	546	429										
01/19/89											1864	1161			465	526
05/22/89	407	389	400	376	436	499	431	414			1871	1118	494	510	527	576
12/01/89											1555	814	526	522	527	558
05/31/90											2100	2230	755	665	685	691
08/15/90																
10/12/90						432	566	595			1000	1450	1141	803	756	756
01/16/91		565	575	443	531	512	461	443			2070	1012	722	694	693	726
03/14/91	543	558	533	438		499		421			1318	1214	716	.717	663	692
04/26/91		559	544	444	499	512	452	454		1356	1743	1184	865	767	696	741
06/19/91	602	604	578	476	524	534	483	490		1212	1741	1431	890	784		774
09/23/91	661	631	584	453	496	519	508	465			1418	1431	1024	872	1232	907
12/10/91	692	675	671	521	526	625	570				1847	1813	878	860	893	

Sample Date	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211
11/21/85	551		694	498	481	503	496	504	441	434	397
02/03/86		927	715	623	488	523	500	596	490	423	510
03/18/86	950	857	730	518	477	504	452	522	535	397	486
03/31/86	971	849	799	518	454	479	456	503	522	403	441
04/17/86	960	1184	737	454	428	435	431	482	467	369	337
05/07/86	1151	1443	715	585	388	327	431	450	423	390	381
05/27/86	1510	1190	869	470	435	417	488	550	570	474	453
05/28/86											
06/18/86	1540	1193	883	431	393	380	429	502	533	435	391
07/14/86		1151	790	406	434	440	470	487	553	447	440
08/11/86		1659	597	432	412	417	460	515	565	491	422
09/17/86		1135	784	440	404	389	457	457	551	458	421
09/22/86											
10/15/86	567	1212	792	531	434	446	459	482	475	496	402
10/28/86	572	960	736	529	484	484	534	545		534	
11/11/86	984	1016	834	570	490	499	523	534	514		
12/09/86	1304	974	696	511	454	468	426	464	494		
01/12/87	1326	994	540	494	445	469	396	428	476	354	459
02/10/87	1178	1041	687				400	420			
03/16/87											
03/31/87	991	1003	699	522	489	491	542	466	483		
05/04/87											
06/10/87			1012	470	409	421	466				
02/03/88			470	616		1127	437	593	564	579	362
06/20/88				580	485	497	522	519	486	416	542
08/17/88				512	448	463	432	431	500	445	535
10/19/88											
01/19/89					1026	705	595	511	491	460	499
05/22/89				196	260	283	671	621	594	468	577
12/01/89				960	846	744	358	450		483	490
05/31/90			1693	1556	1033	616	1047	499	606	489	573
08/15/90				1679		1412	954	854	606	548	421
10/12/90			1000	1952	1514	1395	1012	944	728	612	570
01/16/91			1579	1575	1535	1291	914	922	910		674
03/14/91				1333	1596	1354	866	861	949		511
04/26/91			938	1057	1213	947	822	815	940	503	466
06/19/91			1239	1174	1032	1066	897	1006	962	630	674
09/23/91				1115	1142	1206	1071	870	874	762	809
12/10/91			700	1275	1224	1122	891	945	1029	760	580

Table 19. Site 2 Chemical Oxygen Demand (mg/l oxygen damand)

Sample Date	2001	2002	2003	2004	2005	2006	2007	2008	2101	2102	2103	2104	2105	2106	2107	2108	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211
03/18/86									92.0	84.0	57.6	57.6	31.2	20.0	18.4	17.6	33.6	24.8	15.2	12.8	25.6	23.2	49.6	36.8	20.0	8.0	10.1
09/17/86									150.4	140.8	128.0	84.0	14.4	4.8	8.8	8.0		16.0	12.8	4.0	8.0	8.0	24.0	21.6	4.8	4.8	5.6
09/22/86	16.0	13.7	10.6	9.1	6.8	3.8	3.0																				
01/16/91		12.6	11.6	5.5	<3.0	5.0	16.1	<3.0			141.7	19.3	15.7	<3.0	8.6	12.2			61.0	39.1	41.1	37.6	53.7	33.2	13.2		20.5
12/10/91	8.4	12.3	6.3	8.9	11.4	<3.0	<3.0				126.6	103.7	11.4	8.7	8.3				95.6	42.8	30.2	35.2	44.5	30.1	34.4	7.8	6.5

Table 20. Site 2 Sodium (mg/l)

Sample Date	2001	2002	2003	2004	2005	2006	2007	2008	2101	2102	2103	2104	2105	2106	2107	2108	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211
11/21/85									3.0		16.5	16.5	8.5	8.5	9.0	7.5	13.5		10.0	8.0	8.5	9.0	14.0	9.5	4.5	4.5	4.0
03/18/86									26.0		19.8	9.0	5.7	5.0	5.3	5.4		9.6	6.4	5.4	6.7	6.4	13.3	13.5	4.7	4.1	3.0
09/17/86									50.0	32.2	16.0	16.5	5.0	3.0	3.8	3.6		25.0	8.5	3.2	3.6	3.2	8.8	9.0	5.5	3.0	2.0
09/22/86	2.1	2.3	2.3	2.0	2.1	2.3	2.3																				
08/10/87	2.0	2.0	2.0	2.5	2.0	2.5	2.5	2.5		160.0	26.0	19.0	5.0	3.5	4.0	3.5			16.0	5.0	5.0	5.0	8.0				
02/03/88											23.5	3.0		8.0	3.9	3.1			3.7	8.0		19.0	5.4	13.0	9.3	5.3	7.0

Table 21. Site 2 Alkalinity (mg/l)

Sample Date	2001	2002	2003	2004	2005	2006	2007	2008	2101	2102	2103	2104	2105	2106	2107	2108	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211
03/18/86									188	140	200	220	180	172	156	196	164	200	128	104	96	104	156	200	180	24	172
09/17/86									204	184	264	304	180	136	132	180		232	140	108	92	96	136	152	172	116	132
09/22/86	72	100	88	132	148	136	84																				
02/03/88											308	124		132	148	136			180	144		256	112	152	144	124	76
01/19/89											228	240			120	156					260	164	148	122	152	126	148
05/22/89	56	60	68	84	120	172	164	168			296	196	108	100	100	140				56	72	72	148	136	172	80	132
12/01/89											184	140	112	112	112	144				200	168	156	112	136		156	136
12/10/91	32	36	36	48	76	172	168				288	268	104	112	120				88	88	96	124	180	172	164	168	120

Table 22. Site 2 Total Hardness (mg/l)

Sample Date	2001	2002	2003	2004	2005	2006	2007	2008	2101	2102	2103	2104	2105	2106	2107	2108	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211
03/18/86									228	296	248	116	148	160	136	204		328	260	200	160	184	148	176	200	156	204
09/17/86									404	276	144	228	184	204	184	228		464	324	192	172	176	176	200	272	224	212
09/22/86	172	200	208	208	224	252	232																				
02/03/88											388	232		224	170	162			212	268		224	194	194	200	268	166
01/19/89											352	236			192	240					352	276	224	204	236	220	252
05/22/89	168	164	168	160	192	204	212	208			408	252	172	204	216	240				64	104	120	196	180	260	188	252
12/01/89											224	176	188	236	248	264				420	380	336	156	192		256	248
12/10/91	296	292	288	224	236	308	280				272	568	388	404	408				208	436	484	476	340	380	488	380	300

Table 23. Site 4 Potassium concentrations (mg/l)

Sample Date	4101	4102	4103	4104	4105	4106	4201	4202	4203	4204	4205	4206	4207	4208
11/21/85														
02/05/86														
03/18/86	2.0	1.0	8.0	1.0	1.0	1.0		220.0	230.0	32.0	2.0	<1.0	<1.0	<1.0
03/31/86														
04/18/86														
05/07/86							95.0	105.0	190.0	90.0	1.5	0.5	0.5	0.5
05/28/86														
06/18/86														
07/14/86	2.0	<1.0	6.5	<1.0	<1.0	<1.0		160.0	220.0	110.0	3.0	<1.0	<1.0	<1.0
08/11/86								188.0	9.0	125.0	23.0	2.5	0.5	0.5
09/08/86		0.8	6.2	0.5	0.8	0.5		130.0	158.0	48.5	2.2	0.8	0.8	0.5
10/02/86							108.0	136.0	158.0	<0.2	2.4	<0.2	<0.2	0.6
10/28/86							152.0	157.0	160.0	57.0	2.1	0.6	0.4	0.7
11/11/86							102.0	133.0	169.0	60.0	2.5	0.5	0.3	0.3
12/09/86							165.0	162.5	190.0	55.0	1.5	1.0	0.5	0.5
01/12/87	1.0	0.4	3.1	0.3	0.8	0.8	124.0	131.0	149.0	38.0	1.5	0.8	0.7	0.7
02/10/87								131.0			1.8	0.6	0.6	0.6
03/31/87	1.1	0.6	6.7	0.6	0.7	0.6		170.0	213.0	90.5	1.3	0.8	0.8	0.7
05/04/87	1.1	<0.5	7.3	0.5	0.5	0.5		152.0	194.0	87.0	1.0	0.5	0.5	1.0
08/10/87		0.5	0.5	0.5	0.5	0.5			10.0	1.0	1.0	1.0	1.0	2.0
02/05/88														
02/08/88			5.0		0.5	0.7			95.0	7.5	0.9	0.6	0.5	0.7
06/20/88			7.0		0.5	0.5			180.0	14.0	1.0	0.5	0.5	0.5
10/19/88			5.8		<0.1				228.5	99.0	8.8	0.7	0.7	0.7
01/19/89			3.5	0.5	<0.5	<0.5			222.5	170.0		1.0	0.5	<0.5
05/22/89			3.0	0.5	0.5	0.5			153.0	40.0	14.5	1.0	0.5	0.5
12/28/89									225.0	130.0	94.0	3.5	0.5	0.5
12/29/89			3.5	<0.5	<0.5	0.5								
05/11/90			5.1	0.7	0.4	0.4			160.0	79.0	28.0	2.0	0.4	0.4
08/16/90			8.8	0.7	0.8	0.4								
08/21/90									255.0	195.0	75.0	0.5	0.5	2.5
10/20/90			5.5	0.5	<0.5	<0.5								
10/29/90									236.0	148.0	16.0	6.5	4.5	<0.5
01/17/91			4.8		0.4	0.2			222.0	137.0	36.8	67.0	0.4	0.1
03/15/91			6.0		1.0	0.5			210.0	75.0	80.0	9.0	1.0	0.5
04/25/91		0.5	7.3	1.0	0.8	0.6			179.9	63.1	37.2	3.1	0.7	0.7

