WATER RECYCLING IN SEEPAGE IRRIGATION OF POTATOES

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Final Report

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TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

Seepage irrigation (subirrigation) is frequently used in Florida because of cost-effectiveness and low maintenance requirement. A confining layer or permanently high natural water table is necessary for successful seepage irrigation. Since a large portion of Florida's agriculture is located on flatwoods soils which have spodic restrictive layers and abundant water supplies, seepage irrigation is a major type of irrigation system found in Florida. This type of system with open ditches or water furrows serves as both an irrigation and drainage system depending on the weather and soil moisture conditions.

Currently, approximately 350,000 acres (142,000 ha) of vegetables, 120,000 acres (49,000 ha) of citrus and 600,000 acres (243,000 ha) of pasture are irrigated by seepage irrigation systems in Florida. These systems apply from 6 inches (.15 m) to more than 100 inches (2.54 m) of water per year based on a survey by the U.S. Geological Survey (Duerr and Trommer, 1982).

In 1988 approximately 26,500 areas of potatoes and 4,000 acres of cabbage were planted in the Tri-county (St. Johns, Putnam and Flagler) area. Most of this acreage was seepage irrigated.

STUDY AREA

This research was conducted in the Tri-county area of St. Johns, Putnam and Flagler counties. Potatoes and cabbage are two major seepage irrigated crops in this area.

The typical production system for vegetables consists of 16-row beds with water furrows spaced 60 ft (18 m) apart. Irrigation water is distributed through underground pipelines to individual water furrows. Water is applied continuously to raise and maintain the water table in the crop root zone. Flow rates are set sufficiently large so that the water table can be maintained approximately 18 inches (.46 m) below the surface of the bed during peak water use periods of the day. A management rule widely accepted for potatoes is to apply 8 gpm/acre (75 L/min ha).

Water furrow seepage irrigation systems are normally operated continuously except during rainfall. Water flows in the furrows during irrigation and results in runoff at the lower end of the water furrows. Runoff cannot be totally avoided because the water furrows must be graded to achieve drainage. Also, a certain depth of water is required in the furrows to cause water to move laterally. During routine operation on most of the potato and cabbage farms, runoff is discharged from the fields and therefore lost from the production systems.

PROBLEM STATEMENT

In St. Johns, Putnam and Flagler counties seepage irrigation systems often use groundwater as a water source. High demand for groundwater during the irrigation season creates problems associated with a decrease in potentiometric heads. Problems include increased pumping costs due to greater pumping depths, failure of centrifugal pumps as a result of cavitation, and intrusion of salt water into the aquifer.

Runoff from seepage irrigated fields significantly reduces irrigation efficiency. The efficiency of seepage irrigation systems is often estimated to be 50% but it may range much lower or higher depending on management, runoff, and other site-specific factors (Smajstrla et al., 1988).

Nitrogen (in the nitrate form) and phosphorus are the principal nutrients of concern from a water quality standpoint. Both of these nutrients can accelerate the eutrophication process of surface waters. Nitrate nitrogen is not absorbed by the soil, rather it moves readily with water and is subject to transport by both runoff and deep percolation waters. Phosphorus, on the other hand, is a highly immobile nutrient, and its movement is primarily associated with eroded soil particles. As a result, the largest removal of phosphorus can be expected after heavy rains. Since runoff from seepage irrigated farms may contain fertilizer and other chemicals, the quantity and quality of this runoff must be known for proper evaluation of nonpoint pollution from these fields. It is necessary to document these levels during normal irrigation as well as during storm events.

The management of irrigation water and daily runoff from seepage irrigated farms can potentially influence nutrient losses during rainfall runoff events. Recycling the runoff from a seepage irrigation system may change the daily losses of nitrogen and phosphorus from agricultural areas as well as cause some changes in sediment movement during storm losses.

PURPOSE AND OBJECTIVES

The purpose of this study was to evaluate the potential to conserve ground water used in seepage irrigation by implementing a recycling system for the runoff water. In addition, preliminary water quality testing was performed to better understand the influence of the recycling process on the nutrient discharge from the field.

In order to address the areas of concern, the specific objectives of this study were as follows:

1. To collect, store, and recycle runoff water from a seepage irrigated potato field,
2. To monitor the amounts of water delivered from the aquifer and from the recycling system, and to calculate the water savings due to the recycling process,
3. To monitor the energy savings due to pumping from the recycling ditch (pond) as compared to pumping from the deep aquifer, and
4. To collect and analyze water quality samples in order to determine how recycling can influence the quality of water discharged from the field.

PREVIOUS WORK

The use of a water recycling system in seepage irrigation has been demonstrated at the Hastings Agricultural Research and Education Center Yelvington Research Farm (Haman et al., 1986, 1987). The recycling system reduced groundwater pumping by 46% during 1986. During that year the automatic recycling system operated continuously throughout the potato season. The total water savings during the 1987 season were not measured since the system was not operational during part of the season. However, during the operation of the recycling system, the order of water savings was approximately the same as in 1986 (Haman et al., 1987).

Campbell et al. (1985) conducted a study of nitrogen and phosphorus losses from a sandy, high-water-table soil in the same region. A conventional seepage irrigation system on potatoes was compared with a subsurface drainage-irrigation system. They found that nitrate nitrogen and PO_4-P losses were significantly greater from the conventional seepage irrigated fields than from the subsurface drainage-irrigation field.

Water quality was monitored in the areas adjacent to fern, potato, and livestock production systems in Putnam County by the Putnam Soil and Water Conservation District (Hendrickson, 1987). Six surface water quality monitoring stations were sampled monthly for one year. The objective was to identify possible impacts of nonpoint source contributions. It was found that stormwater was the greatest carrier of nutrient loads.

RESEARCH SITE DESCRIPTION

The research site was located at the Hastings Agricultural Research and Education Center Yelvington Research Farm. The layout of the field is presented in Figure 1.

The total study site was 7.5 acres (3.0 ha) and consisted of 9 beds. The beds were 600 ft (183 m) long and 60 ft (18 m) wide, with .05% slope. Each bed contained 16 rows with water furrows between beds. Three middle beds were planted with potatoes. On both sides of these three beds were three beds planted with a cover crop. Irrigation water was delivered to

