WINTER SPRAY IRRIGATION WITH SECONDARY MUNICIPAL EFFLUENT IN SOUTH CENTRAL MICHIGAN

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David Earl Leland

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ABSTRACT

WINTER SPRAY IRRIGATION WITH SECONDARY
MUNICIPAL EFFLUENT IN SOUTH CENTRAL MICHIGAN

by

David E. Leland

From December, 1975, to March, 1977, a 3 hectare (7.35 acre) unmodified subwatershed at the Michigan State Water Quality Management Project was subjected to irrigation with secondary municipal effluent. The period included a short winter with heavy snowfall (1976) and a long winter with little snowfall and record low temperatures (1977). The objective of the study was to construct seasonal water and nutrient balances for nitrogen and phosphorus.

Hydrologic data was collected on surface runoff and water input due to spray irrigation and natural precipitation. Surface runoff was monitored by a weir and stage recorder. Irrigation and precipitation inputs were measured with rain gages. Evapotranspiration was estimated and infiltration volume was obtained by difference.

Water quality samples were taken of spray input, surface runoff, and infiltrated water. Grab samples of spray input were collected and detailed automatic runoff sampling was achieved using an ISCO sampler at the spray site weir. Infiltrated water was sampled with porous cup lysimeters.

The data were used to compute water balances and nutrient mass balances for chloride, nitrogen, and phosphorus on a seasonal basis. The highest percentage of surface runoff occurred during the winter periods but most of the input water infiltrated during all seasons. Heavy ice buildup occurred during subfreezing temperature spray operations. Quality of runoff and infiltrated water was poorest during the winter seasons. High phosphorus concentrations which violated Michigan standards were observed in ice melt runoff but nearly 90 percent of the input phosphorus mass applied during the winter was retained on the site. Significant nitrate nitrogen infiltration was observed and violation of standards was avoided only by groundwater dilution. Winter spray irrigation may be feasible only if contour plowing or diking is practiced to increase infiltration and if nitrogen levels in the applied wastewater are low.

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By

David Earl Leland

A THESIS

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

1.1 Winter Wastewater Irrigation and the Michigan State University Water Quality Management Project

In recent years there has been growing concern over nitrogen and phosphorus discharge from secondary municipal wastewater treatment plants. These nutrients contribute to the degradation of surface waters by accelerating the eutrophication process. An increasing number of states are setting nitrogen and phosphorus discharge standards and a number of physical, chemical, and biological tertiary systems have been developed to enable treatment plants to meet these new standards.

The Water Quality Management Project (WQMP) is a tertiary treatment system operated by the Institute of Water Research at Michigan State University. The system consists of a series of four man-made lakes and a land disposal facility as shown in Figure 1 (1). The lakes receive unchlorinated secondary effluent from the East Lansing sewage treatment plant at rates of up to two million gallons per day. Nominal detention time in the lake system is about 120 days. The lakes achieve up to 94 percent nitrogen removal but are considerably less effective in taking up phosphorus (2). Nutrients in the lake system are also removed by algae harvesting. Final wastewater nutrient recycling is achieved by land disposal at the 145 acre spray irrigation site. The spray site consists of uncultivated old field areas, cropland, and forest.

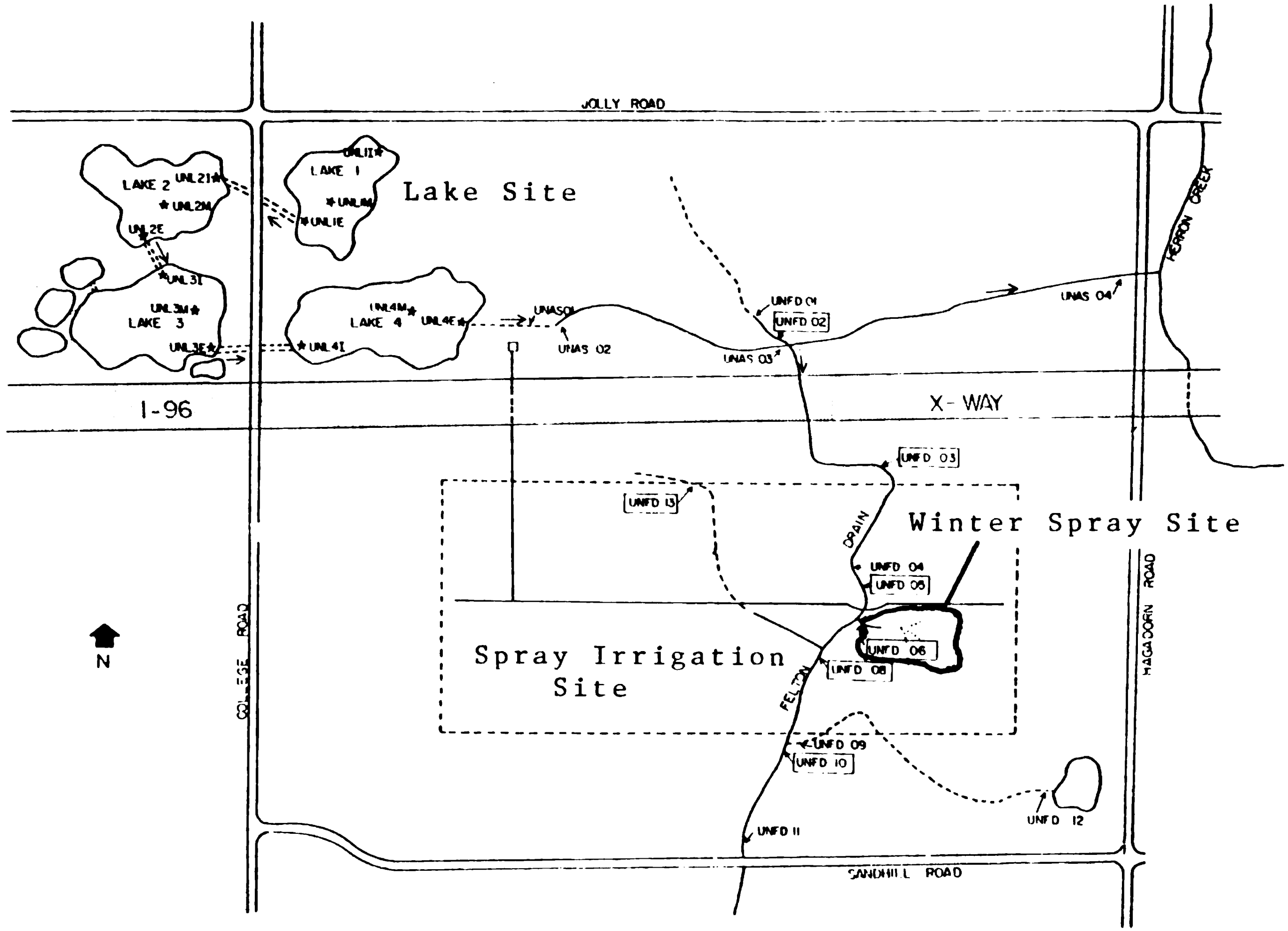

Figure 1.--Map of the M.S.U. Water Quality Management Project.

At the present time the WQMP system is limited to land disposal during the growing season, or about six months per year. Winter wastewater irrigation would be advantageous for two reasons. First, storage requirements for the winter months could be avoided and the required lake volume for this type of system could be reduced. Second, year-round operations would reduce land requirements for the irrigation site.

Little data is currently available on winter land application of municipal wastewater. A complete assessment of winter spray irrigation would include investigation of effects on both groundwater and runoff quality during actual operating conditions. Water quality standards, however, must be met even during the winter months. Regulations resulting from Michigan Public Act 245 call for eighty percent phosphorus concentration reduction in surface discharge or a maximum average monthly concentration of 1 mg-P/l. The federal Safe Drinking Water Act standards call for a maximum nitrate concentration of 10 mg-N/l, which applies to groundwater in this project.

1.2 Fate of Wastewater Nutrients in the Soil - Implications for Winter Land Application

Municipal effluents contain a wide variety of nutrients and contaminants. In land disposal, nitrogen and phosphorus are affected by a number of processes which result in storage or removal from the soil-plant system.

Sufficient nitrogen removal is the most critical factor in land application of wastewater because the nitrate form can move freely through the soil profile into groundwater supplies creating a potential health hazard. Nitrogen is taken up primarily by the vegetation at the land disposal site and is ultimately removed from the system by harvesting (3). Flood resistant perennial grasses are most effective for nitrogen uptake because of their long growing season and high nitrogen requirement (4). Nitrogen loss through denitrification in soils is significant due to the abundance of denitrifying bacteria present (5). These bacteria use nitrate as a hydrogen acceptor in the absence of oxygen resulting in liberation of nitrogen gas. Nitrogen can also be lost to the air as ammonia. This requires considerable air-water contact and may occur during spray operations (3).

Nitrogen can be stored in the soil by several means. Ammonium nitrogen can be incorporated into microbial tissue and either released by cell decay or stored indefinitely in a stable form (6). Ammonia reacts with soil organics to form leaching resistant complexes (7). The ammonium ion can be trapped by expanding layers of clay minerals (3). Finally, ammonium ions can be absorbed by the soil cation exchange complex consisting of negatively charged clay and organic colloids (3).

Phosphorus is retained in the soil by adsorption onto soil particles with ultimate removal by plant uptake and harvesting. The soil-plant system achieves excellent phosphorus renovation and land disposal sites are generally not limited by standards for phosphorus removal (8). Many years of wastewater disposal are required to exhaust the capacity of a site to retain phosphorus (9).

Winter land application of sewage effluent in northern climates presents a variety of potential difficulties for nitrogen and phosphorus removal. The most obvious problem is the absence of vegetative growth during the winter months. Soil frost may present a barrier to infiltration preventing soil-sewage contact and resulting in excessive ice accumulation on the site. Ice buildup could lead to large volumes of low quality surface runoff during thaw periods. Freezing significantly reduces the soil microbe population and causes denitrification to nearly cease (10). Potential interferences, therefore, exist for all nitrogen and phosphorus renovation and retention mechanisms during winter land disposal operations.

1.3 Winter Land Application Projects

1.3.1 Pennsylvania State University

From 1966 to 1969, several studies were conducted at the Pennsylvania State University on small old field subwatersheds subjected to year-round irrigation with secondary municipal effluent (11). Runoff volume and quality were studied as functions of climatic conditions and spray treatments. Water quality was determined with respect to nitrogen and phosphorus.

Minimum runoff occurred during the growing season when evapotranspiration was high. Maximum runoff occurred when the soil was frozen and the air temperature was above freezing during spray operations. On warm days, snow and ice melt contributed heavily to the runoff volume. Runoff nutrient concentrations were minimum when soil percolation occurred and were maximum when the soil was frozen. Nutrient levels were reduced somewhat in the winter runoff when the weekly spray volume was applied over several days rather than on one day.

1.3.2 U.S. Army Cold Regions Research and Engineering Laboratory (CRREL)

Large scale outdoor concrete test cells were constructed for this study in New Hampshire (12). The cells were filled with local soils, Windsor sandy loam and Charlton silt loam, compacted to in-situ density, and planted with forage grasses. The cells were irrigated at different rates for a one year period with secondary and primary sewage effluent from a nearby housing community. Water quality samples were collected at various depths using suction lysimeters. The percolate was collected from the bottom of the cells and its volume and quality were measured. Water balances and nutrient mass balances were constructed for each cell.

The average total nitrogen content of the applied wastewater was 26 mg-N/1 and the average total phosphorus content was 7 mg-P/1. Nitrification was nearly complete in the top forty-five centimeters of soil. Collected percolates showed seasonal nitrate trends with peaks of up to 125 mg-N/1 during late spring to early summer. Generally, the percolate nitrate concentration remained below ten mg-N/1. Phosphorus removal was greater than 99 percent in all cells. A nitrogen mass balance error of five to twenty-eight percent was observed.

Although the study was not conducted on a natural site, several impacts on groundwater quality of winter wastewater land application were indicated. Excellent phosphorus retention was still achieved. Nitrogen renovation, however, was seriously impaired.

1.3.3 Michigan State University

During the winter of 1975, a spray study was conducted by David E. Fritz at the Water Quality Management Project spray irrigation facility (13). A well-defined three hectare (7.35 acre) subwatershed was subjected to six one to two inch applications of wastewater from lake one of the WQMP system over a two-month winter period. Direct secondary effluent was not available. The objective of the study was to construct a water balance and nutrient mass balances for chloride, nitrogen, phosphorus and boron for the study period.

Surface runoff from the site was collected in an excavated channel fitted with a V-notch weir for flow measurement. A Stevens recorder mounted on a stilling well gave a continuous record of stream stage and time. Infiltration was measured with forty-seven gravity collection glass funnel infiltrometers distributed around the site and buried at a depth of three feet. The funnels were evacuated from the surface with a hand pump for volume measurement and water quality sample collection. Grab samples of surface runoff were taken and samples of wastewater spray were collected in plastic-lined cans located around the site. Natural precipitation was monitored with a recording raingage located near the spray site. Water quality determinations were performed by the Institute of Water Research Water Quality Laboratory.

The study was the first conducted during the winter at the WQMP and numerous problems were encountered with procedures and equipment. Instrumental difficulties combined with an insufficient number of samples did not allow for an adequate computation of the water balance or the nutrient mass balances. Because manual sampling techniques were employed, an insufficient number of surface runoff samples were collected to allow computation of accurate mass flows. Hydrograph accuracy was affected by ice buildup in the stilling well. Infiltrometer measurements were probably the greatest source of error in the study. Air-water interfaces within the funnels influenced water flow rates into the funnels depending on the degree of soil saturation. Water quantities obtained from the funnels were highly variable and several funnels showed evidence of direct hydraulic connection to the surface. Only fifty-six percent of the input water was accounted for in the water balance. Nutrient mass balance errors of up to seventy percent were observed.

General conclusions were drawn in spite of the difficulties encountered. Evaporation apparently accounted for fifteen to twenty percent of the input water volume and ammonia gas was liberated during spray operations. Ice buildup occurred during subfreezing spray conditions and contributed to surface runoff during warm weather. Large amounts of nitrate nitrogen apparently infiltrated to the groundwater.

1.4 Purpose and Objectives

Previous studies have provided some insight on the impact of winter land application of secondary municipal effluent. No single study has successfully determined the effect of winter land disposal on both groundwater and surface runoff at a natural unmodified site. In order to fully assess these effects, it is necessary to determine seasonal water and nutrient mass balances for such a site under year-round operating conditions.

The objective of this study was to continue the work begun by Fritz in 1975 and obtain more reliable data on a year-round basis. Seasonal water balances and seasonal nutrient balances for chloride, nitrogen, and phosphorus were determined over a full year. The study was conducted from December, 1975, to March, 1977, a period which included a very short mild winter (1976) and a very long severe winter (1977). While the site was able to retain ninety percent of the applied phosphorus during winter operations, significant nitrate breakthrough to the groundwater was observed. Runoff volume was a small percentage of the input water during the winter but it was of poor quality. Most of the winter input water and nutrients infiltrated.

CHAPTER 2

DESIGN OF EXPERIMENT

2.1 Winter Spray Site Description

The study was conducted on the three hectare (7.35 acre) site used by D. Fritz in 1975 (13). A map of the area is given in Figure 2 showing two foot contours. The site was chosen for its well-defined watershed boundary. Surface runoff was collected in the low area at the west end of the field, and was conducted to Felton Drain by earthen dikes and an excavated channel. The field was well drained with the exception of the marshy western low area which comprised a very small percentage of the total watershed.

A soil map of the WQMP spray irrigation facility was complied by T. Zobeck in 1976 (14). Figure 3 is a map of the major soil types found at the winter spray site. Seventy percent of the site consists of Miami-Marlette soil, which is a loam, silt loam, or silt glacial till. Other types present include Owosso (sandy loam), Kidder (clay loam or sandy clay loam), and Colwood (fine sand). Extreme variation within these soil mapping units was found; the units proved to be only forty-seven percent homogeneous. The general soil profile is also very nonuniform with many alternating layers of clay and sand materials.

2.2 Data Collection

In order to compute a water balance and mass balances for key nutrients, it was necessary to monitor spray and precipitation input, surface

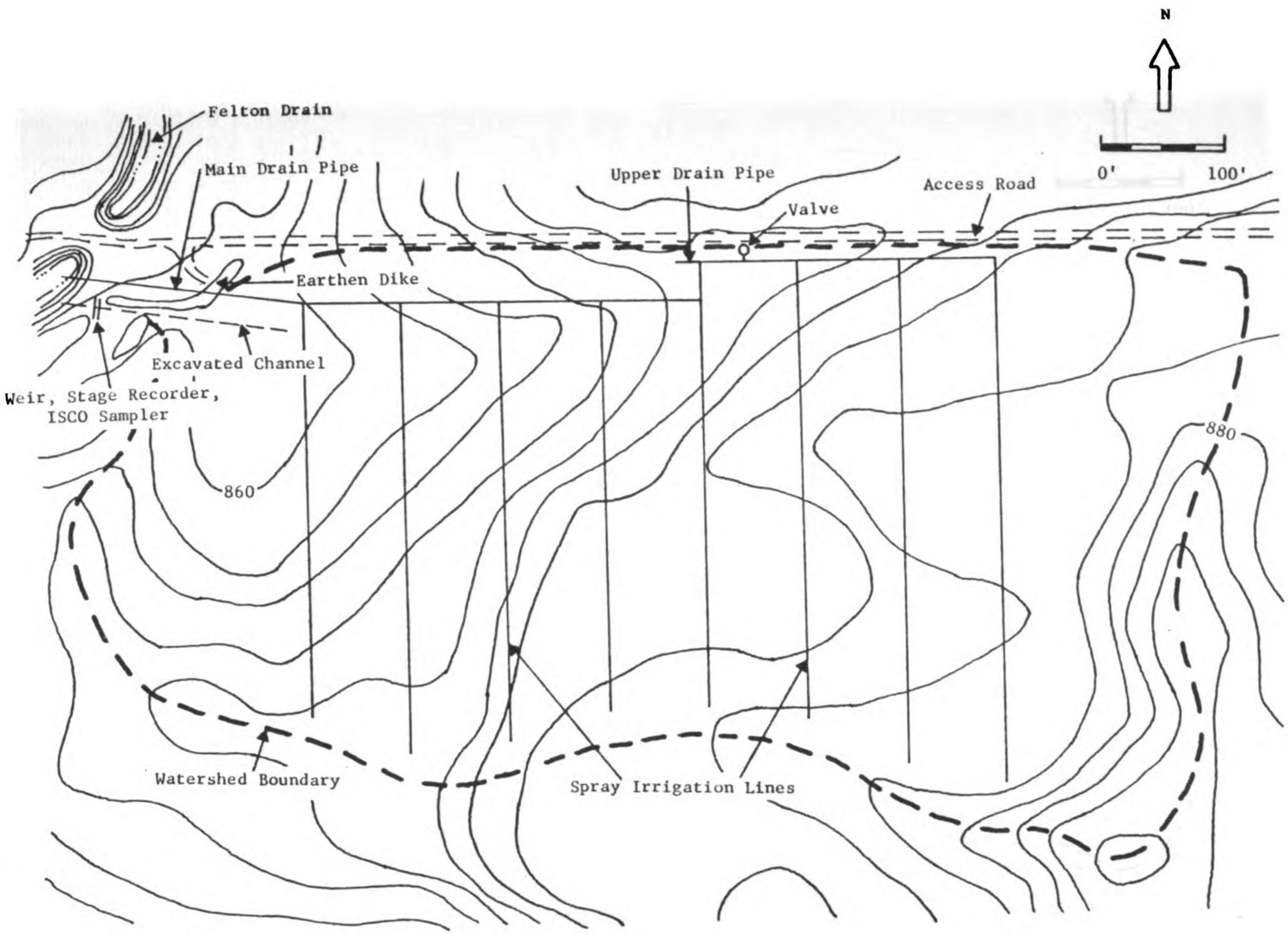

Figure 2.--Detail Map of Winter Spray Site.

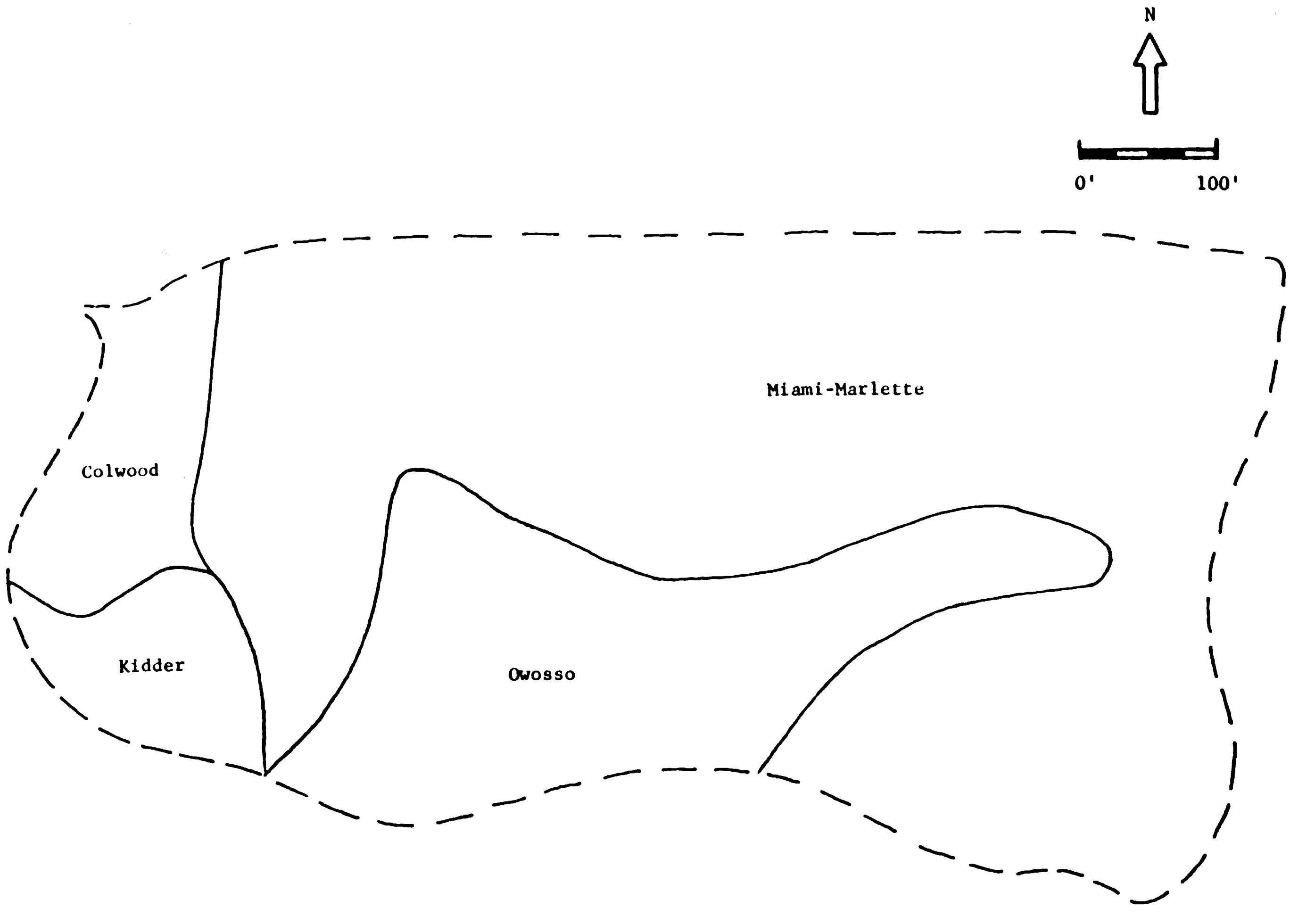

Figure 3.--Soil Map of Winter Spray Site.

runoff, infiltration, and evapotranspiration. Both hydrologic and water quality data were required. Equipment locations are shown in Figure 4.

Spray input volume was determined from pumping records. The depth of spray application was checked with wedge-shaped plastic "Tru-Chek" raingages at fifteen locations around the site. Sample bottles and funnels were used to collect water quality samples of the spray at the same locations as shown in Figure 5. During the winter of 1977, samples of input wastewater were taken from the irrigation system drain pipes because severe cold hampered sample collection by the bottle-funnel devices. There appeared to be no difference between spray samples and drain pipe samples during the winter. Natural precipitation was monitored with a Bendix recording raingage located near the site. Precipitation quality was not monitored, but average precipitation nutrient concentrations have been measured at various locations around the Midwest. The average total phosphorus concentration at points along the shoreline of Lake Michigan is 0.027 mg-P/l (15). Measurements at Akron, Ohio; Urbana, Illinois; and Indianapolis, Indiana, show average precipitation nutrient concentrations of 0.35 mg-Cl/l chloride, 2.67 mg-N/l nitrate, and 0.25 mg-N/l ammonia (16).

A 45° V-notch weir installed in the excavated channel allowed measurement of surface runoff flow from the site. A Stevens recorder and stilling well installed upstream of the weir provided continuous stage-time records. The equipment setup is shown schematically in Figure 6. Freezing was prevented during winter operations by suspending a heat lamp in the stilling well and inserting a heat tape into the intake pipe. Snow and ice were cleared from the channel regularly. Detailed automatic water quality sampling was achieved using an ISCO model 1392 high speed

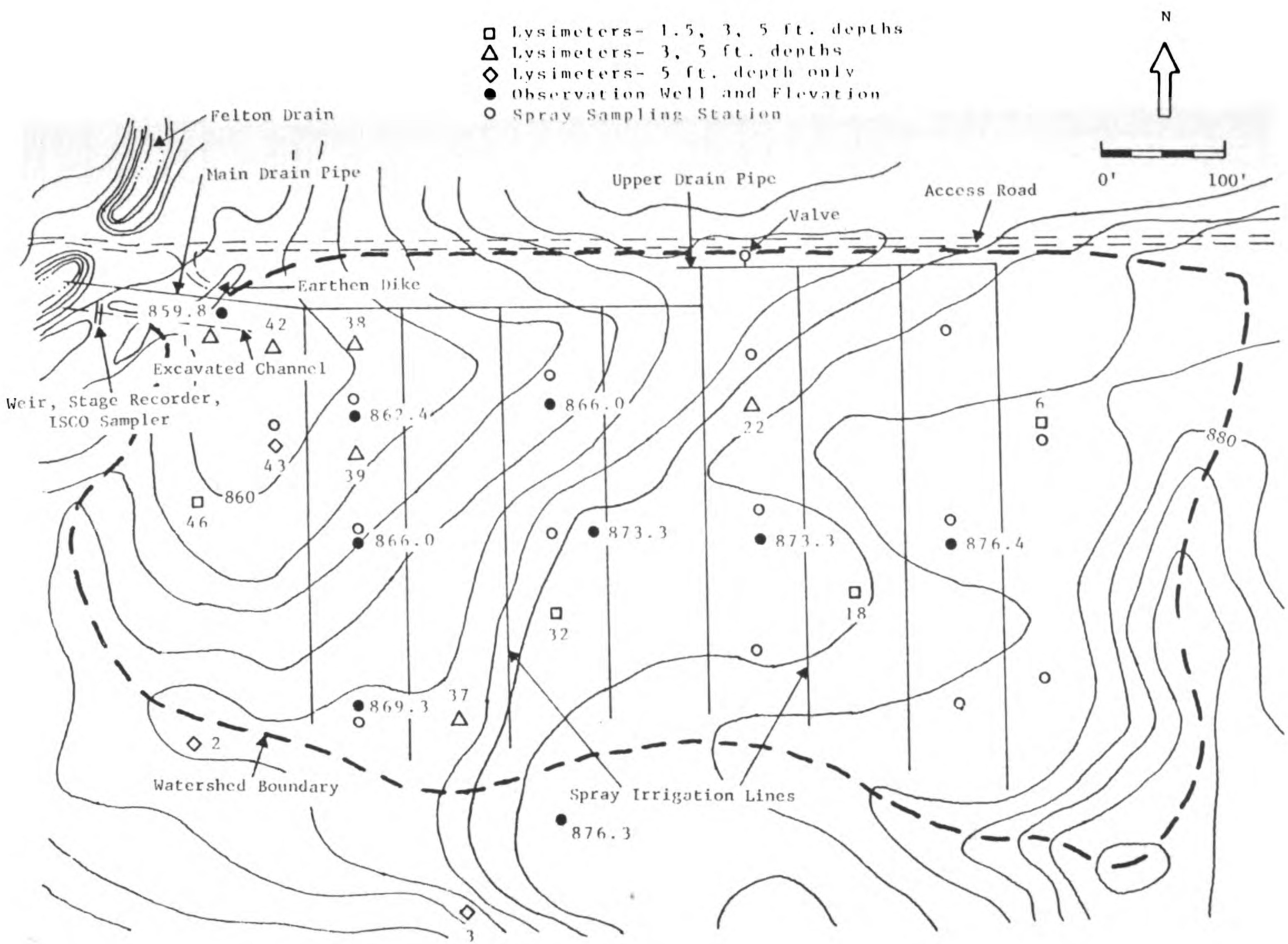

Figure 4.--Winter Spray Site Equipment Locations.

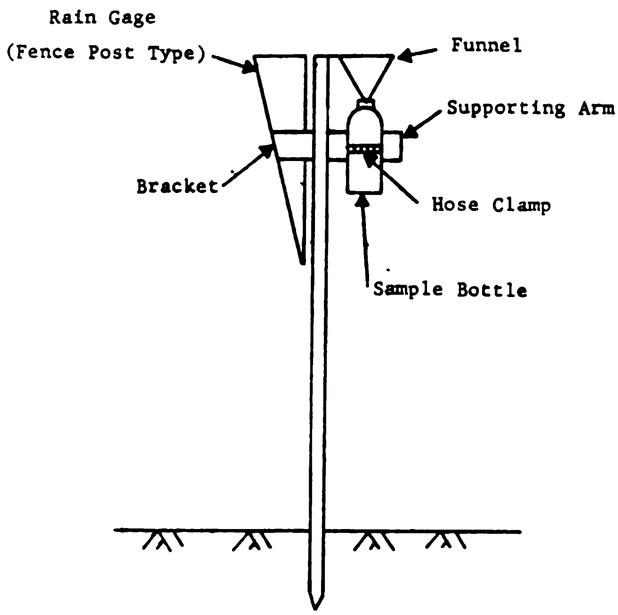

Figure 5.--Spray Sampling Station.

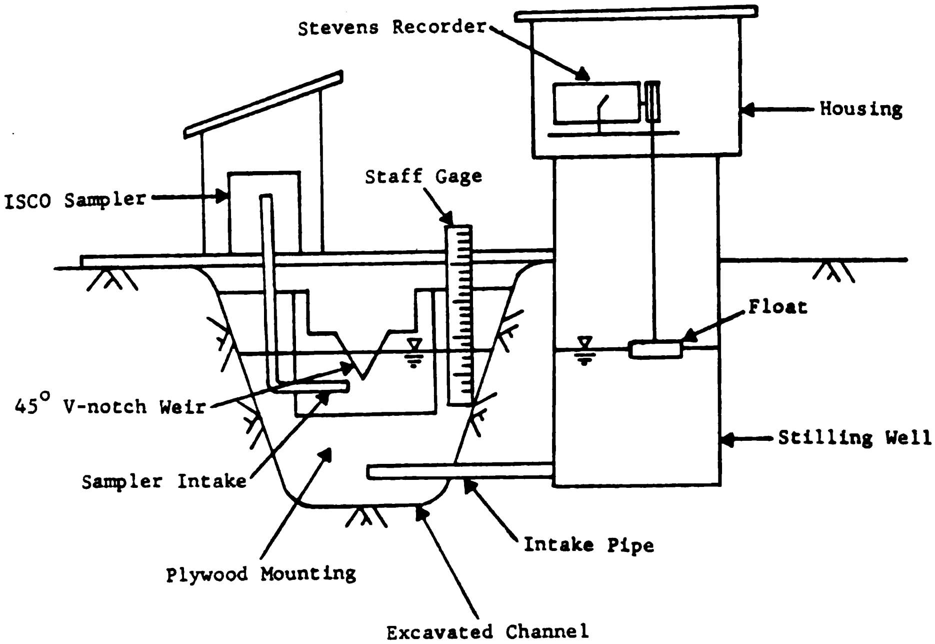

Figure 6.--Weir, Stage Recorder, and ISCO Sampler.

sequential sampler. The sampler collected up to twenty-eight samples at preset intervals of one-half to four hours, and was triggered by the Stevens recorder at the beginning of flow. Freezing protection was provided by an insulated heated housing and a heat tape wrapping on the intake line.