Table 24. Site 4 Nitrate-N concentrations (mg/l)

Sample Date	4101	4102	4103	4104	4105	4106	4201	4202	4203	4204	4205	4206	4207	4208
11/21/85														
02/05/86	4.8	4.8	5.0	29.6	36.4	27.8		27.8	22.2	27.4	33.2	34.4	20.8	12.8
03/18/86	5.0	4.2	4.6	28.5	32.4	21.9		27.6	18.0	23.4	39.6	24.6	20.4	12.4
03/31/86							4.0	2.0	2.0	23.5	38.5	26.8	19.0	13.0
04/18/86							16.0	13.8	29.5	23.0	38.0	25.0	18.0	11.8
05/07/86							8.2	8.5	30.5	17.2	37.8	33.2	16.0	11.2
05/28/86	4.0	5.7	4.7	21.7	27.5	44.2	31.0	23.7	39.2	11.5	21.7		17.5	12.0
06/18/86							21.0	15.0	34.5	9.2	25.5	30.5	19.0	12.5
07/14/86	3.0	6.0	4.7	27.5	30.5	42.7		15.7	40.5	7.7	28.7	35.2	15.0	13.5
08/11/86								17.5	<0.2	20.2	10.2	15.5	23.0	29.5
09/08/86		2.2	4.0	26.2	33.0	42.0		15.5	20.5	22.5	26.0	32.2	22.0	15.5
10/02/86							12.5	17.5	23.5	21.6	23.5	30.5	22.8	15.8
10/28/86							19.0	13.5	26.0	13.5	29.0	37.0	22.0	14.2
11/11/86							19.4	14.2	26.5	5.2	25.0	36.0	21.4	14.5
12/09/86							15.0	12.0	22.5	5.5	17.0	31.5	22.5	15.8
01/12/87	5.6	7.5	1.5	27.5	30.5	38.5	19.5	14.5	24.5	13.2	13.5	35.5	27.0	16.5
02/10/87								17.5			15.5	30.5	30.5	17.0
03/31/87	6.2	7.0	1.2	22.0	25.8	33.5		32.2	28.6	16.2	23.5	34.5	<0.2	19.2
05/04/87	9.0	5.5	2.5	18.5	23.0	37.5		35.2	33.5	27.5	21.5	36.2	35.0	27.0
08/10/87		6.5	2.0	12.7	20.8	30.5			18.2	17.4	27.8	35.9	29.8	21.3
02/05/88														
02/08/88			3.0		12.5	21.5			16.5	12.5	24.0	28.0	23.0	18.8
06/20/88			4.0		11.8	22.5			21.0	12.5	33.5	25.8	20.5	17.0
10/19/88			12.8		7.5				83.0	26.2	24.2	29.5	29.0	20.5
01/19/89			18.8	4.6	5.5	24.8			28.0	26.5		30.0	25.0	15.0
05/22/89			17.0	5.0	6.5	20.0			19.5	22.0	16.5	24.2	20.2	13.5
12/28/89									38.5	31.5	22.2	30.5	23.0	20.5
12/29/89			42.8	9.8	23.8	23.8								
05/11/90			46.0	11.4	4.6	22.0			22.4	4.0	23.0	19.4	17.6	11.5
08/16/90			49.8	32.5	14.0	13.8								
08/21/90									6.2	24.1	31.0	20.3	11.7	31.8
10/20/90			40.4	13.1	7.5	16.2								
10/29/90									45.2	40.6	42.5	29.4	26.8	19.8
01/17/91			44.8		8.4	22.2			38.5	41.2	38.5	39.4	39.7	7.9
03/15/91			36.7		21.0	16.3			32.9	27.7	16.6	17.1	9.4	7.2
04/25/91		1.1	41.6	28.5	20.9	14.0			38.2	25.9	26.1	16.6	13.3	7.2

Table 25. Site 4 Ammonia-N concentrations (mg/l)

Sample Date	4101	4102	4103	4104	4105	4106	4201	4202	4203	4204	4205	4206	4207	4208
11/21/85														
02/05/86	0.05	0.02	<0.02	0.02	0.05	0.02		0.08	0.12	0.05	0.05	0.08	0.05	0.08
03/18/86	0.02	0.02	<0.02	<0.02	<0.02	<0.02		0.04	<0.02	0.02	0.02	<0.02	0.06	0.04
03/31/86							0.08	0.08	0.04	<0.02	<0.02	<0.02	<0.02	<0.02
04/18/86							0.08	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
05/07/86							<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
05/28/86	<0.02	<0.02	0.04	<0.02	<0.02	<0.02	0.08	0.06	0.02	<0.02	<0.02		0.04	<0.02
06/18/86							0.08	0.04	0.12	0.02	0.04	0.04	<0.02	<0.02
07/14/86	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
08/11/86								0.02	0.42	<0.02	<0.02	<0.02	<0.02	<0.02
09/08/86		<0.02	<0.02	<0.02	<0.02	<0.02		0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
10/02/86							1.60	0.52	0.56	0.04	0.02	<0.02	<0.02	0.06
10/28/86							0.20	0.08	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
11/11/86							0.16	0.10	0.04	<0.02	<0.02	<0.02	<0.02	<0.02
12/09/86							<0.02	0.04	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
01/12/87	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
02/10/87								0.04			0.02	0.04	0.02	<0.02
03/31/87	<0.02	<0.02	<0.02	<0.02	0.04	0.04		0.04	0.04	0.04	<0.02	0.04	<0.02	<0.02
05/04/87	0.06	0.02	<0.02	<0.02	0.02	<0.02		<0.02	<0.02	<0.02	0.04	<0.02	<0.02	<0.02
08/10/87		<0.04	<0.04	<0.04	<0.04	<0.04			<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
02/05/88														
02/08/88			<0.02		<0.02	<0.02			<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
06/20/88			0.04		0.02	0.02			0.06	0.02	<0.02	0.04	0.02	0.02
10/19/88					<0.02				<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
01/19/89			<0.02	<0.02	<0.02	<0.02			<0.02	0.03		0.03	0.03	<0.02
05/22/89			0.02	<0.02	<0.02	<0.02			0.02	0.10	<0.02	<0.02	0.02	<0.02
12/28/89									0.05	<0.02	<0.02	0.05	0.02	0.05
12/29/89			0.12	0.05	0.02	0.02								
05/11/90			0.02	<0.02	<0.02	<0.02			0.10	0.62	<0.02	<0.02	<0.02	<0.02
08/16/90			0.05	0.02	0.05	0.02								
08/21/90									2.80	0.32	<0.02	<0.02	<0.02	0.02
10/20/90			<0.02	<0.02	<0.02	<0.02								
10/29/90									<0.02	<0.02	<0.02	0.02	<0.02	<0.02
01/17/91						0.10				0.05				
03/15/91			0.02		0.02	0.02							0.02	0.02
04/25/91		0.02	0.02	0.02	0.02	0.02			0.02	0.02	0.05	0.02	0.02	0.02

Table 26. Site 4 Chloride concentrations (mg/l)