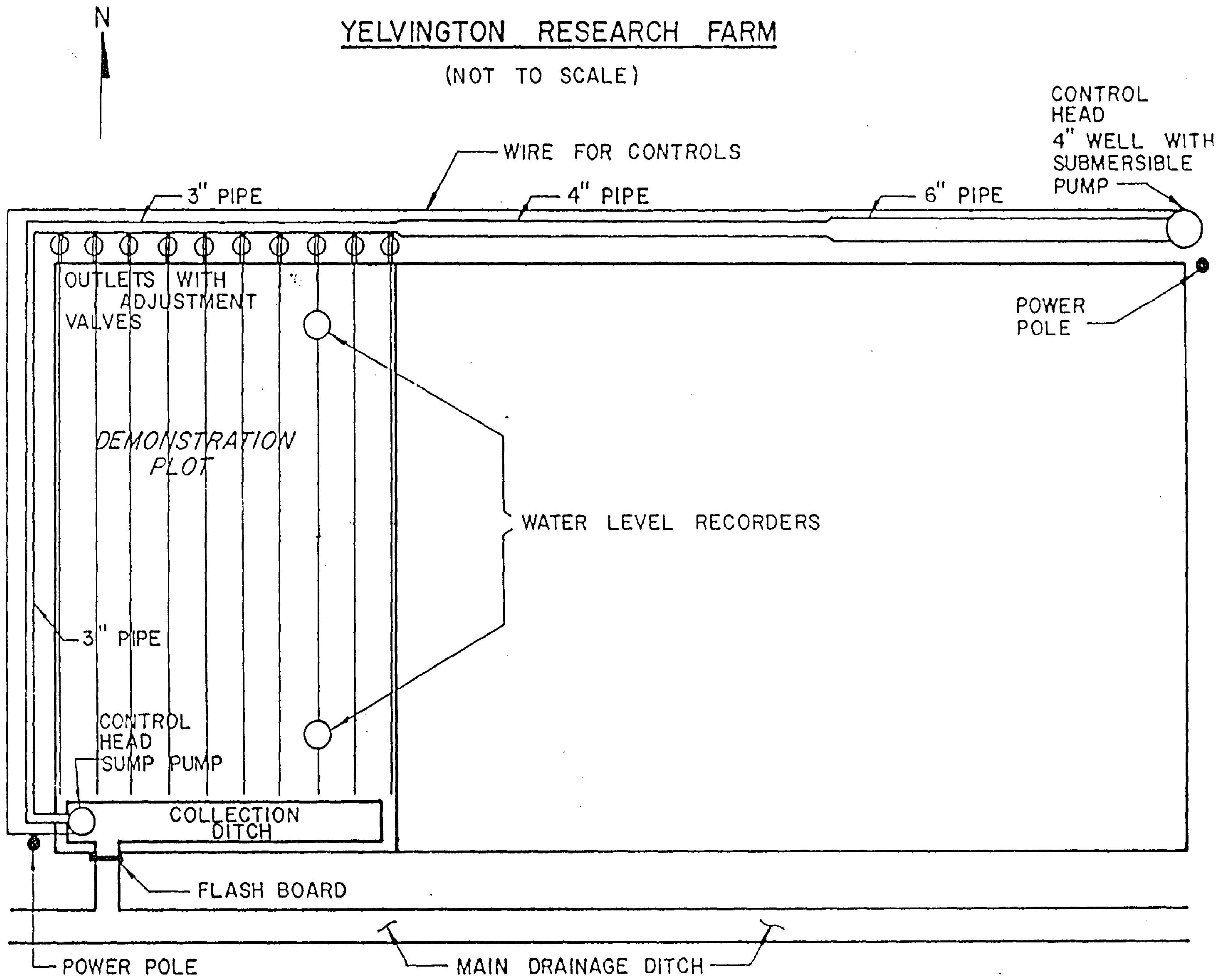

Figure 1. Layout of the research plot for the recycling project.

the field through an underground PVC pipe and distributed to the individual water furrows using PVC ball valves. The irrigation system operated continuously and was only shut off during rainfall. During routine operation on most of the seepage irrigated farms excess water is discharged from the field and lost to production. In this project a ditch parallel to the existing drainage ditch was constructed along the lower end of the research plot (Fig.1). The ditch was 600 ft (183 m) long and 8 ft (2.4 m) wide. This ditch was used as the collection pond for runoff water. An automatic drainage structure was installed for emergency drainage from the collection ditch in the event of heavy rainfall.

A sump pump and two float switches were installed in the collection ditch for runoff recycling. Two switches were installed in order to recycle only the top few inches of collected water. This arrangement avoided large fluctuations in the collected water level which might influence the water table in the field near the ditch. The sump pump flow rate was closely matched with the flow rate from the main well pump, so that recycling water was applied at the same rate as irrigation from the main pump. Less energy was required for recycling because of the reduced pumping lift. Controllers with manual and automatic (remote) capabilities were installed on both pumps.

The upper float switch switched off the main pump when the water level in the collection ditch achieved a predetermined maximum level. This float switch also started the operation of the sump pump. The sump pump continued to operate until the water level reached a predetermined minimum level. At that point, the lower float switch turned the sump pump off and restarted the main pump at the same time (see Figure 2 for the control system).

The pumping system was protected against low voltage startups which frequently occur after power failures during frequent Florida thunderstorms. Two voltage sensing relays were installed, preventing the pumps from starting when the voltage was below the safe operational level.

The amount of water applied to the field by each of the pumps was monitored using two 3-inch (.076 m) impeller flowmeters. The field water table was monitored at two points in the field using float-type water stage recorders. The water table was maintained at an average of 18 inches (.45 m) below the surface of the beds.

A few problems were encountered during the season. At the beginning of the season a flowmeter in the recycling system failed and had to be exchanged. Later, in the season the system was out of operation due to a lightning strike at the site which damaged all of the main controllers.

The amounts of nitrogen and phosphorus applied to a typical potato crop are 200 lbs/acre N (225 kg/ha), 55 lbs/acre P_2O_5 (68 kg/ha) per season, respectively. Before planting, 132 lbs/acre (148 kg/ha) of N, 18 lbs/acre (20kg/ha) of P_2O5 and 66 lbs/acre (74 kg/ha) of K_2O were applied to three beds of potatoes. This fertilizer was not applied to the cover crop. The nitrogen fertilizer was composed of 3% nitrate nitrogen and 9% ammonical nitrogen. Thirty days after planting, an additional 600 lbs/acre of 13-4-13 fertilizer was applied to the whole research site (potatoes and cover crop).