Infiltration is a very difficult parameter to measure in the field when complex soil conditions exist. Because of the infiltration measurement problems encountered by Fritz and others during the 1975 study, infiltration was estimated by subtracting surface runoff volume and evapotranspiration volume from the total water input volume. Infiltrated water was sampled using porous cup lysimeters manufactured by the Soilmoisture Equipment Corporation. Cups were installed at depths of 1.5, 3.0, and 5.0 feet at various locations around the site as shown in Figure 4, previously. Few lysimeters were installed at the 1.5 foot depth because frost problems were anticipated. Cups were installed one to a hole as recommended by Wood (17). A representative lysimeter installation is shown schematically in Figure 7. To collect samples, an eighty centibar (24 inches Hg) vacuum was applied to each cup with a simple hand pump. After sufficient time was allowed for sample collection, the pressure side of the pump was used to evacuate the cups. Twelve lysimeters were installed prior to the winter of 1976, and fifteen additional cups were installed during the summer of 1976. Covers were fashioned to protect the access hoses from surrounding ice buildup. The depth to the groundwater table was monitored in shallow PVC pipe observation wells at eleven locations around the site beginning in the summer of 1976. Differences between observation well elevations and the contours in Figure 4 were due to local topography variations.

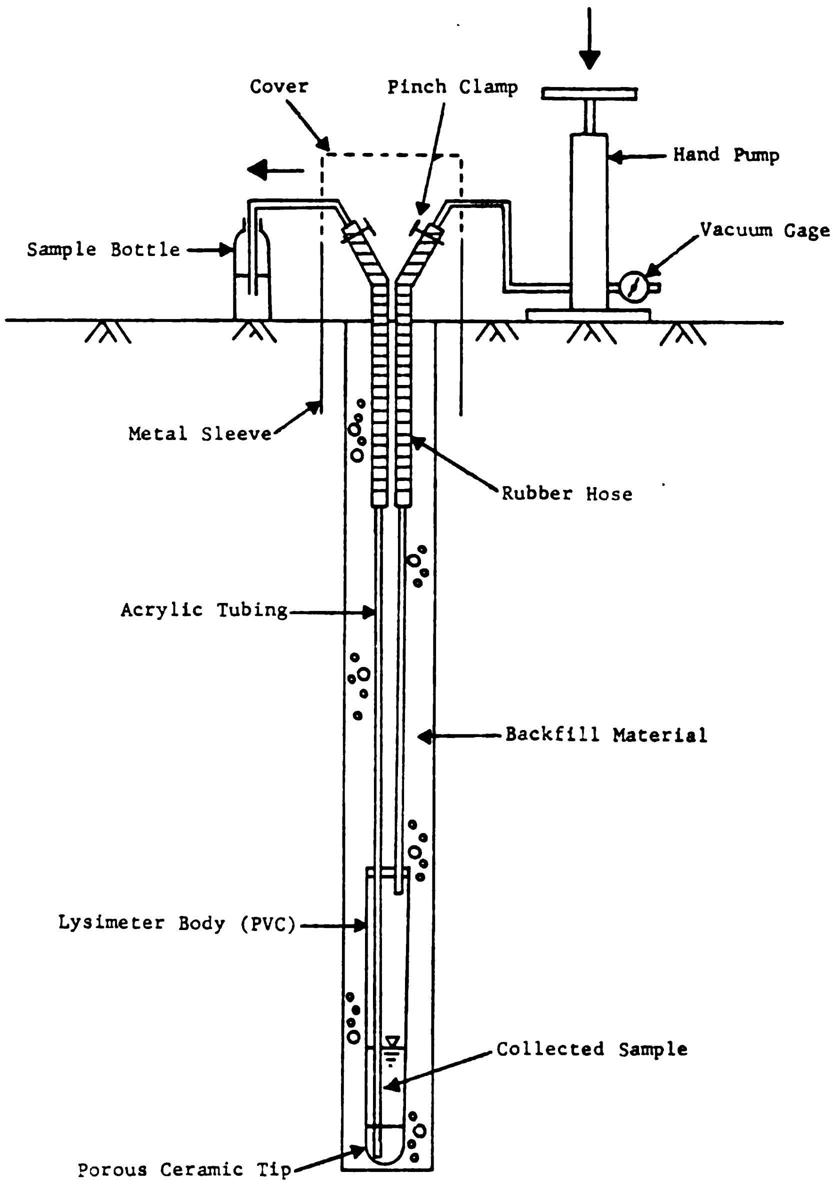

Figure 7.--Typical Lysimeter Installation.

Evapotranspiration was estimated using the empirical method proposed by Thornthwaite (18). Tables and easily obtainable weather data were used to compute monthly values of potential evapotranspiration. The method, based on monthly sunlight duration and mean monthly temperature, was modified in that actual monthly sunlight duration values were substituted for the maximum values given in Thornthwaite's tables. The potential evapotranspiration calculated was assumed to be the actual evapotranspiration. Calculations are given in Appendix A for the study period.

Water quality determinations were performed by the Institute of Water Research Water Quality Laboratory. When necessary, samples were stored at 4°C and were not preserved after winter 1976 operations. Early samples were preserved with H_2SO_4. Determinations were performed with a Technicon Auto Analyzer according to U.S. Environmental Protection Agency approved methods (19). Methods used were Storet 00940 (chloride), 00610 (ammonia nitrogen), 00615 (nitrite nitrogen), 00630 (nitrate-nitrite nitrogen), 00620 (nitrate nitrogen), and 00665 (total phosphorus).

2.3 Operation and Sampling Schedule

Research at the Pennsylvania State University established that two inches (51 mm) per week was a safe secondary effluent application rate for perennial grasses (4). Applications of two inches on one day during Fritz's study in 1975 resulted in several large runoff events. In the present study, wastewater was applied at a rate of two inches per week in two one-inch applications on Tuesdays and Thursdays. No wastewater was applied during surface runoff events. Fifteen spray samples were collected with the bottle-funnel devices during each spray operation and were composited into three samples for analysis according to location in the western, central, or eastern areas of the site. Initially, the lysimeters were evacuated and repressurized before each spray event. Beginning in the summer of 1976, the lysimeters were evacuated and repressurized before every other spray event, or once per week, due to observed slow changes in groundwater quality. The depth to the groundwater table was monitored once per week prior to spraying beginning in the summer of 1976.

2.4 Data Analysis

Data was analyzed on a seasonal basis with seasonal periods delineated according to the hydrologic response of the watershed. Estimation of infiltration and evapotranspiration volume was discussed previously. The calculation of nutrient mass input from spray and precipitation volume and average spray and precipitation nutrient concentration is straightforward. Calculation of runoff nutrient mass and water volume and nutrient reduction in the soil is discussed here.

Runoff data were analyzed using the computer program FLUX, described in detail in Appendix B. Stage-time data and water quality-time data were input and runoff volume and nutrient mass totals were generated on a daily basis. A more detailed analysis option generated nutrient mass flowrates, concentrations, and water flowrates interpolated to fifteen minute intervals. Plots were generated to compare nutrient mass flows with the hydrograph for selected runoff events.

In calculating nutrient reduction in the soil, it was assumed that the difference between the input mass, or the applied nutrient mass, and the runoff nutrient mass gave the total nutrient mass infiltrating (M). A seasonal anticipated infiltrated water nutrient concentration (A) assuming no removal of nutrient was calculated using (M) and the infiltration volume estimate (I) as follows:

$$A, (mg/l) = \frac{M}{I} \tag{1}$$

This concentration reflected dilution and concentration effects of precipitation and evapotranspiration. Seasonal nutrient reduction in the soil (R) was calculated by comparing (A) to the average seasonal nutrient concentration, or maximum seasonal concentration when a significant increasing concentration trend was observed, measured at the five foot depth (B).

$$R, (\%) = \left(\frac{A - B}{A}\right) \times 100 \tag{2}$$

Reduction was assumed to include the effects of lateral inflow-outflow of groundwater and dilution in the groundwater as well as soil nutrient renovation and retention processes. Sample calculations are given in Appendix F. Overall nutrient reduction mass was calculated as follows:

$$\text{Overall Reduction, (kg)} = \frac{R \times M}{100} \tag{3}$$

Nutrient infiltration mass, the nutrient mass penetrating the soil to the five foot depth, was obtained by difference.

$$\text{Infiltration Mass, (kg)} = M - \text{Overall Reduction} \tag{4}$$

Negative seasonal R values were occasionally obtained for chloride when the time lag associated with changes in groundwater quality resulted in carry-over of the high groundwater chloride levels into a season of lower chloride input mass. These negative R values were incorporated into the overall mass balance for the study period but were assumed to be zero for seasonal mass balances to avoid calculation of negative overall reductions. While this procedure introduced some numerical inaccuracy, it allowed construction of approximate seasonal balances to characterize the response of the site during different times of the year. Except when negative R values occur, it can be shown that:

$$\text{Infiltration Mass, (kg)} = B \times I \tag{5}$$

CHAPTER 3

DISCUSSION OF RESULTS

3.1 Summary of Results for Study Period

This section gives a summary of results for the entire study period from December 1, 1975, to March 16, 1977. Subsequent sections give more detailed discussions of results by season.

Table 1 gives the overall water balance for the study period. Wastewater accounted for 68 percent of the total water input. Most of the output water, 67 percent, infiltrated. Evapotranspiration and surface runoff accounted for 19 percent and 14 percent of the output. Table 2 lists runoff, infiltration, and evapotranspiration as a percent of total water input by season. Minimum runoff occurred during the summer and fall and maximum runoff occurred during the winter seasons which included periods of ice melt. Infiltration accounted for most of the water input in all seasons with higher percentages in the fall and winter than during the spring and summer. Evapotranspiration estimates were maximum during the summer growing season (43 percent), moderate during the spring and fall (20 percent and 13 percent), and zero during the winter seasons. Runoff varied inversely with evapotranspiration. In general, higher infiltration occurred with lower evapotranspiration.

Overall nutrient mass balances are given in Table 3. On a year round basis, only two to four percent of the input nitrogen and phosphorus accompanied the surface runoff. Overall reductions of nitrogen and phosphorus were high: 77 percent for ammonia, 85 percent for nitrate, and

Table 1
Overall Water Balance for Study Period
December 1, 1975 to March 16, 1977

Source	Volume (m^3)	Percent of Total
Input		
Wastewater Spray	47,398	68
Precipitation	22,300	32
	69,698	100
Output		
Runoff	9,714	14
Infiltration	46,915	67
Evapotranspiration	13,069	19
	69,698	100

Table 2
Runoff, Infiltration, and Evapotranspiration as
Percent of Total Water Input by Season

Season	Runoff, Percent of Input	Infiltration, Percent of Input	Evapotranspiration, Percent of Input
Winter 1976 12/1/75-2/27/76	27	73	∿0
Spring 1976 2/28/76-5/27/76	23	57	20
Summer 1976 5/28/76-8/31/76	0	57	43
Fall 1976 9/1/76-11/30/76	4	83	13
Winter 1977 12/1/76-3/16/77	29	71	∿0

Table 3
Overall Nutrient Mass Balances for Study Period
December 1, 1975 to March 16, 1977

Nutrient	Input kg spray	Input kg rain	Runoff kg	Runoff % of input	Overall Reduction kg	Overall Reduction % of input	Infiltration kg	Infiltration % of input
Chloride (as Cl)	5,868	8	680	12	109	2	5,087	86
Nitrate (as N)	519	59	24	4	491	85	63	11
Ammonia (as N)	41	6	1	2	36	77	10	21
Total Phosphorus (as P)	163	0.6	6	4	149	91	8.6	5

Table 4
Nutrient Reduction in the Soil by Season

Season	Percent Reduction in Soil, (R) Chloride	Ammonia	Nitrate	Total Phosphorus
Winter 1976 12/1/75-2/27/76	17	75	93	99
Spring 1976 2/28/76-5/27/76	-54	60	98	98
Summer 1976 5/28/76-8/31/76	39	91	99	99
Fall 1976 9/1/76-11/30/76	-20	66	99	99
Winter 1977 12/1/76-3/16/77	-28	60	68	85

91 percent for phosphorus. Only five percent of the input phosphorus infiltrated to the groundwater. Higher percentages of nitrate and ammonia infiltrated primarily due to breakthrough during the winter. In contrast to nitrogen and phosphorus, most of the input chloride infiltrated with little overall reduction taking place.

Calculated nutrient reduction by season is given in Table 4. Negative R values for chloride were obtained following groundwater chloride accumulation during the winter and summer of 1976. Very little ammonia was applied during the study and reduction extent was obscured by ammonia chemistry in the soil. High levels of nitrate and phosphorus reduction were observed throughout the study with the lowest reductions during the winter of 1977.

Nitrogen to chloride ratios for wastewater and groundwater are given in Figure 8. Lake renovated effluent was applied from January through April, 1976. Direct secondary effluent containing higher nitrogen levels was applied to the site from May, 1976, to February, 1977. Nitrogen in the applied wastewater was primarily in the nitrate form. A slightly increased groundwater N/Cl ratio during the winter of 1976 indicated higher levels of nitrogen infiltration since chloride levels remained nearly constant. A low N/Cl ratio was observed in the groundwater during the spring, summer, and fall in spite of higher N/Cl ratio in the applied wastewater indicating significant nitrogen removal in the soil. Increased N/Cl ratio in the groundwater during the winter of 1977 evidenced a breakdown in nitrogen renovation due to winter conditions. The difference between wastewater and groundwater N/Cl ratio during the winter was probably due to dilution of wastewater with the low nitrogen high chloride groundwater present at the beginning of the winter periods.

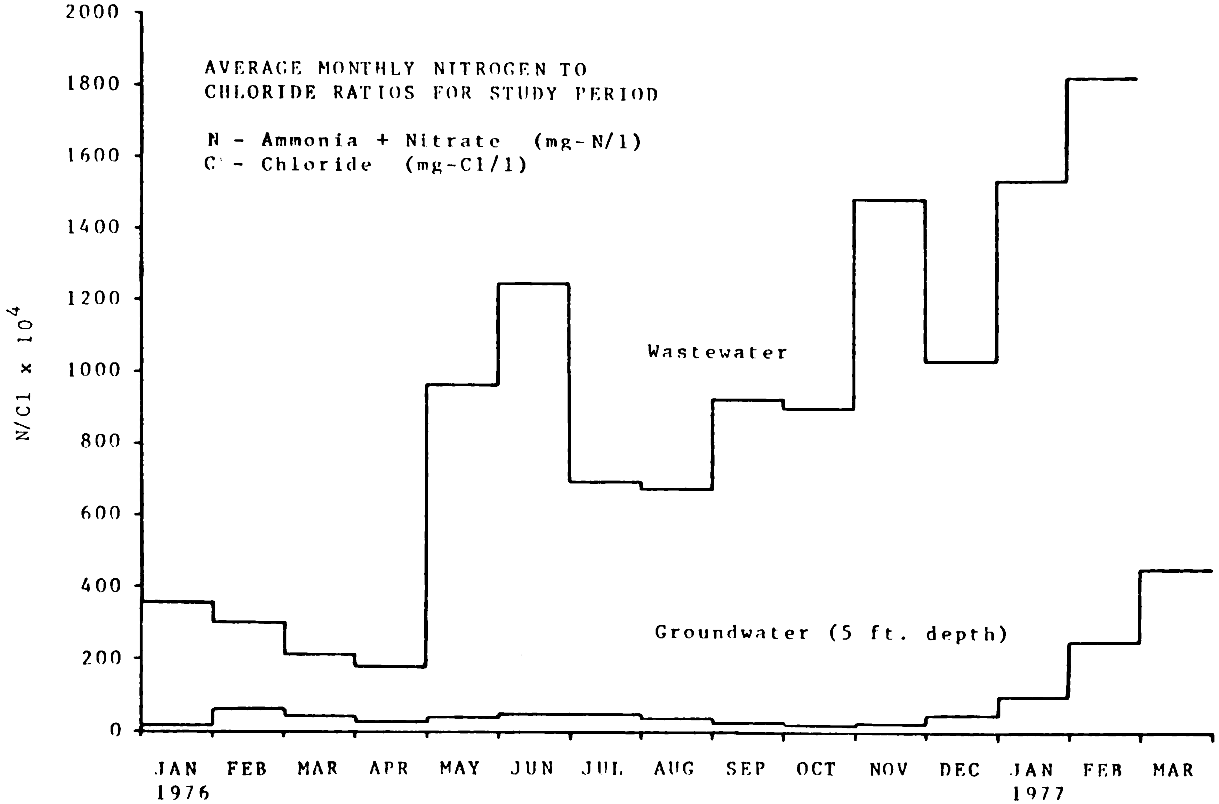

Figure 8.--Monthly Nitrogen to Chloride Ratios for Study Period.

Wastewater spray irrigation operations were generally successful on a year-round basis. Surface runoff amounted to only a small percentage of the total water input even during winter operations, thus, most of the input water infiltrated. Small percentages of the nitrogen and phosphorus input mass were detected in the surface runoff and the groundwater. Nutrient reduction was high on a year-round basis.

3.2 Winter 1976 Results

The winter of 1976 was characterized by considerable early snowfall and an early spring thaw. Early heavy snowfall prevented significant frost penetration into the soil and temperatures remained below freezing from January 9 to February 10. During this period, 10 inches (25 cm) of wastewater from the bottom of lake one of the WQMP system were applied to the winter spray site resulting in considerable ice buildup with no runoff. Minor operating difficulties such as frozen valves and pipe breaks were encountered. Sprinkler heads often froze in position resulting in uneven spray distribution. An early spring thaw with rain beginning on February 10 resulted in saturated soil conditions and constant surface runoff. Runoff came to a halt on February 27 and the winter study period was ended.

Average input concentrations of wastewater nutrients were 167 mg-Cl/l chloride, 2.2 mg-P/l total phosphorus, 5.3 mg-N/l nitrate, and 0.5 mg-N/l ammonia (Appendix C). Nitrite was not expected to be present in significant concentrations and was not monitored. The nitrogen and phosphorus concentrations were quite low compared to average levels found in secondary municipal effluent: 10 mg-P/l phosphorus, 20 mg-N/l nitrate, and 10 mg-N/l ammonia (20). These low levels reflected partial renovation in the lake system during the previous summer.

Table 5 gives the water balance computed for the winter period. Wastewater spray made up 61 percent of the total water input to the site (Appendix C). Most of the input water, 73 percent, infiltrated and surface runoff accounted for only 27 percent of the water input (Appendices D and E). The Thornthwaite estimate of evapotranspiration was zero due to the subfreezing average temperature during the winter study period (Appendix A).

Computed nutrient mass balances for chloride, ammonia, nitrate, and total phosphorus are given in Table 6. Only two percent of the applied nitrate and phosphorus accompanied the surface runoff (Appendix D). Nitrogen and phosphorus reduction in the soil was high; computed R values were 93 percent for nitrate, 75 percent for ammonia, and 99 percent for phosphorus (Appendix F). In contrast, 68 percent of the applied chloride infiltrated. Overall reduction of nutrient mass as a percent of mass applied was 97 percent for phosphorus, 91 percent for nitrate, 70 percent for ammonia, and 14 percent for chloride. Chloride reduction did not give a good estimate of nutrient reduction due to dilution because of high background chloride levels present in the groundwater before the beginning of spray operations.

Figures 9, 10, and 11 are plots of time versus average infiltrated water nutrient concentrations measured in lysimeter samples. Lysimeter averages are tabulated by season in Appendix G. Spray operations took place from day 26 to day 53. Runoff and rainfall occurred from day 53 to day 70. Data prior to day 26 were suspect due to soil disturbance associated with recent lysimeter installation. Phosphorus concentrations in infiltrated water samples remained below 0.10 mg-P/l throughout the

Table 5
Water Balance - Winter 1976
December 1, 1975 to February 27, 1976

Source	Volume m^3	(10^6 gal)	Percent of Total
Input			
Spray	5,832	(1.541)	61
Precipitation	3,777	(.998)	39
	9,609		100
Output			
Runoff	2,618	(.692)	27
Infiltration	6,991	(1.847)	73
Evapotranspiration	0		0
	9,609		100

Table 6
Nutrient Balance, Winter 1976
December 1, 1975, to February 27, 1976

Nutrient	Input		Runoff		Overall Reduction		Infiltration	
	kg spray	kg rain	kg	% of input	kg	% of input	kg	% of input
Chloride (as Cl)	972	1	175	18	136	14	662	68
Nitrate (as N)	30.9	10.1	0.8	2	37.4	91	2.8	7
Ammonia (as N)	2.1	0.9	0.2	7	2.1	70	0.7	23
Total Phosphorus (as P)	12.8	0.1	0.2	2	12.6	97	0.1	1

winter period and are tabulated in Appendix G, but are not plotted.

In Figure 9, lysimeter chloride data are shown. A background chloride level of about 100 mg/l existed prior to the beginning of spray operations. Chloride concentration at the five foot depth increased slightly during spraying and decreased during the runoff period, indicating wastewater infiltration and subsequent dilution by rainfall infiltration. The lysimeter data for the three foot depth showed slightly lower chloride levels than at the five foot depth, however, most of the shallow lysimeters froze during the spray period and few samples were collected. The control outside the spray zone at location 46 showed elevated chloride concentrations at the five foot depth compared to the three foot depth indicating subsurface flow from the sprayed area toward Felton Drain.

Figure 10 shows a rapid increase in nitrate levels at the three foot depth with the beginning of spray operations, reaching a maximum of 1.7 mg-N/l, still far below the average spray concentration of 5.3 mg-N/l. Again, most samples were collected at the five foot depth and these data showed a steady increase in nitrate concentration to 0.6 mg-N/l during spraying. Groundwater dilution and a rising water table with ultimate saturation accounted for lower nitrate levels at the five foot depth and convergence of three and five foot depth data. The flushing effect of rainfall was evident at both depths. The control showed very low nitrate levels throughout the winter.

Lysimeter ammonia data are plotted in Figure 11. Concentrations were low, fluctuating at about 0.1 mg-N/l, both at the control and in the sprayed area and no trends were apparent. These results were due to the very low ammonia input concentration of 0.5 mg-N/l.

Figure 12 gives a typical hydrograph with nutrient mass flowrates

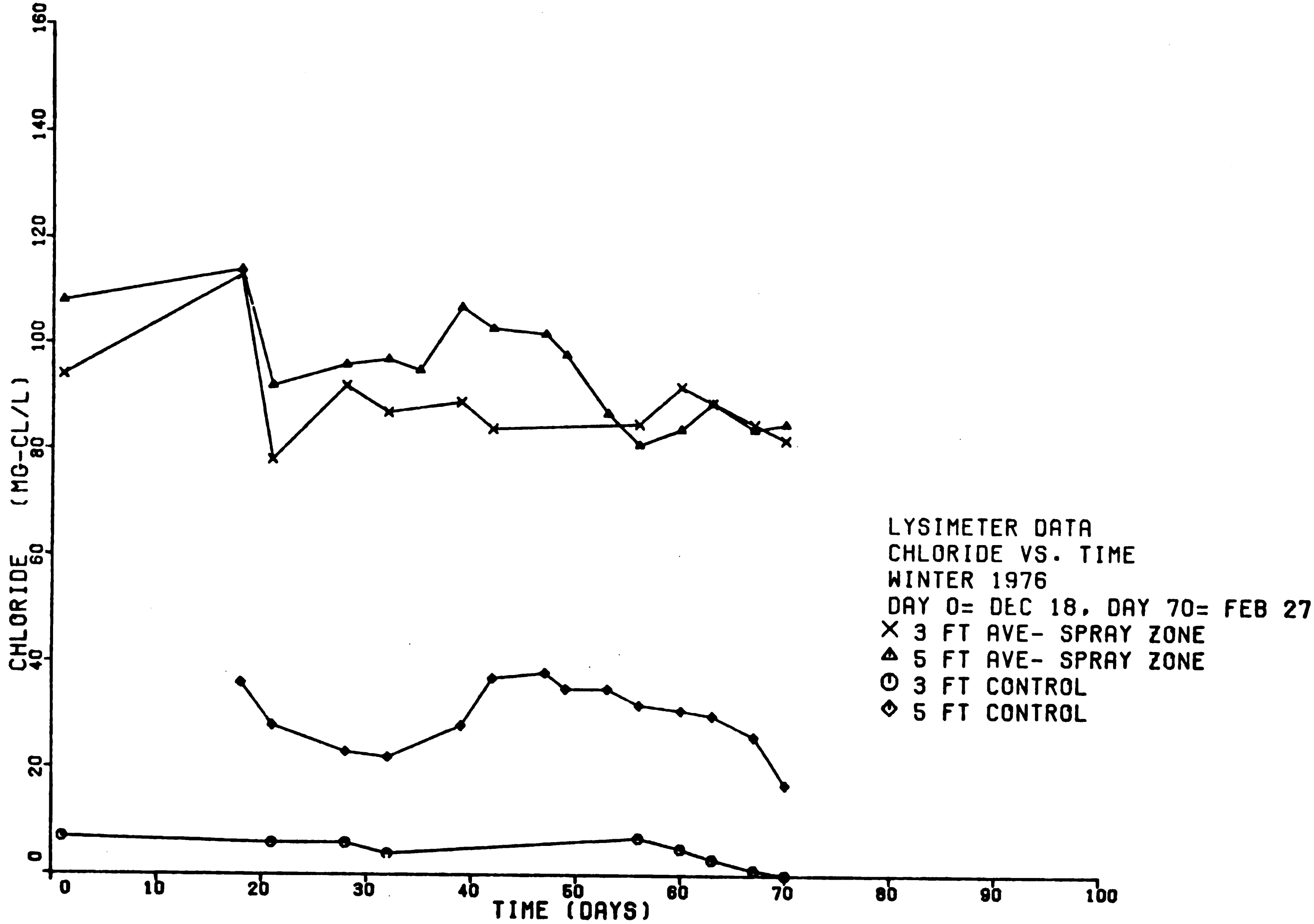

Figure 9.--Lysimeter Chloride Data, Winter 1976.

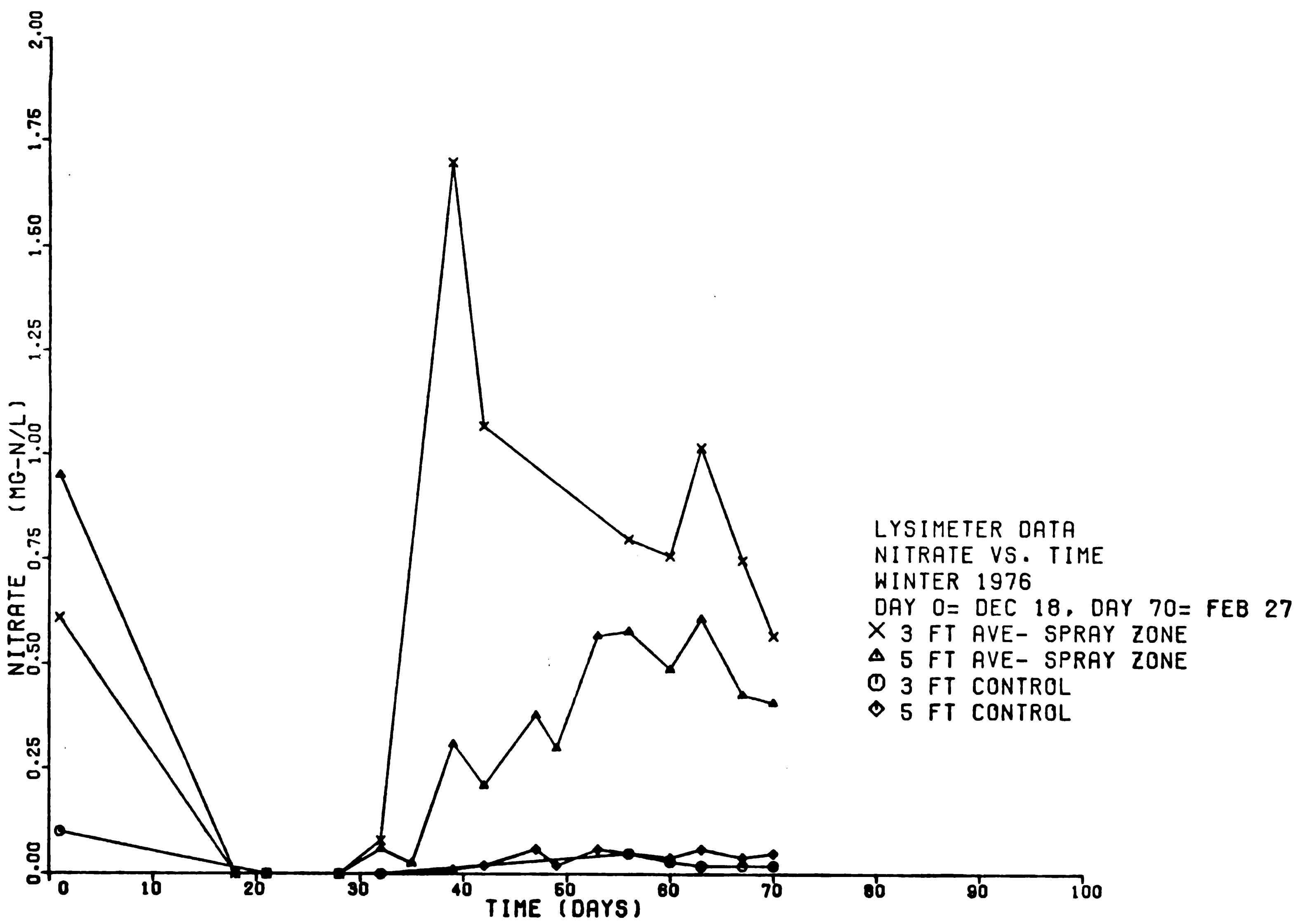

Figure 10.--Lysimeter Nitrate Data, Winter 1976.

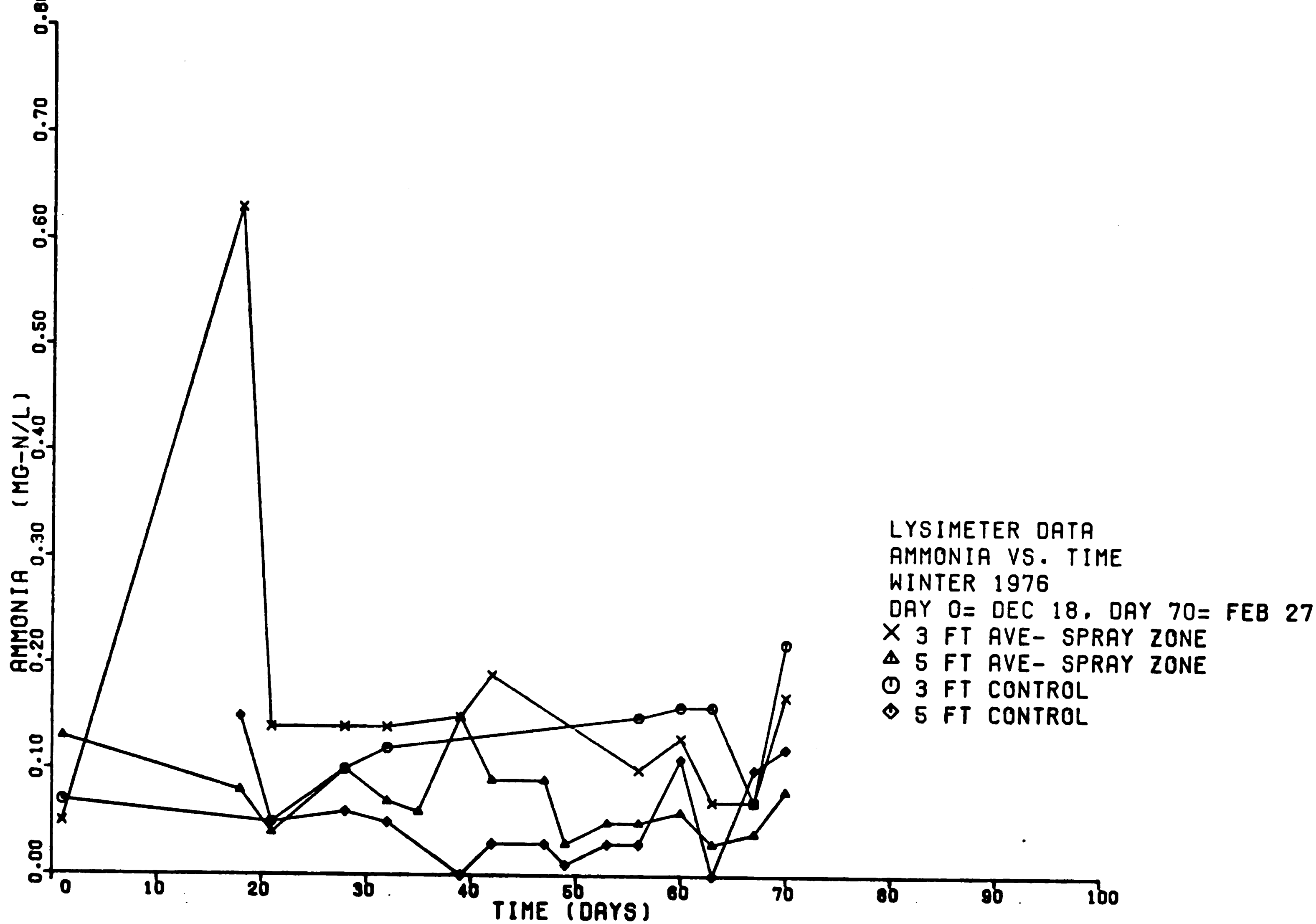

Figure 11.-- Lysimeter Ammonia Data, Winter 1976.