Sample Date	4101	4102	4103	4104	4105	4106	4201	4202	4203	4204	4205	4206	4207	4208
11/21/85														
02/05/86	32.0	31.0	18.0	26.0	32.0	18.0		56.0	90.0	52.0	48.0	35.0	21.0	22.0
03/18/86	38.0	35.0	20.0	28.0	30.0	17.0		69.0	99.0	61.0	50.0	26.0	24.0	23.0
03/31/86							10.0	7.0	7.0	46.0	35.0	21.0	15.0	13.0
04/18/86							32.0	32.0	115.0	61.0	42.0	26.0	23.0	24.0
05/07/86							21.0	23.0	114.0	70.0	53.0	42.0	21.0	22.0
05/28/86	20.0	47.0	25.0	25.0	26.0	35.0	20.0	19.0	101.0	93.0	72.0		20.0	20.0
06/18/86							26.0	16.0	59.0	73.0	52.0	34.0	21.0	21.0
07/14/86	42.0	62.0	38.0	25.0	34.0	35.0		15.0	103.0	67.0	48.0	35.0	14.0	16.0
08/11/86								14.0	3.0	70.0	14.0	33.0	23.0	34.0
09/08/86		48.0	44.0	39.0	59.0	55.0		12.0	73.0	76.0	71.0	55.0	31.0	20.0
10/02/86							50.0	52.0	67.0	60.0	61.0	48.0	23.0	18.0
10/28/86							44.0	37.0	63.0	68.0	53.0	41.0	23.0	20.0
11/11/86							40.0	34.0	65.0	72.0	56.0	45.0	23.0	19.0
12/09/86							34.0	30.0	63.0	66.0	67.0	54.0	26.0	21.0
01/12/87	38.0	42.0	19.0	41.0	47.0	38.0	29.0	29.0	63.0	58.0	74.0	43.0	28.0	20.0
02/10/87								33.0			77.0	51.0	39.0	22.0
03/31/87	40.0	43.0	24.0	37.0	38.0	34.0		30.0	68.0	42.0	48.0	51.0	32.0	22.0
05/04/87	11.0	45.0	31.0	33.0	37.0	38.0		38.0	68.0	59.0	50.0	53.0	37.0	25.0
08/10/87		54.0	27.0	27.0	34.0	30.0			52.0	39.0	52.0	45.0	30.0	24.0
02/05/88														
02/08/88			23.0		19.0	28.0			53.0	43.0	38.0	26.0	24.0	25.0
06/20/88			19.0		25.0	24.0			57.0	22.0	30.0	22.0	23.0	24.0
10/19/88			30.0		30.0				74.0	54.0	27.0	60.0	51.0	26.0
01/19/89			39.0	30.0	23.0	22.0			68.0	75.0		68.0	38.0	30.0
05/22/89			35.0	21.0	19.0	17.0			46.0	44.0	26.0	22.0	23.0	25.0
12/28/89									82.0	78.0	42.0	69.0	40.0	42.0
12/29/89			62.0	29.0	15.0	15.0								
05/11/90			72.0	35.0	26.0	13.0			58.0	43.0	46.0	17.0	17.0	22.0
08/16/90			88.0	72.0	49.0	17.0								
08/21/90									185.0	142.0	62.0	22.0	18.0	69.0
10/20/90			75.0	41.0	30.0	16.0								
10/29/90									46.0	80.0	80.0	55.0	33.0	24.0
01/17/91			64.0		28.0	20.0			60.0	76.0	72.0	71.0	70.0	28.0
03/15/91			64.0		51.0	16.0			55.0	42.0	16.0	17.0	18.0	25.0
04/25/91		1.0	61.0	60.0	42.0	13.0			63.0	50.0	42.0	18.0	16.0	21.0

Table 27. Site 4 Reactive Phosphorous concentrations (mg/l PO4)

Date	4101	4102	4103	4104	4105	4106	4201	4202	4203	4204	4205	4206	4207	4208
11/21/85														
02/05/86														
03/18/86	0.012	0.030	0.012	0.006	0.010	0.010		0.165	0.012	0.008	0.008	0.006	0.020	0.014
03/31/86							0.292	0.600	0.168	0.008	0.008	0.010	0.005	0.018
09/08/86		0.026	0.015	0.012	0.018	0.010		0.575	0.050	0.014	0.010	0.010	0.010	0.018
03/31/87	0.010	0.020	0.010	0.010	0.010	0.005		0.350	0.110	0.010	0.008	0.008	<0.002	0.018
05/04/87														
08/10/87		0.025	0.010	0.010	0.010	0.005			0.020	0.005	<0.005	<0.005	<0.005	0.010
02/05/88														
02/08/88			<0.002		0.010	0.005			<0.002	<0.002	<0.002	<0.002	<0.002	0.002
06/20/88														
10/19/88					0.010				0.048	0.012	0.010	0.010	0.010	0.020
01/19/89			0.002	0.015	0.015	0.005			0.010	<0.002		0.008	0.008	0.015
05/22/89			<0.002	<0.002	0.006	0.002			0.005	0.005	<0.002	<0.002	<0.002	<0.002
12/28/89								<0.002	0.050	<0.002	0.010	<0.002	<0.002	0.005
12/29/89			0.005	<0.002	<0.002	<0.002								
05/11/90			0.008	0.010	0.012	0.005			0.135	0.075	0.008	<0.002	0.005	0.005
08/16/90			<0.002	0.005	<0.002	<0.002								
08/21/90									1.500	<0.002	<0.002	<0.002	0.015	0.012
10/20/90			0.010	0.015	0.018	0.010								
10/29/90									0.278	0.010	0.010	0.010	0.008	0.015
01/17/91			0.008		0.010	0.002			0.075	0.005				0.008
03/15/91			0.005		0.015	0.002			0.060	0.010	0.018	0.015	0.005	0.025
04/25/91		0.005	0.002	0.005	0.002	0.002			0.065	0.002	0.010	0.005	0.002	0.015

Table 28. Site 4 pH

Sample Date	4101	4102	4103	4104	4105	4106	4201	4202	4203	4204	4205	4206	4207	4208
03/18/86	7.25	7.75	7.96	7.60	7.91	7.93		7.05	7.27	7.47	7.77	7.83	7.76	7.68
09/08/86		7.49	7.88	7.94	7.93	7.88		6.89	7.27	7.47	7.78	7.82	7.87	7.72
08/10/87		7.47	8.01	8.05	8.08	8.07			7.69	7.95	7.88	7.96	7.85	7.92
02/05/88														
02/08/88			8.05		8.13	8.06			7.52	7.82	7.85	8.05	7.76	7.72
06/20/88			7.89		8.00	7.83			7.33	7.79	7.78	7.86	7.75	7.61
10/19/88			7.53		7.95	7.94			7.43	7.76	7.74	7.92	7.81	7.77
01/19/89			7.53	7.84	7.91	7.84			6.86	7.60		7.72	7.86	7.74
05/22/89			7.69	7.81	7.92	7.77			7.30	7.50	7.68	7.75	7.69	7.56
12/28/89									7.31	7.71	7.77	7.63	7.70	7.74
12/29/89			7.53	7.95	7.91	7.84								
05/11/90			7.60	7.99	7.97	7.76			7.14	7.72	7.81	7.88	7.81	7.69
08/16/90			7.40	7.86	7.98	8.02								
08/21/90									6.67	7.18	7.75	7.77	7.71	7.62
10/20/90			7.53	7.81	7.98	7.91								
10/29/90									7.26	7.43	7.52	7.63	7.69	7.70
01/17/91			7.52		7.93	7.95			7.16	7.29	7.60	7.63	7.57	7.66
03/15/91			6.91		7.89	7.77			7.08	7.45	7.74	7.66	7.68	7.61
04/25/91		8.01	7.36	7.92	8.52	8.00			7.55	7.54	7.70	7.85	7.86	7.87

Table 29. Site 4 Conductivity (umho)

Sample Date	4101	4102	4103	4104	4105	4106	4201	4202	4203	4204	4205	4206	4207	4208
11/21/85														
02/05/86	528	462	367	517	570	545		1040	1391	760	607	596	503	463
03/18/86	581	466	388	505	536	525		1127	1212	893	674	532	502	459
03/31/86							405	336	461	872	640	526	475	443
04/18/86							620	616	1449	800	599	451	430	396
05/07/86							492	530	1224	753	587	524	365	357
05/28/86	513	514	376	393	453	638	699	674	1271	1001	754		457	436
06/18/86							660	565	1166	915	723	580	498	467
07/14/86	597	529	434	464	539	679		673	1347	860	717	619	466	480
08/11/86								732	545	851	374	427	534	539
09/08/86		433	412	477	576	649		733	892	859	687	647	522	500
10/02/86							798	848	1137	904	872	708	592	524
10/28/86							878	802	1093	752	648	722	595	559
11/11/86							833	778	1114	850	662	677	561	527
12/09/86							709	673	957	798	666	738	554	535
01/12/87	517	436	315	6	540	640	746	611	924	665	705	579	550	490
02/10/87								709			764	615	600	528
03/31/87	611	513	397	514	568	663		757	1236	582	583	650	636	564
05/04/87														
08/10/87		604	378	448	496	609			753	465	564	638	618	582
02/05/88														
02/08/88			403		347	674			843	634	544	551	636	592
06/20/88			461		404	704			1024	496	517	631	658	596
10/19/88			475		482	747			1319	825	607	874	853	683
01/19/89			586	456	394	619			1022	995		820	667	536
05/22/89			573	428	402	648			903	782	563	681	672	589
12/28/89									1227	951	691	791	648	622
12/29/89			998	415	339	1390								
05/11/90			935	436	350	500			821	445	629	515	517	504
08/16/90			1022	693	499	432								
08/21/90									1299	1351	751	559	486	844
10/20/90			764	474	379	470								
10/29/90									1510	1200	1176	808	714	595
01/17/91			807		393	498			1189	1065	937	951	812	479
03/15/91			745		529	451			1060	780	535	527	485	432
04/25/91		539	883	622	391	424			1269	719	677	479	481	450

Table 30. Site 4 Chemical Oxygen Demand (mg/l oxygen demand)