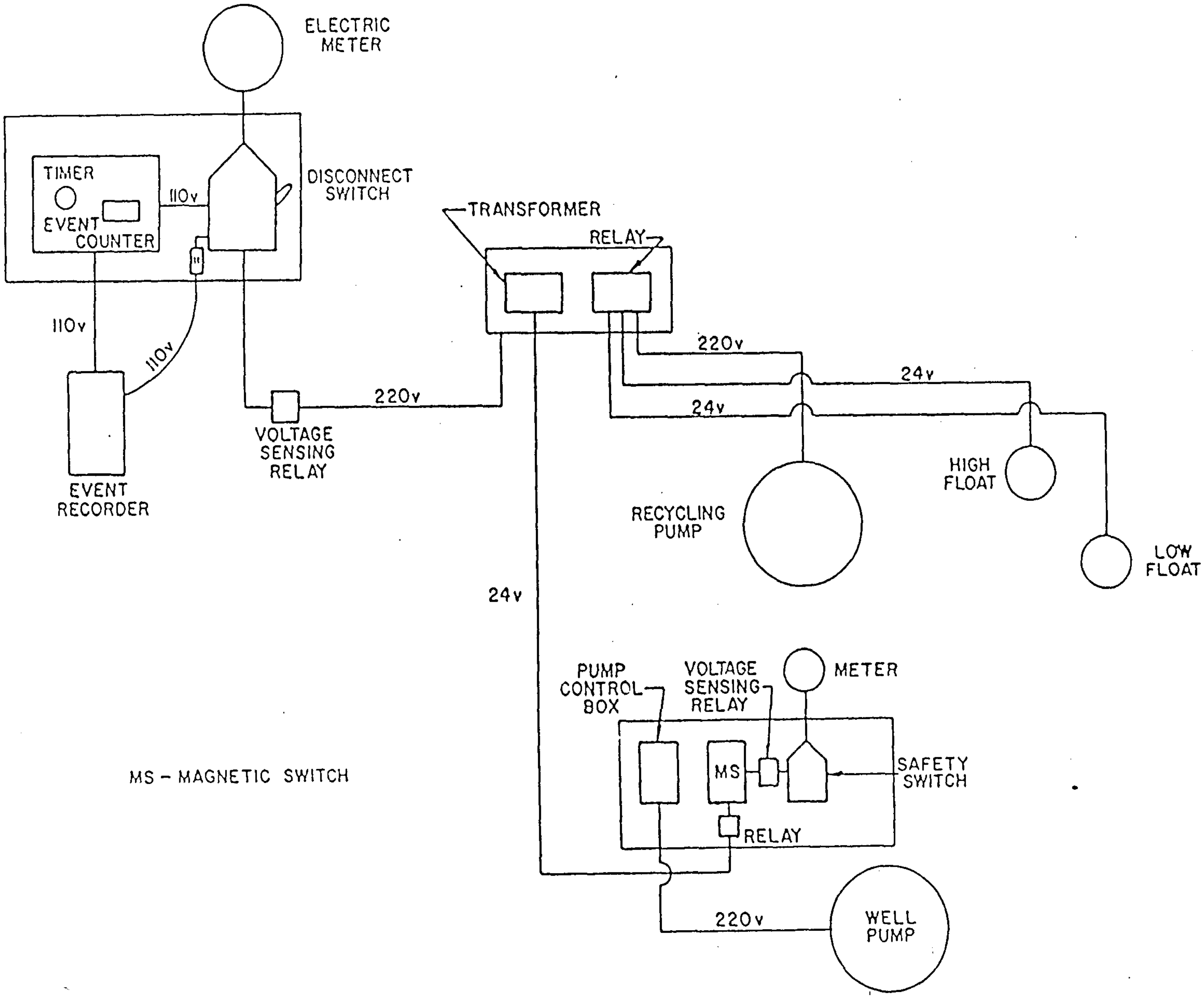

Figure 2. Irrigation pump control system.

PROCEDURE

Water Quantity Monitoring

Water delivered to the field by each pump (main and recycling) was monitored throughout the season using two 3-inch (.08m) flowmeters. Flow readings were taken daily during operation of the recycling system and water savings were calculated for each month and for the total irrigation season. The amount of electric energy used by each pump was recorded using electric meters. Cumulative hour meters were used to record hours of operation of each pump. These data were also recorded daily. Water, energy and hours of operation data and calculations of water and energy savings are presented in Appendix A.

Water Quality Sampling

Each sample was analyzed for total solids, pH, specific conductivity, nitrate, ammonia, TKN, COD, and PO_4-P. Standard methods (APHA-AWWA-WPCF) were used for these analyses.

Samples of runoff water at the research site were collected during the spring of 1988 to provide preliminary indicators of the effect of recycling on runoff water quality. Water samples were taken on April 26, May 25, June 6, June 7, June 17, and June 21. Because these samples were collected on only a few occasions, rather than by continuous monitoring and under different sampling conditions, they are only an indication of water quality in the recycling system.

Two groups of water quality samples were collected. One group was collected during irrigation, while the other was collected after rainfall, during runoff after the storms. All samples were collected from the ends of the water furrows.

The first group of water quality samples (April 26, June 7, and June 21) was taken in three different locations at different times during the irrigation cycle. At each time of sampling, one sample was taken from the water furrow between two beds of potatoes, the second sample was taken between two beds of cover crop, and the third sample was taken from the recycling ditch, next to the sump pump. Sampling continued throughout a full irrigation cycle, which consisted of one full cycle of the recycling pump and one full cycle of the main pump. Samples were taken every 30 minutes except for April 26 when they were taken every hour.

The second group of samples (May 25 and June 6) was taken after rainfall events, when the irrigation system was off. Runoff water was collected at different locations throughout the field. These samples were taken once after the rainfall events (approximately 6-8 hours after the rain) on May 25 and June 6.

Additional samples were collected on June 17, but the total irrigation cycle was not monitored on this day due to the lack of personnel. The locations of the sampling points on these days are presented in Figures B1, B2, and B3.

RESULTS

Water Savings

The recycling system resulted in a significant reduction in the amount of groundwater pumped from the aquifer. Overall, 30% less water was required during the 1988 season due to the use of recycling. These savings are smaller than the result of 1986 and 1987 (46% saving) because part of the runoff was lost due to frequent malfunctioning of the automatic drainage structure (and subsequently, less frequent operation of the recycling pump). Since the amount of discharge into the main drainage ditch was not measured, it is not possible to know how much water was lost.

During the spring of 1988, 3,126,210 gal of irrigation water were applied to the research plot. This amounts to 15.4 inches of water over the 7.5 acre study area. The recycling system provided 4.6 inches (928,570 gal) of this 15.4 inches. All water use data collected during 1988 are summarized in Appendix A.

Water Quality

Water quality data are presented in Appendices B and C. Figures C1, C2, C3, and C4 in Appendix C show the time distribution of concentrations of nitrogen and phosphorus in the runoff water during irrigation from the well and from the recycling ditch on April 26, 1988. The graphs are presented for only one sampling day. The levels of nitrogen and phosphorus were very similar during the whole season as shown in Appendix B.

It must be pointed out that these data are only preliminary and are not statistically significant. Samples were taken only once after each rainfall, and sampling did not follow the total hydrograph. More extensive water quality studies are required to verify or disprove these results. Most importantly, studies of the total runoff hydrograph for a range of expected rainstorm sizes is required.