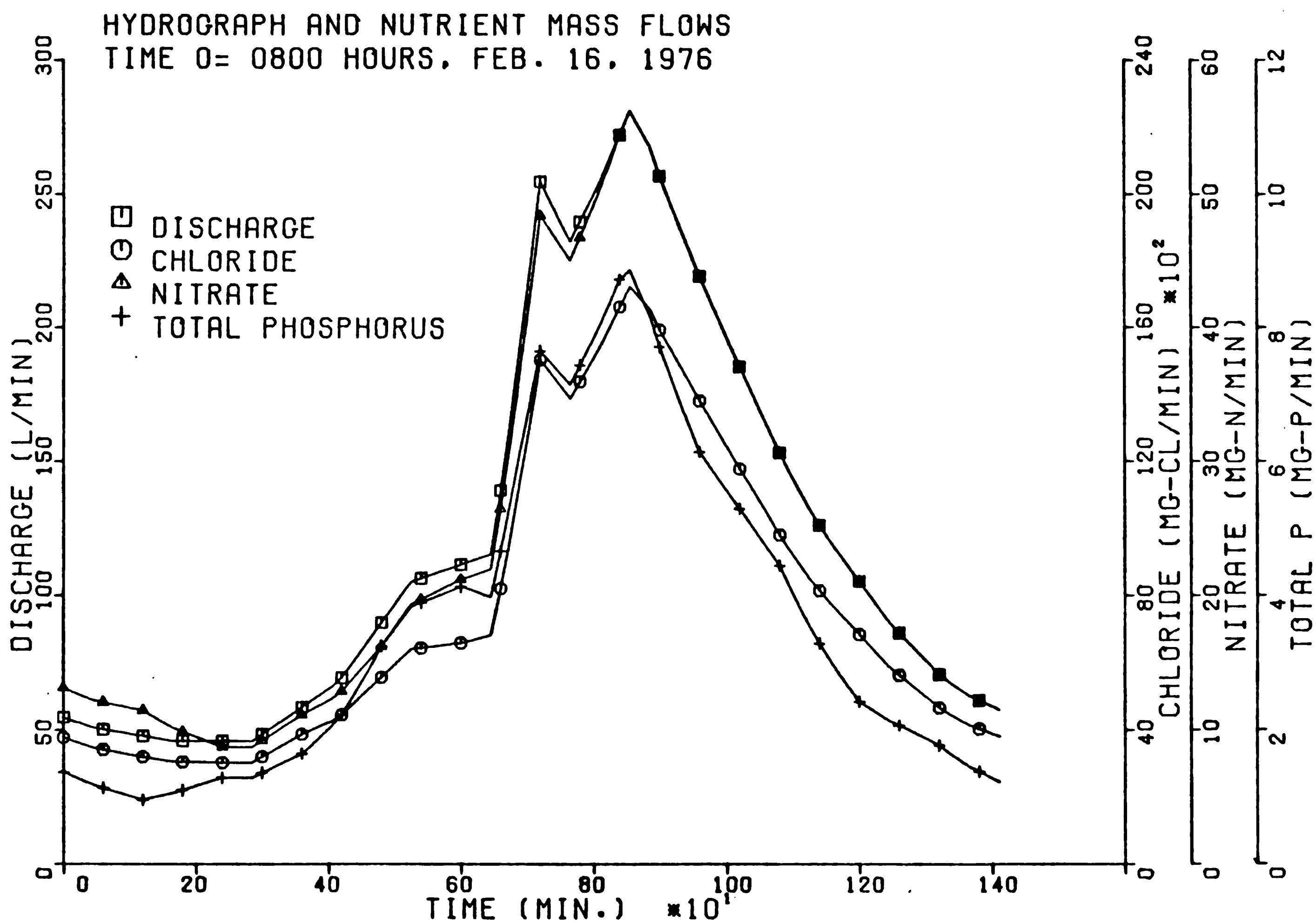

Figure 12.--Hydrograph and Nutrient Mass Flows, February 16, 1976.

during snow and ice melt in February. Nutrient mass flowrates increased and decreased with discharge and peak flowrates coincided with peak discharge. Hydrograph rise time was rapid, in general twenty minutes to an hour.

Peak runoff nutrient concentrations of nitrogen and phosphorus which occurred during the beginning of spray runoff on February 11 to 13 are shown with the hydrograph in Figure 13. Phosphorus reached 0.35 mg-P/l, nitrate reached 1.24 mg-N/l, and ammonia reached 0.5 mg-N/l. The peak runoff nutrient concentrations did not occur at peak discharge due to rainfall dilution of ice melt. With the exception of ammonia, runoff nutrient peak concentrations were far below input levels.

Nitrogen and phosphorus standards for groundwater and surface discharge were met during winter 1976 operations, primarily due to low wastewater input concentrations. Nitrate remained below 10 mg-N/l in the groundwater and runoff phosphorus concentrations remained below 1.0 mg-P/l. Significant reduction of nitrogen and phosphorus was achieved. Nitrate buildup was observed in the groundwater and, therefore, most of the reduction of nitrate reported probably resulted from groundwater dilution. Snow and ice buildup prevented frost penetration and most of the input water infiltrated.

3.3 Spring 1976 Results

Spring 1976, February 28 to May 27, was a period of frequent rainfall and surface runoff from the spray site. Saturated conditions allowed only six applications of wastewater, again from lake one of the WQMP system. Most of the spray applications generated surface runoff. The onset of the growing season in early April brought extensive vegetation growth

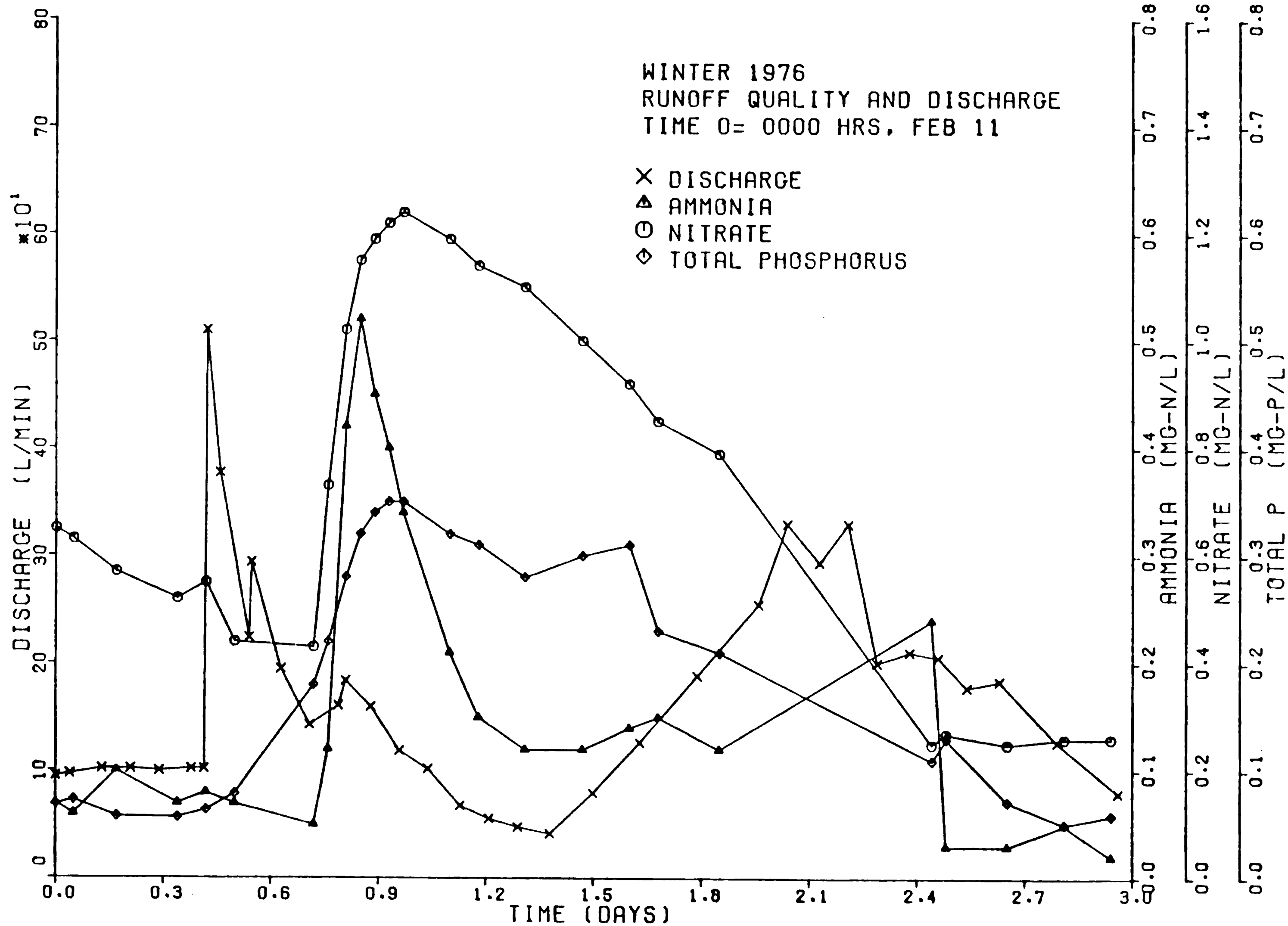

Figure 13.--Runoff Quality and Discharge, February 11-13, 1976.

and the dominant plant types present were goldenrod (Solidago sp.) and quackgrass (Agropyron repens). Average nutrient concentrations in the wastewater applied during the spring period were 100 mg-Cl/l chloride, 0.5 mg-N/l ammonia, 1.3 mg-N/l nitrate, 0.9 mg-P/l total phosphorus. These levels were far below average levels for secondary municipal wastewater and considerably below winter levels due to increased plant activity in the WQMP lake system.

Table 7 gives the water balance for the spring period. Wastewater accounted for only 31 percent of the water input. Twenty-three percent of the output water was surface runoff and infiltration was estimated at 57 percent. Thornthwaite calculations gave an estimated evapotranspiration percentage of 20.

The nutrient mass balances for the season are given in Table 8. Nitrogen and phosphorus mass input from wastewater was very low, 6.2 kg and 3.4 kg. Most of the nitrogen input was from precipitation. Thirty-seven percent of the applied chloride accompanied the runoff but only 0 to 3 percent of the applied nitrogen and 3 percent of the applied phosphorus ran off. High overall reductions of nitrate and phosphorus were observed, 98 and 94 percent. No reduction of chloride was apparent, and most of the applied chloride and ammonia infiltrated.

Figures 14, 15, and 16 are plots of lysimeter data versus time for the period. Phosphorus levels in the soil water remained below 0.03 mg/l and were not plotted. Rainfall and spray events were spread uniformly over the season.

Chloride data plotted in Figure 14 reflected steady flushing of the soil profile by rainfall infiltration. Concentrations at the five foot depth were higher but very close to those at the three foot depth due to

Table 7
Water Balance - Spring 1976
February 28 to May 27

Source	Volume m^3	$(10^6$ gal)	Percent of Total
Input			
Spray	3,617	(0.956)	31
Precipitation	8,227	(2.174)	69
	11,844		100
Output			
Runoff	2,743	(0.725)	23
Infiltration	6,759	(1.786)	57
Evapotranspiration	2,342	(0.619)	20
	11,844		100

Table 8
Nutrient Balance, Spring 1976
February 28 to May 27

Nutrient	Input		Runoff		Overall Reduction		Infiltration	
	kg spray	kg rain	kg	% of input	kg	% of input	kg	% of input
Chloride (as Cl)	363	3	135	37	0	0	231	63
Nitrate (as N)	4.8	22.0	0.1	0	26.2	98	0.5	2
Ammonia (as N)	1.4	2.1	0.1	3	2.0	57	1.4	40
Total Phosphorus (as P)	3.4	0.2	0.1	3	3.4	94	0.1	3

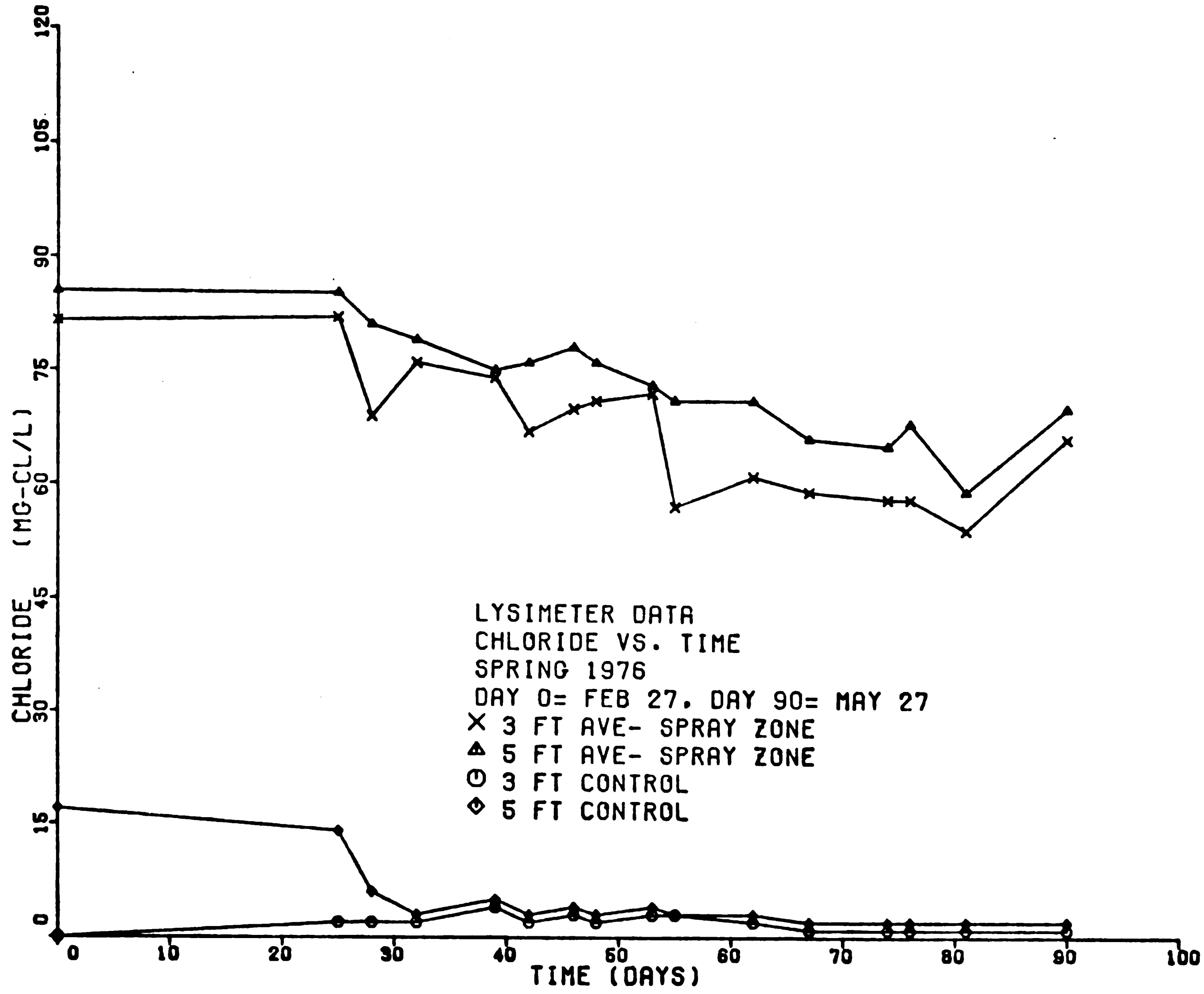

Figure 14.--Lysimeter Chloride Data, Spring 1976.

saturation of the site during the winter period and subsequent rainfall dilution at the shallow depth. Chloride levels at the control decreased to nearly zero indicating subsurface flow conditions at control location 46 different from those during the winter period.

Nitrate levels plotted in Figure 15 showed a rapid decrease in the spray zone to nearly 0.1 mg-N/l by the beginning of April, probably due to both rainfall dilution and increased interception of nitrogen by plants. For the remainder of the season, soil water nitrate concentrations fluctuated near those at the control location, about 0.05 mg-N/l.

Ammonia data from the lysimeters is given in Figure 16. The effects of the very small ammonia input were obscured by soil processes generating ammonia, such as bacterial action. No trends were apparent, but the ammonia levels in the spray zone fluctuated with those at the control location at near input concentration.

Figure 17 shows a typical spray generated hydrograph with nutrient mass flowrates during the spring period. In a manner similar to the winter period, peak nutrient mass flows occurred at peak discharge. Hydrograph rise time was very rapid throughout the season. During the spring period, runoff phosphorus concentrations remained below 0.5 mg-P/l and nitrate and ammonia levels remained below 0.3 mg-N/l.

Hydrologic and water quality patterns during the spring were similar to those observed during the winter period. Standards for groundwater and surface runoff quality were met, again largely because of the very small amount of wastewater nutrient input to the site.

3.4 Summer 1976 Results

Summer 1976, May 28 to August 31, was a very dry period; only 7.5

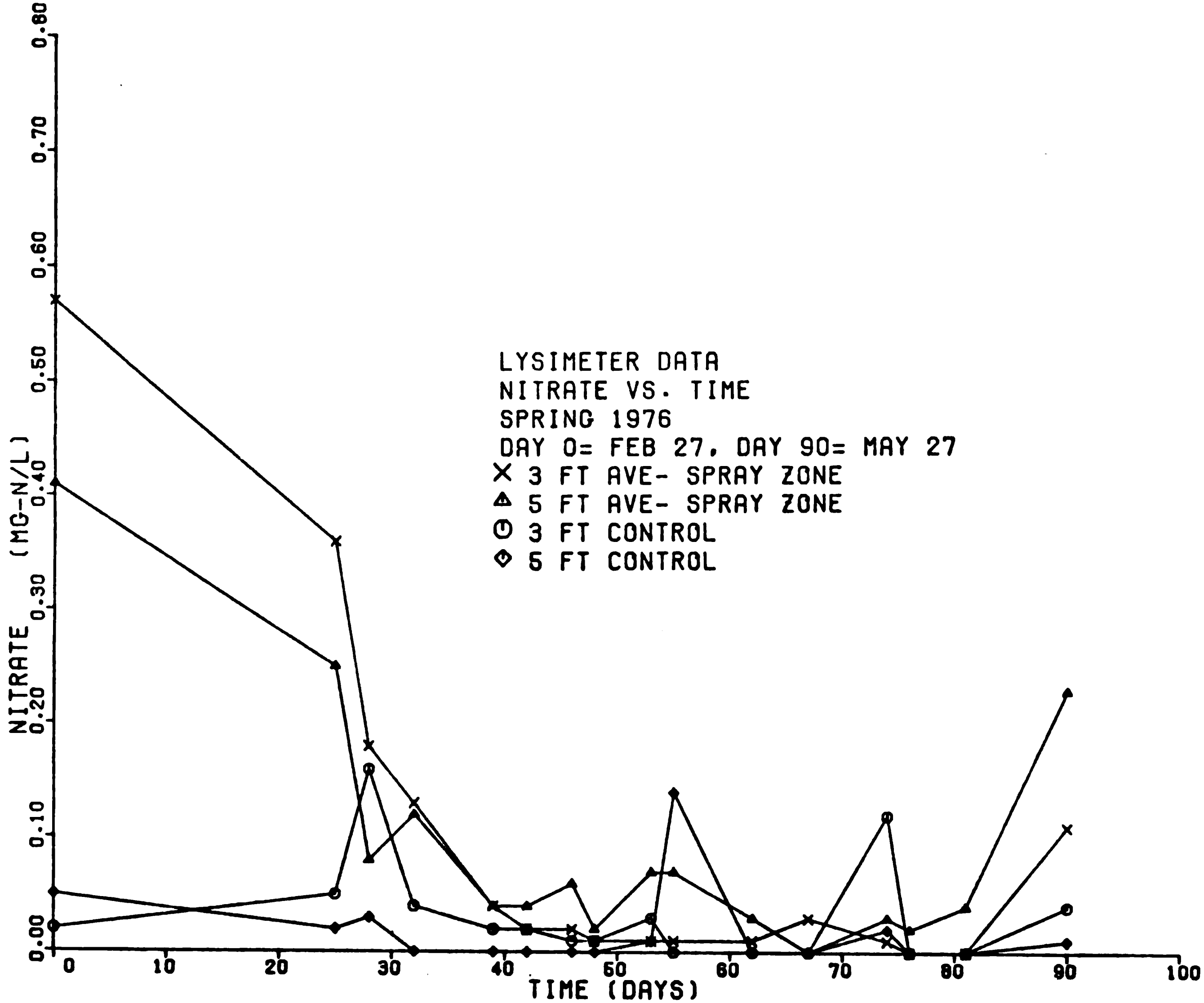

Figure 15.--Lysimeter Nitrate Data, Spring 1976.

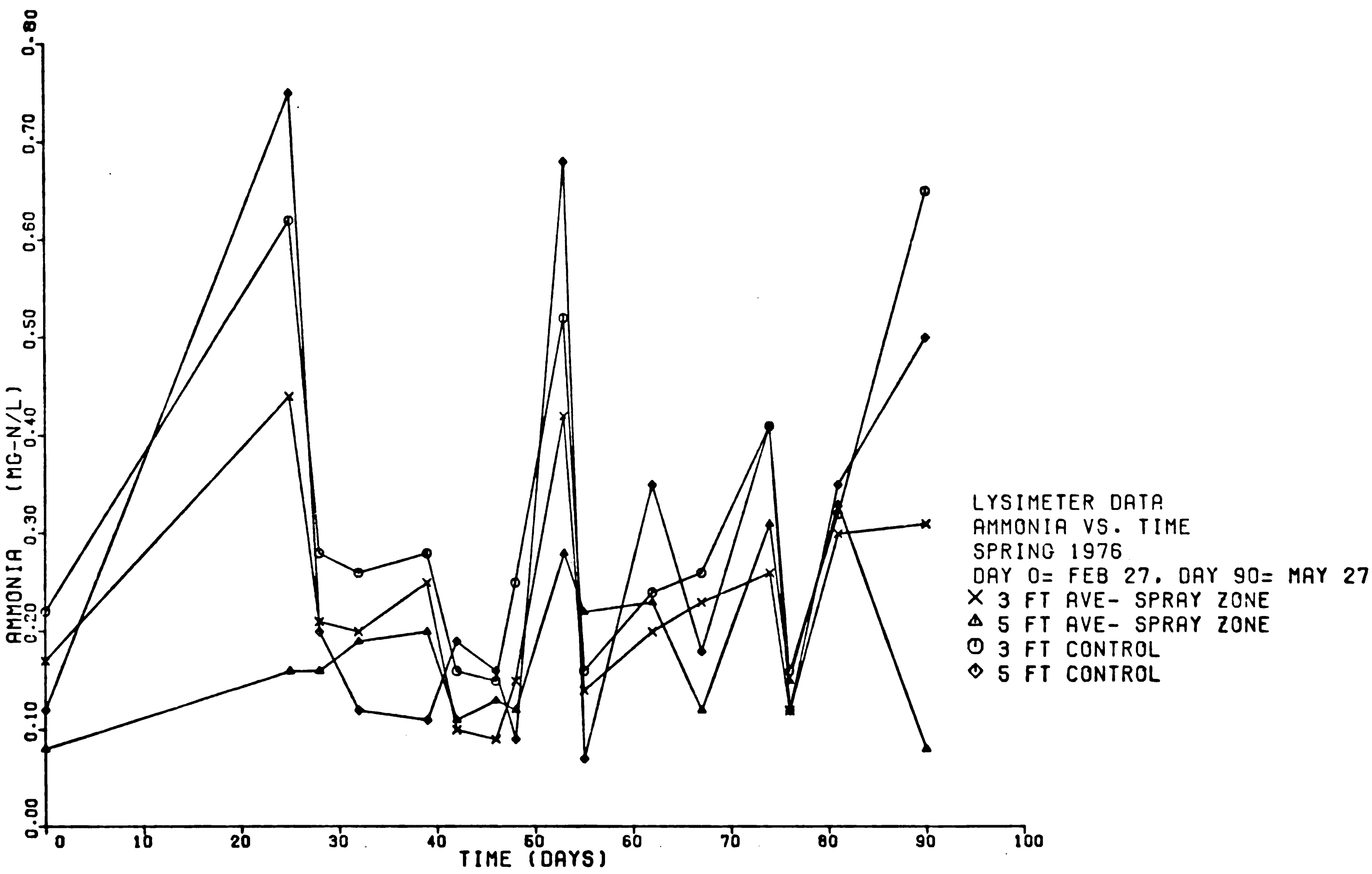

Figure 16.--Lysimeter Ammonia Data, Spring 1976.

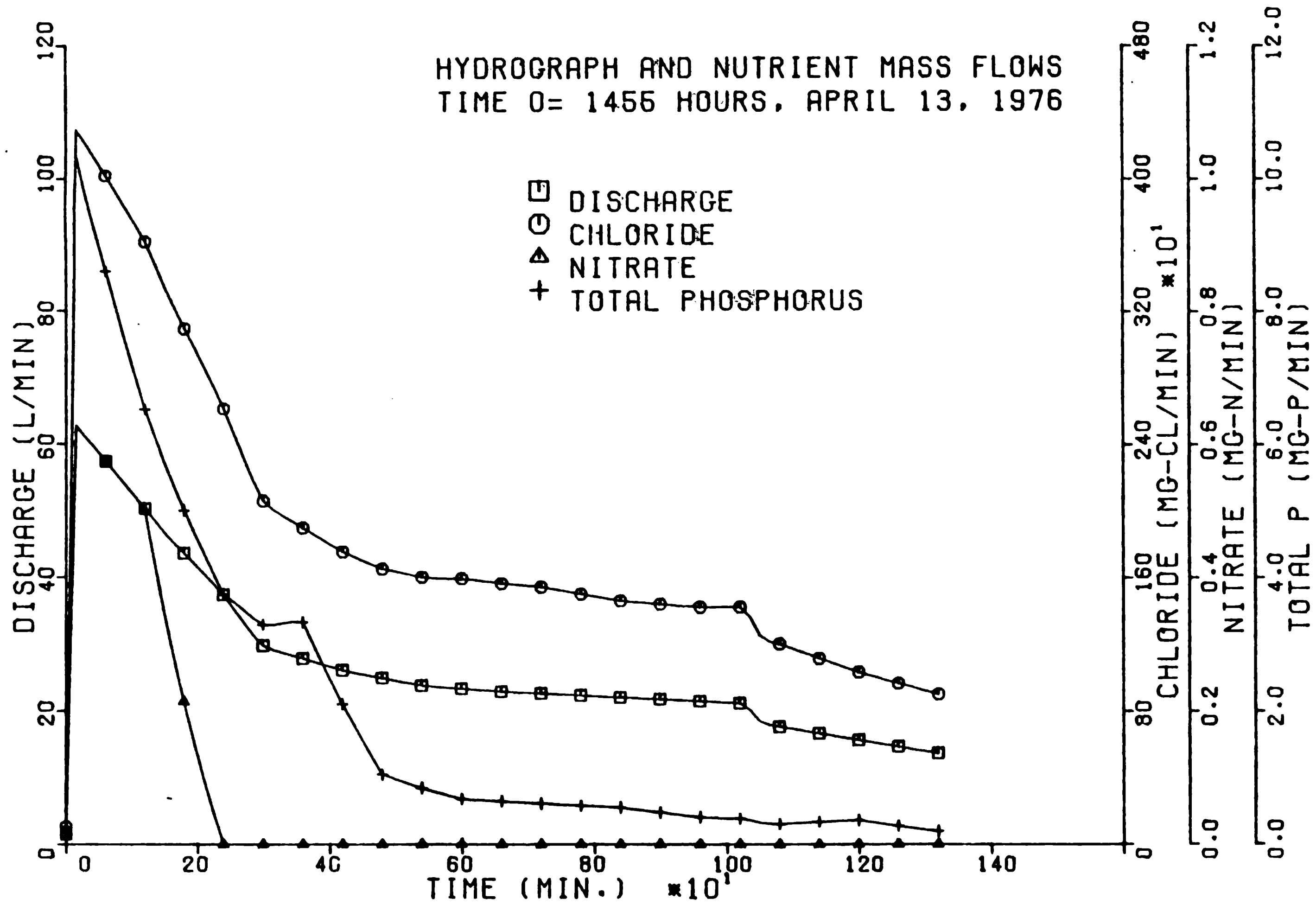

Figure 17.--Hydrograph and Nutrient Mass Flows, April 13, 1976.

inches of rain fell allowing 24 one-inch (2.54 cm) wastewater applications with negligible runoff. There was extensive vegetative growth with goldenrod and grasses reaching up to five feet in height. Beginning in May, secondary effluent was available for irrigation directly from the East Lansing sewage treatment plant. Nitrate and total phosphorus levels in the applied wastewater were considerably higher than in the lake renovated effluent applied during the winter and spring. Average input wastewater concentrations during the summer period were 118 mg-Cl/l chloride, 1.7 mg-N/l ammonia, 9.1 mg-N/l nitrate, and 2.5 mg-P/l total phosphorus.

The water balance for the summer is given in Table 9. Wastewater spray accounted for 72 percent of the input water to the site. One runoff event of negligible volume occurred during the period. Most of the input water infiltrated as in previous seasons. The Thornthwaite estimate of evapotranspiration was 43 percent.

Table 10 gives the summer nutrient mass balances. High overall reductions and reductions in the soil of nitrogen and phosphorus were observed - 91 percent for ammonia, 99 percent for nitrate, and 99 percent for phosphorus. The chloride reduction of 39 percent was due to dilution of wastewater in the low chloride groundwater present after the spring period.

Figures 18, 19, and 20 are plots of lysimeter data versus time for the summer period. The lysimeter population was further divided according to whether or not surrounding area was ponded following spraying (see Appendix G). Lysimeters were sampled once per week.