Sample Date	4101	4102	4103	4104	4105	4106	4201	4202	4203	4204	4205	4206	4207	4208
03/18/86	8.6	5.8	5.0	2.9	7.2	2.9		2.9	32.4	17.3	2.9	5.0	5.8	5.0
09/08/86		11.5	5.1	<0.5	3.8	1.3		109.4	23.0	14.1	55.0	21.8	2.6	4.5
01/17/91			9.8		<3.0	<3.0			28.5	12.7	15.6	8.3	4.3	<3.0

Table 31. Site 4 Sodium (mg/l)

Sample Date	4101	4102	4103	4104	4105	4106	4201	4202	4203	4204	4205	4206	4207	4208
03/18/86	5.0	4.0	4.0	6.0	6.0	4.0		14.0	18.0	13.0	12.0	4.0	3.0	3.0
09/08/86		5.5	5.0	5.5	6.3	5.0		7.9	13.0	13.2	8.0	7.0	4.2	3.2
08/10/87		6.0	4.0	4.0	4.0	3.5			11.5	5.0	5.5	4.0	3.5	3.0
12/28/89									13.0	10.0	5.0	7.0	3.5	2.4
12/29/89			3.0	3.0	3.2	3.2								

Table 32. Site 4 Alkalinity (mg/l)

Sample Date	4101	4102	4103	4104	4105	4106	4201	4202	4203	4204	4205	4206	4207	4208
03/18/86	216	164	132	84	88	140		320	380	252	96	124	128	148
09/08/86		160	136	84	168	108		280	256	276	164	132	140	148
02/05/88														
02/08/88			156		92	224			236	172	104	232	188	180
06/20/88														
10/19/88														
01/19/89			152	172	128	184			236	240		200	188	168
05/22/89			120	132	128	168			220	172	120	164	168	160
12/28/89									280	184	144	156	164	160
12/29/89			264	128	140	140								

Table 33. Site 4 Total Hardness (mg/l)

Sample Date	4101	4102	4103	4104	4105	4106	4201	4202	4203	4204	4205	4206	4207	4208
03/18/86	216	184	160	188	168	184		180	224	296	248	200	204	184
09/08/86		232	192	224	272	328		180	196	356	340	328	264	248
02/05/88														
02/08/88			200		160	350			276	200	244	268	316	296
01/19/89			268	232	188	332			156	244		416	348	276
05/22/89			252	200	180	308			156	276	224	320	308	272
12/28/89									288	276	192	384	340	328
12/29/89			520	220	276	276								

Table 34. Site 5 Potassium concentrations (mg/l)

Sample Date	5101	5102	5103	5104	5105	5106	5201	5202	5203	5204	5205	5206	5207	5208	5301	5302	5303	5304	5305	5306	5307	5308
11/21/85	1.5		1.5	<1.0	1.0	1.0			8.0	10.0	22.0	5.0	3.5	1.5	9.5		20.0	38.0	20.0	6.5	4.0	1.5
02/05/86																						
03/18/86		<1.0	<1.0	<1.0	<1.0	<1.0			15.0	18.0	32.0	4.0	3.0	<1.0		8.0	22.0	37.0	23.0	7.0	4.0	2.0
03/31/86																						
04/18/86																						
05/07/86									15.0	15.0	29.0	29.0	25.0	2.5								
05/28/86																						
06/18/86																						
07/14/86	1.5	1.0	<1.0	5.0	1.0	1.0			11.0	23.5	31.5	1.0			7.5	7.0	33.0	33.5	16.0	4.5	3.5	2.0
08/11/86									250.0	22.5	3.0	1.0	1.5	0.5								
09/08/86	0.8	0.8	0.8	0.8	0.8	0.8			7.5	23.0	29.8	2.4	1.6	7.0		28.2	33.2	0.8	4.2	3.2	1.5	1.8
10/02/86								5.6	5.0	17.8	23.6	2.4	1.8	0.6								
10/28/86									4.8	29.5	34.9	2.4	1.3	0.7								
12/09/86									6.5	23.5	25.5	2.0	2.0	0.5								
01/12/87	1.3	0.8	0.4	0.7	0.7	0.7		5.8	6.8	19.0	19.2	1.8	1.3	0.8	3.1		25.8	19.5	9.0	3.0	2.6	1.3
02/10/87									7.9		16.3	1.6	1.2									
03/31/87	0.8	0.8	0.4	0.6	0.6	0.7			8.2	13.0	11.7	1.3	1.3	0.6	3.9	8.5	28.0	21.0	9.6	3.0	2.3	1.6
05/04/87	0.8	<0.5	<0.5	0.5	0.5	0.5			5.9	12.3	11.9	1.3	1.0	0.5	3.9	8.0	27.7	17.9	8.2	2.7	1.9	1.2
08/10/87		1.0	1.0	1.0	1.0	1.0				24.0	34.0	2.0	4.5	1.0	18.5	1.0	3.0	2.0	1.5			35.0
02/08/88			0.5	0.5	0.7	0.6				168.0	14.0	9.0	4.5	0.9			38.5	32.0	11.5	4.5	2.0	1.8
06/20/88			0.5	0.5	0.5	0.5				117.5	137.5	9.5	5.0	0.5			24.5	37.0	34.5	34.5	2.0	2.0
10/19/88			0.4	0.7	0.7	0.4				90.0	41.0	15.1	13.4	1.0			20.0	22.6	32.0	23.8	8.7	4.7
01/19/89			<0.5								37.0	4.3	3.5	<0.5			16.0	14.5	28.0	19.3	11.0	5.2
05/22/89			0.5	0.5	0.5	1.0				36.5	12.0	3.0	1.5	0.5			14.5	48.5	37.5	17.5	11.0	8.5
12/28/89				0.5	<0.5	0.5				66.0	7.0	1.0	1.0	<0.5				150.0	68.0	45.0	21.5	7.5
05/11/90			0.4	0.4	0.4	0.6				14.9	5.2	1.1	1.0	0.4			23.3	119.0	119.0	72.0	38.0	38.0
08/16/90				0.7	0.6	0.4				11.5	7.0	1.4	1.2	0.4			22.0	115.0	100.0	145.0	38.8	18.0
10/20/90			<0.5	<0.5	<0.5	<0.5				68.0	4.5	0.5	0.5	<0.5								
10/29/90																	21.5	108.0	124.0	72.0	43.5	17.0
01/17/91			0.1	0.8	0.2					71.0	8.2	2.2	2.4	0.3			25.0	95.0	87.0	62.0	37.8	32.4
03/15/91			0.5		1.0					130.0	6.5	1.5	1.0	1.0				100.0	105.0	90.0	36.0	23.0
04/25/91		1.1	0.5	1.0	0.6	0.4				59.5	5.5	1.7	1.9	0.6			24.2	139.0	129.5	74.9	35.2	14.4

Table 35. Site 5 Nitrate-N concentrations (mg/l)

Sample Date	5101	5102	5103	5104	5105	5106	5201	5202	5203	5204	5205	5206	5207	5208	5301	5302	5303	5304	5305	5306	5307	5308
11/21/85	15.8		22.5	16.5	34.0	31.0			<0.2	0.2	16.5	28.2	22.2	29.5	7.5		13.0	13.0	36.8	34.5	18.5	16.4
02/05/86								15.2	0.4	16.0	24.4	32.2	35.8	23.8		11.6	14.8	14.0	34.8	45.0	28.6	18.8
03/18/86		10.2	11.0	20.0	36.6	24.0			<0.2	25.5	24.8	30.2	33.6	24.6		18.0	13.5	14.4	32.4	37.5	28.5	15.0
03/31/86								<0.2	<0.2	26.0	40.0	29.4	32.2	26.0								
04/18/86								<0.2	<0.2	15.0	29.0	19.8	24.0	26.4								
05/07/86									<0.5	3.5	11.2	20.0	23.0	22.5								
05/28/86	12.0	8.0	10.5	17.0	31.5	28.7			0.2	1.0	8.5	18.0	19.0	24.5	3.0	3.7	21.0	17.7	28.2	34.0	29.0	28.5
06/18/86									<0.2	1.0	14.5	17.8	18.0	27.8								
07/14/86	12.5	10.5	13.0	17.5	27.5	30.7			0.2	1.0	12.2	28.5			3.5	2.5	25.0	19.5	25.2	40.0	38.0	22.5
08/11/86									47.2	2.0	26.8	37.4	15.0	13.0								
09/08/86		14.2	15.5	17.5	24.0	34.8			<0.2	7.2	12.0	13.5	13.0	30.0		10.8	15.6	27.0	26.0	37.5	35.0	23.0
10/02/86								<0.2	<0.2	<0.2	12.8	25.0	26.0	31.0								
10/28/86									<0.2	2.5	11.5	12.6	10.6	30.0								
12/09/86									<0.2	1.5	14.5	13.0	10.5	28.8								
01/12/87	9.5	20.0	13.8	13.0	25.5	37.6		8.8	<0.2	2.2	14.5	11.8	13.5	26.8	1.2		26.0	24.8	30.2	29.5	38.8	28.2
02/10/87									<0.2		16.5	12.8	14.5									
03/31/87	9.0	20.0	15.0	12.5	23.8	37.0			<0.2	23.0	15.0	10.5	12.5	26.5	6.5	6.0	13.0	23.8	24.5	18.5	30.5	31.2
05/04/87	8.2	22.0	16.5	13.0	28.0	37.8			<0.2	28.0	26.5	13.5	13.0	28.5	17.5	6.5	12.5	21.8	23.0	18.8	29.5	31.0
08/10/87		16.7	16.4	13.6	29.0	36.0				16.3	40.7	17.0	19.2	31.5	17.5	17.5	21.6	27.5	27.2			8.7
02/08/88			14.0	16.0	26.0	22.5				5.5	6.5	18.5	24.2	29.2			17.0	3.8	1.8	18.5	6.5	6.2
06/20/88			11.0	18.5	22.5	20.0				6.5	12.5	22.0	24.0	21.0			14.8	6.5	7.8	1.8	5.5	13.8
10/19/88			7.0	14.5	18.2	19.5				3.5	14.2	17.8	18.8	20.2			10.0	8.0	19.5	23.5	23.8	19.2
01/19/89			8.2								14.5	17.8	19.5	16.5			12.5	9.0	10.5	18.6	18.8	20.0
05/22/89			5.0	5.5	11.2	21.5				7.5	7.0	8.2	11.0	19.0			11.0	3.0	1.8	5.5	8.2	15.0
12/28/89				4.5	8.0	2.0				4.2	8.2	7.5	8.5	18.8				3.0	10.8	9.0	2.5	7.0
05/11/90			2.5	5.0	6.4	20.6				13.5	6.8	8.0	10.0	19.0			13.0	10.7	5.6	5.0	0.8	0.8
08/16/90				6.6	13.3	14.9				8.8	9.6	7.4	7.5	18.5			32.2	3.7	10.9	<0.2	0.8	11.7
10/20/90			6.0	4.6	6.3	12.7				16.2	9.7	6.3	6.5	9.0								
10/29/90																	23.2	2.3	<0.2	7.6	1.8	10.6
01/17/91			6.1	13.8	12.1					9.2	13.0	11.1	10.0	20.8			18.3		3.3	1.2	15.7	9.6
03/15/91			8.8		17.3					14.0	7.7	10.8	9.8	23.8				0.2	0.2	1.8	1.9	7.7
04/25/91		1.6	5.6	17.5	18.0	9.7				14.5	11.6	15.5	15.9	22.6			12.9	3.0	1.1	15.9	4.7	9.0