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APPENDIX A

WATER AND ENERGY SAVINGS

IRRIGATION RECYCLING PROJECT - 1988

Water and Energy Savings

	Recycling Pump			Main Pump		
date 1988	electric KWH	water gal	operation hours	electric KWH	water gal	operation hours
4/14	93096.0	0.0	2592.4	11854.0	427690.0	1338.6
4/15	93107.0	29810.0	2601.8	11889.0	459530.0	1349.3
4/16	93121.0	59980.0	2612.4	11927.0	493720.0	1360.8
4/17	93137.0	91430.0	2624.3	11961.0	535610.0	1373.9
4/18	93156.0	131450.0	2638.8	11006.0	568740.0	1384.1
4/19	93174.0	165770.0	2651.5	11043.0	599548.0	1395.1
4/20	93179.0	198270.0	2662.7	11184.0	633130.0	1407.4
4/21	93205.0	232580.0	2674.7	12130.0	675960.0	1421.5
4/22	93218.0	263620.0	2684.9	12168.0	710490.0	1433.1
4/23	93228.0	263700.0	2693.0	12214.0	751510.0	1446.8
4/24	93243.0	263700.0	2704.2	12259.0	792830.0	1457.7
4/25	93255.0	263700.0	2713.6	12309.0	837910.0	1460.8
4/26	93277.0	272310.0	2729.9	12331.0	858080.0	1482.3
4/27	93289.0	292520.0	2738.8	12378.0	901790.0	1496.9
4/28	93301.0	320930.0	2748.1	12429.0	946660.0	1511.0
4/29	93309.0	339630.0	2754.3	12485.0	998100.0	1529.0
4/30	93319.0	361600.0	2761.4	12534.0	1042740.0	1544.5
5/1	93328.0	404440.0	2774.9	12544.0	1051090.0	1546.7
5/4	93328.0	404440.0	2774.9	12549.0	1056080.0	1548.2
5/5	93342.0	412560.0	2778.2	12615.0	1116360.0	1568.2
5/6	93357.0	430730.0	2784.9	12662.0	1167170.0	1585.2
5/7	93358.0	444570.0	2789.9	12720.0	1219410.0	1602.8
5/8	93365.0	460170.0	2795.7	12781.0	1274220.0	1621.4
5/9	93358.0	485980.0	2805.2	12840.0	1318260.0	1636.3
5/10	93388.0	507590.0	2813.2	12892.0	1365510.0	1652.1
5/11	93404.0	537710.0	2824.5	12934.0	1402920.0	1664.5
5/12	93419.0	570290.0	2836.1	12975.0	1439950.0	1676.9
5/13	93441.0	606240.0	2851.8	12099.0	1460950.0	1684.0
5/14	93465.0	653800.0	2868.5	13016.0	1475520.0	1689.0
5/18	93465.0	653800.0	2868.5	13016.0	1475520.0	1689.0
5/19	93466.0	654750.0	2868.8	13193.0	1542790.0	1711.9
5/20	93470.0	668520.0	2873.6	13151.0	1593580.0	1792.4
5/21	93471.0	668600.0	2879.7	13230.0	1663270.0	1753.1
5/22	93487.0	681380.0	2884.4	13269.0	1696960.0	1764.6
5/23	93495.0	697780.0	2890.4	13334.0	1753890.0	1784.1
5/24	93504.0	715800.0	2896.8	13395.0	1807600.0	1802.4
5/25	93508.0	724160.0	2900.1	13499.0	1811620.0	1803.7
6/01	93508.0	724160.0	2900.1	13499.0	1811620.0	1803.7
6/07	93535.0		2918.3		2372180.0	
6/17		826900.0	2947.3			1990.6
6/21	93620.0	928570.0	2979.3	13571.0	2625330.0	2055.6
Total	524.0	928570.0	386.9	1717.0	2197640.0	717.0

TOTAL WATER USED DURING 1988	3126210.0 GAL
WATER SAVED (PERCENT)	29.7 %
TOTAL ENERGY USED	2241.0 KWH
REQUIRED ENERGY WITHOUT RECYCLING	2442.5 KWH
ENERGY SAVED (PERCENT)	8.2 %

Application of 203,640 gal of water over 7.5 acres is equivalent to 1 inch depth of water

Depth of water applied from the main well during the 1988 season	10.8 inches
Depth of water applied from the recycling pump during the 1988 season	4.6 inches
Total depth of water applied to the field during the 1988 season	15.4 inches

MONTHLY AND SEASONAL WATER AND ENERGY USE
FOR THE RECYCLING PUMP

Electricity (KWH)		Water (gal)	
April	223.0	April	361600.0
May	189.0	May	362560.0
June	112.0	June	204410.0
Total	524.0 KWH	Total	928570.0 gal

Average number of gallons pumped per KWH using the recycling pump — 1772.1 gal/KWH

MONTHLY AND SEASONAL WATER AND ENERGY SAVINGS
FOR THE MAIN IRRIGATION PUMP

Electricity (KWH)		Water use	
April	680.0	April	615050.0
May	965.0	May	768880.0
June	72.0	June	813710.0
Total	1717.0 KWH	Total	2197640.0 gal

Average number of gallons pumped per KWH using the main irrigation pump — 1279.9 gal/KWH

APPENDIX B

WATER QUALITY DATA

WATER QUALITY DATA

COLUMN DEFINITIONS

Time	-	time of sampling
T.S.	-	total solids
pH	-	sample pH
S.C.	-	specific conductivity
NO3-N	-	nitrate
NH3-N	-	ammonia
TKN	-	total nitrogen
COD	-	chemical oxygen demand
PO4-P	-	phosphate

April 26, 1988

At each time three samples were taken: one from the recycling ditch (pond), one from the lower end of the water furrow between two beds of potatoes, and one from the lower end of the water furrow between two beds of cover crop.

The main pump operated from 8:50 a.m. to 11:15 a.m.
The recycling pump operated from 11:15 a.m. to 1:40 p.m.

Recycling ditch (pond)

Time	T.S. %	pH	S.C. mmho	NO3-N mg/l	NH3-N mg/l	TKN mg/l	COD mg/l	PO4-P mg/l
8:50	0.3136	8.0	NM*	2.59	3.50	3.50	NM*	0.0916
9:50	0.3136	8.2	NM	2.41	3.50	4.20	NM	0.0890
11:15	0.3038	8.6	NM	2.59	2.80	3.50	NM	0.0840
12:00	0.3038	8.7	NM	2.06	2.80	3.42	NM	0.0943
12:45	0.3080	8.7	NM	2.41	2.80	3.50	NM	0.0903
1:40	0.3234	8.2	NM	2.94	2.80	4.90	NM	0.0852

Potatoes

Time	T.S. %	pH	S.C. mmho	NO3-N mg/l	NH3-N mg/l	TKN mg/l	COD mg/l	PO4-P mg/l
8:50	0.2870	7.1	NM	2.23	2.10	2.80	NM	0.0865
9:50	0.3038	7.5	NM	2.41	3.50	4.20	NM	0.0840
11:15	0.3024	7.7	NM	2.23	2.80	4.20	NM	0.1058
12:00	0.3038	8.3	NM	2.23	3.50	4.20	NM	0.0770
12:45	0.3094	8.5	NM	2.23	2.80	3.50	NM	0.0816
1:40	0.3248	8.5	NM	2.23	2.80	4.90	NM	0.0865

Cover crop

Time	T.S. %	pH	S.C. mmho	NO3-N mg/l	NH3-N mg/l	TKN mg/l	COD mg/l	PO4-P mg/l
8:50	0.3066	8.3	NM	2.76	2.80	3.50	NM	0.0816
9:50	0.3052	7.9	NM	2.59	2.80	4.20	NM	0.0816
11:15	0.3066	7.8	NM	2.41	2.10	2.80	NM	0.0793
12:00	0.3052	7.8	NM	2.23	2.80	4.20	NM	0.0816
12:45	0.3094	7.8	NM	2.94	2.80	3.50	NM	0.0770
1:40	0.3192	7.8	NM	2.41	2.80	4.90	NM	0.1028

*NM = not measured

May 25, 1988

These water samples were taken after the storm which occured during the night. Samples were taken at 9:30 a.m. next morning All sample were taken at the same time.
Location of sampling is presented in Figure B1.