Chloride levels in the soil increased steadily at both the three and five foot depths during the summer as shown in Figure 18. This trend reflected the increased chloride input, high evapotranspiration, and

Table 9
Water Balance - Summer 1976
May 28 to August 31

Source	Volume m^3	Volume (10^6 gal)	Percent of Total
Input			
Spray	14,643	(3.869)	72
Precipitation	5,643	(1.490)	28
	20,286		100
Output			
Runoff	39	(0.010)	0
Infiltration	11,484	(3.034)	57
Evapotranspiration	8,763	(2.315)	43
	20,286		100

Table 10
Nutrient Balance, Summer 1976
May 28 to August 31

Nutrient	Input		Runoff		Overall Reduction		Infiltration	
	kg		kg	% of input	kg	% of input	kg	% of input
	spray	rain						
Chloride (as Cl)	1723	2	3	0	672	39	1050	61
Nitrate (as N)	134	15	0	0	148	99	1	1
Ammonia (as N)	25	1.4	0	0	24	91	2.4	9
Total Phosphorus (as P)	36	0.2	0	0	35.8	99	0.4	1

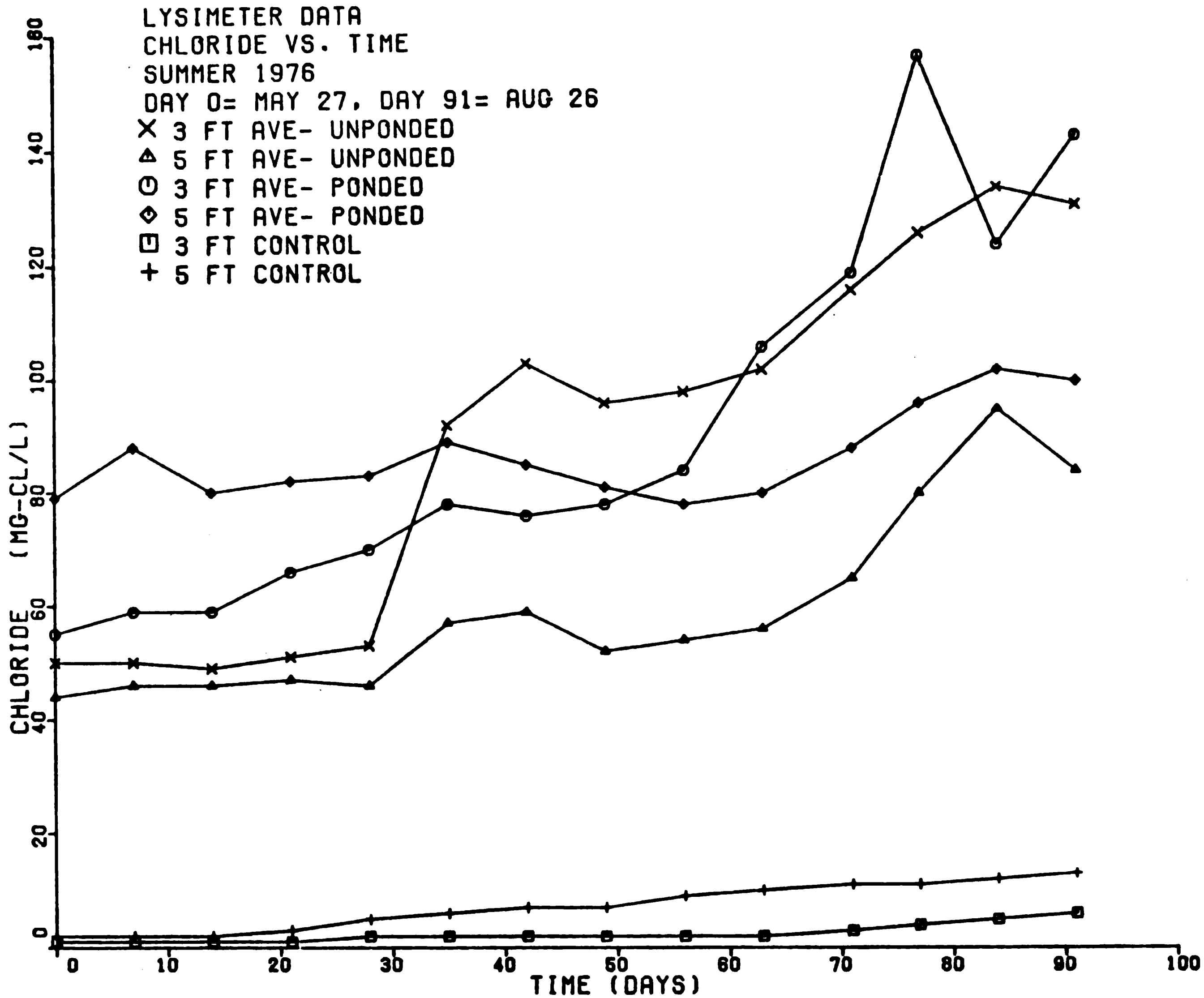

Figure 18.--Lysimeter Chloride Data, Summer 1976.

falling water table leading to unsaturated conditions first at the three foot depth and later in the summer at the five foot depth. Ponding had little effect at the three foot depth but at the five foot depth, chloride levels were considerably higher for most of the summer in ponded areas than in unponded areas. Low concentrations at the control location indicated little subsurface flow from the spray zone.

Figure 19 shows the low nitrate levels measured in the lysimeter samples throughout the summer months. There was some fluctuation, but the average nitrate level was about 0.1 mg-N/l. There was no significant difference between the samples obtained from the sprayed area and the control location.

Ammonia levels in the soil water are given in Figure 20. Data was erratic during the entire summer period but soil water levels remained below input levels in general. No significant trends were apparent; the control showed the highest ammonia levels. These results were probably due to the low input ammonia concentrations.

In spite of much increased nutrient loadings, nutrient reduction during the summer was high due to a high level of plant activity supported by the irrigation water and nutrient input. The site was able to accept two inches (5.1 cm) per week of effluent without soil saturation or runoff. Chloride levels in the groundwater, however, were increased due to high input and high evapotranspiration. Once again standards were met.

3.5 Fall 1976 Results

The fall 1976 study period lasted from September 1 to November 30 and was characterized by the end of the growing season, the onset of cold temperatures, and increasing frequency of surface runoff. Twenty-one

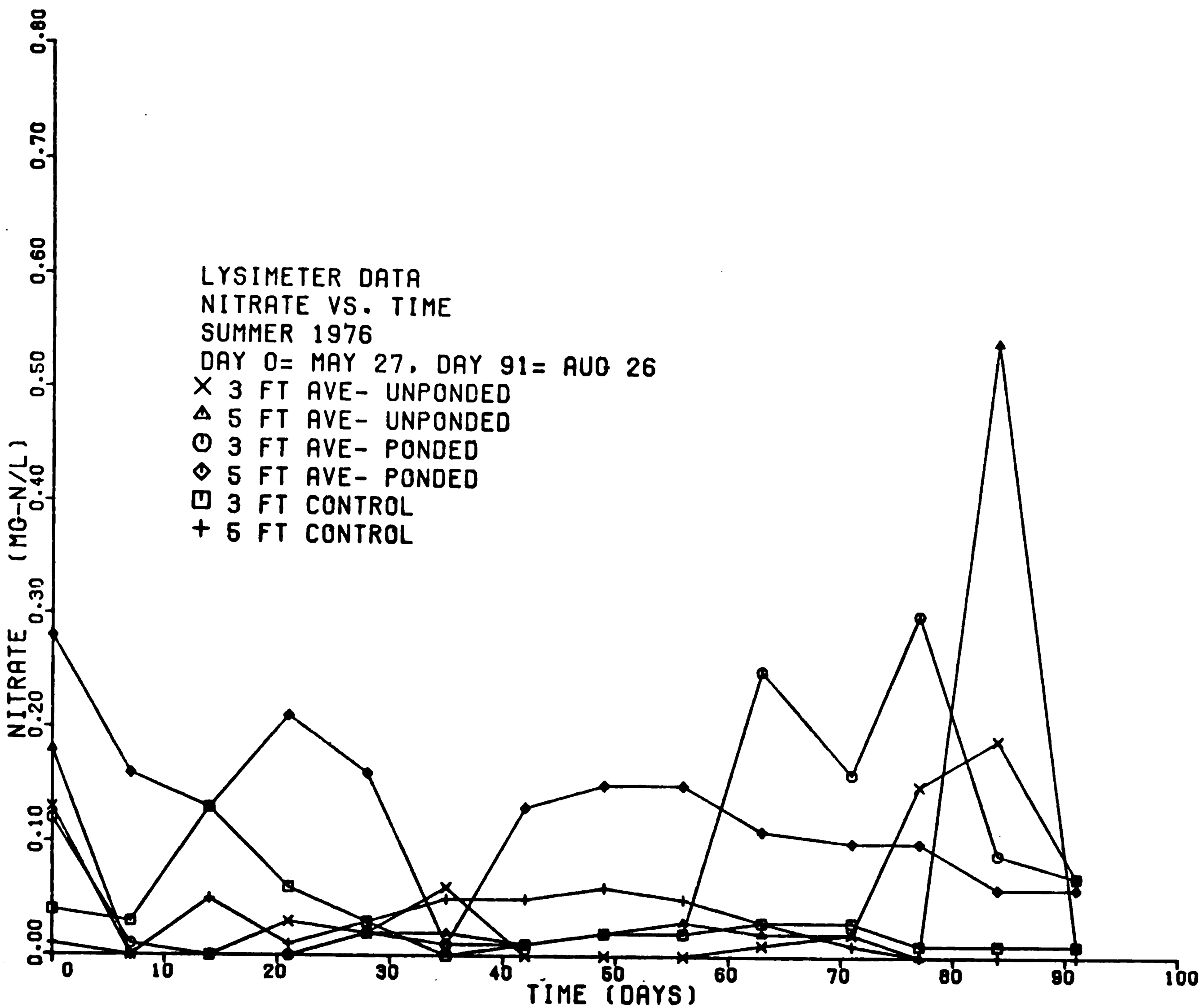

Figure 19.--Lysimeter Nitrate Data, Summer 1976.

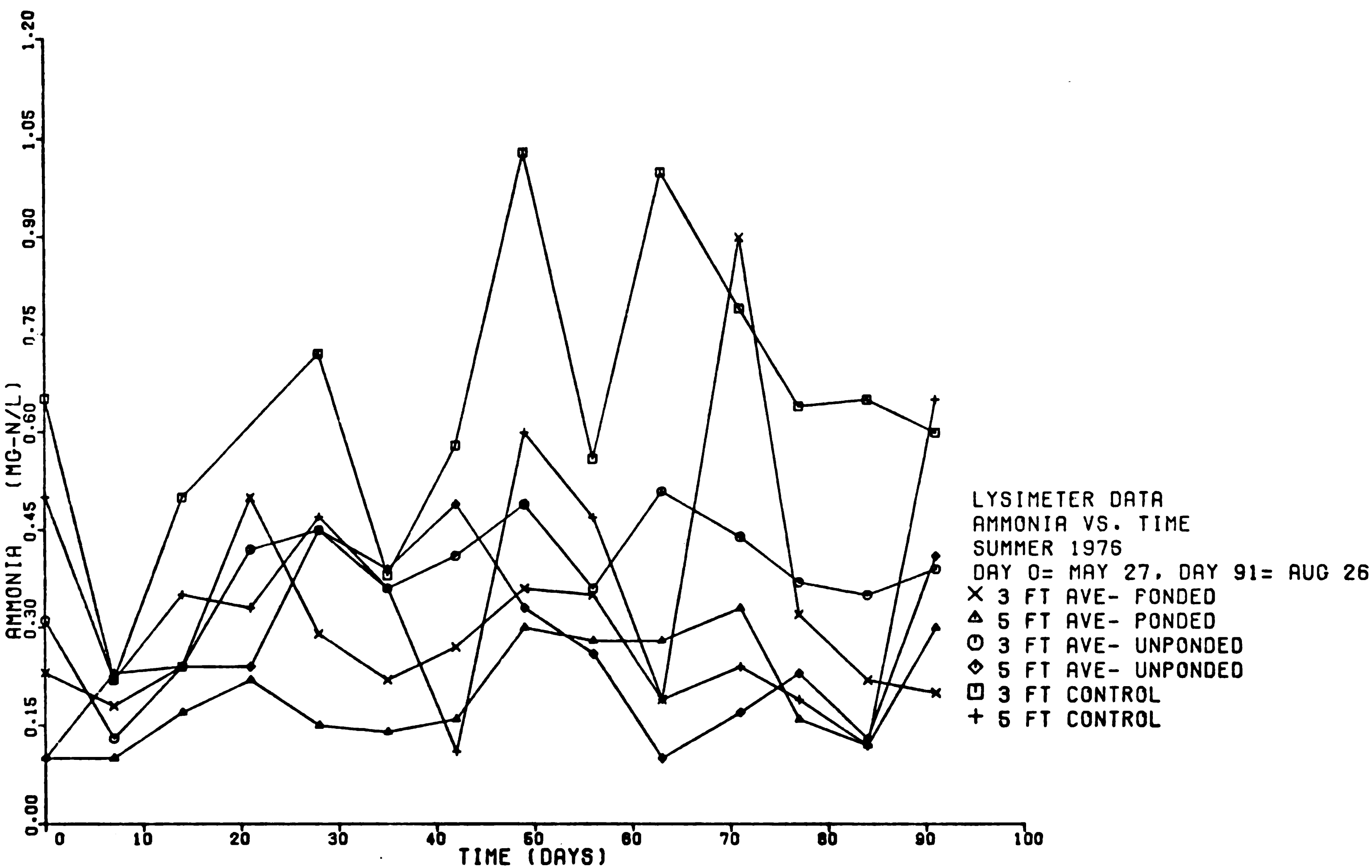

Figure 20.--Lysimeter Ammonia Data, Summer 1976.

inches (53 cm) of direct secondary effluent were applied and spray operations frequently initiated runoff from the site. Average wastewater input nutrient concentrations were 115 mg-Cl/l chloride, 0.6 mg-N/l ammonia, 12.1 mg-N/l nitrate, and 4.0 mg-P/l total phosphorus. Nitrate and phosphorus levels were somewhat higher than the summer average levels.

Table 11 gives the fall water balance. Wastewater accounted for 83 percent of the total water input to the site; only 3.5 inches (8.9 cm) of precipitation were recorded. Surface runoff volume percentage was low, 4 percent, and evapotranspiration estimate was 13 percent due to colder temperatures. Most of the input water, 83 percent, infiltrated.

Table 12 gives the nutrient mass balances for the fall period. Trace masses of the applied nitrogen and phosphorus accompanied the surface runoff. High overall reductions of nitrogen and phosphorus were again observed - 99 percent for nitrate, 66 percent for ammonia, and 99 percent for phosphorus. Most of the chloride infiltrated.

Figures 21 through 24 are plots of average lysimeter sample nutrient concentrations versus time for the fall period. Late in the summer, additional lysimeters were installed in the spray zone at depths of 1.5, 3.0, and 5.0 feet, and several more lysimeters were located outside the spray zone to intercept subsurface flow at locations 1, 2, and 3 (see Figure 4). The lysimeter population was divided according to location in ponded or unponded areas as in the summer study period. Phosphorus concentrations in the groundwater remained below 0.2 mg-P/l and were not plotted.

Figure 21 shows lysimeter chloride data for the fall period. Surface ponding had little effect on lysimeter sample concentrations. The trend of steadily increasing chloride levels seen during the summer was not evident during the fall due to reduced evapotranspiration.

Table 11
Water Balance - Fall 1976
September 1 to November 30

Source	Volume m^3	(10^6 gal)	Percent of Total
Input			
Spray	12,660	(3.344)	83
Precipitation	2,659	(0.703)	17
	15,319		100
Output			
Runoff	614	(0.162)	4
Infiltration	12,741	(3.366)	83
Evapotranspiration	1,964	(0.519)	13
	15,319		100

Table 12
Nutrient Balance, Fall 1976
September 1 to November 30

Nutrient	Input		Runoff		Overall Reduction		Infiltration	
	kg spray	kg rain	kg	% of input	kg	% of input	kg	% of input
Chloride (as Cl)	1461	1	80	5	0	0	1382	95
Nitrate (as N)	153	7.1	0.5	0	158	99	1.6	1
Ammonia (as N)	7	0.7	0	0	5.1	66	2.6	34
Total Phosphorus (as P)	51	0.1	0.1	0	50.6	99	0.4	1

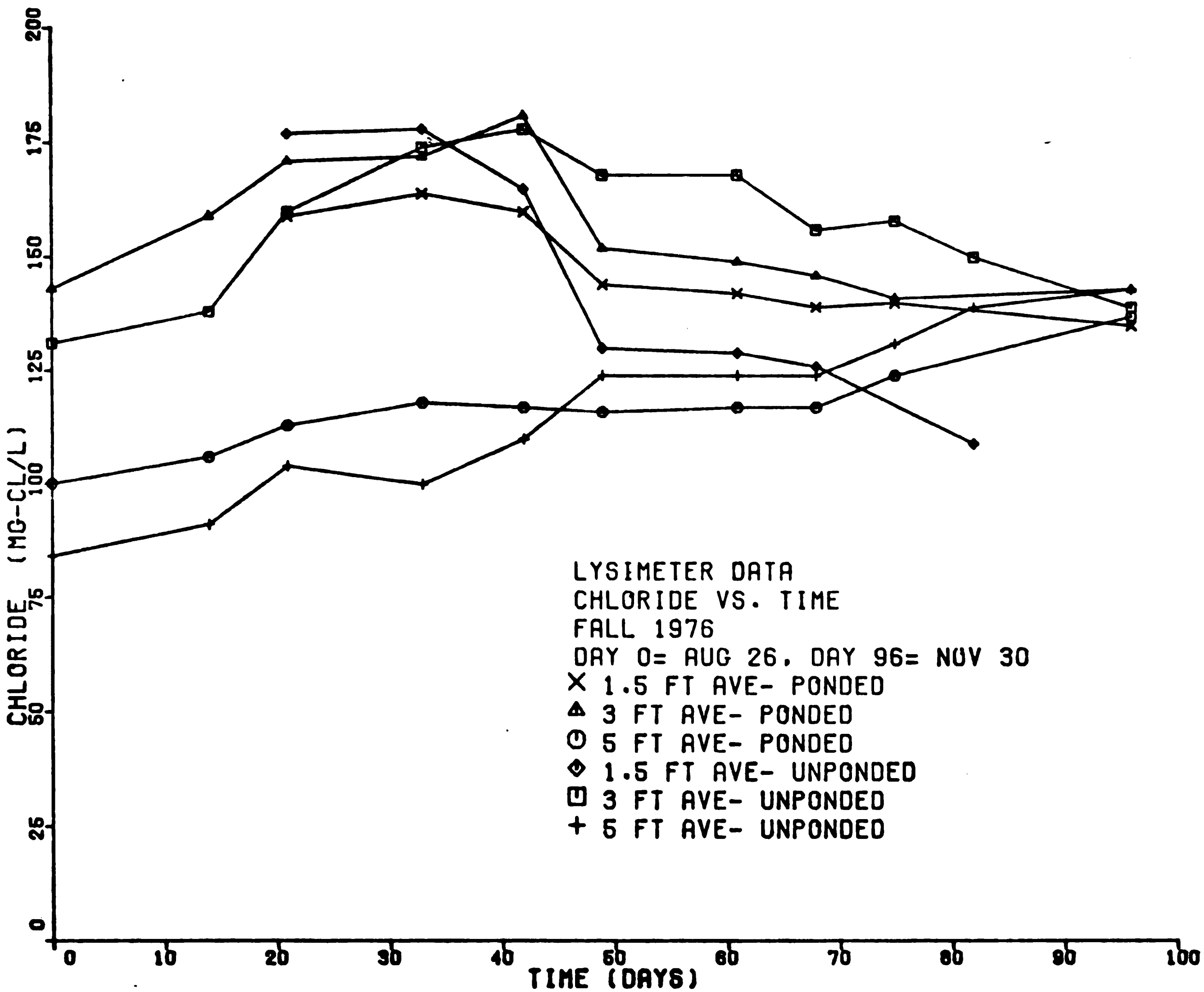

Figure 21.--Lysimeter Chloride Data, Fall 1976.

Observation well measurements showed a water table depth of two to five feet. Replacement of the soil water with wastewater was reflected in the lysimeter data which showed no difference in chloride concentration with depth by the end of the fall. Figure 22 gives chloride levels at the various control locations. Elevated levels comparable to those in the sprayed area measured at location 1 indicated that most of the subsurface flow from the site occurred in the sandy area near the excavated channel.

Nitrate levels during the fall remained very low, as shown in Figure 23, particularly at the five foot depth. Nitrate concentrations at all depths were below 1.0 mg-N/l in general. A slight trend toward increasing nitrate levels was apparent. Figure 24 gives lysimeter ammonia data. Many fluctuations occurred but a trend toward decreasing concentration with time was observed due largely to decreasing input concentrations.

A typical spray generated hydrograph with nutrient mass flows which occurred on November 18 is given in Figure 25. Hydrograph rise time was rapid and peak nutrient flowrates occurred at peak discharge. During the fall, runoff phosphorus concentrations remained below 1.0 mg-P/l and nitrogen concentrations were less than 3.0 mg-N/l in general, but these concentrations were higher than those observed during previous seasons.

The winter spray site was able to accept significant wastewater input during the relatively dry fall period. While runoff frequently occurred, its volume as a percent of total input was low. Surface discharge and groundwater standards were met throughout the fall period. Significant reduction of nitrogen and phosphorus was achieved; nitrogen reduction at the end of the fall was probably due primarily to dilution in the groundwater.

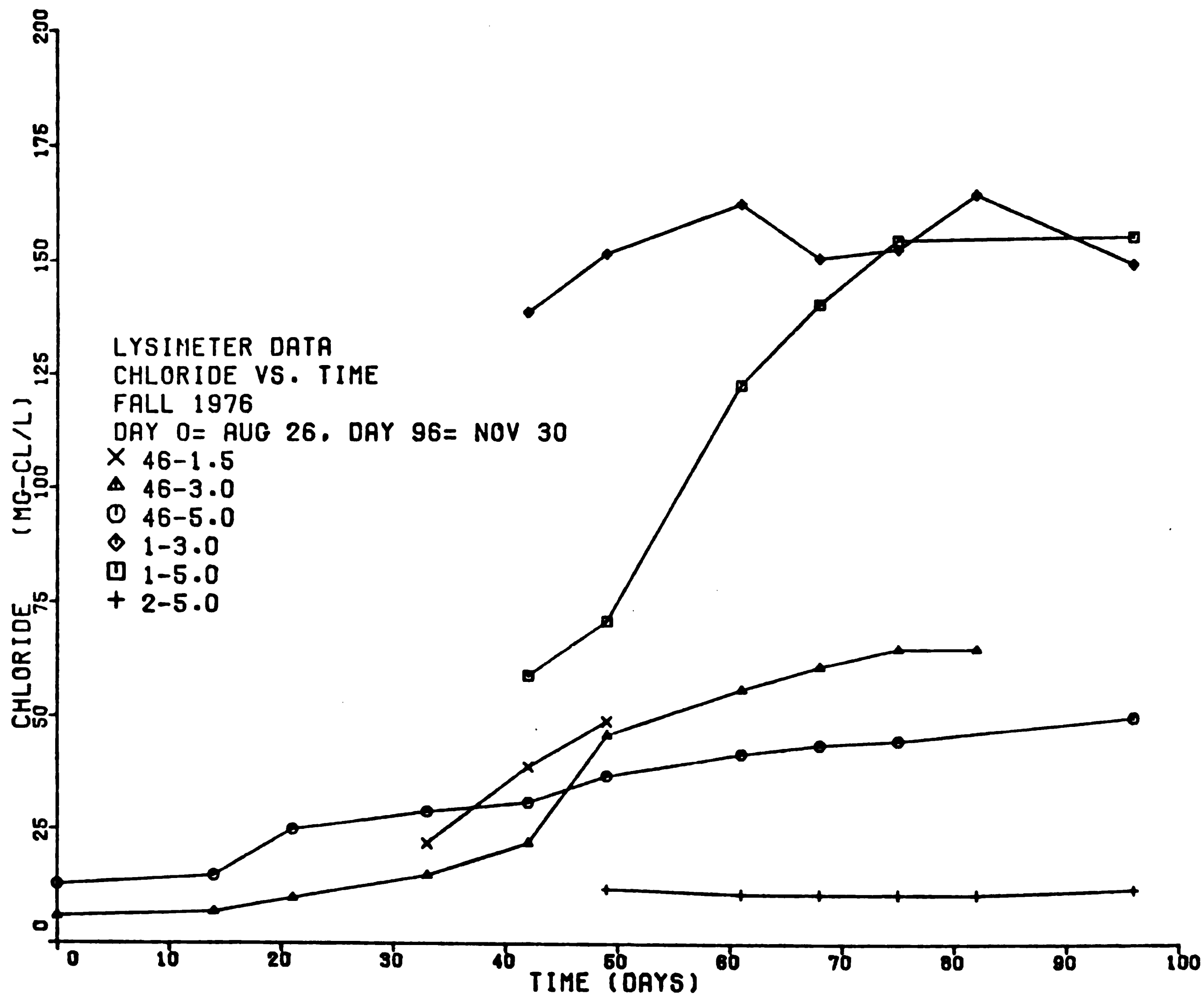

Figure 22.--Lysimeter Control Chloride Data, Fall 1976.

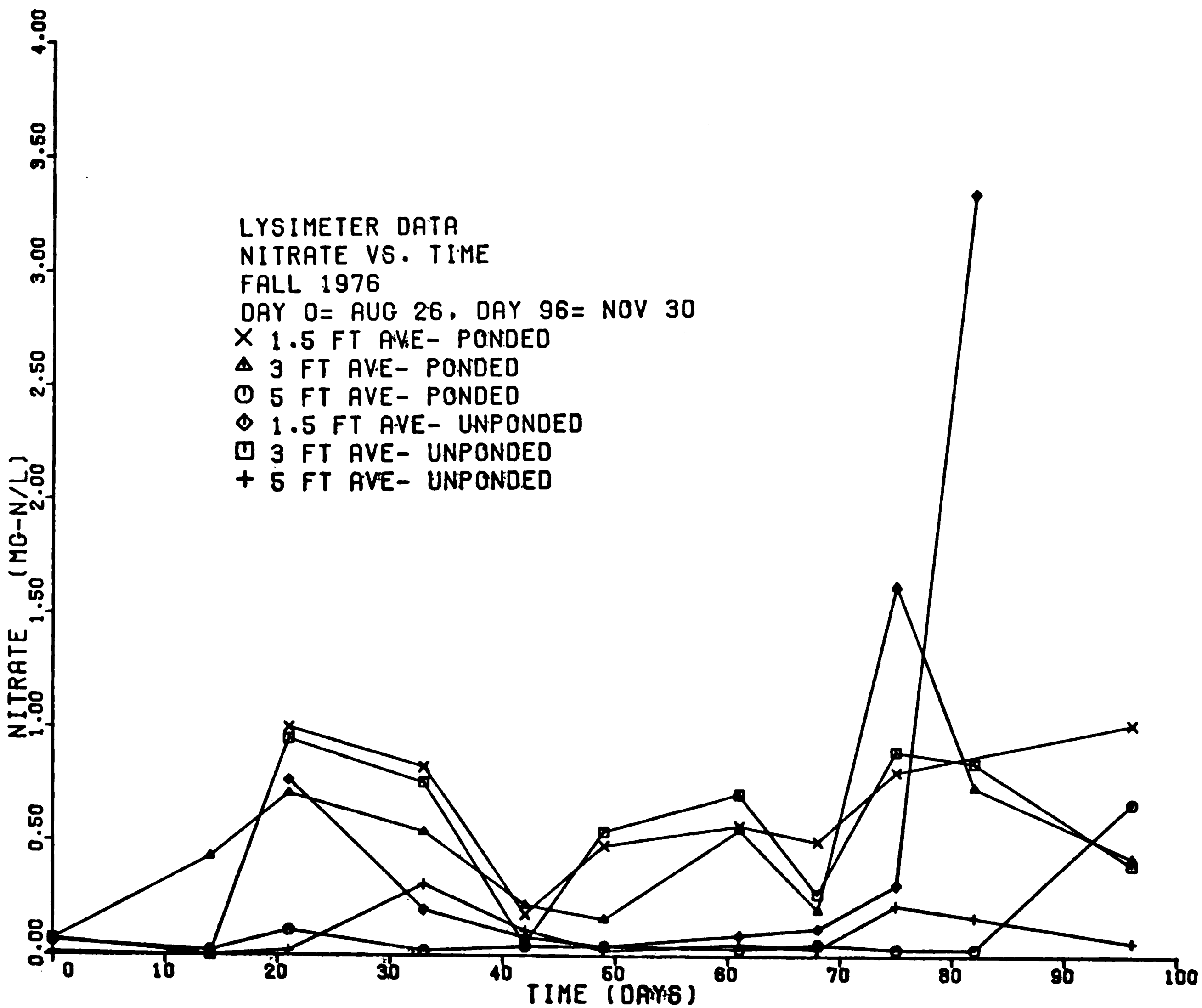

Figure 23.--Lysimeter Nitrate Data, Fall 1976.

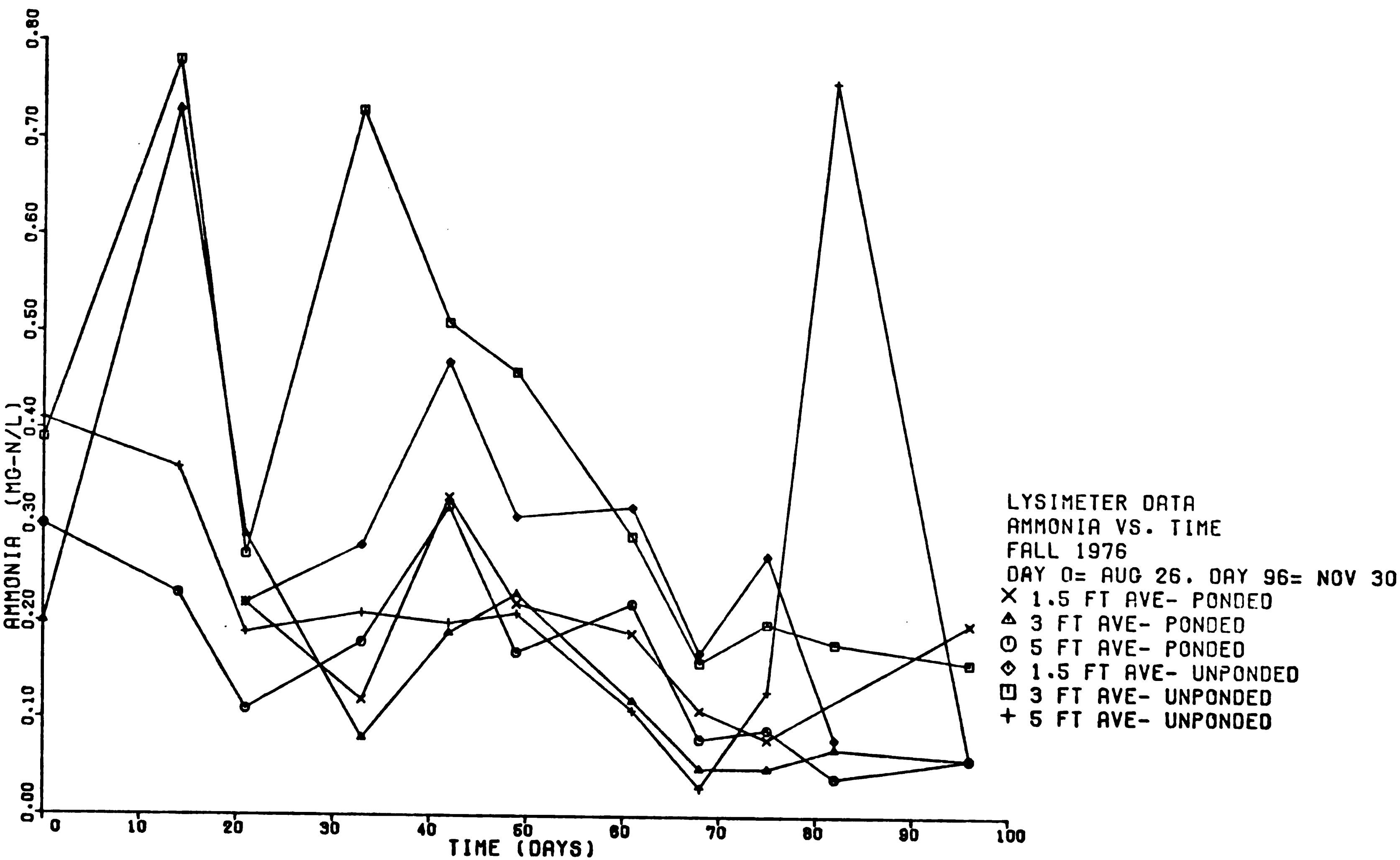

Figure 24.--Lysimeter Ammonia Data, Fall 1976.