Table 36. Site 5 Ammonia-N concentrations (mg/l)

Sample Date	5101	5102	5103	5104	5105	5106	5201	5202	5203	5204	5205	5206	5207	5208	5301	5302	5303	5304	5305	5306	5307	5308
11/21/85	<0.01		<0.01	<0.01	<0.01	<0.01			0.54	0.46	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	0.04	0.08	0.04
02/05/86								0.10	1.48	0.10	0.10	0.06	0.05	0.12		0.05	0.05	0.05	0.05	0.02	<0.02	0.05
03/18/86		<0.02	<0.02	0.04	<0.02	<0.02			1.36	0.04	0.02	0.02	0.04	<0.02		<0.02	0.02	<0.02	<0.02	0.02	<0.02	<0.02
03/31/86								<0.02	0.24	<0.02	<0.02	<0.02	<0.02	<0.02								
04/18/86								<0.02	0.36	0.04	<0.02	<0.02	<0.02	<0.02								
05/07/86									<0.05	<0.05	<0.05	<0.05	<0.05	<0.05								
05/28/86	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02			0.22	0.04	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
06/18/86									0.32	0.10	0.02	0.02	<0.02	0.02								
07/14/86	<0.02	<0.02	0.08	0.02	<0.02	0.06			0.52	0.04	0.02	0.06			0.04	0.02	<0.02	0.04	<0.02	<0.02	<0.02	0.04
08/11/86									<0.02	<0.02	<0.02	<0.02	0.08	<0.02								
09/08/86		<0.02	<0.02	<0.02	<0.02	<0.02			0.48	<0.02	0.02	<0.02	<0.02	<0.02		0.04	0.06	0.02	0.04	0.10	0.08	0.06
10/02/86								0.32	0.30	0.08	<0.02	0.04	0.04	0.06								
10/28/86									0.32	<0.02	<0.02	<0.02	<0.02	<0.02								
12/09/86									0.50	0.02	<0.02	<0.02	<0.02	<0.02								
01/12/87	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02		<0.02	0.60	<0.02	<0.02	<0.02	<0.02	<0.02								
02/10/87									0.82		0.04	0.02	0.02									
03/31/87	0.02	0.04	<0.02	<0.02	<0.02	0.02			0.76	0.04	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02	0.02	<0.02	<0.02	<0.02
05/04/87	<0.02	<0.02	<0.02	0.02	0.02	<0.02			0.72	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
08/10/87		<0.04	<0.04	<0.04	<0.04	<0.04				<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04			<0.04
02/08/88			<0.02	<0.02	<0.02	<0.02				0.24	<0.02	<0.02	<0.02	<0.02			<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
06/20/88			0.02	<0.02	<0.02	0.02				0.20	3.08	0.08	0.02	0.02			0.04	1.80	5.20	10.40	0.04	0.02
10/19/88			<0.02	<0.02	<0.02	<0.02				0.25	<0.02	<0.02	<0.02	<0.02			<0.02	1.48	5.00	1.75	4.25	0.90
01/19/89			<0.02								<0.02	0.06	<0.02	<0.02			<0.02	0.80	2.40	0.03	1.80	1.44
05/22/89			<0.02	<0.02	0.02	0.02				<0.02	<0.02	0.10	<0.02	0.12			0.05	0.15	<0.02	<0.02	<0.02	<0.02
12/28/89				<0.02	<0.02	<0.02				<0.02	0.02	0.08	0.02	<0.02				0.03	0.05	0.18	0.22	<0.02
05/11/90			<0.02	<0.02	<0.02	<0.02				0.15	<0.02	<0.02	0.05	0.02			<0.02	0.02	3.15	2.78	0.28	0.28
08/16/90				0.10	<0.02	<0.02				0.05	<0.02	0.02	<0.02	0.05			0.08	1.58	5.05			0.05
10/20/90			<0.02	<0.02	<0.02	<0.02				<0.02	<0.02	<0.02	<0.02	<0.02								
10/29/90																	<0.02	7.50	7.50	3.95	0.55	<0.02
01/17/91			0.05															5.75	3.15			
03/15/91										0.02	0.02	0.02	0.02	0.02				5.00	1.70	0.02	0.02	0.02
04/25/91		0.02	0.05	0.05	0.02	0.02				0.02	0.02	0.02	0.02	0.02			0.02	8.00	7.00	4.08	0.65	0.02

Table 37. Site 5 Chloride concentrations (mg/l)

Sample Date	5101	5102	5103	5104	5105	5106	5201	5202	5203	5204	5205	5206	5207	5208	5301	5302	5303	5304	5305	5306	5307	5308
11/21/85	19.0		44.0	27.0	36.0	31.0			7.0	9.0	21.0	45.0	38.0	27.0	7.0		11.0	22.0	38.0	9.0	8.0	2.0
02/05/86								14.0	9.0	14.0	52.0	41.0	40.0	26.0		7.0	9.0	19.0	41.0	40.0	27.0	22.0
03/18/86		25.0	30.0	44.0	50.0	34.0			6.0	40.0	53.0	44.0	45.0	34.0		11.0	11.0	30.0	45.0	35.0	35.0	27.0
03/31/86								4.2	3.3	22.2	60.7	26.8	28.6	23.6								
04/18/86								6.0	5.0	8.0	36.0	33.0	34.0	32.0								
05/07/86									5.0	5.0	1.0	41.0	41.0	32.0								
05/28/86	43.0	26.0	28.0	49.0	48.0	38.0			4.0	3.0	10.0	38.0	38.0	33.0	4.0	4.0	11.0	34.0	44.0	54.0	28.0	29.0
06/18/86									5.0	3.0	28.0	39.0	38.0	32.0								
07/14/86	32.0	19.0	24.0	41.0	32.0	31.0			3.0	3.0	15.0	29.0			3.0	4.0	12.0	24.0	34.0	35.0	26.0	16.0
08/11/86									100.0	5.0	53.0	43.0	32.0	17.0								
09/08/86		24.2	41.9	60.3	60.3	49.5			5.5	36.8	20.7	39.1	35.9	44.0		9.5	24.5	25.3	59.9	51.1	51.1	26.9
10/02/86								<1.0	<1.0	8.0	22.0	48.0	42.0	39.0								
10/28/86									1.0	8.0	11.0	26.0	22.0	37.0								
12/09/86									1.3	8.2	16.0	27.0	25.0	35.0								
01/12/87	25.0	20.0	31.0	32.0	43.0	43.0		7.0	3.0	7.0	23.0	25.0	28.0	30.0	5.0		9.0	19.0	49.0	40.0	35.0	26.0
02/10/87									3.0		35.0	31.0	33.0									
03/31/87	24.0	30.0	48.0	28.0	38.0	41.0			<1.0	37.0	28.0	29.0	34.0	30.0	6.0	5.0	8.0	24.0	45.0	35.0	32.0	27.0
05/04/87	29.0	25.0	52.0	32.0	40.0	39.0			3.0	42.0	40.0	38.0	43.0	32.0	4.0	5.0	8.0	27.0	43.0	38.0	31.0	29.0
08/10/87		23.0	40.0	23.0	40.0	37.0				37.0	73.0	48.0	54.0	38.0	25.0	35.0	38.0	34.0	29.0			10.0
02/08/88			40.0	27.0	34.0	29.0				91.0	63.0	37.0	31.0	33.0			42.0	51.0	44.0	58.0	39.0	42.0
06/20/88			40.0	28.0	29.0	28.0				85.0	115.0	100.0	110.0	24.0			47.0	64.0	77.0	67.0	65.0	74.0
10/19/88			78.0	41.0	40.0	26.0				64.0	69.0	47.0	44.0	29.0			16.0	60.0	45.0	38.0	34.0	30.0
01/19/89			66.0								62.0	42.0	41.0	29.0			12.0	49.0	60.0	47.0	54.0	53.0
05/22/89			35.0	27.0	19.0	20.0				49.0	46.0	33.0	21.0	24.0			36.0	66.0	85.0	72.0	69.0	36.0
12/28/89				42.0	14.0	100.0				46.0	46.0	<1.0	28.0	18.0				65.0	44.0	70.0	88.0	101.0
05/11/90			44.0	37.0	22.0	20.0				6.0	41.0	25.0	19.0	17.0			43.0	59.0	73.0	50.0	100.0	100.0
08/16/90				39.0	49.0	20.0				16.0	86.0	36.0	36.0	17.0			24.0	61.0	24.0	74.0	47.0	37.0
10/20/90			23.0	56.0	31.0	27.0				34.0	57.0	40.0	43.0	23.0								
10/29/90																	18.0	39.0	59.0	34.0	57.0	37.0
01/17/91			50.0	43.0	43.0					43.0	55.0	52.0	50.0	18.0			21.0	30.0	31.0	39.0	20.0	28.0
03/15/91			53.0		54.0					66.0	39.0	48.0	42.0	15.0				33.0	45.0	47.0	43.0	34.0
04/25/91		3.0	23.0	50.0	48.0	18.0				33.0	49.0	58.0	52.0	16.0			22.0	53.0	62.0	37.0	64.0	46.0