Sample I.D.	T.S. %	pH	S.C. mmho	NO3-N mg/l	NH3-N mg/l	TKN mg/l	COD mg/l	PO4-P mg/l
1	0.1846	7.54	2790.0	1.7050	0.70	1.40	25.19	0.1496
2	0.1639	7.78	1900.0	1.4970	2.10	2.80	60.45	0.0943
3	0.1870	8.27	2220.0	1.7800	1.96	2.80	246.85	0.1058
4	0.1174	7.59	1300.0	1.5550	1.40	2.10	85.64	0.0916
5	0.1590	8.29	1810.0	2.1170	2.80	3.50	100.76	0.0816
6	0.1334	7.85	1450.0	1.3730	1.40	2.10	30.23	0.0890
7	0.0871	7.63	1100.0	1.0140	1.40	2.10	90.68	0.1058
8	0.2026	8.25	2100.0	2.0270	1.40	2.80	125.94	0.1058
9	0.0757	7.47	1000.0	0.9715	2.38	2.80	35.26	0.0970
10	0.2150	7.40	2400.0	2.5170	1.40	4.59	110.83	0.1028
11	0.1231	7.22	1330.0	1.6330	2.10	2.52	85.64	0.1028
12	0.2095	7.40	2990.0	1.4930	2.80	3.50	110.83	0.0999

June 06, 1988

These water samples were taken after the storm which occured during the night. Sampling was performed at 9:30 a.m. All sample were taken at the same time. Location of sampling is presented in Figure B2.

Sample I.D.	T.S. %	pH	S.C. mmho	NO3-N mg/l	NH3-N mg/l	TKN mg/l	COD mg/l	PO4-P mg/l
1	0.1890	7.27	2100.0	1.579	2.80	3.50	89.89	0.1804
2	0.2132	6.88	2300.0	1.723	2.80	3.50	40.45	0.0943
3	0.1845	8.21	2150.0	1.800	2.80	4.59	85.39	0.0865
4	0.1839	7.87	2300.0	1.881	2.80	3.50	22.47	0.1089
5	0.1862	7.41	2190.0	2.053	2.52	3.50	130.34	0.0793

June 07, 1988

At each time three samples were taken: one from the recycling ditch (pond), one from the lower end of the water furrow between two beds of potatoes, and one from the lower end of the water furrow between two beds of cover crop.

recycling ditch

Time	T.S. %	pH	S.C. mmho	NO3-N mg/l	NH3-N mg/l	TKN mg/l	COD mg/l	PO4-P mg/l
11:00	0.1701	7.05	2250.0	6.982	3.36	3.78	58.25	0.1517
11:30	0.1864	7.47	2250.0	1.965	2.24	4.59	49.94	0.0816
12:00	0.1682	7.35	2200.0	2.195	2.24	2.52	58.25	0.0865
12:30	0.1887	7.27	2200.0	1.723	2.10	2.80	112.36	0.0852
01:00	0.1713	7.23	2120.0	2.291	2.80	3.22	48.54	0.0943
01:30	0.1885	7.42	2150.0	2.340	2.38	2.80	53.93	0.0749

potatoes

Time	T.S. %	pH	S.C. mmho	NO3-N mg/l	NH3-N mg/l	TKN mg/l	COD mg/l	PO4-P mg/l
11:00	0.1894	7.44	2400.0	2.392	2.10	3.22	29.13	0.1295
11:30	0.2730	7.54	2300.0	1.965	2.80	4.59	53.93	0.1857
12:00	0.2135	7.80	2300.0	2.450	2.52	4.59	80.90	0.1295
12:30	0.2018	8.01	2400.0	1.881	2.52	4.59	44.94	0.1222
01:00	0.1941	7.89	2250.0	1.965	2.80	4.59	58.43	0.1679
01:30	0.1757	8.03	2250.0	2.291	2.24	3.08	72.81	0.0999

cover crop

Time	T.S. %	pH	S.C. mmho	NO3-N mg/l	NH3-N mg/l	TKN mg/l	COD mg/l	PO4-P mg/l
11:00	0.2020	7.94	2250.0	1.965	2.80	4.59	777.5	0.3988
11:30	0.1840	7.77	2200.0	2.450	2.52	4.59	85.4	0.0865
12:00	0.1882	7.68	2220.0	1.881	2.80	4.59	53.9	0.1679
12:30	0.1978	8.38	2320.0	1.965	2.10	3.50	112.4	0.1105
01:00	0.1936	8.11	2310.0	1.965	2.52	3.50	85.4	0.1205
01:30	0.1926	8.45	2350.0	2.420	2.80	3.50	44.9	0.1121

June 17, 1988

This set of samples was taken at the same time.
Location of sampling points is presented in Figure B3.

sample id	T.S. %	pH	S.C. mmho	NO3-N mg/l	NH3-N mg/l	TKN mg/l	COD mg/l	PO4-P mg/l
1	0.2187	7.26	2500.0	2.420	2.80	3.50	89.9	0.0916
2	0.1889	7.64	2300.0	2.144	2.52	3.50	85.4	0.0865
3	0.1827	7.52	2290.0	2.050	2.38	4.59	53.9	0.0749
4	0.1949	7.62	2310.0	2.144	3.22	3.50	53.9	0.1028
5	0.3270	7.10	3850.0	3.470	2.94	3.50	36.0	0.0916

June 21, 1988

Recycling pump operated from 11:00 a.m. to 1:55 p.m.
Main pump operated from 1:55 p.m. to 2:35 p.m.
At 3:00 p.m., when the last sample was taken, the recycling pump was operating.

recycling ditch

Time	T.S. %	pH	S.C. mmho	NO3-N mg/l	NH3-N mg/l	TKN mg/l	COD mg/l	PO4-P mg/l
11:00	0.1893	7.54	2300.0	2.050	2.10	3.08	53.93	0.0865
11:30	0.1856	7.84	2200.0	2.392	2.24	2.80	92.23	0.0793
12:00	0.1861	7.71	2250.0	2.392	1.82	3.50	72.81	0.0793
12:30	0.1868	7.64	2100.0	2.720	2.24	3.22	97.09	0.0793
01:00	0.1822	7.92	2200.0	2.210	2.10	2.80	55.42	0.0865
01:30	0.1883	7.54	2310.0	2.606	3.36	2.80	91.35	0.0970
02:00	0.1869	7.64	2220.0	2.606	2.80	2.80	105.77	0.0943
02:30	0.1865	7.70	2150.0	2.720	2.80	2.52	63.11	0.0970
03:00	0.1888	7.82	2100.0	2.720	2.10	3.08	48.54	0.0890

potatoes

Time	T.S. %	pH	S.C. mmho	NO3-N mg/l	NH3-N mg/l	TKN mg/l	COD mg/l	PO4-P mg/l
11:00	0.1906	7.97	2300.0	2.144	2.24	3.50	24.27	0.0793
11:30	0.1717	7.97	2210.0	2.117	2.10	3.50	20.15	0.0749
12:00	0.1857	8.03	2300.0	2.720	2.52	4.34	43.24	0.0727
12:30	0.1913	7.93	2200.0	2.720	1.68	2.80	96.15	0.0749
01:00	0.1986	7.96	2180.0	2.720	2.10	3.50	144.23	0.1333
01:30	0.1908	8.02	2300.0	2.720	3.92	2.52	139.42	0.0890
02:00	0.1935	8.10	2250.0	2.720	2.80	2.24	110.58	0.0840
02:30	0.1818	8.06	2250.0	2.240	2.80	3.78	22.47	0.0816
03:00	0.1904	8.08	2290.0	2.610	2.80	2.52	100.96	0.0890

cover crop

Time	T.S. %	pH	S.C. mmho	NO3-N mg/l	NH3-N mg/l	TKN mg/l	COD mg/l	PO4-P mg/l
11:00	0.1849	8.28	2100.0	2.420	2.80	3.78	53.40	0.0816
11:30	0.1724	8.26	2210.0	2.392	2.10	2.80	72.81	0.0816
12:00	0.1722	8.42	2270.0	2.496	2.10	2.52	48.54	0.0793
12:30	0.1785	8.55	2100.0	2.913	2.10	3.50	22.47	0.0916
01:00	0.2046	8.25	2300.0	2.240	2.52	3.50	40.45	0.0865
01:30	0.1895	8.18	2350.0	2.610	2.52	2.52	86.54	0.0840
02:00	0.1321	8.77	1450.0	2.103	3.22	4.20	76.92	0.0865
02:30	0.1713	8.69	2300.0	2.496	2.10	4.90	67.96	0.0916
03:00	0.0968	8.95	1200.0	1.370	2.52	3.22	24.27	0.0840