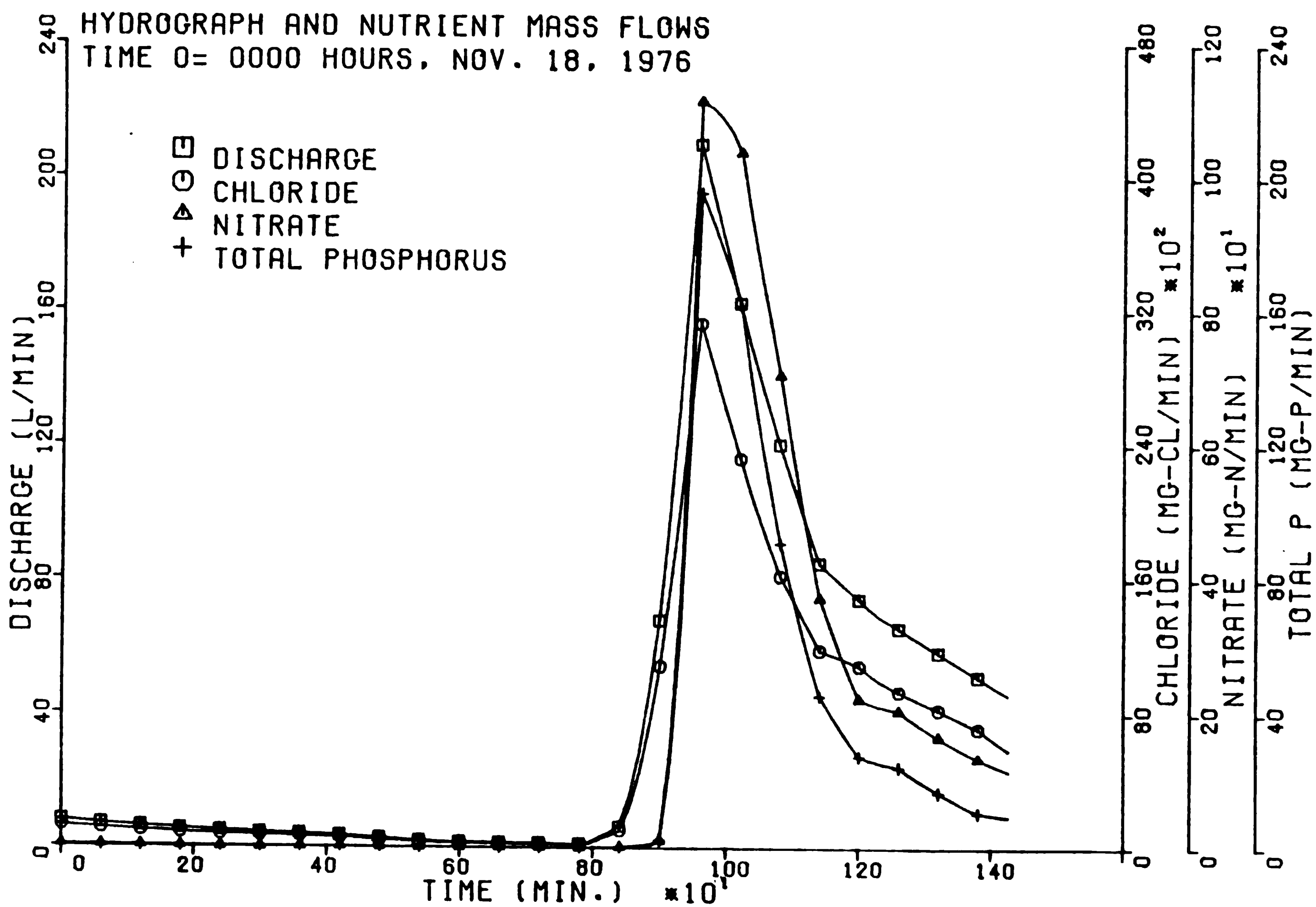

Figure 25.--Hydrograph and Nutrient Mass Flows, November 18, 1976.

3.6 Winter 1977 Results

The winter of 1977 was a record period of severe cold weather with little snowfall. From December 1, 1976, to February 22, 1977, eighteen inches (45.7 cm) of direct secondary effluent were applied to the winter spray site resulting in heavy ice buildup. Frozen pipes and valves shut down operations several times and spray distribution was uneven. Average wastewater input nutrient concentrations were higher than in previous seasons - 127 mg-Cl/l chloride, 18.4 mg-N/l nitrate, 5.6 mg-P/l total phosphorus, and 0.5 mg-N/l ammonia. Nitrite was monitored and as previously assumed was present at low levels, less than 0.1 mg-N/l, in the applied wastewater. Several unexpected runoff events occurred following spraying during subfreezing conditions in December and January. Spring thaw brought considerable runoff from rainfall and ice melt during February and March. Runoff ceased on March 16 and the winter study period was ended.

Table 13 gives the water balance for the winter study period. Wastewater accounted for 84 percent of the water input to the site. Twenty-nine percent of the applied water ran off and the evapotranspiration estimate was zero due to subfreezing temperatures during most of the winter. The infiltration estimate was 71 percent. Field observations frequently revealed unfrozen conditions at the bottom of the ice pack in the spray zone. Apparently the ice buildup protected the underlying soil from freezing allowing infiltration from ice melt at the ground surface throughout the winter.

The winter nutrient mass balances are given in Table 14. Very little nitrite was applied and the mass balance was not significant. The lowest overall reductions of nitrate and phosphorus observed during the

Table 13
Water Balance - Winter 1977
December 1, 1976 to March 16, 1977

Source	Volume m^3	$(10^6$ gal)	Percent of Total
Input			
Spray	10,646	(2.813)	84
Precipitation	1,994	(0.527)	16
	12,640		100
Output			
Runoff	3,700	(0.978)	29
Infiltration	8,940	(2.362)	71
Evapotranspiration	0		0
	12,640		100

Table 14
Nutrient Balance, Winter 1977
December 1, 1976, to March 16, 1977

Nutrient	Input		Runoff		Overall Reduction		Infiltration	
	kg spray	kg rain	kg	% of input	kg	% of input	kg	% of input
Chloride (as Cl)	1349	1	287	21	0	0	1063	79
Nitrate (as N)	196	5	23	11	121	61	57	28
Nitrite (as N)[1]	0.6	-	0.4	66	0	0	0.2	34
Ammonia (as N)	5.5	0.5	1.1	18	2.9	49	2.0	33
Total Phosphorus (as P)	60	0.1	6	10	46.0	77	8.1	13

[1]Precipitation concentration estimate not available

entire study period occurred, 61 percent for nitrate, 77 percent for phosphorus, and 49 percent for ammonia. Soil water levels of up to 0.9 mg-P/l phosphorus were observed at the five foot depth at the end of the winter. Most of the nitrate reduction was probably due to dilution with low nitrogen groundwater and, therefore, the mass infiltration figure was probably much higher. Higher percentages of the nutrient input masses accompanied the runoff than during previous seasons; 11 percent for nitrate, 18 percent for ammonia, and 10 percent for phosphorus.

Figures 26 through 29 show lysimeter data obtained during the winter period. Severe cold resulted in many of the lysimeters freezing and few samples were collected until after the thaw in March. The effect of winter spraying on the groundwater was apparent, however. The lysimeter population was not divided into ponded and unponded groups. Spring runoff began on day 58. Dashed lines on the plots indicate extended periods when frozen lysimeters yielded no samples.

Figure 26 gives lysimeter chloride data. Chloride concentrations remained at about 135 mg/l except near the beginning of the winter when higher chloride level wastewater was applied. No difference in chloride concentration with depth was observed at the end of the winter when the site was saturated. Figure 27 shows lysimeter control chloride data. Location 1 showed considerable influence from the spray site indicating subsurface flow toward Felton Drain in the area of the excavated channel. Location 46 showed somewhat lower chloride levels and location 2 did not show significant levels. The lysimeter at location 3 was dry during the winter period.

High observed soil water nitrate concentrations are given in Figure 28. Prior to soil saturation, several large average nitrate peaks

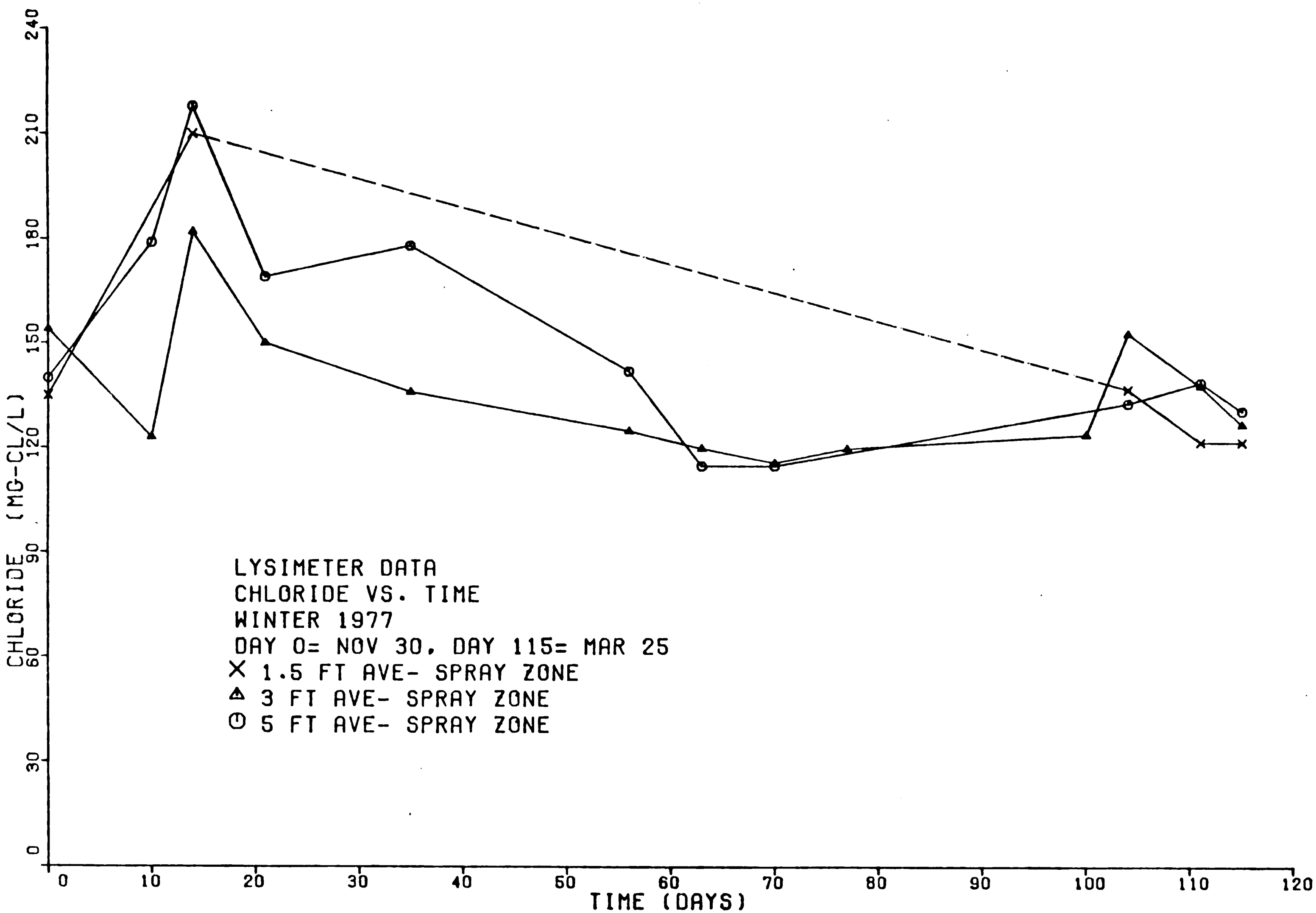

Figure 26.--Lysimeter Chloride Data, Winter 1977.

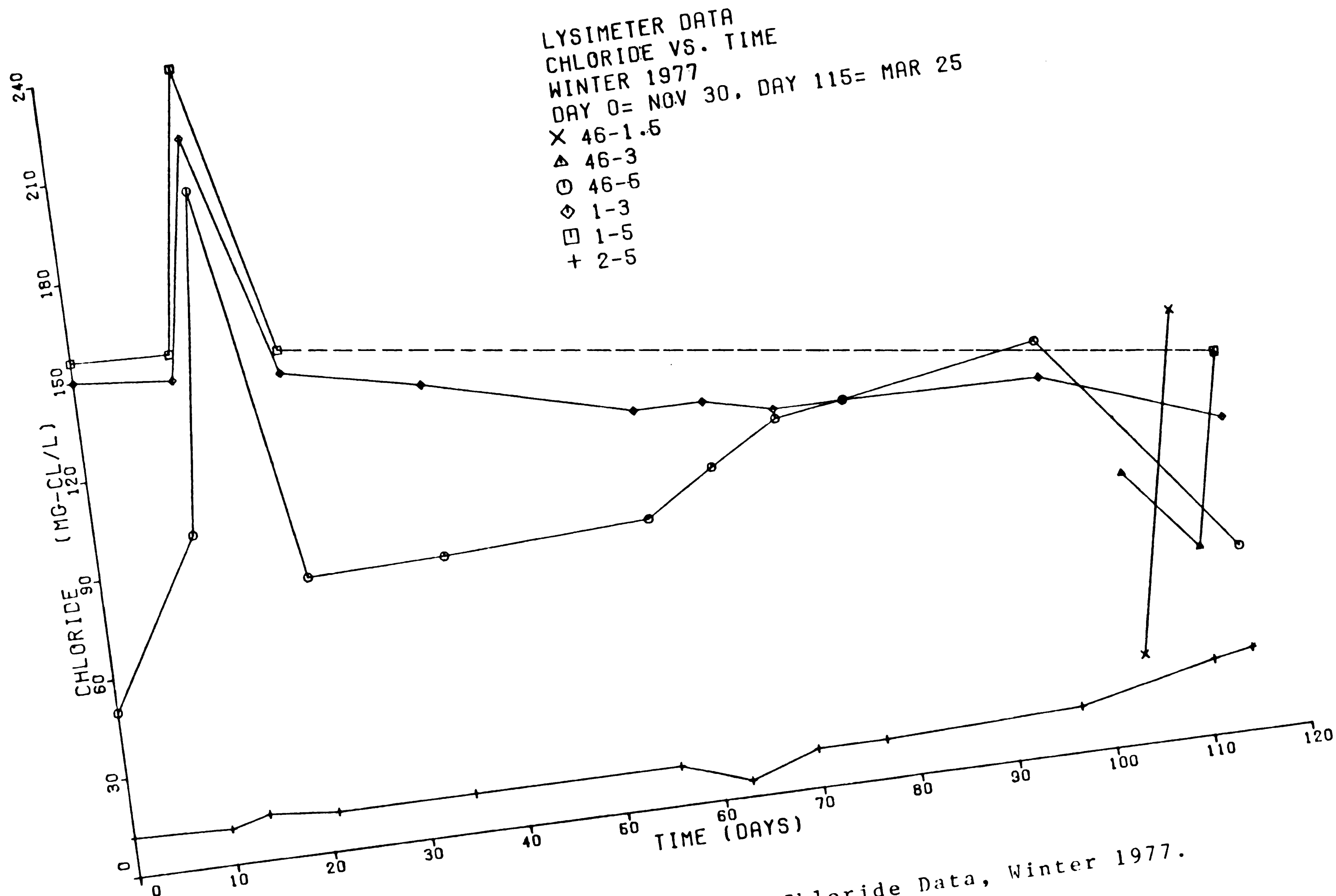

Figure 27.--Lysimeter Control Chloride Data, Winter 1977.

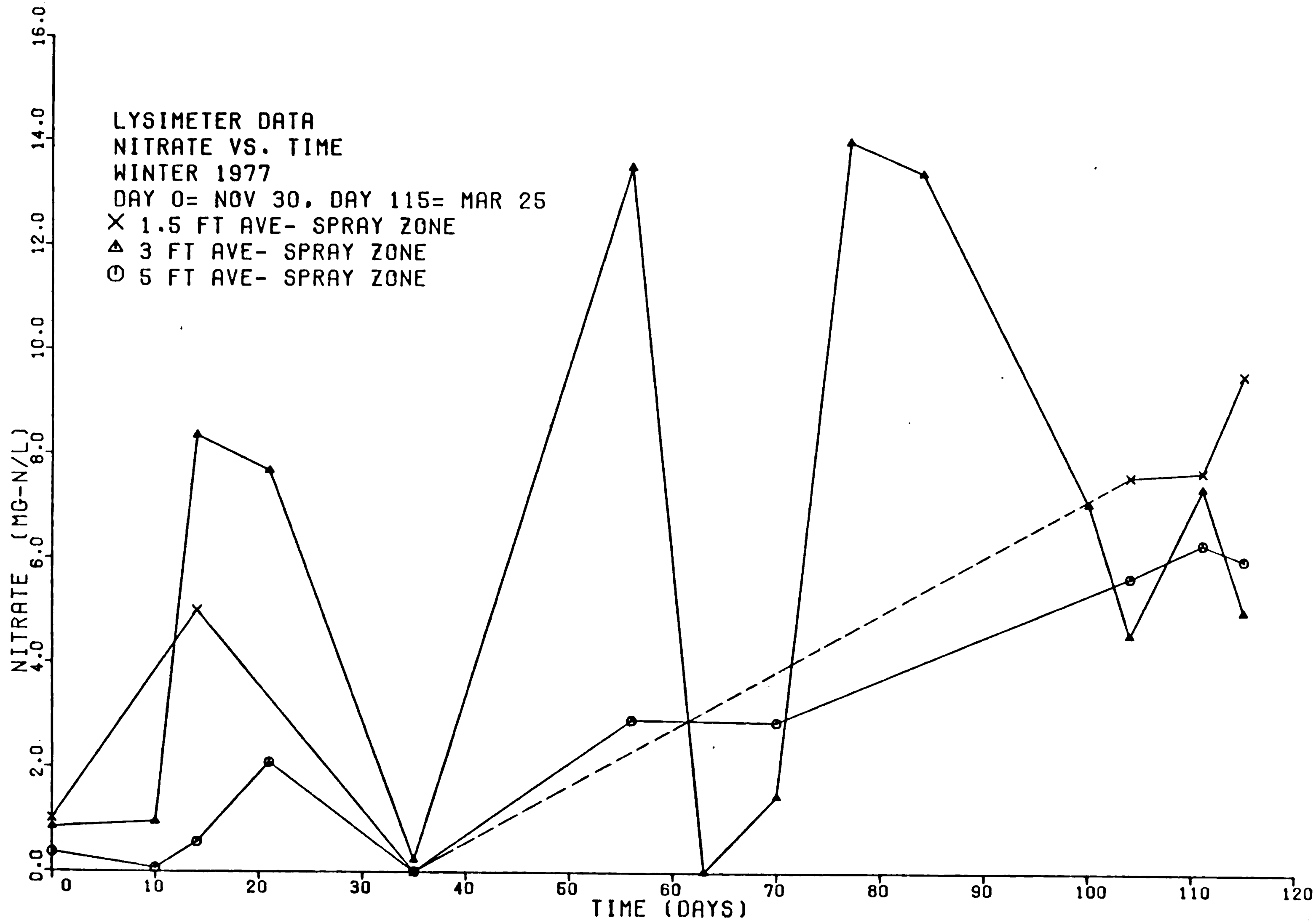

Figure 28.--Lysimeter Nitrate Data, Winter 1977.

greater than 10 mg-N/l occurred at the three foot depth. At the five foot depth, the average nitrate level reached about 6 mg-N/l due to groundwater dilution. A six to eight mg-N/l average nitrate concentration was measured at all depths at the end of the winter period. Ammonia levels fluctuated at about 0.15 mg-N/l during the winter as shown in Figure 29.

Groundwater contour maps compiled from observation well data are given in Figures 30 and 31. Figure 30 shows the low water table conditions of December 13, 1976. A significant gradient toward Felton Drain was apparent in spite of dry conditions. Water table contours for the saturated conditions on March 10, 1977, resulting from rain and ice melt are shown in Figure 31. The water table was within inches of the ground surface at most of the observation well locations in the spray zone. Comparison of the two figures shows water table elevation differences of up to six feet.

Average daily discharge and nutrient concentrations during the runoff period are plotted in Figure 32. Initial runoff concentrations were higher than input levels, probably due to freeze-out of pure water. Concentrations decreased steadily and phosphorus levels showed some increase with discharge possibly due to soil erosion. Phosphorus concentrations remained above 1.0 mg-P/l during most of the runoff period compared to average input of 5.6 mg-P/l. Nutrient mass flowrates again varied with discharge as shown in Figure 33.

Soil water and runoff water quality during the winter period were the poorest of the entire study period. Significant nitrate buildup and some phosphorus breakthrough was observed at a depth of five feet in the soil. Nitrate levels in the deep soil water remained below 10 mg-N/l primarily due to dilution. In terms of total mass applied, the phosphorus

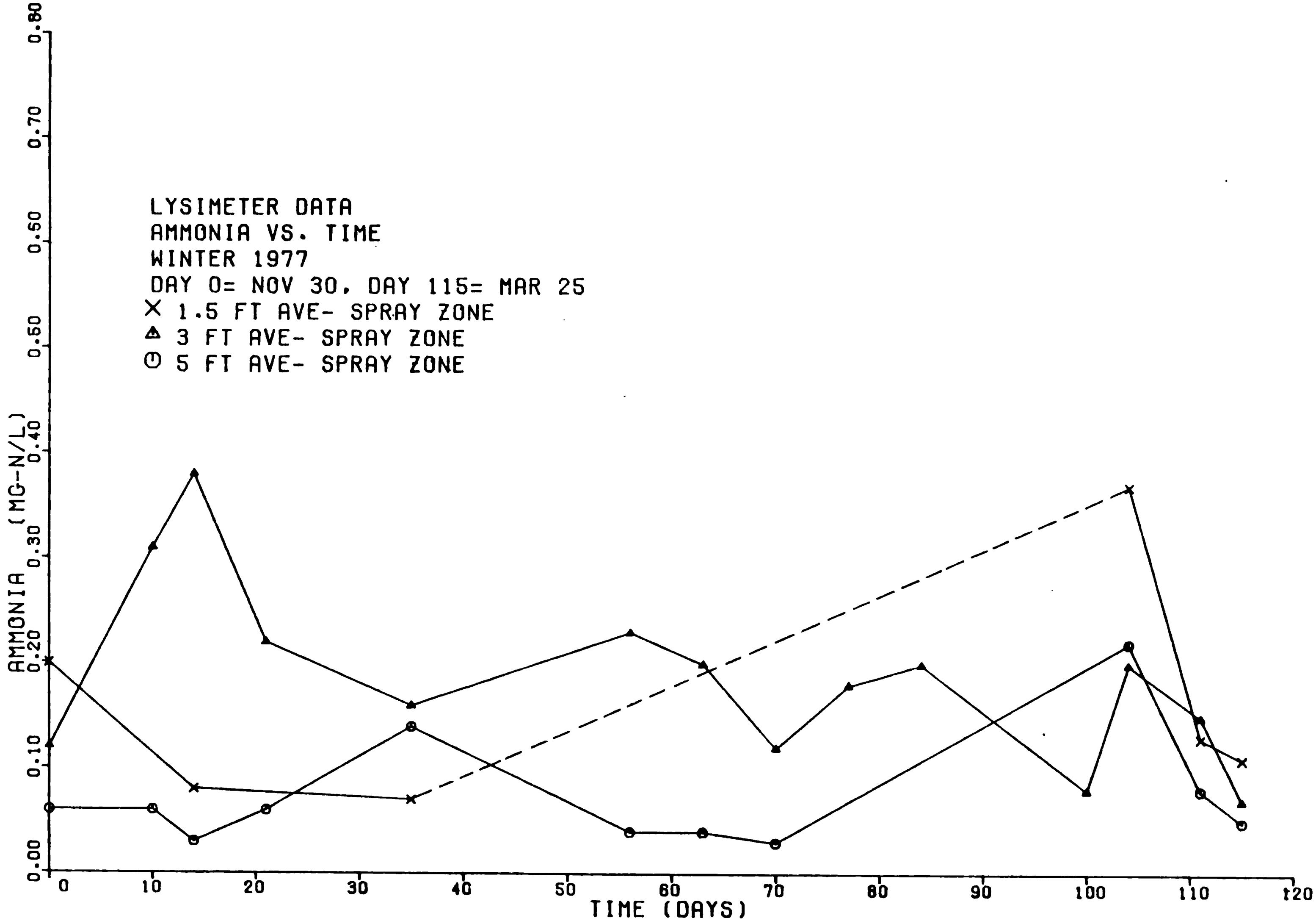

Figure 29.--Lysimeter Ammonia Data, Winter 1977.

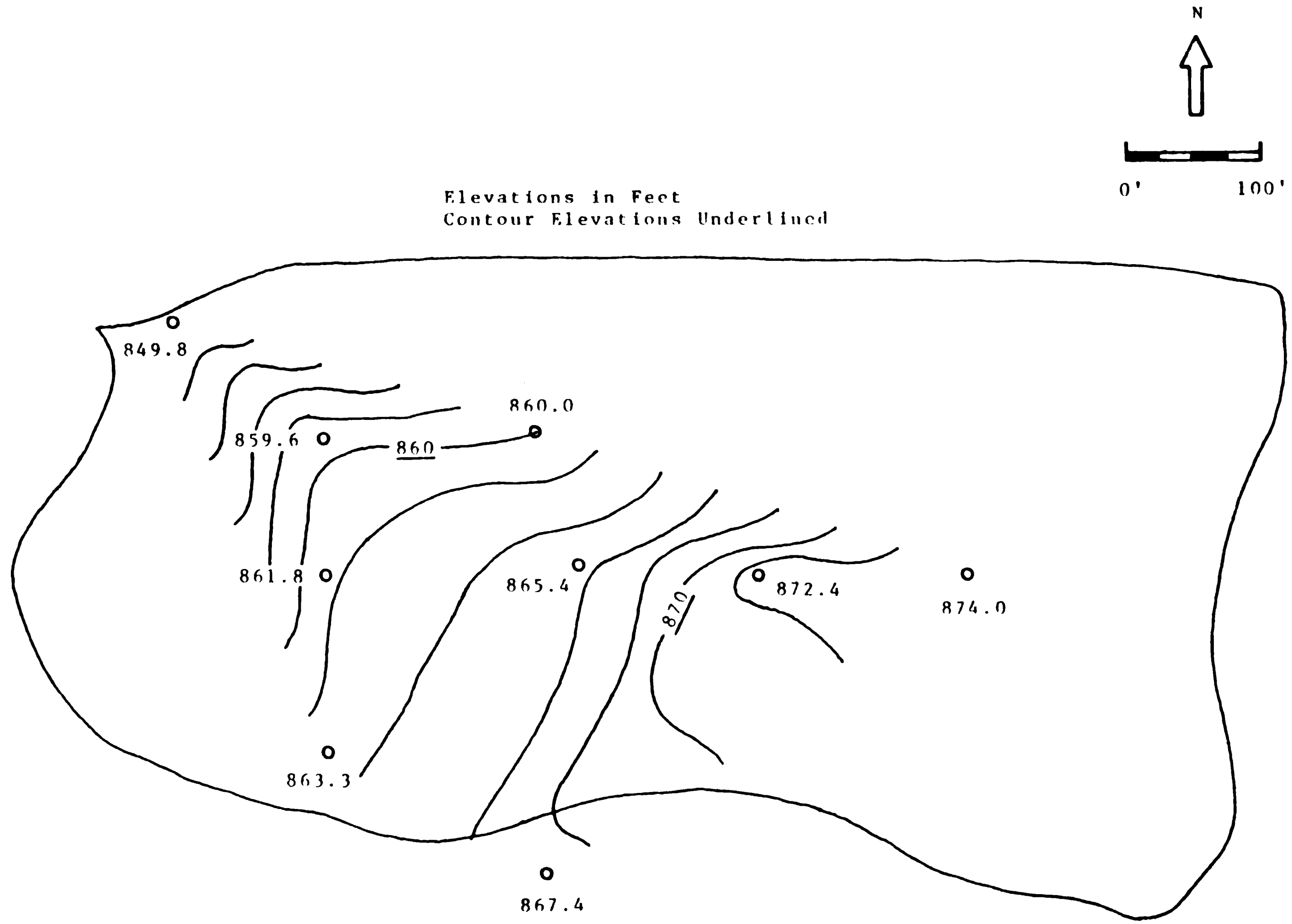

Figure 30.--Low Groundwater Contours at the Winter Spray Site, December 13, 1976.

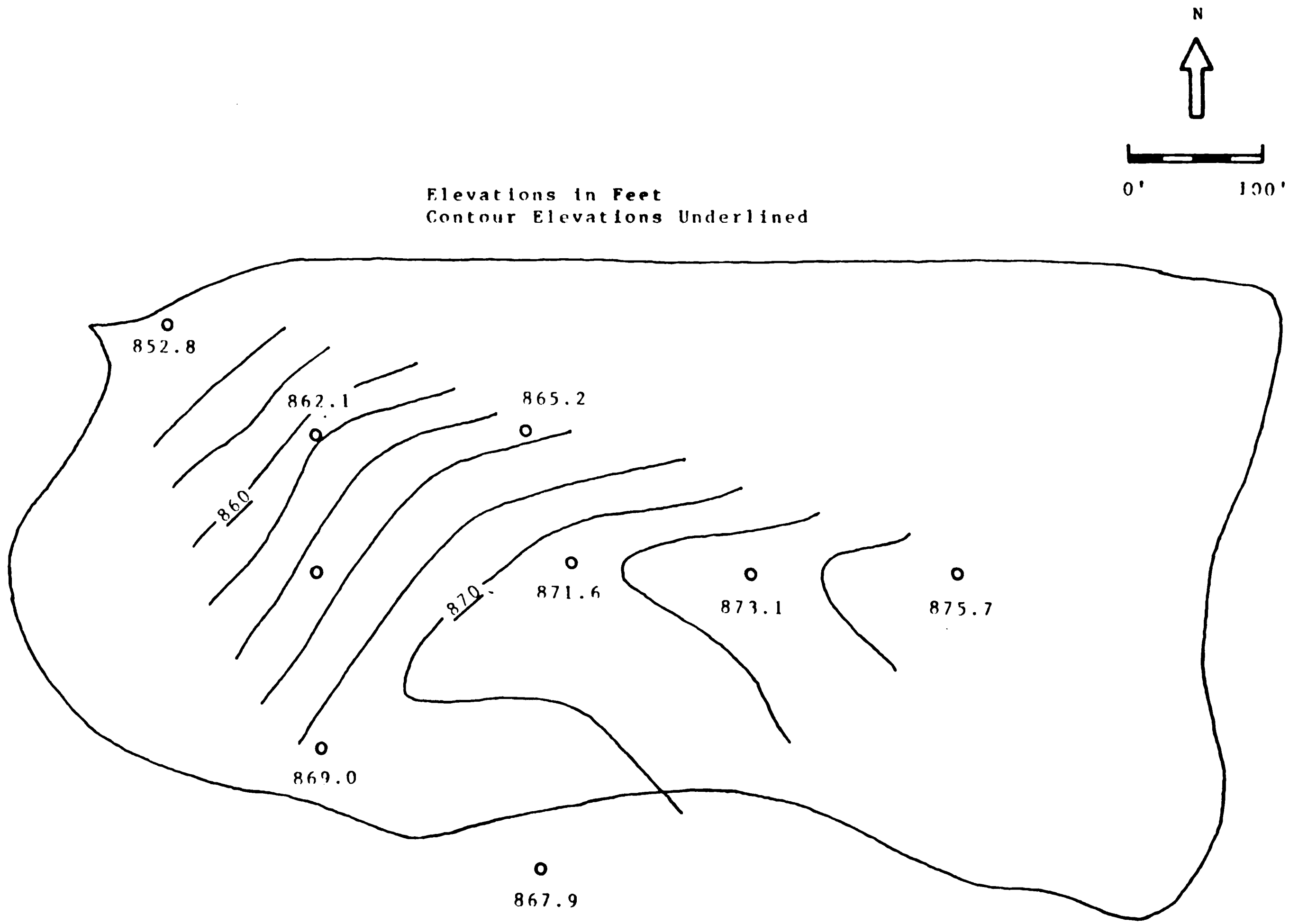

Figure 31.--High Groundwater Contours at the Winter Spray Site, March 10, 1977.

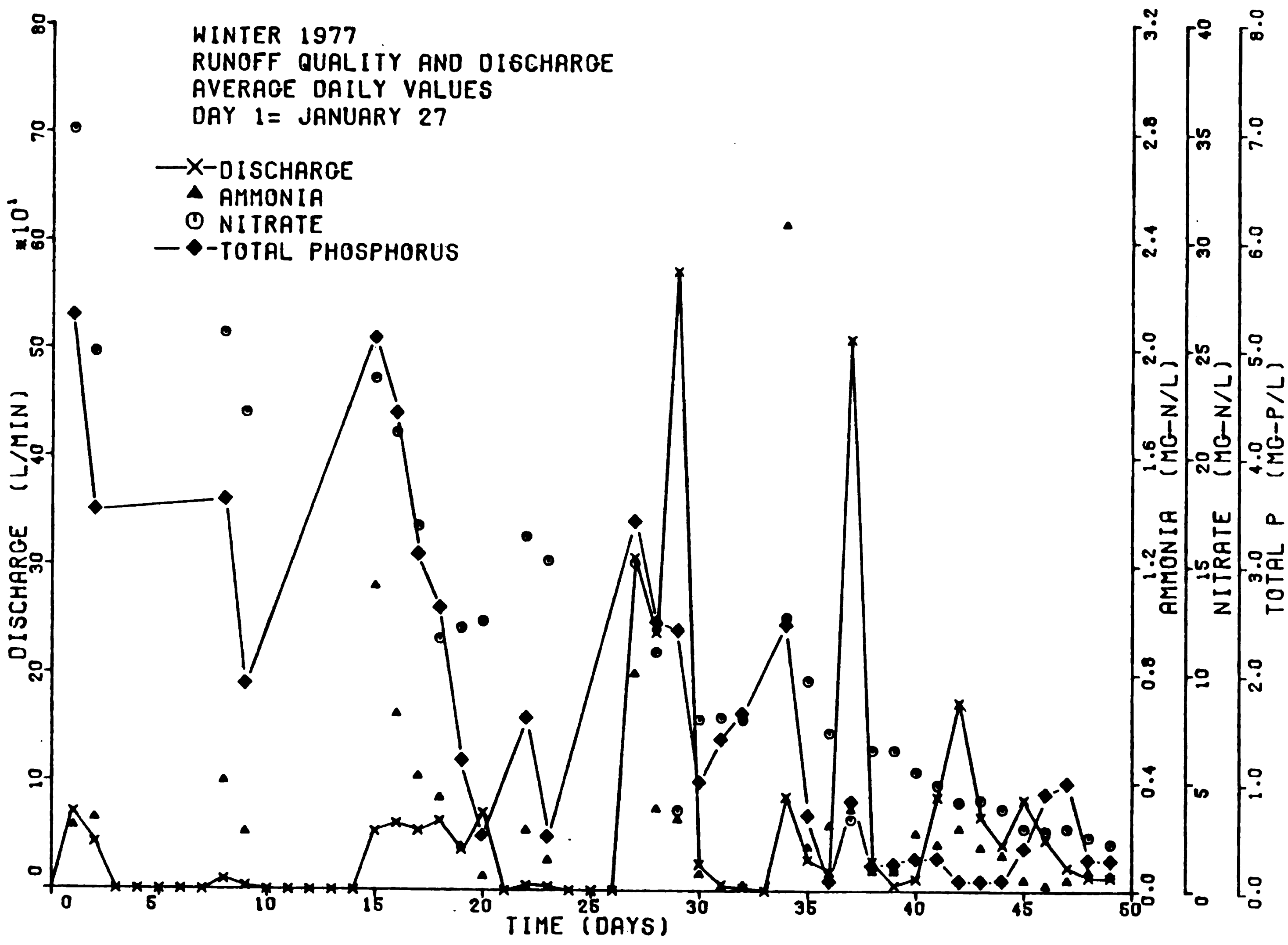

Figure 32.--Average Daily Runoff Discharge and Quality, Winter 1977.