Table 38. Site 5 Reactive Phosphorous concentrations (mg/l PO4)

Sample Date	5101	5102	5103	5104	5105	5106	5201	5202	5203	5204	5205	5206	5207	5208	5301	5302	5303	5304	5305	5306	5307	5308
11/21/85	0.018		0.010	0.012	0.008	<0.002			<0.002	0.018	0.042	0.012	<0.002	<0.002	0.008		0.095	0.080	0.050	0.015	0.010	0.006
03/18/86		0.030	0.015	0.005	0.012	0.008			0.010	0.282	0.700	0.035	0.020	0.012		0.020	0.172	0.068	0.082	0.045	0.012	0.088
03/31/86								0.005	0.008	0.350	0.650	0.025	0.010	0.010								
09/08/86		0.020	0.018	0.012	0.010	0.008			<0.002	0.562	0.925	0.025	0.012	0.010		0.025	0.196	0.070	0.080	0.055	0.025	0.010
03/31/87	0.010	0.010	0.012	0.010	0.010	0.010			<0.002	0.200	0.465	0.020	0.010	0.008	0.010	0.005	0.140	0.050	0.065	0.035	0.002	<0.002
05/04/87																						
08/10/87		0.005	0.010	0.005	0.005	<0.005				0.360	0.420	0.020	0.010	0.005	0.055	0.075	0.030	<0.005	<0.005			0.155
02/08/88			<0.002	<0.002	0.008	<0.002				0.310	0.228	0.010	0.010	0.002			0.175	0.115	0.078	0.020	0.002	<0.002
10/19/88			0.010	0.012	0.010	0.010				0.060	0.135	0.012	0.010	0.010			2.880	23.800	3.310	<0.002	0.230	0.005
01/19/89			0.010								0.100	0.010	0.002	0.005			3.700	5.600	4.850	0.132	0.050	0.005
05/22/89			<0.002	<0.002	0.005	<0.002				0.060	0.045	0.002	<0.002	<0.002			3.720	3.180	1.600	0.068	<0.002	<0.002
12/28/89				0.002	<0.002	0.005				0.072	0.052	<0.002	0.010	0.005				2.350	1.500	0.700	0.448	0.002
05/11/90			0.005	0.008	0.010	0.005				0.035	0.040	0.010	0.010	0.012			1.600	1.550	0.900	0.250	0.140	0.140
08/16/90				<0.002	<0.002	<0.002				0.080	<0.002	<0.002	<0.002	0.040			0.820	1.580	0.800	0.255	0.062	<0.002
10/20/90			0.005	0.008	0.012	0.010				0.095	0.048	0.012	0.012	0.008								
10/29/90																	1.050	1.880	1.380	0.295	0.090	0,005
01/17/91										0.100	0.035	0.010	0.002	0.002			1.700	2.120	0.800	0.270	0.040	0.002
03/15/91					0.002					0.090	0.025	0.012	0.002	0.002				1.550	0.880	0.270	0.060	0.025
04/25/91		0.002	0.010	0.012	0.005	0.005				0.100	0.030	0.002	0.008	0.005			1.200	1.120	0.620	0.160	0.018	0.002

Table 39. Site 5 pH

Sample Date	5101	5102	5103	5104	5105	5106	5201	5202	5203	5204	5205	5206	5207	5208	5301	5302	5303	5304	5305	5306	5307	5308
11/21/85	7.95		7.90	8.01	8.03	7.95			6.94	6.86	7.32	7.80	7.75	7.79	7.92		7.96	7.79	7.76	7.81	7.92	7.85
02/05/86																						
03/18/86		7.91	7.96	7.95	7.94	7.96			6.38	6.93	7.72	7.77	7.75	7.65		7.46	7.63	7.59	7.71	7.76	7.68	7.73
09/08/86		7.94	7.97	7.91	7.93	7.91			6.26	6.76	7.69	7.84	7.86	7.85		7.34	7.61	7.57	7.80	7.79	7.80	7.66
08/10/87		7.82	8.02	7.95	8.05	8.05				6.97	7.82	7.93	7.92	7.98	7.81	8.02	8.03	7.95	7.88			7.74
02/08/88			8.02	8.04	7.96	8.00				6.74	7.41	7.81	7.78	7.87			7.31	7.05	7.44	7.57	7.71	7.69
06/20/88			8.04	8.04	8.01	7.93				6.61	7.06	7.52	7.52	7.82			7.51	6.98	6.87	7.21	7.51	7.60
10/19/88			7.71	7.91	7.96	7.94				6.66	7.48	7.73	7.65	7.83			7.28	6.98	6.97	7.50	7.62	7.64
01/19/89			7.68								7.42	7.86	7.82	7.86			7.39	7.13	7.24	7.65	7.64	7.63
05/22/89			7.50	8.00	8.07	7.80				6.89	7.48	7.75	7.69	7.75			7.20	7.07	7.25	7.41	7.48	7.65
12/28/89				7.92	7.95	7.48				6.99	7.45	7.96	7.83	7.97				7.34	7.48	7.38	7.44	7.40
05/11/90			7.35	7.87	8.03	8.04				6.92	7.49	7.85	8.02	8.03			7.44	7.51	7.47	7.82	7.69	7.54
08/16/90				7.61	7.96	7.93				6.65	7.12	7.74	7.78	7.94			7.25	7.32	7.55	7.27	7.36	7.38
10/20/90			7.38	7.59	7.95	7.93				6.87	7.47	7.76	7.90	8.01								
10/29/90																	7.42	7.29	7.22	7.40	7.33	7.43
01/17/91			7.25		7.90					7.01	7.26	7.59	7.63	7.83			7.51	7.39	7.46	7.53	7.58	7.51
03/15/91			7.18		7.87					6.72	7.30	7.56	7.68	7.82				7.33	7.41	7.43	7.45	7.45
04/25/91		7.43	7.42	7.74	7.98	8.08				7.00	7.29	7.72	7.85	7.83			7.43	7.45	7.48	7.61	7.64	7.65

Table 40. Site 5 Conductivity (umho)

Sample Date	5101	5102	5103	5104	5105	5106	5201	5202	5203	5204	5205	5206	5207	5208	5301	5302	5303	5304	5305	5306	5307	5308
11/21/85	455		453	423	563	564			723	636	765	530	500	556	412		410	370	591	559	482	465
02/05/86								822	622	825	579	550	276	578		333	465	394	611	656	580	527
03/18/86		299	376	472	659	579			565	904	579	541	573	592		381	444	400	575	624	583	501
03/31/86								934	474	809	961	526	559	588								
04/18/86								701	544	708	656	407	445	481								
05/07/86									429	540	396	408	423	398								
05/28/86	372	268	303	457	586	602			475	486	308	460	457	555	264	283	489	449	547	606	605	603
06/18/86									435	453	493	461	448	566								
07/14/86	422	297	319	468	564	629			543	490	435	553			442	244	519	457	506	610	626	539
08/11/86									1	627	735	671	433	489								
09/08/86		341	382	454	517	623			535	582	466	424	411	568		346	494	558	542	597	600	540
10/02/86								646	432	800	553	595	612	611								
10/28/86									449	747	665	395	386	584								
12/09/86									452	622	445	400	377	589								
01/12/87	362	376	335	384	516	597		265	383	522	367	336	349	514	218		505	416	505	475	552	524
02/10/87									471		423	383	397									
03/31/87	361	422	416	369	508	643			568	816	440	401	410	586	435	349	466	492	525	445	558	595
05/04/87																						
08/10/87		427	396	343	549	628				857	966	475	546	594	449	446	472	525	541			479
02/08/88			402	411	543	586				1099	834	617	520	686			762	838	678	601	657	821
06/20/88			440	466	547	655				1278	1415	1241	1139	605			733	933	1074	968	821	882
10/19/88			703	461	523	624				900	848	626	618	638			615	814	697	693	689	677
01/19/89			585								720	487	508	577			551	514	651	646	690	757
05/22/89			582	434	444	721				686	558	492	413	714			756	890	991	941	939	772
12/28/89				514	380	833				945	670	455	466	601				873	733	901	956	1084
05/11/90			682	569	381	578				709	775	447	421	502			754	893	999	817	1134	1073
08/16/90				571	595	467				776	1040	536	551	579			756	865	636	1050	752	721
10/20/90			672	745	460	443				1048	720	641	654	485								
10/29/90																	733	843	944	682	832	717
01/17/91			718		506					931	813	820	838	529			625	538	558	604	579	588
03/15/91			703		540					1095	567	794	703	516				521	600	637	597	622
04/25/91		418	623	588	546	398				935	825	679	638	542			567	836	898	727	818	738