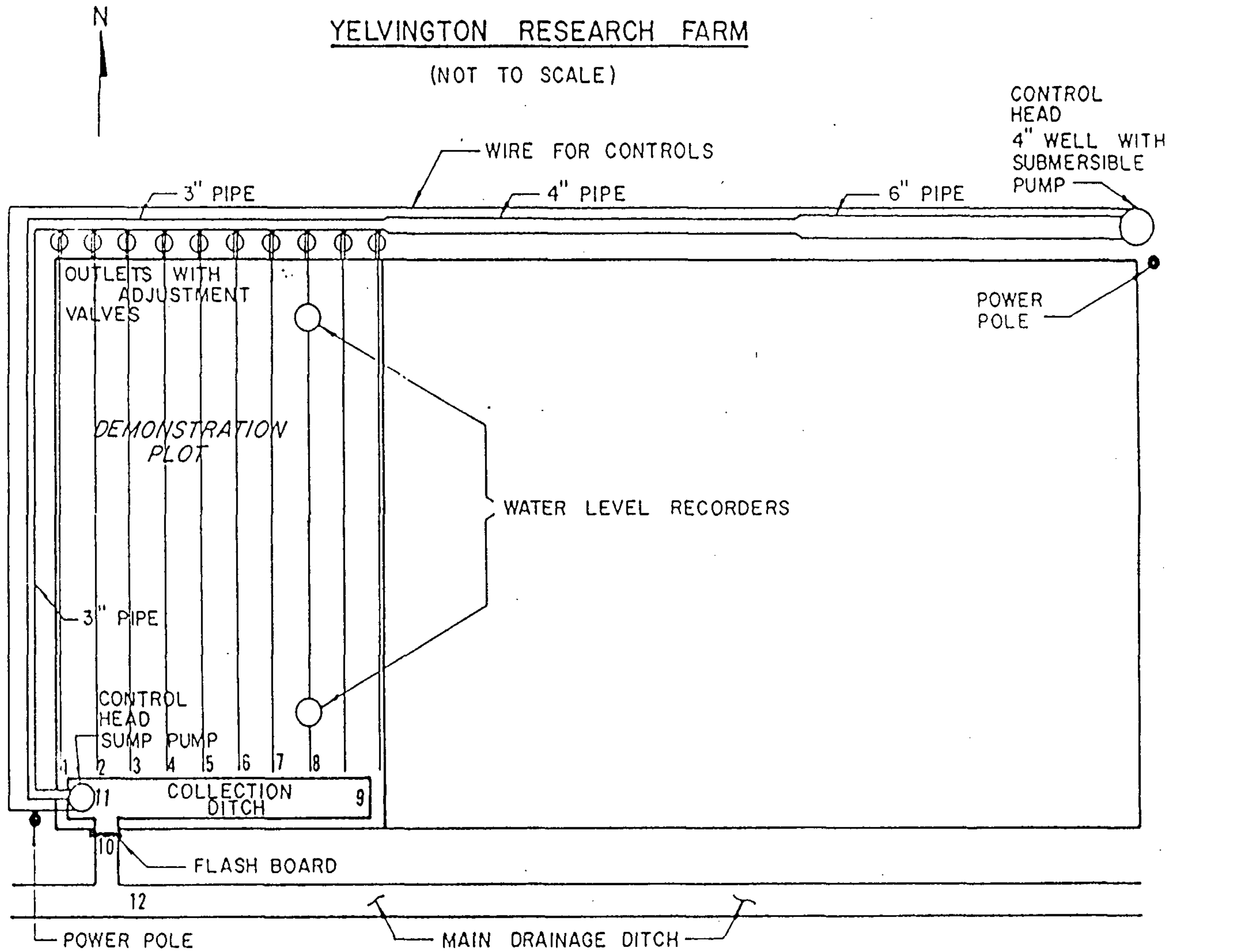
main pump sample

T.S. %	pH	S.C. mmho	NO3-N mg/l	NH3-N mg/l	TKN mg/l	COD mg/l	PO4-P mg/l
0.1894	7.51	2100.0	2.839	1.82	2.10	254.81	0.0840

recycling ditch sample *

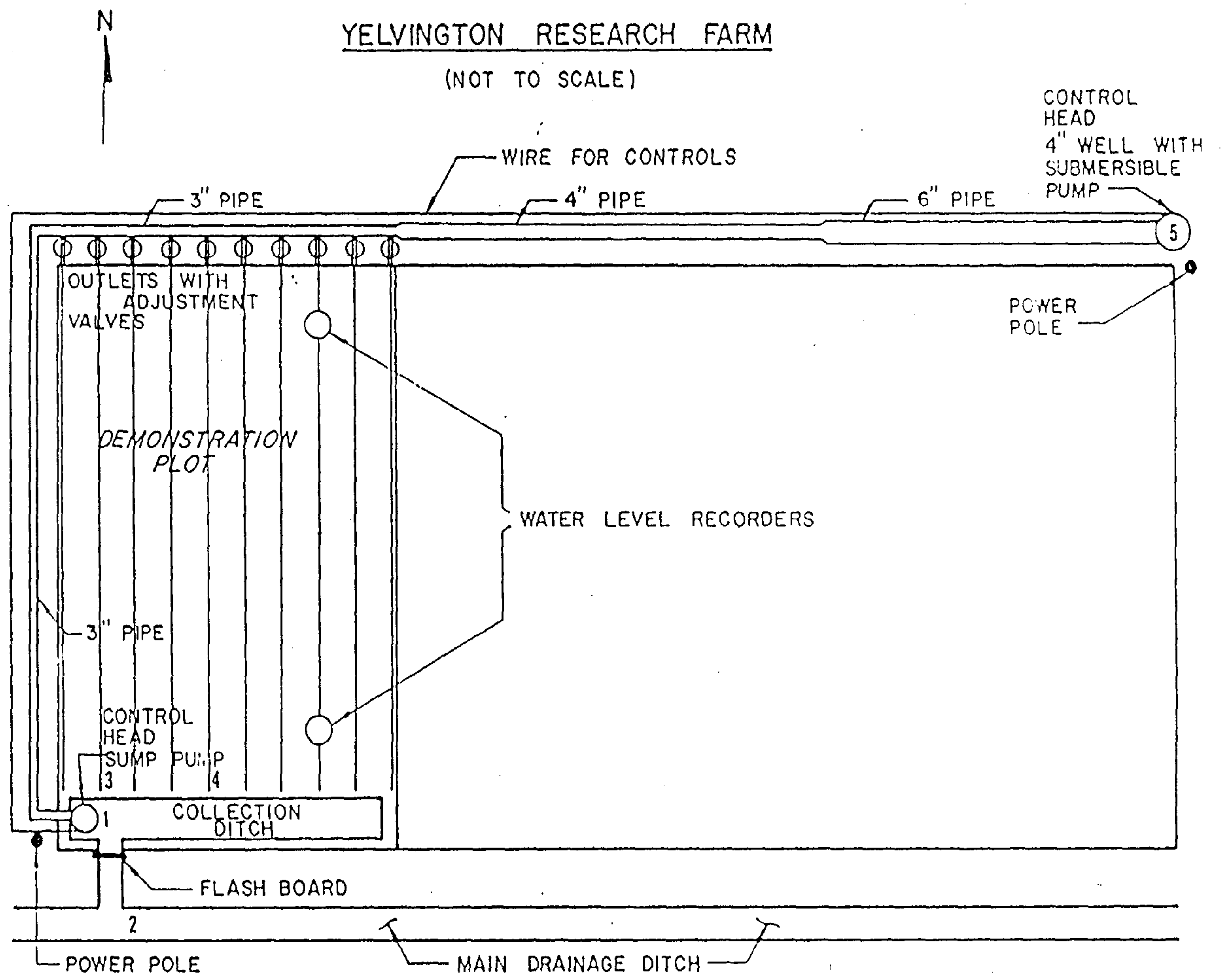
T.S. %	pH	S.C. mmho	NO3-N mg/l	NH3-N mg/l	TKN mg/l	COD mg/l	PO4-P mg/l
0.1886	7.65	2050.0	2.720	2.24	2.52	120.19	0.0793