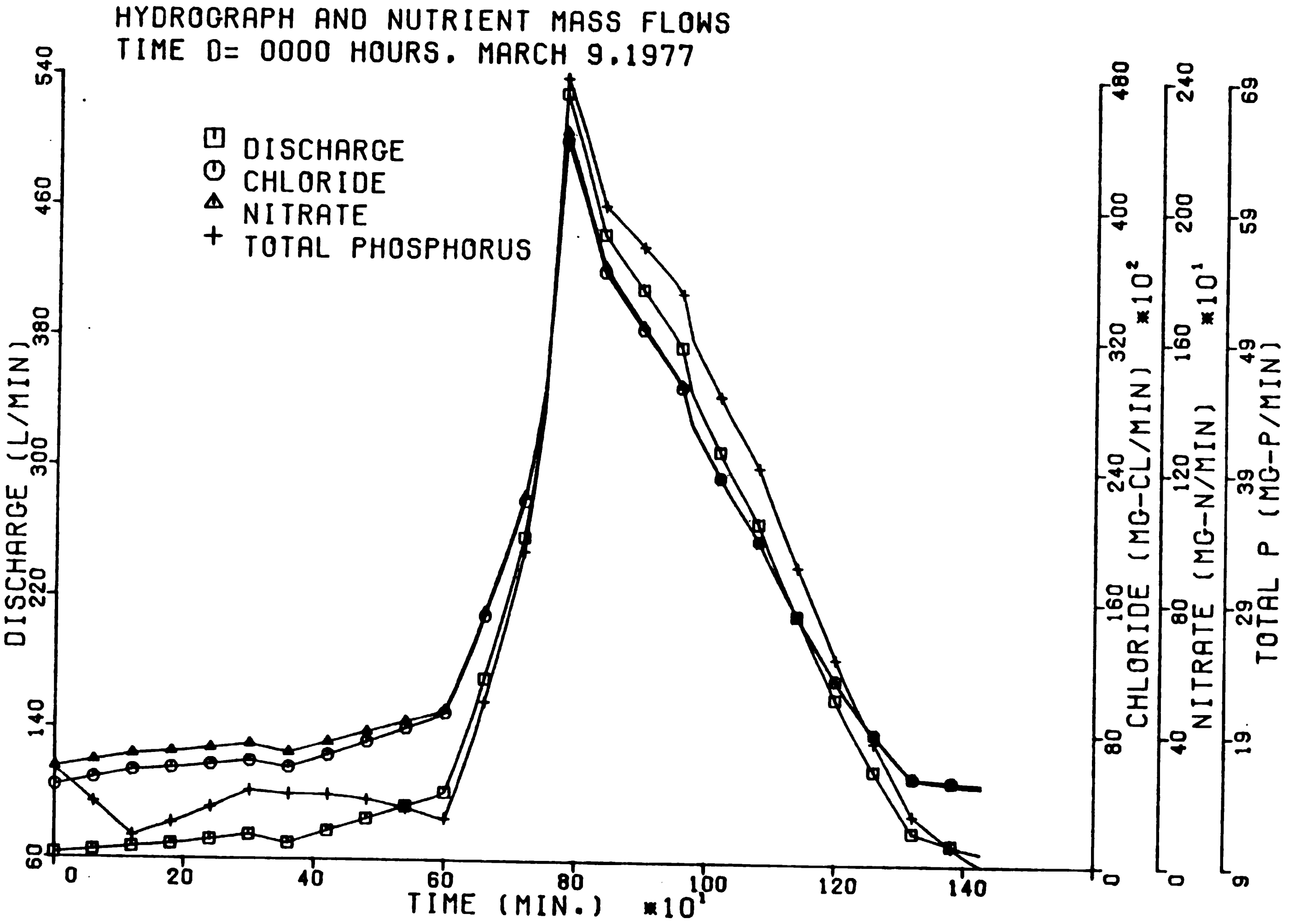

Figure 33.--Hydrograph and Nutrient Mass Flows, March 9, 1977.

runoff mass amounted to only 10 percent, giving a removal of 90 percent. However, the discharge standard calling for a reduction of 80 percent of the input concentration, or a maximum of 1.0 mg-P/1, was violated during most of the runoff period. Runoff volume was small allowing most of the water to infiltrate. Winter 1977 operations were not successful in meeting Michigan standards for phosphorus discharge.

CHAPTER IV

ERRORS AND DATA RELIABILITY

In general, sufficient data were obtained to accurately assess those components of the water and nutrient mass balances which could be measured. In each balance, however, at least two components could not be measured and had to be estimated or evaluated by difference between the known and estimated components. These estimations were the primary sources of error in the experiment.

The water balance computations required volume measurement or estimation of input wastewater and precipitation, surface runoff, evapotranspiration, and infiltration. Water input and surface runoff measurements were highly accurate. Few problems were encountered with the recording raingage and checks were provided with other nearby raingages. The V-notch weir was rated in the field during both winter runoff periods and ratings agreed very closely with each other and with the theoretical rating using the weir equation. A sufficient number of high flow measurements were obtained to accurately extend the stage-discharge curve above the weir notch. The Stevens recorder gave continuous hydrograph records with very infrequent problems such as clock stoppage. Wastewater pumping figures were not directly checked in the field but raingage observations at various places in the spray zone showed the depth of spray to be very nearly one inch per application. The Thornthwaite estimation was the most likely source of error in the water balance. Evapotranspiration was certainly greater than zero during the winter due to sublimation but the true value was probably small. The Thornthwaite estimates were probably correct within ± 10 percent of the water input. Infiltration percentage was obtained by difference.

The nutrient mass balance computations required measurements of nutrient mass input, runoff nutrient mass, soil renovation, and nutrient infiltration mass. Sufficient spray samples were collected to compute nutrient input due to wastewater accurately. Very complete runoff sampling was achieved; 97 percent of the recorded runoff volume was adequately sampled and the laboratory reported complete data sets on 92 percent of the total runoff volume. Runoff events which were not sampled due to errors in procedure or equipment failure were small ones and errors introduced were probably not significant. Data lost by the laboratory was not critical. Porous cup measurements were the most questionable aspect of the experiment. Extreme variability was encountered as shown in the example data given in Table 15. The standard deviations for the sample sets approached the means in some cases. Chloride data seemed to be less variable than nitrogen or phosphorus data. Some of the variability was due to the complex soil conditions at the site. Hansen and Harris reported nitrogen and phosphorus variabilities of ± 30 percent for porous cup lysimeter populations in a uniform sand profile subjected to irrigation with simulated secondary effluent and suggested procedures for reducing variability which were not followed in this study (21). The errors introduced by the lysimeters affected computations of soil nutrient reduction, overall reduction, and nutrient mass infiltration and were most significant during the winter when soil water nutrient levels were high. A small amount of water quality data was lost by the laboratory, but data

Table 15
Example Statistical Analysis of Data
from Spray Zone Lysimeters

February 17, 1976 - 5 ft. depth

Lysimeter Location	Chloride (mg-Cl/1)	Nitrate (mg-N/1)	Ammonia (mg-N/1)	Total Phosphorus (mg-P/1)
18	92	0.47	0.02	0.001
22	77	0.72	0.11	0.006
32	94	0.53	0.06	0.002
37	95	1.07	0.07	0.002
38	47	0.09	0.00	0.002
42	100	0.06	0.10	0.003
Mean ($\bar{y}$)	84	0.49	0.06	0.003
Standard Deviation (s)	20	0.39	0.04	0.002

March 21, 1977 - 5 ft. depth

Lysimeter Location	Chloride (mg-Cl/1)	Nitrate (mg-N/1)	Ammonia (mg-N/1)	Total Phosphorus (mg-P/1)
6	157	9.0	0.21	1.49
18	135	8.7	0.05	0.14
37	130	0.9	0.01	1.61
38	98	4.0	0.09	0.31
42	151	3.1	0.01	1.62
43	165	12.2	0.10	0.23
Mean ($\bar{y}$)	139	6.3	0.08	0.90
Standard Deviation (s)	24	4.3	0.07	0.74

March 21, 1977 - 3 ft. depth

Lysimeter Location	Chloride (mg-Cl/1)	Nitrate (mg-N/1)	Ammonia (mg-N/1)	Total Phosphorus (mg-P/1)
6	151	5.0	0.08	0.22
18	135	9.0	0.11	0.17
22	129	3.3	0.27	0.37
32	103	9.0	0.22	0.12
37	151	10.1	0.12	0.03
38	151	10.8	0.09	0.25
39	140	10.6	0.10	0.33
42	135	1.3	0.17	0.21
Mean ($\bar{y}$)	137	7.4	0.15	0.21
Standard Deviation (s)	16	3.7	0.07	0.11

from spiked and split samples submitted generally showed good laboratory accuracy and precision.

CHAPTER V

CONCLUSIONS

From the results of this study, a number of conclusions can be drawn concerning the impacts of secondary effluent irrigation on an unmodified natural watershed during northern winters.

Soil frost penetration can be prevented by beginning irrigation early in the winter season to build up a protective ice pack. This procedure will allow significant infiltration from ice melt at the ground surface to occur throughout the winter on a site with good infiltration characteristics. A greatly raised water table with possible site saturation will result. Significant runoff will occur from ice melt during thaw periods but the runoff volume will be small because of infiltration.

Groundwater and surface runoff quality will be poor during winter periods compared to that during the rest of the year. Significant nitrate accumulation will occur in the groundwater and concentrations may ultimately exceed the standard of 10 mg-N/1, although they did not in this experiment. Some phosphorus breakthrough into the groundwater may be observed, but up to 90 percent of the input phosphorus mass will be retained on the site. The total nitrogen and phosphorus mass accompanying the surface runoff will be as low as 10 to 20 percent of the applied mass, but high concentrations of these nutrients present in the runoff will result in violation of the Michigan phosphorus discharge standards and probable violation of future nitrogen discharge standards. Thus, phosphorus retention remains high during winter irrigation, but nitrogen renovation is seriously impaired.

CHAPTER VI

RECOMMENDATIONS FOR FURTHER WORK

It appears that significant phosphorus retention can be achieved during winter land application; however, stringent phosphorus discharge standards cannot be met if surface runoff is allowed to occur naturally. Surface runoff could be controlled by constructing earthen dikes or by contour plowing to induce ponding and increase infiltration. Further data should be collected under these conditions.

Winter land application results in serious nitrate buildup in the groundwater with possible accumulation over time to high levels. There is no solution to this problem other than to irrigate with low nitrogen water. This low nitrogen water is available in the WQMP lake system in the late fall and it would be possible to irrigate from the end of the lake system during the winter while taking in new effluent at the head of the system. Winter irrigation could proceed until the lake effluent reached 10 mg-N/l nitrate, effectively increasing the operating season of the WQMP system by several months.

Recommendations for future field studies during winter conditions concern the suction lysimeters. First, more lysimeters should be installed if laboratory facilities to handle the increased sample load are available. The minimum time to collect full or nearly full samples should be determined, and porous cups should be allowed to collect samples under vacuum for only this period to reduce variability. Finally, some means must be found to keep the lysimeter access tubes from freezing closed during the winter months.

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APPENDICES

APPENDIX A

Thornthwaite Evapotranspiration Estimates

Evapotranspiration Estimates

Method and tables proposed by Thornthwaite (18)

Variables

- T - mean monthly temperature (^{o}F)
- I - heat index based on T, found from tables
- I_a - sum of monthly I values
- UPE - unadjusted potential evapotranspiration based on I_a and T, found from tables
- L - mean possible monthly duration of sunlight in units of 12 hours (actual monthly sunlight used here)
- APE - actual potential evapotranspiration (in.)

Assumptions

1) Evapotranspiration is zero when the mean monthly temperature falls below 32^{o} F (0^{o}C).

2) Use of actual monthly duration of sunlight will give a more accurate estimate than use of mean monthly values from tables.

Mean monthly temperature and duration of sunlight were obtained from U. S. Weather Bureau records, Lansing, Michigan.

Evapotranspiration Estimates - 1976

	T(°F)	I	UPE	L(12 hrs)	APE (in) (Lx UPE)
JAN	17.4	0	0	6.67	0
FEB	29.9	0	0	12.93	0
MAR	38.2	0.56	0.02	14.18	0.3
APR	48.1	2.41	0.05	23.28	1.2
MAY	54.0	3.87	0.07	22.63	1.6
JUN	69.1	8.54	0.13	27.69	3.6
JUL	70.9	9.17	0.14	30.50	4.3
AUG	66.8	7.75	0.13	28.19	3.7
SEP	59.3	5.37	0.09	21.78	2.0
OCT	44.8	1.70	0.04	14.87	0.6
NOV	31.6	0	0	9.10	0
DEC	18.0	0	0	10.97	0
		I_a = 39.37			17.3 in

Evapotranspiration Estimate - 1975

Evapotranspiration for December 1975 was zero because the mean monthly temperature was 27.8°F.

Evapotranspiration Estimate - 1977

Mean monthly temperature for January and February was below zero; evapotranspiration was zero. Evapotranspiration for the first half of March was assumed negligible from above analysis.

APPENDIX B

Listing of Computer Program FLUX

```
      PROGRAM FLUX(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      INTEGER MT(192),NT(192),IBUF(513)
      INTEGER ITITLE1(2),ITITLE2(2),ITITLE3(2),ITITLE4(2)
      REAL Q(12,192),STAGE(35),CFS(35),TITLE(8),BUF(192)
      REAL NTIM(96),FLOW(96,12)
      REAL TMASS(21)
      DIMENSION ATITLE(8),BTITLE(8),TITLE1(2),TITLE2(2),TITLE3(2),TITLE4
     1(2)
C WINTER SPRAY SITE WEIR- STAGE DISCHARGE RELATION (CM AND CFS)
      DATA STAGE/13.1,14.6,15.0,15.6,16.0,16.6,17.0,17.6,18.0,18.6,19.0,
     119.6,20.0,21.0,22.0,23.0,24.0,25.0,26.0,27.0,28.0,29.0,30.0,31.0,
     132.0,33.0,34.0,35.0,36.0,37.0,38.0,39.0,40.0,41.0,42.0/
      DATA CFS/0.0,.001,.002,.003,.004,.006,.008,.012,.014,.018,.022,
     1.027,.031,.041,.056,.071,.088,.108,.128,.150,.176,.206,.285,.354,
     1.431,.519,.621,.739,.877,1.04,1.2,1.4,1.6,1.9,2.15/
C PROGRAM ASSUMES AT MOST 21 WATER QUALITY PARAMETERS AT 96 TIMES SEPARATED BY
C 15 MINUTES. DATA CAN BE READ IN AT ARBITRARY TIMES OVER A DAY AND WILL BE
C INTERPOLATED TO 15 MINUTE INTERVALS. WATER FLOW AND QUALITY CONCENTRATIONS
C ARE READ IN SEPARATELY. WATER FLOW IS READ IN AS STREAM STAGE AND DATA MATRICE
C S TO CALCULATE DISCHARGE MUST BE INCLUDED IN PROGRAM. QUALITY CONCENTRATIONS
C SHOULD BE IN MG/LITER. READ TITLE CARD TO BE WRITTEN ON PRINTED OUTPUT.
   10 READ(5,1000) TITLE
 1000 FORMAT(8A10)
      IF(EOF(5)) 999,20
20    CONTINUE
C SIG1= BLANK, SHORT OUTPUT   SIG1= NONBLANK , FULL OUTPUT
      READ(5,1500) SIG1
1500  FORMAT(A1)
      WRITE(6,2000) TITLE
 2000 FORMAT(1H1 40X 8A10)
C READ NUMBER OF FLOW DATA POINTS
      READ(5,3000) NFLOW
 3000 FORMAT(2I5)
C READ IN TIMES AND STREAM STAGE
      READ(5,4000) (NT(K),BUF(K),K=1,NFLOW)
 4000 FORMAT(8(I4,F6.0))
      WRITE(6,5000) (NT(K),BUF(K),K=1,NFLOW)
5000  FORMAT(1H0*INPUT TIMES AND STAGES(CM)*//(1X10(I5,F6.1)))
      NFST=NT(1)
      MT(1)=0
      DO 40 K=2,NFLOW
C CONVERT CLOCK TIME TO MINUTES
      NHB=NT(K)/100
      NMB=NT(K)-NHB*100
      NHA=NT(K-1)/100
      NMA=NT(K-1)-NHA*100
      NTB=NMB+NHB*60
      NTA=NMA+NHA*60
      NDIF=NTB-NTA
C TEST AND CORRECT FOR POSSIBLE CHANGE OF DAY
      IF(NDIF.LT.0) NDIF=NDIF+1440
   40 MT(K)=MT(K-1)+NDIF
C READ NUMBER OF WATER SAMPLES AND NUMBER OF PARAMETERS.
      READ(5,3000) NQUAL,NPARM
      NPAR=NPARM+1
C READ IN SAMPLE TIMES AND PARAMETER CONCENTRATIONS.
      DO 70 K=1,NQUAL
      READ(5,6000) NT(K),(Q(L,K),L=2,NPAR)
 6000 FORMAT(I4,12F6.0/9F6.0)
   70 CONTINUE
      NDIF=0
      NQST=NT(1)
      IF(NQST.EQ.NFST) GO TO 45
      NHB=NQST/100
      NHA=NFST/100
      NMB=NQST-NHB*100
      NMA=NFST-NHA*100
      NTB=NMB+NHB*60
      NTA=NMA+NHA*60
      NDIF=NTB-NTA
      IF(NDIF.LT.0) NDIF=NDIF+1440
C INTERPOLATE FLOW DATA TO 15 MINUTE INTERVALS
   45 NTIME=NDIF
      NPTS=0
      NHIGH=2
      NLOW=1
   50 IF(NTIME.LE.MT(NHIGH)) GO TO 60
```

```
      NLOW=NHIGH
      NHIGH=NHIGH+1
      GO TO 50
60    IONE=NTIME-MT(NLOW)
      ITWO=MT(NHIGH)-MT(NLOW)
      FRAC=FLOAT(IONE)/FLOAT(ITWO)
      NPTS=NPTS+1
      Q(1,NPTS)=BUF(NLOW)*(1.-FRAC)+BUF(NHIGH)*FRAC
      NTIME=NTIME+15
      IF(NTIME.LE.MT(NFLOW)) GO TO 50
C CONVERT STREAM STAGE(H) TO DISCHARGE(CFS)
      DO 500 K=1,NPTS
      DO 200 N=1,34
      H=Q(1,K)
      IF(H.GE.STAGE(N).AND.H.LE.STAGE(N+1)) GO TO 400
  200 CONTINUE
  400 FRAC=(H-STAGE(N))/(STAGE(N+1)-STAGE(N))
      Q(1,K)=(1.-FRAC)*CFS(N)+FRAC*CFS(N+1)
  500 CONTINUE
C CONVERT FLOWS TO LITERS/MIN AND TIMES TO MINUTES MEASURED FROM NT(1).
      DO 30 K=1,NPTS
30    Q(1,K)=Q(1,K)*28.32*60.
      WRITE(6,7000)
 7000 FORMAT(1H0*INPUT TIMES AND PARAMETER CONCENTRATIONS(MG/L)*//)
      DO 80 K=1,NQUAL
      WRITE(6,8000) NT(K),(Q(L,K),L=2,NPAR)
8000  FORMAT(1XI4,15F8.3/5X5F8.3)
   80 CONTINUE
C CONVERT TIMES TO MINUTES MEASURED FROM NT(1)
      MT(1)=0
      DO 90 K=2,NQUAL
      NHB=NT(K)/100
      NMB=NT(K)-NHB*100
      NHA=NT(K-1)/100
      NMA=NT(K-1)-NHA*100
      NTB=NMB+NHB*60
      NTA=NMA+NHA*60
      NDIF=NTB-NTA
C TEST AND CORRECT FOR POSSIBLE CHANGE OF DAY
      IF(NDIF.LT.0) NDIF=NDIF+1440
   90 MT(K)=MT(K-1)+NDIF
C INTERPOLATE CONCENTRATION DATA TO 15 MINUTE INTERVALS
      DO 150 J=2,NPAR
      BUF(1)=Q(J,1)
      NHIGH=2
      NLOW=1
C ASSUME THAT DATA HAS NOT BEEN COLLECTED MORE FREQUENTLY THAN EVERY 15 MINUTES
      NTIME=15
      NPTS=1
100   IF(NTIME.LE.MT(NHIGH)) GO TO 110
      NLOW=NHIGH
      NHIGH=NHIGH+1
  110 IONE=NTIME-MT(NLOW)
      ITWO=MT(NHIGH)-MT(NLOW)
      FRAC=FLOAT(IONE)/FLOAT(ITWO)
      NPTS=NPTS+1
      BUF(NPTS)=Q(J,NLOW)*(1.-FRAC)+Q(J,NHIGH)*FRAC
      NTIME=NTIME+15
      IF(NTIME.LE.MT(NQUAL)) GO TO 100
C  STORE BUFFER DATA BACK IN Q
      DO 120 K=1,NPTS
  120 Q(J,K)=BUF(K)
  150 CONTINUE
C CALCULATE AND WRITE OUT FLUXES.
      SUM=0.
      DO 160 K=1,NPTS
  160 SUM=SUM+Q(1,K)
      SUM=(SUM-0.5*(Q(1,1)+Q(1,NPTS)))*15.
      IF(SIG1.EQ.1H ) GO TO 165
      WRITE(6,9000)
 9000 FORMAT(1H120X*WATER INPUT(LITERS)*)
      WRITE(6,9100)
 9100 FORMAT(1H0*TIME(MIN)*8X*FLOW(LITERS/MIN)*6X*CUM FLUX*10X*IND PERCE
     1NT*6X*PERCENT TOTAL*//)
165   CONTINUE
      NTIME=0
      CUMF=0.
```

```
      PADD=0.
      PERC=0.
      IF(SIG1.EQ.1H ) GO TO 166
      WRITE(6,9200) NTIME,Q(1,1),CUMF,PADD,PERC
 9200 FORMAT(I7,9XE12.4,10XE12.4,10XF6.2,10XF6.2)
166   CONTINUE
      CUMF=0.
      DO 170 K=2,NPTS
      ADD=0.5*(Q(1,K)+Q(1,K-1))*15.
      PADD=ADD/SUM*100.
      CUMF=CUMF+ADD
      NTIME=NTIME+15
      PERC=CUMF/SUM*100.
      IF(SIG1.EQ.1H ) GO TO 170
      WRITE(6,9200) NTIME,Q(1,K),CUMF,PADD,PERC
170   CONTINUE
      VOL=CUMF
      DO 250 J=2,NPAR
      SUM=0.
      DO 180 K=1,NPTS
      ADD=Q(J,K)*Q(1,K)
      IF(K.EQ.1.OR.K.EQ.NPTS) ADD=ADD*0.5
  180 SUM=SUM+ADD
      SUM=SUM*15.
      JM=J-1
      IF(SIG1.EQ.1H ) GO TO 185
      WRITE(6,9300) JM
 9300 FORMAT(1H12JX*WATER QUALITY PARAMETER*I5)
      WRITE(6,9400)
 9400 FORMAT(1H0*TIME(MIN)*10X*FLUX(MG/MIN)*10X*CONC(MG/L)*10X*CUM FLUX*
     110X*INC PERCENT*6X*PERCENT TOTAL*//)
185   CONTINUE
      NTIME=0
      CUMF=0.
      PADD=0.
      PERC=0.
      QJK=Q(1,1)*Q(J,1)
      IF(SIG1.EQ.1H ) GO TO 186
      WRITE(6,9500) NTIME,QJK,Q(J,1),CUMF,PADD,PERC
186   CONTINUE
      FLOW(1,J)=QJK
      CUMF=0.
      DO 190 K=2,NPTS
      ADD=0.5*(Q(1,K)*Q(J,K)+Q(1,K-1)*Q(J,K-1))*15.
      PADD=ADD/SUM*100.
      CUMF=CUMF+ADD
      NTIME=NTIME+15
      PERC=CUMF/SUM*100.
      QJK=Q(1,K)*Q(J,K)
      IF(SIG1.EQ.1H ) GO TO 187
      WRITE(6,9500) NTIME,QJK,Q(J,K),CUMF,PADD,PERC
 9500 FORMAT(I7,9XE12.4,10XE12.4,10XE12.4,10XF6.2,10XF6.2)
187   CONTINUE
      FLOW(K,J)=QJK
  190 CONTINUE
      L=J-1
      TMASS(L)=CUMF
  250 CONTINUE
      IF(SIG1.NE.1H ) GO TO 300
      WRITE(6,9700) VOL
9700  FORMAT(1H0*RUNOFF VOLUME (LITERS)=*,F10.1)
      WRITE(6,9800)(J,TMASS(J),J=1,NPARM)
9800  FORMAT(* PARAMETER*,1X,I2,5X,*MASS IN RUNOFF(MG)=*,E12.4)
300   CONTINUE
C PLOTTING OPTION-  NTIM= TIME ARRAY, FLOW= FLOW AND FLUX ARRAYS
C TO PLOT PLACE TWO CARDS AFTER DATA VALUES-
C     (1) BLANK= NO PLOT, NONBLANK= PLOT
C     (2) COL 1= NUMBER OF LINES TO PLOT,COL 2-5 CONTAINS PARAMETER ID NOS.
C     (3) VERTICAL AXIS LABELS IN ORDER OF CARD (2) PARAMETER ID NOS. IN
C     GROUPS OF 20 CHARACTERS
      READ(5,9600) SIG2
9600  FORMAT(A1)
      IF(SIG2.EQ.1H ) 10,800
800   CONTINUE
      READ(5,801)I5,I1,I2,I3,I4
  801 FORMAT(5I1)
      IF(EOF(5))899,802
```

```
 902 READ(5,1000)ITITLE1,ITITLE2,ITITLE3,ITITLE4
     READ 805,ITYPE
805  FORMAT(I1)
     CALL PLOTS(IBUF,513,ITYPE)
     NTIME=0
     DO 810 M=1,NPTS
     NTIM(M)=NTIME
     NTIME=NTIME+15
 810 FLOW(M,1)=C(1,M)
     CALL PLOT(0.0,0.5,-3)
     CALL SCALE(NTIM,8.0,NPTS,1)
     CALL AXIS(0.0,0.0,11HTIME  (MIN.),-11,8.0,0.0,NTIM(NPTS+1),NTIM(NPT
    1S+2))
     CALL SCALE(FLOW(1,I1),6.0,NPTS,1)
     CALL AXIS(0.0,0.0,ITITLE1,20,6.0,90.0,FLOW(NPTS+1,I1),FLOW(NPTS+2,
    1I1))
     CALL LINE(NTIM,FLOW(1,I1),NPTS,1,4,0)
     IF(I5.EQ.1) GO TO 804
     X=8.0
     L=I5-1
     DO 803 N=1,L
     IF(N.EQ.1) I=I2
     IF(N.EQ.2) I=I3
     IF(N.EQ.2) ITITLE2(1)=ITITLE3(1)
     IF(N.EQ.2) ITITLE2(2)=ITITLE3(2)
     IF(N.EQ.3) I=I4
     IF(N.EQ.3) ITITLE2(1)=ITITLE4(1)
     IF(N.EQ.3) ITITLE2(2)=ITITLE4(2)
     CALL SCALE(FLOW(1,I),6.0,NPTS,1)
     CALL AXIS(X,0.,ITITLE2,-20,6.0,90.0,FLOW(NPTS+1,I),FLOW(NPTS+2,I))
     X=X+0.5
     CALL LINE(NTIM,FLOW(1,I),NPTS,1,4,N)
 803 CONTINUE
     READ 880,ATITLE,BTITLE
     READ 880,TITLE1,TITLE2,TITLE3,TITLE4
880  FORMAT(8A10)
     CALL SYMBOL(1.0,8.5,.14,ATITLE,0.,80)
     CALL SYMBOL(1.0,8.25,.14,BTITLE,0.,80)
     CALL SYMBOL(2.0,7.5,.14, TITLE1,0.,20)
     CALL SYMBOL(1.75,7.65,.14,0,0.,-1)
     IF( TITLE2(1).EQ.10H          ) GO TO 804
     CALL SYMBOL(2.0,7.25,.14, TITLE2,0.,20)
     CALL SYMBOL(1.75,7.4,.14,1,0.,-1)
     IF( TITLE3(1).EQ.10H          ) GO TO 804
     CALL SYMBOL(2.0,7.0,.14, TITLE3,0.,20)
     CALL SYMBOL(1.75,7.15,.14,2,0.,-1)
     IF( TITLE4(1).EQ.10H          ) GO TO 804
     CALL SYMBOL(2.0,6.75,.14, TITLE4,0.,20)
     CALL SYMBOL(1.75,6.9,.14,3,0.,-1)
 804 CONTINUE
     CALL PLOT(12.0,0.0,999)
 999 CONTINUE
     END
```

APPENDIX C

Seasonal Spray Input - Water and Nutrients

Spray Input - Water and Nutrients, Winter 1976

Spray Date	Net Gallons Delivered to Site[1]	Average Chloride Concentration (mg-Cl/l)	Total lbs. Chloride	Average Total Phosphorus Concentration (mg-P/l)	Total lbs. Phosphorus	Average Nitrate Concentration (mg-N/l)	Total lbs. Nitrate	Average Ammonia Concentration (mg-N/l)	Total lbs. Ammonia
JAN 9	143,796	127(3)[2]	152.3	1.68	2.01	5.60	6.71	0.54	0.65
JAN 13	157,873	112(4)	147.5	1.54	2.03	5.60*	7.38	0.29	0.38
JAN 16	154,494	212(3)	273.3	2.25	2.90	5.70*	7.35	0.36	0.46
JAN 20	154,744	175(3)	225.8	2.14	2.76	5.70*	7.35	0.37	0.48
JAN 23	154,640	174(3)*[3]	224.3	2.40*	3.09	2.80*	3.61	0.34*	0.44
JAN 27	154,494	173(2)	222.8	2.59	3.34	8.17	10.52	0.30	0.39
JAN 30	154,494	197(3)	253.7	2.30	2.96	5.53	7.12	0.47	0.61
FEB 4	154,494	215(3)	276.9	3.03	3.90	5.85	7.53	0.47	0.61
FEB 6	157,314	138(4)	181.0	2.23	2.92	1.13	1.48	0.43	0.56
FEB 10	154,494	144(3)	185.5	1.81	2.33	7.03	9.05	0.00	0.00

Total Input -

Water	1,540,837	gal. (5,832,068 liters)
Total Phosphorus	28.2	lbs. (12.8 kg) as P
Nitrate	68.1	lbs. (30.9 kg) as N
Ammonia	4.6	lbs. (2.1 kg) as N
Chloride	2143	lbs. (972 kg) as Cl

[1] Net gallons delivered = pumping volume - 3000 gallons drained from system after spraying

[2] (x) Number of samples

[3] * Missing data, estimates obtained by ratio of known data points to samples taken at lake one outlet structure