Table 41. Site 5 Chemical Oxygen Demand (mg/l oxygen demand)

Sample Date	5101	5102	5103	5104	5105	5106	5201	5202	5203	5204	5205	5206	5207	5208	5301	5302	5303	5304	5305	5306	5307	5308
03/18/86		0.7	1.4	1.4	1.4	1.4			14.4	6.5	2.9	1.4	2.2	1.4		1.4	2.9	5.0	1.4	0.7	0.7	0.7
09/08/86		3.8	<0.1	2.6	3.8	28.8			30.1	20.5	3.8	3.8	9.0	1.3		9.0	5.8	5.8	13.3	16.8	18.6	<0.1
01/17/91			11.0	4.8	9.6					14.9	12.0	11.5	13.4	9.1			14.9	14.3	13.9	17.2	17.2	11.5

Table 42. Site 5 Sodium (mg/l)

Sample Date	5101	5102	5103	5104	5105	5106	5201	5202	5203	5204	5205	5206	5207	5208	5301	5302	5303	5304	5305	5306	5307	5308
11/21/85	6.0		8.5	6.5	8.0	4.5			4.0	5.0	8.0	7.0	6.5	4.5	6.5		4.5	5.0	6.5	7.0	4.0	4.0
03/18/86		5.0	6.0	7.0	7.0	4.0			4.0	9.0	6.0	6.0	6.0	6.0		5.0	4.0	2.0	6.0	5.0	3.0	3.0
09/08/86		5.5	6.2	7.0	7.0	5.4			3.5	3.5	5.4	5.4	5.8	5.3		5.8	5.4	4.9	6.5	6.5	4.2	3.6
08/10/87		3.5	4.5	5.0	6.0	5.0				8.0	19.5	10.5	12.0	4.5	4.0	5.5	5.5	4.5	3.5			8.5
12/28/89				3.8	3.5	4.0				7.7	9.2	4.3	3.2	3.3				16.0	13.7	16.6	18.2	20.0

Table 43. Site 5 Alkalinity (mg/l)

Sample Date	5101	5102	5103	5104	5105	5106	5201	5202	5203	5204	5205	5206	5207	5208	5301	5302	5303	5304	5305	5306	5307	5308
03/18/86		40	78	84	108	148			288	312	104	84	88	156		116	164	92	84	104	140	168
09/08/86		56	40	68	84	124			280	260	148	104	96	104		120	152	132	80	80	100	148
02/08/88			64	80	84	144				372	292	164	84	168			236	328	264	136	260	352
01/19/89			160								216	88	88	180			220	124	174	164	188	220
05/22/89			188	120	116	212				208	152	128	100	208			264	320	360	356	356	256
12/28/89				180	132	292				416	244	136	140	196				320	244	324	368	416

Table 44. Site 5 Total Hardness (mg/l)

Sample Date	5101	5102	5103	5104	5105	5106	5201	5202	5203	5204	5205	5206	5207	5208	5301	5302	5303	5304	5305	5306	5307	5308
03/18/86		124	160	168	240	196			164	332	196	212	228	112		144	104	168	204	232	196	168
09/08/86		152	14	208	244	288			300	300	164	192	192	264		156	200	216	228	248	276	260
02/08/88			176	184	244	268				312	316	288	232	336			307	304	300	280	340	448
01/19/89			288								308	208	236	300			260	220	264	280	324	356
05/22/89			272	192	208	352				268	240	216	188	352			344	352	416	420	424	344
12/28/89				272	196	440				428	344	236	236	332				340	280	396	468	560

Table 45. Chemical and Physical Charactoristics of soils in the drainway and fence line adjacent to sites 1 and 2.

Sample Location	Sample Depth (ft)	NH4 (mg/kg)	NO2+NO3-N (mg/kg)	pH	% Moisture	%Organic Matter	% Sand	%Silt+Cla	%Organic Carbon
Drainway	0.0-0.4	2.26	15.83	6.04	16.72	3.42	78.0	22.0	5.88
	0.5-0.9	1.34	7.34	6.50	10.17	1.52	79.8	20.2	2.61
	1.0-1.9	0.70	4.54	6.53	6.14	0.27	84.0	16.0	0.46
	2.0-2.9	0.70	5.95	6.62	5.37	0.17	88.6	11.4	0.29
	3.0-3.9	0.74	6.70	6.72	6.20	0.22	91.6	8.4	0.38
	4.0-4.9	0.00	7.53	6.86	7.94	0.17	94.2	5.8	0.29
Field Depression receiving runoff from sites 1 and 2	0.0-0.4	2.70	24.28	5.88	16.86	3.03	76.4	23.6	5.21
	0.5-0.9	0.60	12.66	6.15	9.93	0.76	82.0	18.0	1.31
	1.0-1.9	0.82	9.07	6.40	7.76	0.27	86.0	14.0	0.46
	2.0-2.9	0.00	6.58	6.35	7.61	0.12	92.2	7.8	0.21
	3.0-3.9	0.00	4.72	6.53	14.34	0.20	87.8	12.2	0.34
Under East Fence Line Site 2	0.0-0.4	10.86	18.33	7.52	17.92	3.93	85.2	14.8	6.76
	0.5-0.9	3.61	12.04	7.49	13.62	3.13	86.2	13.8	5.38
	1.0-1.9	0.35	3.46	7.41	7.80	0.45	92.0	8.0	0.77
	2.0-2.9	0.00	2.34	7.03	6.18	0.22	94.8	5.2	0.38
	3.0-3.9	0.00	1.11	6.71	5.03	0.13	93.0	7.0	0.22
	4.0-4.9	0.00	1.48	6.81	4.98	0.10	96.0	4.0	0.17
Under South Fence Line Site 2	0.0-0.4	7.63	22.04	6.80	26.44	5.06	68.0	32.0	8.70
	0.5-0.9	5.00	9.29	6.65	18.58	3.00	73.0	27.0	5.16
	1.0-1.9	1.35	4.50	6.75	9.45	0.63	84.4	15.6	1.08
	2.0-2.9	0.71	3.91	6.85	7.23	0.22	90.8	9.2	0.38
	3.0-3.9	2.21	3.32	6.95	7.60	0.16	92.4	7.6	0.28
	4.0-4.9	3.02	4.16	6.97	8.80	0.16	93.0	7.0	0.28
Road Ditch on Porter Road receiving runoff from site 2	0.0-0.4	31.68	36.01	6.06	156.77	24.72	50.2	49.8	42.52
	0.5-0.9	31.28	57.96	5.97	54.29	7.99	38.2	61.8	13.74
	1.0-1.9	13.00	53.17	6.26	27.35	3.36	72.8	27.2	5.78
	2.0-2.9	12.79	8.66	6.59	13.08	0.56	90.2	9.8	0.96
Under East Fence Line	0.0-0.4	10.52	10.52	6.61	13.35	2.34	87.6	12.4	4.02
	0.5-0.9	4.27	4.88	6.75	7.37	0.50	91.8	8.2	0.86
	1.0-1.9	1.76	2.94	6.74	6.37	0.25	95.0	5.0	0.43
	2.0-2.9	2.61	2.87	6.75	5.80	0.17	98.4	3.8	0.29
	3.0-3.9	0.87	2.90	6.70	6.89	0.10	96.2	3.8	0.17
	4.0-4.9	1.62	1.35	6.66	6.76	0.13	95.6	4.4	0.22
	5.0-5.9	2.34	3.12	6.17	6.23	0.00	95.8	4.2	
	6.0-6.9	1.67	2.23	6.15	7.29	0.13	96.6	3.4	0.22
	7.0-7.9	0.30	2.09	6.18	7.64	0.07	98.2	2.4	0.12
	8.0-8.9	1.49	2.99	6.30	7.11	0.07	98.4	3.2	0.12
	9.0-9.9	0.57	2.00	6.32	7.45	0.03	98.8	2.2	0.05

Table 45. (continued)