* the sample from the recycling ditch (pond) was taken at the end of the recycling process.



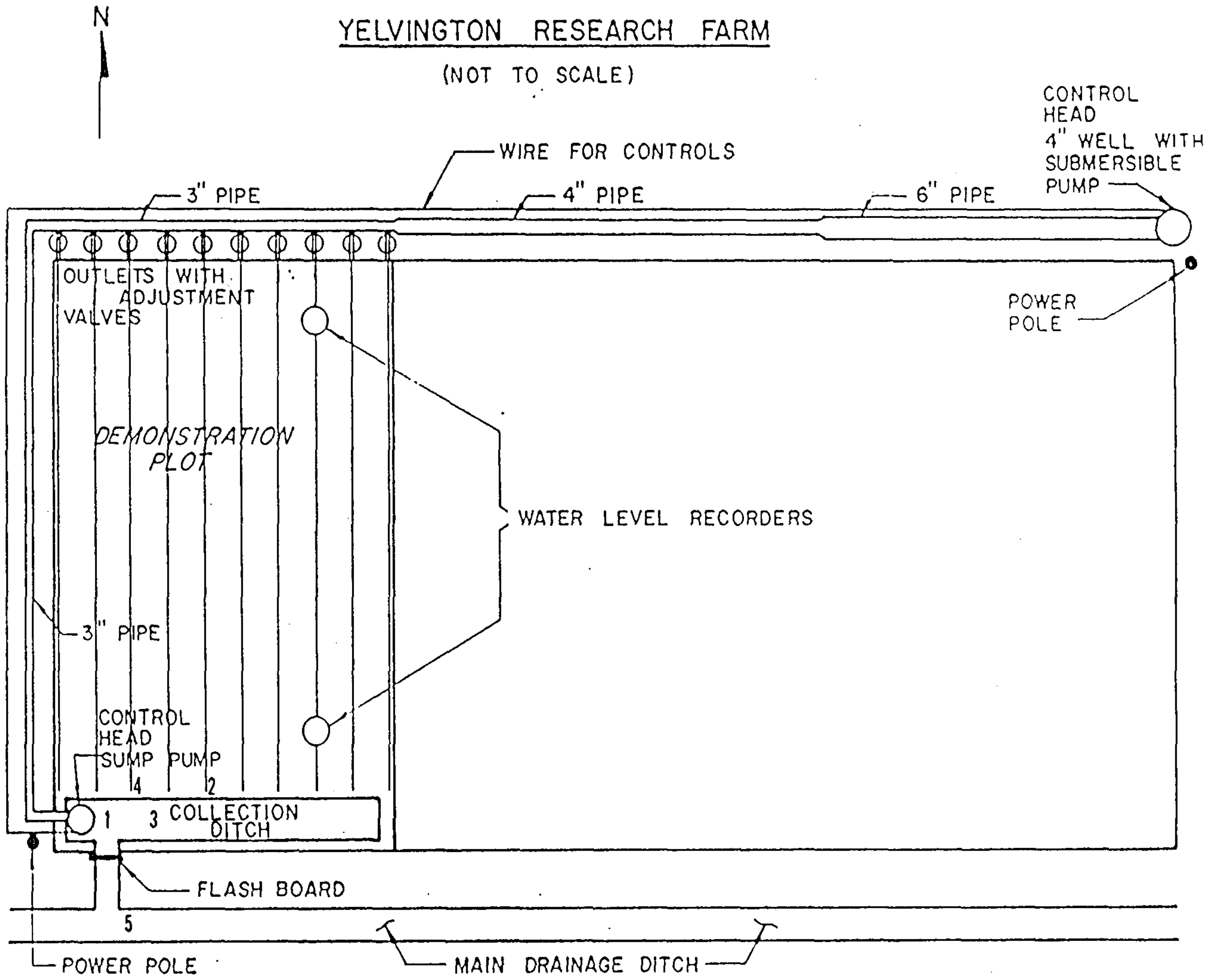
From West to East:
First three beds were planted with a cover crop,
middle three beds were planted with potatoes,
remaining three beds were planted with a cover crop.

Figure B1. Sampling locations (1-12) on May 25, 1988.



From West to East:
First three beds were planted with a cover crop,
middle three beds were planted with potatoes,
remaining three beds were planted with a cover crop.

Figure B2. Sampling locations (1-5) on June 6, 1988.



From West to East:
First three beds were planted with a cover crop,
middle three beds were planted with potatoes,
remaining three beds were planted with a cover crop.

Figure B3. Sampling location (1-5) on June 17, 1988.

APPENDIX C

NUTRIENT CONCENTRATIONS ON APRIL 26 1988

Time distribution of nutrient concentrations on April 26. Samples were taken at three different locations: from the recycling pond, from the water furrow between two beds of potatoes, and from the water furrow between two rows of cover crop. The time interval between sampling was approximately 1 hour.