Spray Input - Water and Nutrients - Spring 1976

Spray Date	Net Gallons Delivered to Site	Average Chloride Concentration (mg-Cl/1)	Total lbs. Chloride	Average Ammonia Concentration (mg-N/1)	Total lbs. Ammonia	Average Nitrate Concentration (mg-N/1)	Total lbs. Nitrate	Average Total Phosphorus Concentration (mg-P/1)	Total lbs. Phosphorus
MAR 23	157,500	112(3)[1]	147.2	0.05	0.07	2.33	3.06	1.50	1.97
APR 6	157,800	93(3)	122.5	0.06	0.08	0.98	1.29	0.73	0.96
APR 9	164,000	94(3)	128.7	0.98	1.34	0.20	0.27	0.69	0.94
APR 13	157,800	104(3)	136.9	1.19	1.57	0.09	0.12	0.72	0.95
APR 20	164,000	100(3)*[2]	136.9	0.01	0.01	2.71	3.71	0.96	1.31
MAY 13	154,491	100(3)*	128.9	0.08	0.10	1.68	2.17	1.00*	1.29

Total Input -

Water	955,591 gal (3,616,912 l)
Chloride	801.1 lbs. (363 kg) as Cl
Nitrate	10.6 lbs. (4.8 kg) as N
Ammonia	3.2 lbs. (1.4 kg) as N
Total Phosphorus	7.4 lbs. (3.4 kg) as P

[1] (x) Number of samples

[2] * Missing data- estimates are given

Spray Input - Water and Nutrients - Summer 1976

Spray Date	Net Gallons Delivered to Site	Average Chloride Concentration (mg-Cl/1)	Total lbs. Chloride	Average Ammonia Concentration (mg-N/1)	Total lbs. Ammonia	Average Nitrate Concentration (mg-N/1)	Total lbs. Nitrate	Average Total Phosphorus Concentration (mg-P/1)	Total lbs. Phosphorus
MAY 27	163,500	112(3)[1]	152.8	0.01	0.01	18.77	25.61	2.59	3.53
JUN 1	163,500	110(3)	150.1	0.00	0.00	16.50	22.51	2.75	3.75
JUN 3	162,000	124(3)	167.7	0.53	0.72	16.80	22.71	2.68*[2]	3.62
JUN 8	159,000	127(3)	168.5	0.74	0.98	14.80	19.64	2.61	3.46
JUN 10	163,500	130(3)	177.4	0.35	0.48	15.77	21.52	2.37	3.23
JUN 15	162,750	155(3)	210.5	0.20	0.27	17.70	24.04	2.11	2.87
JUN 17	163,500	110(3)	150.1	0.13	0.18	12.97	17.70	2.59	3.53
JUN 22	157,500	114(3)	149.9	0.18	0.24	13.10	17.22	3.19	4.19
JUN 24	158,250	56(3)	74.0	0.11	0.15	6.30	8.32	2.33	3.08
JUN 29	163,500	115(3)	156.9	0.13	0.18	13.13	17.92	3.77	5.14
JUL 6	163,888	100(3)	136.8	0.16	0.22	11.63	15.91	1.98	2.71
JUL 8	163,500	115(3)	156.9	0.02	0.27	11.63	15.87	1.21	1.65
JUL 13	163,500	133(3)	181.5	4.13	5.64	5.67	7.74	0.70	0.96
JUL 15	147,520	123(3)	151.2	0.71	0.87	4.88	6.00	0.68	0.84
JUL 20	156,660	122(3)	159.5	0.46	0.60	4.93	6.45	1.25	1.63
JUL 22	162,858	130(3)	176.7	4.27	5.80	3.04	4.13	1.38	1.88
JUL 27	161,250	117(3)	157.5	6.01	8.09	0.80	1.08	2.32	3.12
AUG 3	166,770	111(3)	154.5	4.19	5.83	3.87	5.39	2.63	3.66
AUG 10	163,500	116(3)	158.3	3.69	5.04	4.37	5.96	2.54	3.47
AUG 12	163,500	116(3)	158.3	1.97	2.69	1.97	2.69	2.94	4.01
AUG 17	157,500	121(3)	159.1	3.73	4.90	4.14	5.44	3.24	4.26
AUG 19	158,250	130(3)	171.7	4.88	6.45	3.38	4.46	3.78	4.99
AUG 24	165,000	119(3)	163.9	2.78*	3.83	5.38*	7.41	4.14	5.70
AUG 26	158,039	118(3)	155.6	0.67	0.88	7.37	9.72	3.63	4.79

Total Input -

Water	3,868,735 gal (14,643,162 l)
Chloride	3799.4 lbs (1723 kg) as Cl
Ammonia	54.3 lbs (25 kg) as N
Nitrate	295.4 lbs (134 kg) as N
Total Phosphorus	80.1 lbs (36 kg) as P

[1] (x) Number of samples

[2] * Missing data, estimates are given

Spray Input - Water and Nutrients - Fall 1976

Spray Date	Net Gallons Delivered to Site[1]	Average Chloride Concentration (mg-Cl/1)	Total lbs. Chloride	Average Ammonia Concentration (mg-N/1)	Total lbs. Ammonia	Average Nitrate Concentration (mg-N/1)	Total lbs. Nitrate	Average Total Phosphorus Concentration (mg-P/1)	Total lbs. Phosphorus
AUG 31	167,750	116*[2]	162.4	0.60*	0.84	11.41*	15.97	4.11*	5.75
SEP 2	151,876	132(3)[3]	167.3	0.37	0.46	11.47	14.54	4.07	5.16
SEP 7	156,000	126(3)	164.0	0.51	0.66	9.60	12.50	3.12	4.06
SEP 9	156,668	93(3)	121.6	0.32	0.42	8.83	11.50	2.26	2.96
SEP 14	163,170	140(3)	190.7	0.13	0.18	10.48	14.27	2.67*	3.64
SEP 16	158,250	119(3)	157.2	0.22	0.29	10.90	14.40	3.07*	4.05
SEP 21	160,928	110(3)	147.7	0.21	0.28	11.10	14.91	3.48*	4.67
SEP 23	156,416	127(3)	165.8	2.67	3.49	10.30	13.45	3.88	5.07
SEP 28	162,756	114(3)	154.9	1.82	2.47	9.03	12.27	3.26	4.43
SEP 30	162,000	112(3)	151.4	1.36	1.84	10.00	13.52	3.40	4.60
OCT 5	158,470	115(3)	152.1	0.78	1.03	8.60	11.37	3.85	5.09
OCT 12	158,250	124(3)	163.8	0.50	0.66	10.77	14.22	4.14	5.47
OCT 14	159,636	110(3)	146.6	0.71	0.95	7.45	9.93	2.95	3.93
OCT 26	164,000	115(3)	157.4	0.56	0.77	8.20	11.22	4.17	5.71
OCT 28	164,700	105(3)	144.3	0.18	0.25	13.33	18.32	4.80	6.60
NOV 2	161,657	101(3)	136.3	0.04	0.05	14.47	19.52	4.50	6.07
NOV 9	160,153	102(3)	136.3	0.09	0.12	16.77	22.42	4.97	6.64
NOV 11	160,400	140(3)	187.4	0.08*	0.11	16.82*	22.52	5.90	7.90
NOV 16	160,800	103(3)	138.2	0.06	0.08	16.87	22.64	5.13	6.88
NOV 18	147,500	110(3)	135.4	0.26	0.32	17.17	21.14	5.33	6.56
NOV 30	153,400	110(4)*	140.8	0.35	0.45	20.20	25.86	5.88	7.53

Total Input -

Water	3,344,780 (12,659,992 1)
Chloride	3221.6 lbs.(1461 kg) as Cl
Ammonia	15.7 lbs.(7 kg) as N
Nitrate	336.5 lbs.(153 kg) as N
Total Phosphorus	112.8 lbs.(51 kg) as P

[1] Irrigation lines drained after OCT 28 to prevent freezing - volume delivery reduced by 3000 gallons

[2] * Missing data - estimates are given

[3] (x) Number of samples

Spray Date	Net Gallons Delivered to Site[1]	Average Chloride Concentration (mg-Cl/l)	Total lbs. Chloride	Average Ammonia Concentration (mg-N/l)	Total lbs. Ammonia	Average Nitrate Concentration (mg-N/l)	Total lbs. Nitrate	Average Nitrite Concentration (mg-N/l)	Total lbs. Nitrite	Average Total Phosphorus Concentration (mg-P/l)	Total lbs. Phosphorus
Dec 2	154,500	160(3)[2]	206.3	6.63	8.55	13.8	17.79	0.03	0.04	4.27	5.51
Dec 14	156,400	211(3)	275.4	0.37	0.48	16.1	21.02	0.05	0.07	4.03	5.26
Dec 16	154,700	120(3)	154.9	0.32	0.41	12.8	16.53	0.04	0.05	4.40	5.68
Dec 21	154,800	126(3)	162.8	0.06	0.07	13.9	17.96	0.00	0.00	4.00	5.17
Jan 4	154,500	128(1)	165.0	0.06	0.08	19.5	25.14	0.05	0.06	5.00	6.45
Jan 6	154,500	136(3)	175.4	0.07	0.09	21.4	27.59	0.26	0.34	5.30	6.83
Jan 11	154,500	124(3)	159.9	0.06	0.08	14.9	19.21	0.03	0.04	5.75	7.41
Jan 14	154,600	111(3)	143.2	0.05	0.06	17.0	21.93	0.02	0.03	5.16	6.66
Jan 18	167,500	107(3)	149.6	0.10	0.14	19.5	27.26	0.05	0.07	5.64	7.88
Jan 20	154,500	127(3)	163.8	0.17	0.22	21.0	27.08	0.09	0.12	5.85	7.54
Jan 25	154,500	101(3)	130.2	0.04	0.05	18.0	23.21	0.00	0.00	5.72	7.38
Jan 27	158,200	121(2)	159.8	0.12	0.15	14.4	19.01	0.06	0.08	6.16	8.13
Feb 1	154,500	105(3)	135.4	0.12	0.15	22.0	28.37	0.06	0.07	6.33	8.55
Feb 3	154,500	113(3)	145.7	0.17	0.22	22.9	29.53	0.08	0.10	6.85	8.83
Feb 8	151,200	115(3)	145.1	0.15	0.19	20.9	26.37	0.04	0.05	7.37	9.30
Feb 10	154,500	112(3)	144.4	0.34	0.44	21.1	27.21	0.07	0.09	5.02	6.47
Feb 17	159,300	154(3)	204.7	0.41	0.55	21.0	27.92	0.03	0.04	7.18	9.55
Feb 22	165,500	110(3)*[3]	151.9	0.14	0.19	20.2	27.90	0.04	0.06	6.80	9.39

Total Input -

Water	2,812,700	gal	(10,646,070 l)
Chloride	2,973.5	lbs	(1349 kg) as N
Ammonia	12.1	lbs	(5.5 kg) as N
Nitrate	431.0	lbs	(196 kg) as N
Nitrite	1.3	lbs	(0.6 kg) as N
Total Phosphorus	132.0	lbs	(60 kg) as P

[1] Net gallons delivered = pumping volume - 3000 gallons drained from system after spraying

[2] (x) Number of samples

[3] * Missing data, estimates are given

Spray Input - Water and Nutrients - Winter 1976-77

APPENDIX D

Results of Seasonal Computer Runoff Analysis

Results of Computer Runoff Analysis
Winter 1976
January 1 to February 27

Date	Runoff Volume (liters)	Chloride (gms-Cl)	Ammonia (gms-N)	Nitrate (gms-N)	Total Phosphorus (gms-P)
FEB 7-8	17,628	1,728	1.500	1.519	1.588
10	145,824	13,610	9.992	84.56	10.43
11	156,688	14,530	31.79	133.1	36.96
12	297,212	26,000	49.79	182.5	54.73
13	139,756	10,540	5.209	35.79	10.91
14	47,412	4,161	1.022	11.32	1.661
15	831,366	49,350	23.69	158.9	51.41
16	171,725	10,740	14.33	33.96	5.056
17	73,301	4,648	1.769	13.37	3.182
18	128,282	7,986	2.084	17.56	8.984
19	34,805	2,371	1.064	7.827	1.264
20	19,113	1,369	0.630	4.095	0.576
21	409,898	19,150	7.586	84.32	35.61
22	60,052	3,503	0.633	13.27	2.731
23	30,423	1,939	0.487	6.441	1.057
23-24	21,491	1,405	0.918	2.712	0.722
24	14,780	976	0.122	1.098	0.550
25	11,906	776	0.240	0.629	0.435
26	4,724	309	0.044	0.033	0.172
27	1,513	98	0.002	0.019	0.050
Totals	2,617,899 l (691,649 gal)	175,200 gm (386 lbs)	153 gm (0.3 lbs)	793 gm (1.7 lbs)	228 gm (0.5 lbs)

Results of Computer Runoff Analysis
Spring, 1976
March 2 to April 1

Date	Runoff Volume (liters)	Chloride (gms-Cl)	Ammonia (gms-N)	Nitrate (gms-N)	Total Phosphorus (gms-P)
MAR 2	234,459	13,080	18.90	3.87	8.756
3	187,580	9,032	12.78	16.97	6.670
4	173,423	9,227	23.53	14.52	6.436
5	136,396	6,844	12.66	3.988	4.556
6	91,529	5,100	1.252	11.87	2.122
7	74,494	4,396	0.210	7.611	1.099
8	41,502	2,568	- [1]	1.619	0.791
9	17,618	1,140	-	-	0.521
10	17,503	1,089	0.136	0.136	0.381
11	10,494	672	0.105	0.105	0.170
12	7,538	457	0.167	0.124	0.217
13	7,538	451	0.266	0.252	0.404
13-14	7,538	489	0.088	0.133	0.188
14	7,538	513	0.075	0.075	0.161
15	7,538	582	0.115	0.075	0.162
16	1,153	80	0.012	0.012	0.028
23	39,025	2,240	4.854	2.307	3.337
24	46,620	2,857	0.475	0.099	1.795
25	13,450	854	0.079	-	0.385
26	3,175	-	-	-	0.107
27	98,571	-	0.391	2.182	4.950
28	28,723	-	0.387	0.182	0.874
29	14,799	-	-	0.052	0.136
30	9,278	524	0.127	0.285	0.146
31	9,834	894	0.192	0.603	0.185
31-Apr 1	11,664	977	0.183	0.802	0.283
Totals	1,298,980	64,066	76.984	67.872	44.860

[1] - Data not reported by lab

Results of Computer Runoff Analysis
Spring, 1976 (Cont'd)
April 1 to April 30

Date	Runoff Volume (liters)	Chloride (gms-Cl)	Ammonia (gms-N)	Nitrate (gms-N)	Total Phosphorus (gms-P)
APR 1	24,450	3,442	0.583	1.306	0.691
2	2,144	298	0.043	0.095	0.084
6	26,054	- [1]	-	-	-
7	7,005	-	-	-	-
9	31,222	1,920	0.737	1.057	1.067
10	7,157	445	-	0.146	0.142
13	35,677	2,437	0.872	0.091	2.651
14	12,226	830	0.080	0.213	0.175
15	125,853	7,352	4.565	2.684	10.360
16	48,266	2,792	1.372	0.966	3.805
17	18,919	1,183	0.363	0.118	1.915
18	4,778	316	0.211	-	0.440
20	51,129	-	1.482	10.09	-
21	70,318	-	1.274	1.425	-
22	26,758	-	2.878	0.224	-
23	21,825	1,417	0.289	0.107	0.378
24	147,903	7,502	7.708	1.240	5.262
25	192,129	9,429	4.863	0.657	6.111
26	89,857	4,778	1.588	0.353	1.911
27	44,059	2,453	0.357	0.161	0.579
28	22,645	1,268	0.063	0.036	0.885
29	15,488	867	-	-	0.502
30	10,687	620	0.210	-	0.196
Totals	1,036,549	49,349	29.538	20.969	37.154

[1]-Data not reported by lab

Results of Computer Runoff Analysis
Spring, 1976 (Cont'd)
May 1 to May 31

Date	Runoff Volume (liters)	Chloride (gms-Cl)	Ammonia (gms-N)	Nitrate (gms-N)	Total Phosphorus (gms-P)
May 1	6,168	370	0.304	0.000	0.110
2	15,543	893	1.141	0.235	0.410
3	17,286	1,019	0.983	0.000	0.549
3-4	5,053	298	0.202	0.000	0.298
4	3,281	183	0.015	0.000	0.162
6	111,498	5,975	0.239	0.000	1.426
6-7	73,124	4,075	0.132	0.000	0.590
7	40,926	2,292	0.409	0.000	0.287
8	35,092	1,965	0.351	0.000	0.246
9	20,521	1,149	0.205	0.000	0.144
10	10,305	577	0.103	0.000	0.072
13	13,273	735	0.181	0.000	0.193
14	7,220	401	0.052	0.000	0.081
15	12,575	701	0.251	0.000	0.189
16	11,630	694	0.176	0.000	0.792
17	19,668	---[1]	---	---	---
18	4,551	---	---	---	---
Totals	407,714	21,328	4.744	0.235	5.549
Spring 1976 Totals	2,743,243[1] (724,765 gal)	134,743 gms (297 lbs)	111.266 gms (0.3 lbs)	89.076 gms (0.2 lbs)	87.563 gms (0.2 lbs)

[1] Data not reported by lab

Results of Computer Runoff Analysis
Summer 1976
June 1 to August 31

Date	Runoff Volume (liters)	Chloride (gms-Cl)	Ammonia (gms-N)	Nitrate (gms-N)	Total Phosphorus (gms-P)
JUN 24	38,724	2,804	0.013	17.24	-- [1]
Totals	38,724 (10,231 gal)	2,804 (6.2 lbs.).	0.013 (0 lbs.)	17.24 (0 lbs.)	(0 lbs.)[2]

[1]Data not reported by laboratory

[2]Estimate

Results of Computer Runoff Analysis
Fall 1976
September 1 to November 30

Date	Runoff Volume (liters)	Chloride (gms-Cl)	Ammonia (gms-N)	Nitrate (gms-N)	Total Phosphorus (gms-P)
Sep 29	122	--[1]	--	--	--
Sep 30	19,678	--	--	--	--
Oct 6	136,439	20,960	3.481	22.270	24.38
Oct 7	37,791	6,355	0.610	1.714	2.960
Oct 8	7,765	1,242	0.279	0.180	0.340
Oct 12	931	--	--	--	--
Oct 13	7,736	--	--	--	--
Oct 14	21,937	--	--	--	--
Oct 15	33,475	--	--	--	--
Oct 16	222	--	--	--	--
Oct 28	6,351	986	0.656	8.157	1.095
Oct 29	17,913	2,917	0.671	8.770	1.304
Oct 30	12,259	1,724	0.123	0.000	0.483
Oct 31	70,466	10,730	3.607	6.400	4.813
Nov 1	5,190	796	0.127	0.000	0.387
Nov 2	24,638	4,164	1.269	53.480	6.728
Nov 3	33,613	5,331	1.292	25.140	2.171
Nov 4	8,144	1,279	0.163	1.629	0.244
Nov 9-10	4,191	--	--	--	--
Nov 11	9,688	1,545	0.718	13.570	2.903
Nov 12	11,568	1,972	0.531	9.249	0.688
Nov 13	859	--	--	--	--
Nov 16	5,052	798	0.227	6.049	0.491
Nov 17	17,988	2,825	0.837	12.940	1.009
Nov 18	56,950	8,256	2.233	232.1	33.30
Nov 19	37,688	5,333	0.912	74.55	3.245
Nov 20	8,518	--	--	--	--
Nov 21	333	--	--	--	--
Nov 27	15,738	2,235	0.630	1.682	0.772
Nov 28	419	670	0.017	0.017	0.131
Totals	613,662 1 (162,130 gal)	80,118 gm (177 lbs)	18.383 gm (0 lbs)	477.9 gm (1.1 lbs)	87.44 gm (0.2 lbs)

[1]No samples taken

Results of Computer Runoff Analysis
Winter 1977
December 1, 1976 to March 16, 1977

Date	Runoff Volume (liters)	Chloride (gms-Cl)	Ammonia (gms-N)	Nitrate (gms-N)	Nitrite (gms-N)	Total Phosphorus (gms-P)
DEC 21	23,680	-[1]	-	-	-	-
DEC 22	9,346	-	-	-	-	-
JAN 20	64,707	-	-	-	-	-
JAN 21	44,550	-	-	-	-	-
JAN 27	29,873	5,613	6.984	1050	16.14	156.9
JAN 28	39,065	7,225	9.970	967.2	12.58	138.4
FEB 3	2,807	547	1.127	72.1	0.425	10.08
FEB 4	1,580	308	0.337	34.8	0.175	3.080
FEB 10	32,469	4,850	36.35	766.1	9.943	165.0
FEB 11	88,719	12,780	57.32	187.0	14.27	392.5
FEB 12	79,155	9,499	33.40	1328	10.32	242.9
FEB 13	92,024	11,280	30.95	1072	12.47	237.6
FEB 14	54,283	6,420	8.927	659.0	6.126	63.96
FEB 15	64,337	8,033	3.399	795.2	5.227	29.33
FEB 17	1,124	157	0.244	18.3	0.231	1.840
FEB 18	4,610	583	0.488	70.0	0.297	2.450
FEB 22	147,206	12,680	118.4	2228	34.24	497.5
FEB 23	342,947	33,990	101.8	3758	29.71	829.3
FEB 24	822,986	38,630	217.3	3011	56.75	1937
FEB 25	35,271	3,719	2.212	277.1	1.764	36.24
FEB 26	8,131	1,007	0.081	64.8	0.586	11.37
FEB 27	2,367	304	0.040	18.8	0.169	3.78
MAR 1	52,087	6,094	128.1	655.1	11.65	132.1
MAR 2	41,402	4,631	6.682	402.4	4.752	30.60
MAR 3	25,787	3,126	6.110	188.3	3.678	3.390
MAR 4	732,241	39,480	216.2	2450	71.40	563.3
MAR 5	39,298	4,065	2.930	256.0	4.596	8.410
MAR 6	7,358	810	0.511	48.68	0.935	1.240
MAR 7	16,116	1,651	3.316	88.41	0.851	5.411
MAR 8	124,898	10,450	21.20	606.3	6.220	31.59
MAR 9	251,179	19,800	58.63	1020	13.58	36.37
MAR 10	98,956	8,183	15.45	419.1	4.114	13.87
MAR 11	61,940	5,350	7.785	235.3	2.630	6.864
MAR 12	121,615	11,410	4.393	355.5	54.14	43.99
MAR 13	68,385	7,207	1.672	194.2	18.74	61.21
MAR 14	32,215	3,451	1.268	94.65	2.543	33.61
MAR 15	19,021	2,127	1.262	47.14	1.052	5.655
MAR 16	16,113	1,822	0.907	35.04	1.058	4.807
Totals	3,699,848 1	287,282 gms	1105 gms	23,474 gms	413 gms	5,742 gms
	(977,450 gal)	(633 lbs)	(2.4 lbs)	(51.8 lbs)	(0.9 lbs)	(12.7 lbs)

[1] No samples taken due to equipment failure

APPENDIX E

Calculation of Infiltration Estimates

Season	Spray Input[1]	Precipitation[2]		Evapotranspiration[3]		Surface Runoff	Infiltration[4]
	volume (gal)	inches	volume (gal)	inches	volume (gal)	volume (gal)	volume (gal)
Winter 1976 (Dec. 19, 1975 to Feb. 27, 1976)	1,540,837	5.0	997,984	0	0	691,649	1,847,172
Spring 1976 (Feb. 28 to May 27)	955,591	10.89	2,173,609	3.1	618,750	724,765	1,785,685
Summer 1976 (May 28 to Aug. 31)	3,868,735	7.47	1,490,988	11.6	2,315,323	10,231	3,034,169
Fall 1976 (Sept. 1 to Nov. 30)	3,344,780	3.52	702,581	2.6	518,952	162,130	3,366,279
Winter 1977 (Dec. 1, 1976 to March 16, 1977)	2,812,700	2.64	526,936	0	0	977,450	2,362,186

[1] Spray input volume from pumping records.

[2] Precipitation from station four raingage records.

[3] Evapotranspiration estimate by Thornthwaite method.

[4] Infiltration volume = (spray input volume + precipitation volume - evapotranspiration volume - surface runoff volume)

APPENDIX F

Calculation of Nutrient Reduction in the Soil

Calculation of Nutrient Reduction in the Soil by Season

$$A = \frac{M}{I} \times 10^3$$

M = Nutrient mass infiltrating =(Spray input mass + Precipitation input mass - Runoff mass), kg

I = Infiltration volume estimate, m^3

A = Anticipated infiltrated water nutrient concentration assuming no retention or removal in the soil, mg/l

$$R = \left(\frac{A - B}{A} \right) \times 100$$

R = Seasonal nutrient reduction in the soil, %

B = Average measured infiltrated water nutrient concentration at the five foot depth in the soil, or maximum seasonal concentration when a significant increasing concentration trend exits, mg/l

Assumptions:

1) Nutrient application is uniform during a season.

2) Precipitation, infiltration, and evapotranspiration are uniform during a season.

3) Reduction includes dilution in the groundwater pool, dilution from subsurface lateral flow, and removal and retention processes in the soil.

Average Measured Infiltrated Water Nutrient Concentrations at the Five Foot Depth by Season, mg/l

Season	Chloride (mg-Cl/l)	Nitrate (mg-N/l)	Nitrite (mg-N/l)	Ammonia (mg-N/l)	Total Phosphorus (mg-P/l)
Winter 1976	95	0.4	-	0.1	0.02
Spring 1976	74	0.1	-	0.2	0.01
Summer 1976	92*	0.1	-	0.2	0.03
Fall 1976	130*	0.1	-	0.2	0.04
Winter 1977	152	6.3*	0.03	0.2	0.90*

*Maximum buildup at end of season

Sample Calculation

Winter 1977

1) Chloride

$$A = \left(\frac{1349 + 1 - 287}{8,940} \right) \times 10^3 = 119 \text{ mg-Cl/l}$$

$$R = \left(\frac{119 - 152}{119} \right) \times 100 = -28\%$$

2) Nitrate

$$A = \left(\frac{196 + 5 - 23}{8,940} \right) \times 10^3 = 19.9 \text{ mg-N/l}$$

$$R = \left(\frac{19.9 - 6.3}{19.9} \right) \times 100 = 68\%$$

3) Ammonia

$$A = \left(\frac{5.5 + 0.5 - 1.1}{8,940} \right) \times 10^3 = 0.5 \text{ mg-N/l}$$

$$R = \left(\frac{0.5 - 0.2}{0.5} \right) \times 100 = 60\%$$

4) Total Phosphorus

$$A = \left(\frac{60 + 0.1 - 6}{8,940} \right) \times 10^3 = 6 \text{ mg-P/l}$$

$$R = \left(\frac{6 - 0.9}{6} \right) \times 100 = 85\%$$

APPENDIX G

Average Nutrient Concentrations in Lysimeter Samples

List of Lysimeter Locations in Ponded and Unponded Areas

Ponded	Unponded
6	18
42	22
43	32
	37
	38
	39

Lysimeter Data - Winter 1976 - Chloride

Date	Averages over Spray Site (mg-Cl/1)		Control (location 46) (mg-Cl/1)	
	3 ft depth	5 ft depth	3 ft depth	5 ft depth
DEC 19	94 (3)[1]	108 (3)	7	-
JAN 6	113 (3)	114 (5)	-	36
JAN 9	78 (2)	92 (5)	6	28
JAN 16	92 (5)	96 (7)	6	23
JAN 20	87 (4)	97 (7)	4	22
JAN 23	-[2]	95 (2)	-	-
JAN 27	89 (1)	107 (4)	-	28
JAN 30	84 (1)	103 (4)	-	37
FEB 4	-	102 (4)	-	38
FEB 6	-	98 (3)	-	35
FEB 10	-	87 (4)	-	35
FEB 13	85 (2)	81 (5)	7	32
FEB 17	92 (2)	84 (6)	5	31
FEB 20	89 (2)	89 (6)	3	30
FEB 24	85 (3)	84 (6)	1	26
FEB 27	82 (2)	85 (7)	0	17

[1] (x) Number of samples

[2] - No samples due to frozen lysimeters

Lysimeter Data - Winter 1976 - Nitrate

Date	Averages over Spray Site (mg-N/l)		Control (location 46) (mg-N/l)	
	3 ft depth	5 ft depth	3 ft depth	5 ft depth
DEC 19	0.61 (4)[1]	0.95 (3)	0.10	-
JAN 6	0.00 (3)	0.00 (5)	-	0.00
JAN 9	0 00 (2)	0.00 (5)	0.00	0.00
JAN 16	0.00 (5)	0.00 (7)	0.00	0.00
JAN 20	0.08 (4)	0.06 (6)	0.00	0.00
JAN 23	-[2]	0.03 (2)	-	-
JAN 27	1.70 (1)	0.31 (4)	-	0.01
JAN 30	1.07 (1)	0.21 (4)	-	0.02
FEB 4	-	0.38 (4)	-	0.06
FEB 6	-	0.30 (3)	-	0.02
FEB 10	-	0.57 (4)	-	0.06
FEB 13	0.80 (2)	0.58 (5)	0.05	0.05
FEB 17	0.76 (2)	0.49 (6)	0.03	0.04
FEB 20	1.02 (2)	0.61 (6)	0.02	0.06
FEB 24	0.75 (3)	0.43 (6)	0.02	0.04
FEB 27	0.57 (2)	0.41 (7)	0.02	0.05

[1] (x) Number of samples

[2] - No samples taken due to frozen lysimeters

Lysimeter Data - Winter 1976 - Ammonia

Date	Averages over Spray Site (mg-N/1) 3 ft depth	5 ft depth	Control (location 46) (mg-N/1) 3 ft depth	5 ft depth
DEC 19	0.05 (4)[1]	0.13 (3)	0.07	-[2]
JAN 6	0.63 (3)	0.08 (4)	-	0.15
JAN 9	0.14 (2)	0.04 (5)	0.05	0.05
JAN 16	0.14 (5)	0.10 (7)	0.10	0.06
JAN 20	0.14 (4)	0.07 (7)	0.12	0.05
JAN 23	-	0.06 (2)	-	-
JAN 27	0.15 (1)	0.15 (4)	-	0.00
JAN 30	0.19 (1)	0.09 (4)	-	0.03
FEB 4	-	0.09 (4)	-	0.03
FEB 6	-	0.03 (3)	-	0.01
FEB 10	-	0.05 (4)	-	0.03
FEB 13	0.10 (2)	0.05 (5)	0.15	0.03
FEB 17	0.13 (2)	0.06 (6)	0.16	0.11
FEB 20	0.07 (2)	0.03 (6)	0.16	0.00
FEB 24	0.07 (3)	0.04 (6)	0.07	0.10
FEB 27	0.17 (2)	0.08 (7)	0.22	0.12

[1] (x) Number of samples

[2] - No samples due to frozen lysimeters

Lysimeter Data - Winter 1976 - Total Phosphorus

Date	Averages over Spray Site (mg-P/1) 3 ft depth	5 ft depth	Control (location 46) (mg-P/1) 3 ft depth	5 ft depth
DEC 19	0.004 (4)[1]	0.074 (2)	*[2]	-[3]
JAN 6	0.036 (3)	0.036 (5)	-	0.019
JAN 9	0.011 (2)	0.015 (5)	0.008	*
JAN 16	0.012 (5)	0.024 (7)	0.006	0.008
JAN 20	0.026 (4)	0.042 (7)	0.010	0.060
JAN 23	-	0.008 (2)	-	-
JAN 27	0.002 (1)	0.003 (4)	-	0.002
JAN 30	0.001 (1)	0.003 (4)	-	0.002
FEB 4	-	0.006 (4)	-	0.001
FEB 6	-	0.009 (3)	-	0.010
FEB 10	-	0.012 (4)	-	0.002
FEB 13	0.004 (2)	0.005 (5)	0.003	0.004
FEB 17	0.002 (2)	0.003 (6)	0.002	0.008
FEB 20	0.002 (2)	0.002 (6)	0.004	0.001
FEB 24	0.002 (3)	0.004 (6)	0.000	0.001
FEB 27	0.008 (2)	0.001 (7)	0.000	0.000

[1] (x) Number of samples

[2] * Data not reported by lab

[3] - No samples due to frozen lysimeters

Lysimeter Data - Spring 1976 - Chloride

Date	Averages over Spray Site (mg-Cl/1) 3 ft depth	Averages over Spray Site (mg-Cl/1) 5 ft depth	Control (location 46) (mg-Cl/1) 3 ft depth	Control (location 46) (mg-Cl/1) 5 ft depth
FEB 27	82(2)[1]	85(7)	0	17
MAR 23	82(3)	85(6)	2	14
MAR 26	69(2)	81(6)	2	6
MAR 30	76(2)	79(6)	2	3
APR 6	74(2)	75(6)	4	5
APR 9	67(2)	76(5)	2	3
APR 13	70(2)	78(6)	3	4
APR 15	71(2)	76(5)	2	3
APR 20	72(2)	73(6)	3	4
APR 22	57(3)	71(6)	3	3
APR 29	61(3)	71(6)	2	3
MAY 4	59(3)	66(6)	1	2
MAY 11	58(3)	65(6)	1	2
MAY 13	58(2)	68(5)	1	2
MAY 18	54(3)	59(5)	1	2
MAY 27	66(5)	70(5)	1	2