Sample Location	Sample Depth (ft)	NH4 (mg/kg)	NO2+NO3-N (mg/kg)	pH	% Moisture	%Organic Matter	% Sand	%Silt+Clay	%Organic Carbon
Under North Fence Line Site 1	0.0-0.4	4.92	9.14	6.13	4.42	2.46	90.0	10.0	4.23
	0.5-0.9	2.5[illegible]	5.75	6.36	3.11	1.16	92.0	8.0	2.00
	1.0-1.9	0.00	2.94	6.50	3.75	0.35	93.8	6.2	0.60
	2.0-2.9	1.33	2.66	6.68	3.79	0.15	94.0	6.0	0.26
	3.0-3.9	0.28	3.31	6.72	4.64	0.00	93.6	6.4	
	4.0-4.9	1.34	3.02	6.68	5.37	0.08	91.4	8.6	0.14
	5.0-5.9	0.34	3.05	6.64	5.44	0.07	92.2	7.8	0.12
	6.0-6.9	0.86	3.16	6.78	4.57	0.07	95.8	4.2	0.12
	7.0-7.9	2.75	4.40	6.77	4.17	0.05	98.0	2.0	0.09
	8.0-8.9	1.50	4.51	6.75	3.71	0.00	98.6	4.0	
	9.0-9.9	1.45	3.49	6.58	3.75	0.00	98.8	2.8	
Upgradient Field	0.5-0.9	5.64	21.35	5.61	14.14	2.32	84.0	16.0	3.99
	1.0-1.9	4.05	12.16	5.93	10.20	1.35	83.2	16.8	2.32
	2.0-2.9	3.49	8.14	5.25	7.74	0.24	88.0	12.0	0.41
	3.0-3.9	2.7	5.06	4.5	6.31	0.13	90.6	9.4	0.22
	4.0-4.9	2.64	3.81	4.86	6.27	0	92.6	13.2	
	5.0-5.9	2.04	4.38	5.17	12.09	0	89.4	10.6	

Table 46. Summary of soil N and related chemical data for the irrigated field soil adjacent to site 1.

Depth cm	NH4-N mg/kg	NO3-N mg/kg	Organic-N mg/kg	NH4/NO3~	pH	K mg/kg	NO3-N^ (Soil Solution) mg/l	Water Content* %
0-15	2.7	12.7	871	0.2	5.8	240	42	10.0
15-30	2.3	11.3	388	0.2	5.8	185	25	6.3
30-60	2.3	8.0	89	0.3	5.8	95	84	5.7
60-90	2.0	8.3	65	0.2	5.8	140	114	6.3
90-120	1.3	5.0	34	0.3	5.8	140	133	5.3
120-150	0.7	4.0	46	0.2	5.7	115	94	6.3
150-180	0.7	3.7	20	0.2	5.6	107	52	4.3
180-210	2.0	4.0	12	0.5	5.5	115	72	4.3
210-240	0.7	4.7	10	0.1	5.5	62	68	4.3
240-270	1.0	10.7	19	0.1	5.6	79	89	10.3
270-300	3.0	13.7	21	0.2	5.6	87	48	17.3

Table 47. Summary of soil N and related chemical data for the moderately well drained soil of site 1.

Depth cm	NH4-N* mg/kg	NO3-N* mg/kg	Organic-N mg/kg	NH4/NO3~	pH	K mg/kg	NO3-N^ (Soil Solution) mg/l	Water Content* %
0-15	42.6 a c	20.6 a	5483	2.0	8.2	1956	44	30.9 a
15-30	50.3 ab	7.6 b	1031	6.6	7.9	1124	52	12.3 b
30-60	56.7 b	2.1 c	642	27.0	8.1	1125	23	8.9 bc
60-90	37.4 c	2.6 c	143	14.4	8.5	985	39	7.0 cd
90-120	36.7 c	1.6 c	74	22.9	8.1	815	29	5.1 d
120-150	24.9 d	0.7 c	43	35.6	8.1	555	14	4.4 d
150-180	27.3 d	0.3 c	57	91.0	8.2	515	10	4.4 d
180-210	38.0 c	1.1 c	16	34.5	7.8	700	23	5.1 d
210-240	30.9 cd	1.0 c	30	30.9	7.1	375	15	4.9 d
240-270	19.4 de	0.9 c	22	21.6	7.0	315	10	8.6 c
270-300	14.3 e	1.1 c	22	13.0	7.5	250	8	13.3 b
	L.S.D=10.4	L.S.D.=4.8						L.S.D=3.3

Table 48. Summary of soil N and related chemical data for the poorly drained soil of site 1.

Depth cm	NH4-N* mg/kg	NO3-N* mg/kg	Organic-N mg/kg	NH4/NO3~	pH	K mg/kg	NO3-N^ (Soil Solution) mg/l	Water Content* %
0-15	80.0 a	28.4 a	5550	2.8	8.3	2399	44	38.1 a
15-30	107.7 b	15.6 b	2048	6.9	7.1	1595	68	18.9 b
30-60	48.4 c	2.0 c	155	24.2	7.3	699	25	6.9 d
60-90	34.4 cd	2.0 c	86	17.2	7.2	699	27	5.6 d
90-120	26.1 de	1.4 c	90	18.6	7.1	749	23	5.7 d
120-150	15.6 ef	2.0 c	79	7.8	7.2	950	30	6.1 d
150-180	8.3 f	1.6 c	52	5.2	7.0	590	31	5.1 d
180-210	4.9 f	1.3 c	33	3.8	6.8	276	29	4.0 d
210-240	4.3 f	1.6 c	30	2.7	6.6	225	22	5.3 d
240-270	2.6 f	3.1 c	35	0.8	6.4	188	22	10.7 c
270-300	2.9 f	4.3 c	33	0.7	6.0	151	23	15.0 b
	L.S.D.=15.0	L.S.D=7.0						L.S.D.=4.0

* Data represents an average of 7 samplings form May 3 to September 2, 1986. Numbers with different letters are significantly different at the 5% level.

~ The ratio of NH4-N to NO3-N calculated by division of NH4-N values by NO3-N values.

^ Data represents season mean of soil NO3-N calculated on a soil solution basis.

Table 49. Summary of soil N and related chemical data for the poorly and well drained soils of site 2.

Depth cm	NH4-N mg/kg	NO3-N mg/kg	Organic-N mg/kg	NH4/NO3~	pH	K mg/kg	NO3-N^ (Soil Solution) mg/l	Water Content* %
Poorly Drained Position								
0-15	68.3 a	16.9 a	4322	4.0	7.8	2359	43	29.9 a
15-30	33.3 b	12.9 a	880	2.6	7.5	1270	98	12.1 b
30-60	13.7 bc	1.3 b	133	10.5	7.6	380	15	7.1 c
60-90	13.1 bc	0.7 b	86	18.7	6.8	330	15	4.6 cd
90-120	14.6 bc	0.9 b	134	16.2	6.4	295	14	6.3 c
120-150	11.0 c	0.9 b	106	12.2	6.3	275	12	9.9 b d
	L.S.D.=18.8	L.S.D.=7.1						L.S.D.=4.4
Well Drained Position								
0-15	26.4 a	16.7 a	1535	1.6	7.5	1229	121	11.7 a
15-30	17.1 b	5.3 b	526	3.2	7.5	750	57	8.6 b
30-60	12.4 bc	0.9 c	177	13.8	6.8	230	14	5.7 c
60-90	6.3 cd	1.3 c	68	4.8	6.6	63	17	6.3 c
90-120	3.3 d	1.4 c	71	2.4	6.3	26	17	8.0 bc
120-150	2.4 d	1.4 c	159	1.7	6.3	30	10	11.4 ab
	L.S.D.=6.8	L.S.D.=2.7						L.S.D.=2.2

Table 50. Summary of soil N and related chemical data for the well drained soils of site 4.

Depth cm	NH4-N mg/kg	NO3-N mg/kg	Organic-N mg/kg	NH4/NO3~	pH	K mg/kg	NO3-N^ (Soil Solution) mg/l	Water Content* %
0-15	6.7 a	28.4 a	3041	0.2	6.7	1014	169	13.1 a
15-30	0.6 b	7.3 b	210	0.1	6.7	395	130	5.4 b
30-60	1.1 b	9.4 b	177	0.1	6.8	575	99	8.7 c
60-90	1.6 b	9.6 b	175	0.2	6.8	656	81	10.7 a c
90-120	1.6 b	9.1 b	66	0.2	6.7	549	93	9.3 c
120-150	2.6 b	12.0 b	44	0.2	6.6	562	97	11.1 a c
	L.S.D.=2.9	L.S.D=10.8						L.S.D.=2.4

Table 51. Summary of soil N and related chemical data for the well drained soils of site 5.

Depth cm	NH4-N mg/kg	NO3-N mg/kg	Organic-N mg/kg	NH4/NO3~	pH	K mg/kg	NO3-N^ (Soil Solution) mg/l	Water Content* %
0-15	6.6 a	25.0 a	419	0.3	6.9	673	280	8.4 a c
15-30	6.1 ab	10.4 b	151	0.6	7.5	498	139	6.9 a
30-60	6.1 ab	6.9 b	158	0.9	7.1	899	59	10.9 b d
60-90	2.9 ab	6.1 b	90	0.5	6.8	675	56	9.9 bc
90-120	1.0 b	5.3 b	40	0.2	6.6	395	66	7.0 a
120-150	2.6 ab	7.3 b	34	0.4	6.6	350	55	12.4 d
	L.S.D.=4.6	L.S.D.=5.4						L.S.D.=2.2

* Data represents an average of 7 samplings form May 3 to September 2, 1986. Numbers with different letters are significantly different at the 5% level.

~ The ratio of NH4-N to NO3-N calculated by division of NH4-N values by NO3-N values.

^ Data represents season mean of soil NO3-N calculated on a soil solution basis.

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