[1] (x) Number of samples

Lysimeter Data - Spring 1976 - Nitrate

Date	Averages over Spray Site (mg-N/1) 3 ft depth	Averages over Spray Site (mg-N/1) 5 ft depth	Control (location 46) (mg-N/1) 3 ft depth	Control (location 46) (mg-N/1) 5 ft depth
FEB 27	0.57(2)[1]	0.41(7)	0.02	0.05
MAR 23	0.36(3)	0.25(6)	0.05	0.02
MAR 26	0.18(3)	0.08(6)	0.16	0.03
MAR 30	0.13(3)	0.12(6)	0.04	0.00
APR 6	0.04(3)	0.04(6)	0.02	0.00
APR 9	0.02(3)	0.04(5)	0.02	0.00
APR 13	0.02(3)	0.06(6)	0.01	0.00
APR 15	0.01(3)	0.02(5)	0.01	0.00
APR 20	0.01(3)	0.07(6)	0.03	0.01
APR 22	0.01(3)	0.07(6)	0.00	0.14
APR 29	0.01(3)	0.03(6)	0.00	0.00
MAY 4	0.03(3)	0.00(6)	0.00	0.00
MAY 11	0.01(3)	0.03(6)	0.12	0.02
MAY 13	0.00(2)	0.02(5)	0.00	0.00
MAY 18	0.00(3)	0.04(5)	0.00	0.00
MAY 27	0.11(5)	0.23(4)	0.04	0.01

[1](x) Number of samples

Lysimeter Data - Spring 1976 - Ammonia

Date	Averages over Spray Site (mg-N/1)		Control (location 46) (mg-N/1)	
	3 ft Depth	5 ft depth	3 ft depth	5 ft depth
FEB 27	0.17(2) [1]	0.08(7)	0.22	0.12
MAR 23	0.44(3)	0.16(6)	0.62	0.75
MAR 26	0.21(3)	0.16(6)	0.28	0.20
MAR 30	0.20(3)	0.19(6)	0.26	0.12
APR 6	0.25(3)	0.20(6)	0.28	0.11
APR 9	0.10(3)	0.11(5)	0.16	0.19
APR 13	0.09(3)	0.13(6)	0.15	0.16
APR 15	0.15(3)	0.12(5)	0.25	0.09
APR 20	0.42(3)	0.28(6)	0.52	0.68
APR 22	0.14(3)	0.22(6)	0.16	0.07
APR 29	0.20(3)	0.23(6)	0.24	0.35
MAY 4	0.23(3)	0.12(6)	0.26	0.18
MAY 11	0.26(3)	0.31(6)	0.41	0.41
MAY 13	0.12(2)	0.15(5)	0.16	0.12
MAY 18	0.30(3)	0.33(5)	0.32	0.35
MAY 27	0.31(5)	0.08(5)	0.65	0.50

[1] (x) Number of samples

Lysimeter Data - Spring 1976 - Total Phosphorus

Date	Averages over Spray Site (mg-P/1) 3 ft depth	5 ft depth	Control (location 46) (mg-P/1) 3 ft depth	5 ft depth
FEB 27	0.008(2)[1]	0.001(7)	0.000	0.000
MAR 23	0.006(3)	0.023(6)	0.170	0.002
MAR 26	0.015(3)	0.008(6)	0.014	0.012
MAR 30	0.013(3)	0.008(6)	0.006	0.005
APR 6	0.011(3)	0.013(6)	0.011	0.010
APR 9	0.016(3)	0.012(5)	0.017	0.001
APR 13	0.012(3)	0.007(6)	0.017	0.022
APR 15	0.017(3)	0.011(5)	0.006	0.015
APR 20	0.006(3)	0.010(6)	0.006	0.008
APR 22	0.009(3)	0.010(6)	0.013	0.009
APR 29	0.011(3)	0.011(6)	0.003	0.002
MAY 4	0.004(3)	0.010(6)	0.017	0.007
MAY 11	0.007(3)	0.009(6)	0.013	0.004
MAY 13	0.006(2)	0.010(5)	0.039	0.008
MAY 18	0.013(3)	0.013(5)	0.008	0.004
MAY 27	0.012(5)	0.022(5)	0.004	0.013

[1](x) Number of samples

Lysimeter Data - Summer 1976 - Chloride

Date	Averages over Spray Site (mg-Cl/l) Ponded Lysimeters 3 ft depth	Ponded Lysimeters 5 ft depth	Unponded Lysimeters 3 ft depth	Unponded Lysimeters 5 ft depth	Control (location 46) (mg-Cl/l) 3 ft depth	Control 5 ft depth
MAY 27	55(1)[1]	79(2)	50(3)	44(2)	1	2
JUN 3	59(1)	88(3)	50(3)	46(2)	1	2
JUN 10	59(1)	80(3)	49(3)	46(2)	1	2
JUN 17	66(1)	82(3)	51(3)	47(2)	1	3
JUN 24	70(1)	83(3)	53(3)	46(2)	2	5
JUL 1	78(1)	89(3)	92(3)	57(3)	2	6
JUL 8	76(1)	85(3)	103(3)	59(3)	2	7
JUL 15	78(1)	81(3)	96(3)	52(2)	2	7
JUL 22	84(1)	78(3)	98(3)	54(2)	2	9
JUL 29	106(2)	80(3)	102(3)	56(2)	2	10
AUG 6	119(1)	88(3)	116(3)	65(2)	3	11
AUG 12	157(1)	96(3)	126(3)	80(2)	4	11
AUG 19	124(1)	102(3)	134(3)	95(3)	5	12
AUG 26	143(2)	100(3)	131(3)	84(2)	6	13

[1](x) Number of samples

Lysimeter Data - Summer 1976 - Nitrate

Date	Averages over Spray Site (mg-N/1)				Control (location 46) (mg-N/1)	
	Ponded Lysimeters		Unponded Lysimeters			
	3 ft depth	5 ft depth	3 ft depth	5 ft depth	3 ft depth	5 ft depth
MAY 27	0.12(1)[1]	0.28(2)	0.13(3)	0.18(2)	0.04	0.01
JUN 3	0.01(1)	0.16(3)	0.00(3)	0.00(2)	0.03	0.00
JUN 10	0.00(1)	0.13(3)	0.00(3)	0.00(2)	0.13	0.05
JUN 17	0.00(1)	0.21(3)	0.03(3)	0.00(2)	0.06	0.01
JUN 24	0.02(1)	0.16(3)	0.02(3)	0.02(2)	0.03	0.03
JUL 1	0.01(1)	0.01(3)	0.06(3)	0.02(3)	0.00	0.05
JUL 8	0.01(1)	0.13(3)	0.00(3)	0.01(3)	0.01	0.05
JUL 15	0.02(1)	0.15(3)	0.00(3)	0.02(2)	0.02	0.06
JUL 22	0.02(1)	0.15(3)	0.00(3)	0.03(2)	0.02	0.05
JUL 29	0.25(2)	0.11(3)	0.01(3)	0.02(2)	0.03	0.03
AUG 6	0.16(2)	0.10(3)	0.02(3)	0.02(2)	0.03	0.01
AUG 12	0.30(2)	0.10(3)	0.15(3)	0.00(2)	0.01	0.00
AUG 19	0.09(2)	0.06(3)	0.19(3)	0.54(3)	0.01	0.00
AUG 26	0.07(2)	0.06(3)	0.07(3)	0.01(2)	0.01	0.00

[1] (x) Number of samples

Lysimeter Data - Summer 1976 - Ammonia

Date	Averages over Spray Site (mg-N/1)				Control (location 46) (mg-N/1)	
	Ponded Lysimeters		Unponded Lysimeters			
	3 ft depth	5 ft depth	3 ft depth	5 ft depth	3 ft depth	5 ft depth
MAY 27	0.23(1)[1]	0.10(2)	0.31(3)	0.10(2)	0.65	0.50
JUN 3	0.18(1)	0.10(3)	0.13(3)	0.23(2)	0.22	0.22
JUN 10	0.24(1)	0.17(3)	0.24(3)	0.24(2)	0.50	0.35
JUN 17	0.50(1)	0.22(3)	0.42(3)	0.24(2)	----[2]	0.33
JUN 24	0.29(1)	0.15(3)	0.45(3)	0.45(2)	0.72	0.47
JUL 1	0.22(1)	0.14(3)	0.36(3)	0.39(3)	0.38	0.36
JUL 8	0.27(1)	0.16(3)	0.41(3)	0.49(3)	0.58	0.11
JUL 15	0.36(1)	0.30(3)	0.49(3)	0.33(2)	1.03	0.60
JUL 22	0.35(1)	0.28(3)	0.36(3)	0.26(2)	0.56	0.47
JUL 29	0.19(2)	0.28(3)	0.51(3)	0.10(2)	1.00	0.19
AUG 6	0.90(2)	0.33(3)	0.44(3)	0.17(2)	0.79	0.24
AUG 12	0.32(2)	0.16(3)	0.37(3)	0.23(2)	0.64	0.19
AUG 19	0.22(2)	0.12(3)	0.35(3)	0.13(3)	0.65	0.12
AUG 26	0.20(2)	0.30(3)	0.39(3)	0.41(2)	0.60	0.65

[1] (x) Number of samples

[2] --- Data not reported by lab

Lysimeter Data - Summer 1976 - Total Phosphorus

Date	Averages over Spray Site (mg-P/1)				Control (location 46) (mg-P/1)	
	Ponded Lysimeters		Unponded Lysimeters			
	3 ft depth	5 ft depth	3 ft depth	5 ft depth	3 ft depth	5 ft depth
MAY 27	0.013(1)[1]	0.009(2)	0.014(3)	0.009(2)	0.004	0.013
JUN 3	0.007(1)	0.005(3)	0.008(3)	0.011(2)	0.005	0.015
JUN 10	0.017(1)	0.045(3)	0.014(3)	0.083(2)	0.079	0.047
JUN 17	0.047(1)	0.053(3)	0.048(3)	0.049(2)	0.050	0.012
JUN 24	0.047(1)	0.053(3)	0.048(3)	0.049(2)	0.050	0.012
JUL 1	0.028(1)	0.044(3)	0.007(3)	0.053(3)	0.100	0.004
JUL 8	0.030(1)	0.043(3)	0.018(3)	0.033(3)	0.028	0.037
JUL 15	0.024(1)	0.038(3)	0.024(3)	0.021(2)	0.009	0.007
JUL 22	0.028(1)	0.014(2)	0.021(3)	0.010(2)	0.006	0.045
JUL 29	0.055(1)	0.013(3)	0.018(3)	0.012(2)	0.017	0.023
AUG 6	0.063(1)	0.018(3)	0.005(3)	0.019(2)	0.020	0.029
AUG 12	0.031(1)	0.009(3)	0.012(3)	0.016(2)	0.022	0.018
AUG 19	0.013(1)	0.005(3)	0.004(3)	0.008(3)	0.013	0.014
AUG 26	0.022(2)	0.010(3)	0.005(3)	0.004(2)	0.012	0.019

[1] (x) Number of samples

Lysimeter Data - Fall 1976 - Chloride

Averages over Spray Site
(mg-Cl/l)

Date	Ponded Lysimeters			Unponded Lysimeters		
	1.5 ft depth	3 ft depth	5 ft depth	1.5 ft depth	3 ft depth	5 ft depth
AUG 26	----[1]	143(2)	100(3)	----	131(3)	84(2)
SEP 9	----	159(2)	106(3)	----	138(2)	91(2)
SEP 16	159(1)[2]	171(2)	113(2)	177(2)	160(6)	104(2)
SEP 28	164(1)	172(2)	118(3)	178(2)	174(6)	100(3)
OCT 7	160(1)	181(2)	117(3)	165(2)	178(4)	110(3)
OCT 14	144(1)	152(2)	116(3)	130(2)	168(6)	124(2)
OCT 26	142(1)	149(2)	117(3)	129(2)	168(6)	124(2)
NOV 2	139(1)	146(2)	117(3)	126(2)	156(5)	124(2)
NOV 9	140(1)	141(2)	124(3)	---(1)	158(6)	131(3)
NOV 16	----	---(1)[3]	---(1)	109(2)	150(5)	139(3)
NOV 30	135(1)	143(2)	137(3)	----	139(4)	143(3)

[1] --- Lysimeter dry, no sample

[2] (x) Number of samples

[3] -(1)Bad data point

Lysimeter Data - Fall 1976 - Chloride

Lysimeter Controls outside Spray Site
(mg-Cl/l)

Date	Locations 4.6-1.5	46-3	46-5	1-3	1-5	2-5	3-5
AUG 26	---[1]	6	13	+[2]	+	+	+
SEP 9	---	7	15	+	+	+	+
SEP 16	---	10	25	+	+	+	+
SEP 28	22	15	29	+	+	+	+
OCT 7	39	22	31	139	59	+	+
OCT 14	49	46	37	152	71	12	---
OCT 26	---	56	42	163	123	11	---
NOV 2	---	61	44	151	141	11	---
NOV 9	---	65	45	153	155	11	---
NOV 16	---	65	+	165	+	11	---
NOV 30	...	+	50	150	156	12	---

[1] --- Lysimeter dry, no sample
[2] + Lysimeter not sampled

Lysimeter Data - Fall 1976 - Nitrate

Averages over Spray Site
(mg-N/1)

Date	Ponded Lysimeters 1.5 ft depth	3 ft depth	5 ft depth	Unponded Lysimeters 1.5 ft depth	3 ft depth	5 ft depth
AUG 26	---[1]	0.07(2)	0.06(3)	---	0.07(3)	0.01(2)
SEP 9	---	0.43(2)	0.02(3)	---	0.00(3)	0.00(2)
SEP 16	1.00(1)[2]	0.71(2)	0.11(3)	0.77(2)	0.95(6)	0.02(2)
SEP 28	0.83(1)	0.54(2)	0.02(3)	0.20(2)	0.76(6)	0.31(3)
OCT 7	0.18(1)	0.22(2)	0.04(3)	0.08(2)	0.05(5)	0.11(3)
OCT 14	0.48(1)	0.16(2)	0.04(3)	0.04(2)	0.54(6)	0.02(2)
OCT 26	0.57(1)	0.55(2)	0.03(3)	0.09(2)	0.71(6)	0.05(2)
NOV 2	0.50(1)	0.20(2)	0.05(3)	0.12(2)	0.27(5)	0.03(2)
NOV 9	0.81(1)	1.63(2)	0.03(3)	0.31(2)	0.90(6)	0.22(2)
NOV 16	---	0.74(1)	0.03(3)	3.36(2)	0.85(5)	0.17(3)
NOV 30	1.02(1)	0.43(2)	0.67(3)	---	0.40(4)	0.06(3)

[1] --- Lysimeter(s) dry, no sample

[2] (x) Number of samples

Lysimeter Data - Fall 1976 - Nitrate

Lysimeter Controls outside Spray Site
(mg-N/1)

	Locations						
Date	4.6-1.5	46-3	46-5	1-3	1-5	2-5	3-5
AUG 26	---[1]	0.01	0.00	+[2]	+	+	+
SEP 9	---	0.03	0.00	+	+	+	+
SEP 16	---	0.03	0.17	+	+	+	+
SEP 28	1.02	0.07	0.01	+	+	+	+
OCT 7	0.43	0.06	0.02	0.84	0.04	+	+
OCT 14	0.20	0.06	0.01	0.06	0.02	0.31	---
OCT 26	---	0.04	0.00	0.05	0.05	0.22	---
NOV 2	---	0.01	0.00	0.28	0.01	0.07	---
NOV 9	---	0.01	0.00	0.05	0.01	0.05	---
NOV 16	---	0.05	---	0.13	---	0.08	---
NOV 30	---	---	0.03	0.34	0.00	0.02	---

[1] --- Lysimeter dry, no sample

[2] + Lysimeter not sampled

Lysimeter Data - Fall 1976 - Ammonia

Averages over Spray Site
(mg-N/1)

Date	Ponded Lysimeters 1.5 ft depth	3 ft depth	5 ft depth	Unponded Lysimeters 1.5 ft depth	3 ft depth	5 ft depth
AUG 26	----[1]	0.20(2)	0.30(3)	----	0.39(3)	0.41(2)
SEP 9	----	0.73(2)	0.23(3)	----	0.78(3)	0.36(2)
SEP 16	0.22(1)[2]	0.29(2)	0.11(3)	0.22(2)	0.27(6)	0.19(2)
SEP 28	0.12(1)	0.08(2)	0.18(3)	0.28(2)	0.73(6)	0.21(3)
OCT 7	0.33(1)	0.19(2)	0.32(3)	0.47(2)	0.51(5)	0.20(3)
OCT 14	0.22(1)	0.23(2)	0.17(3)	0.31(2)	0.46(6)	0.21(2)
OCT 26	0.19(1)	0.12(2)	0.22(3)	0.32(2)	0.29(6)	0.11(2)
NOV 2	0.11(1)	0.05(2)	0.08(3)	0.17(2)	0.16(5)	0.03(2)
NOV 9	0.08(1)	0.05(2)	0.09(3)	0.27(1)	0.20(6)	0.13(3)
NOV 16	----	0.07(1)	0.04(1)	0.08(2)	0.18(5)	0.76(3)
NOV 30	0.20(1)	0.06(2)	0.06(3)	----	0.16(4)	0.06(3)

[1]--- Lysimeter(s) dry, no sample

[2](x) Number of samples

Lysimeter Data - Fall 1976 - Ammonia

Lysimeter Controls outside Spray Site
(mg-N/l)

Date	46-1.5	46-3	46-5	1-3	1-5	2-5	3-5
AUG 26	---[1]	0.60	0.65	+[2]	+	+	+
SEP 9	---	0.90	0.24	+	+	+	+
SEP 16	---	0.40	0.02	+	+	+	+
SEP 28	1.80	0.61	0.07	+	+	+	+
OCT 7	0.40	0.78	0.14	0.65	0.24	+	+
OCT 14	0.58	0.23	0.70	0.41	0.56	0.73	---
OCT 26	---	0.29	0.19	0.34	0.29	0.34	---
NOV 2	---	0.10	0.08	0.08	0.13	0.22	---
NOV 9	---	0.14	0.07	0.10	0.09	0.10	---
NOV 16	---	0.05	---	0.10	---	0.05	---
NOV 30	---	---	0.02	0.11	0.08	0.10	---

[1] -- Lysimeter dry, no sample

[2] + Lysimeter not sampled

Lysimeter Data - Fall 1976 - Total Phosphorus

Averages over Spray Site
(mg-P/1)

Date	Ponded Lysimeters 1.5 ft depth	Ponded Lysimeters 3 ft depth	Ponded Lysimeters 5 ft depth	Unponded Lysimeters 1.5 ft depth	Unponded Lysimeters 3 ft depth	Unponded Lysimeters 5 ft depth
AUG 26	---[1]	0.022(2)	0.010(3)	---	0.005(3)	0.004(2)
SEP 9	---	0.090(2)	0.004(3)	---	0.013(3)	0.011(2)
SEP 16	*[2]	*	*	*	*	*
SEP 28	0.002(1)[3]	0.018(2)	0.012(3)	0.006(2)	0.033(6)	0.035(3)
OCT 7	0.005(1)	0.007(2)	0.028(3)	0.024(2)	0.025(5)	0.014(3)
OCT 14	0.024(1)	0.040(2)	0.036(3)	0.025(2)	0.060(6)	0.031(2)
OCT 26	0.003(1)	0.007(2)	0.106(3)	0.073(2)	0.011(6)	0.007(2)
NOV 2	0.013(1)	0.005(2)	0.199(3)	0.009(2)	0.142(5)	0.009(2)
NOV 9	0.007(1)	0.032(2)	0.008(3)	0.110(1)	0.038(6)	0.046(3)
NOV 16	---	0.008(1)	0.004(1)	0.007(1)	0.020(5)	0.138(3)
NOV 30	0.010(1)	0.031(2)	0.046(3)	---	0.019(4)	0.130(3)

[1] -- Lysimeter dry, no sample

[2] * Data not reported by lab

[3] (x) Number of samples taken

Lysimeter Data - Fall 1976 - Total Phosphorus

Lysimeter Controls outside Spray Site
(mg-P/1)

Date	46-1.5	46-3	46-5	1-3	1-5	2-5	3-5
AUG 26	---[1]	0.012	0.019	+[2]	+	+	+
SEP 9	---	0.001	0.001	+	+	+	+
SEP 16	---	*[3]	*	+	+	+	+
SEP 28	0.040	0.006	0.002	+	+	+	+
OCT 7	0.021	0.048	0.059	0.025	0.006	+	+
OCT 14	0.040	0.028	0.028	0.022	0.022	0.020	---
OCT 26	---	0.006	0.008	0.010	0.002	0.006	---
NOV 2	---	0.006	0.007	0.004	0.002	0.028	---
NOV 9	---	*	0.004	0.012	0.007	0.046	---
NOV 16	---	0.014	---	0.005	---	0.064	---
NOV 30	---	---	0.093	0.013	0.015	0.003	---

[1] --- Lysimeter dry, no sample

[2] + Lysimeter not sampled

[3] * Data not reported by lab

Lysimeter Data - Winter 1977 - Chloride

Averages over Spray Site
(mg-Cl/l)

Date	1.5 ft depth	3 ft depth	5 ft depth
NOV 30	135 (1)[1]	154 (7)	140 (6)
DEC 10	-[2]	123 (2)	179 (3)
DEC 14	210 (1)	182 (2)	218 (2)
DEC 21	-	150 (3)	169 (2)
JAN 4	-	136 (1)	178 (2)
JAN 25	-	125 (1)	142 (2)
FEB 1	-	120 (1)	115 (1)
FEB 8	-	116 (1)	115 (1)
FEB 15	-	120 (1)	-
FEB 22	-	*[3]	-
MAR 7	-	-	-
MAR 10	-	124 (2)	-
MAR 14	137 (3)	153 (4)	133 (5)
MAR 21	122 (3)	138 (8)	139 (6)
MAR 25	122 (2)	127 (8)	131 (5)

[1] (x) Number of samples

[2] - No samples due to frozen lysimeters

[3] * Data not reported by lab

Lysimeter Data - Winter 1977 - Chloride

Lysimeter Controls Outside Spray Site
(mg-Cl/l)

Date	46-1.5	46-3	46-5	1-3	1-5	2-5	3-5
	Locations						
Nov 30	+[1]	+	50	150	156	12	+
Dec 10	+	-[2]	100	147	155	11	+
Dec 14	+	-	203	219	240	14	+
Dec 21	+	-	83	145	152	12	+
Jan 4	+	-	84	136	-	12	+
Jan 25	+	-	87	120	-	12	+
Feb 1	+	-	100	120	-	5	+
Feb 8	+	-	112	115	-	12	+
Feb 15	+	-	115	115	-	12	+
Feb 22	+	-	-	*[3]	-	*	+
Mar 7	+	-	125	114	-	14	+
Mar 14	27	82	-	-	-	-	+
Mar 21	129	57	-	-	-	23	+
Mar 25	+	114	56	95	115	25	+

[1] + Lysimeter dry, no sample

[2] - No sample due to frozen lysimeter

[3] * Data not reported by lab

Lysimeter Data - Winter 1977 - Nitrate

Averages over Spray Site
(mg-N/1)

Date	1.5 ft depth	3 ft depth	5 ft depth
NOV 30	1.02 (1)[1]	0.85 (7)	0.37 (6)
DEC 10	-[2]	0.96 (2)	0.07 (3)
DEC 14	5.0 (1)	8.35 (2)	0.57 (2)
DEC 21	-	7.68 (3)	2.10 (1)
JAN 4	0.01 (1)	0.24 (2)	0.01 (2)
JAN 25	-	13.50 (1)	2.93 (2)
FEB 1	-	0.02 (1)	*[3]
FEB 8	-	1.47 (1)	2.90 (1)
FEB 15	-	14.00 (1)	-
FEB 22	-	13.40 (1)	-
MAR 7	-	-	-
MAR 10	-	7.08 (2)	-
MAR 14	7.60 (3)	4.56 (4)	5.67 (4)
MAR 21	7.69 (3)	7.38 (8)	6.32 (6)
MAR 25	9.55 (2)	5.02 (7)	6.01 (5)

[1] (x) Number of samples
[2] - No samples due to frozen lysimeters
[3] * Data not reported by lab

Lysimeter Data - Winter 1977 - Nitrate

Lysimeter Controls Outside Spray Zone
(mg-N/1)

	Locations						
Date	46-1.5	46-3	46-5	1-3	1-5	2-5	3-5
Nov 30	+[1]	+	0.03	0.34	0.00	0.02	+
Dec 10	+	-[2]	0.05	0.28	0.07	0.03	+
Dec 14	+	-	0.03	0.46	0.00	0.00	+
Dec 21	+	-	0.02	0.42	0.01	0.01	+
Jan 4	+	-	2.01	2.50	-	0.31	+
Jan 25	+	-	0.05	1.06	-	0.05	+
Feb 1	+	-	0.01	0.02	-	1.56	+
Feb 8	+	-	0.05	0.92	-	0.02	+
Feb 15	+	-	0.10	13.0	-	0.15	+
Feb 22	+	-	-	13.3	-	0.09	+
Mar 7	+	-	0.50	9.90	-	0.80	+
Mar 14	0.21	0.06	-	-	-	-	+
Mar 21	1.20	0.50	-	-	-	4.20	+
Mar 25	+	0.34	0.13	5.10	7.00	0.13	+

[1] + Lysimeter dry, no sample

[2] - No sample due to frozen lysimeter

Lysimeter Data - Winter 1977 - Ammonia

Averages over Spray Site
(mg-N/1)

Date	1.5 ft depth	3 ft depth	5 ft depth
NOV 30	0.20(1)[1]	0.12(6)	0.06(6)
DEC 10	-[2]	0.31(2)	0.06(3)
DEC 14	0.08(1)	0.38(2)	0.03(2)
DEC 21	-	0.22(3)	0.06(2)
JAN 4	0.07(1)	0.16(2)	0.14(2)
JAN 25	-	0.23(1)	0.04(2)
FEB 1	-	0.20(1)	0.04(1)
FEB 8	-	0.12(1)	0.03(1)
FEB 15	-	0.18(1)	-
FEB 22	-	0.20(1)	-
MAR 7	-	-	-
MAR 10	-	0.08(2)	-
MAR 14	0.37(3)	0.20(4)	0.22(5)
MAR 21	0.13(3)	0.15(8)	0.08(6)
MAR 25	0.11(2)	0.07(8)	0.05(5)

[1] (x) Number of samples
[2] - No samples due to frozen lysimeters

Lysimeter Data - Winter 1977 - Ammonia

Lysimeter Controls outside Spray Zone
(mg-N/1)

Date	Locations						
	46-1.5	46-3	46-5	1-3	1-5	2-5	3-5
NOV 30	+[1]	+	0.02	0.11	0.08	0.10	+
DEC 10	+	-[2]	0.02	0.18	0.10	0.12	+
DEC 14	+	-	0.04	0.15	0.07	0.10	+
DEC 21	+	-	0.05	0.22	0.09	0.08	+
JAN 4	+	-	0.02	0.18	-	0.02	+
JAN 25	+	-	0.04	0.14	-	0.04	+
FEB 1	+	-	0.10	0.20	-	0.06	+
FEB 8	+	-	0.03	0.26	-	0.10	+
FEB 15	+	-	0.01	0.18	-	0.17	+
FEB 22	+	-	-	0.09	-	0.25	+
MAR 7	+	-	0.01	0.12	-	0.20	+
MAR 14	0.77	0.17	-	-	-	-	+
MAR 21	0.21	0.09	-	-	-	0.21	+
MAR 25	+	0.02	0.05	0.25	0.14	0.12	+

[1] + Lysimeter dry, no sample

[2] - No sample due to frozen lysimeter

Lysimeter Data - Winter 1977 - Nitrite

Averages over Spray Site
(mg-N/1)

Date	1.5 ft depth	3 ft depth	5 ft depth
DEC 10	-[1]	0.00 (2)	0.00 (3)
DEC 14	0.01 (1)[2]	0.00 (2)	0.00 (2)
DEC 21	-	0.00 (3)	0.01 (2)
JAN 4	0.00 (1)	0.01 (2)	0.04 (2)
JAN 25	-	0.20 (1)	0.01 (2)
FEB 1	-	0.05 (1)	0.05 (1)
FEB 8	-	0.00 (1)	0.01 (1)
FEB 15	-	0.00 (1)	-
FEB 22	-	0.01 (1)	-
MAR 7	-	-	-
MAR 10	-	0.08 (2)	-
MAR 14	0.00 (3)	0.00 (4)	0.00 (5)
MAR 21	0.03 (3)	0.05 (8)	0.03 (6)
MAR 25	0.01 (3)	0.02 (8)	0.02 (5)

[1] - No samples due to frozen lysimeters

[2] (x) Number of samples

Lysimeter Data - Winter 1977 - Nitrite

Lysimeter Controls Outside Spray Zone
(mg-N/1)

Date	Locations						
	46-1.5	46-3	46-5	1-3	1-5	2-5	3-5
Dec 10	+[1]	+	0.00	0.00	0.00	0.00	+
Dec 14	+	-[2]	0.00	0.00	0.00	0.00	+
Dec 21	+	-	0.00	0.00	0.00	0.00	+
Jan 4	+	-	0.04	0.70	-	0.02	+
Jan 25	+	-	0.00	0.00	-	0.01	+
Feb 1	+	-	0.05	0.05	-	0.04	+
Feb 8	+	-	0.00	0.01	-	0.00	+
Feb 15	+	-	0.00	0.02	-	0.00	+
Feb 22	+	-	-	0.01	-	0.01	+
Mar 7	+	-	0.01	0.01	-	0.01	+
Mar 14	0.00	0.00	-	-	-	-	+
Mar 21	0.01	0.01	-	-	-	0.01	+
Mar 25	+	0.00	0.00	0.00	0.00	0.00	+

[1] + Lysimeter dry, no sample

[2] - No sample due to frozen lysimeter

Lysimeter Data - Winter 1977 - Total Phosphorus

Averages over Spray Site
(mg-P/1)

Date	1.5 ft depth	3 ft depth	5 ft depth
NOV 30	0.010 (1) [1]	0.021 (7)	0.088 (6)
DEC 10	- [2]	0.028 (2)	0.022 (3)
DEC 14	0.007 (1)	0.025 (2)	0.026 (2)
DEC 21	-	0.013 (3)	0.011 (2)
JAN 4	0.003 (1)	0.004 (2)	0.003 (2)
JAN 25	-	0.062 (1)	0.049 (2)
FEB 1	-	0.076 (1)	0.020 (1)
FEB 8	-	0.18 (1)	0.10 (1)
FEB 15	-	0.012 (1)	-
FEB 22	-	0.095 (1)	-
MAR 7	-	-	-
MAR 10	-	0.030 (2)	-
MAR 14	0.059 (3)	0.032 (4)	0.017 (5)
MAR 21	1.02 (3)	0.21 (8)	0.90 (6)
MAR 25	0.58 (2)	0.18 (6)	0.72 (8)

[1] (x) Number of samples

[2] - No samples due to frozen lysimeters

Lysimeter Data - Winter 1977 - Total Phosphorus

Lysimeter Controls Outside Spray Site
(mg-P/1)

	Locations						
Date	46-1.5	46-3	46-5	1-3	1-5	2-5	3-5
Nov 30	+[1]	+	0.093	0.013	0.003	0.015	+
Dec 10	+	-[2]	0.008	0.026	0.015	0.014	+
Dec 14	+	-	0.010	0.019	0.015	0.005	+
Dec 21	+	-	0.005	0.015	0.007	0.072	+
Jan 4	+	-	0.001	0.001	-	0.001	+
Jan 25	+	-	0.012	0.052	-	0.036	+
Feb 1	+	-	0.037	0.120	-	0.006	+
Feb 8	+	-	0.230	0.130	-	0.140	+
Feb 15	+	-	0.014	0.02	-	0.014	+
Feb 22	+	-	-	0.072	-	0.084	+
Mar 7	+	-	0.240	0.019	-	0.020	+
Mar 14	0.034	0.013	-	-	-	-	+
Mar 21	0.880	0.210	-	-	-	1.190	+
Mar 25	+	0.650	0.580	0.60	0.280	0.080	+

[1] + Lysimeter dry, no sample

[2] - No sample due to frozen lysimeter