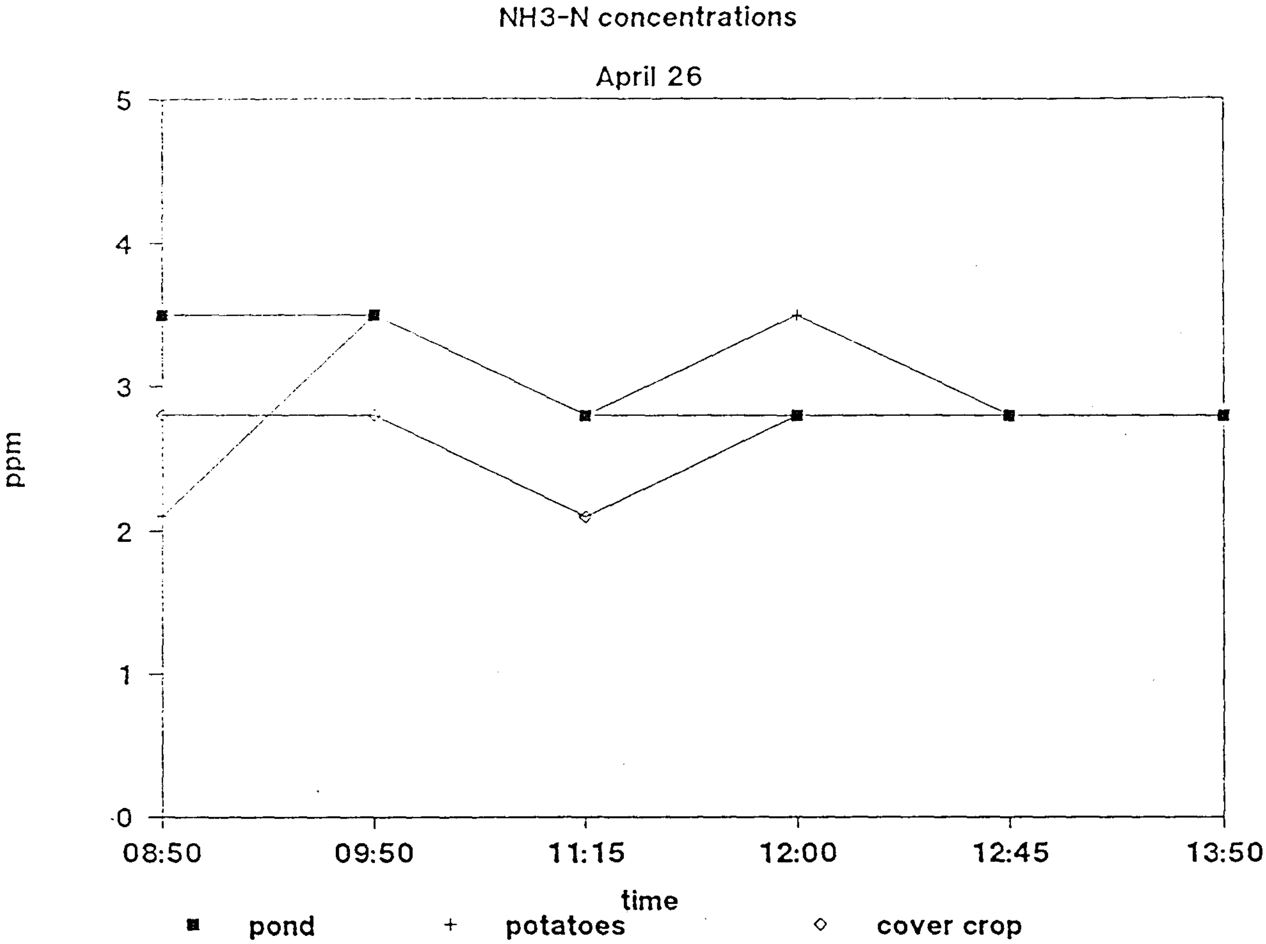


Figure C1. Time distribution of Ammonia - N on April 26, 1988.

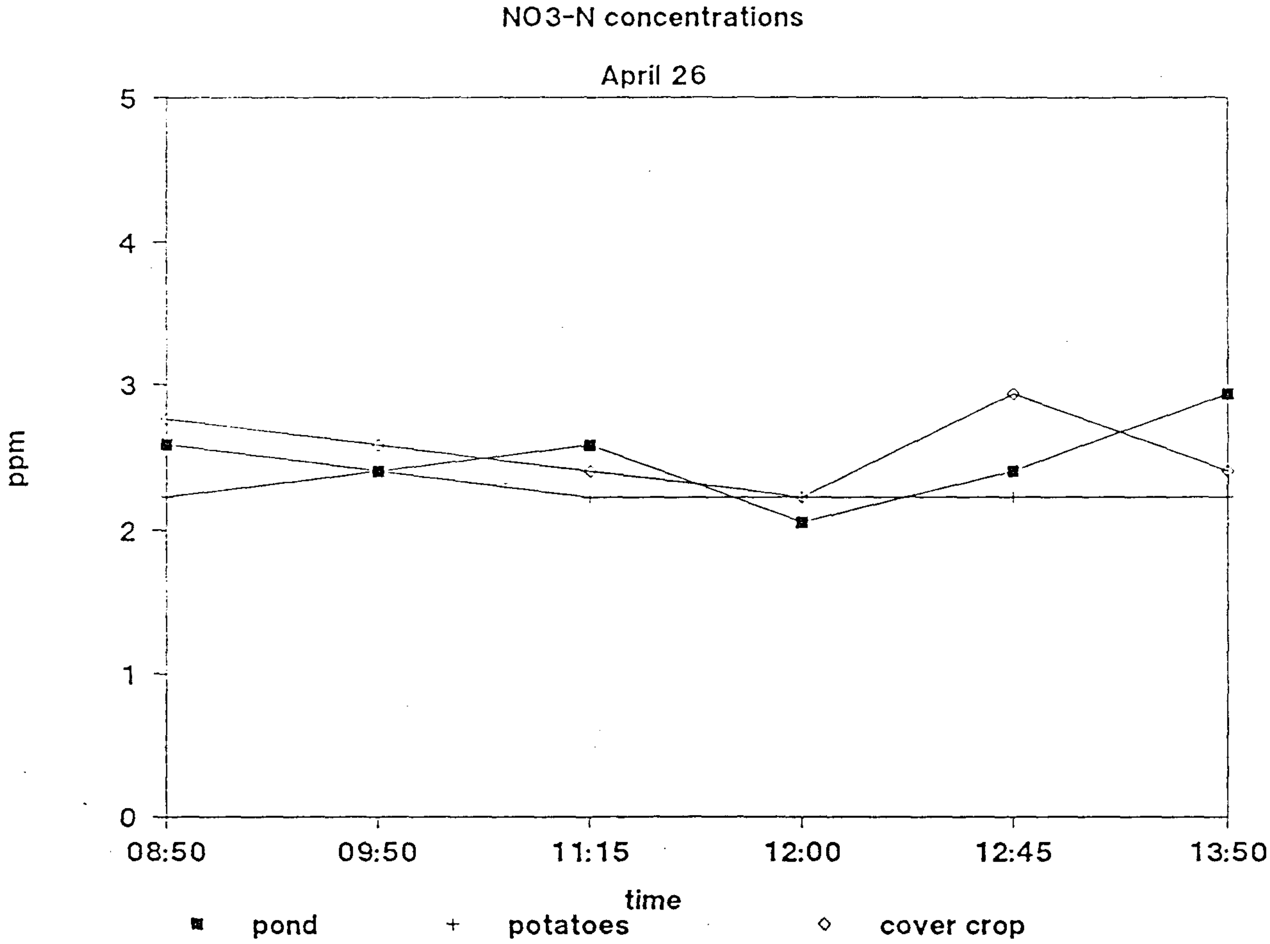


Figure C2. Time distribution of Nitrate - N on April 26, 1988.

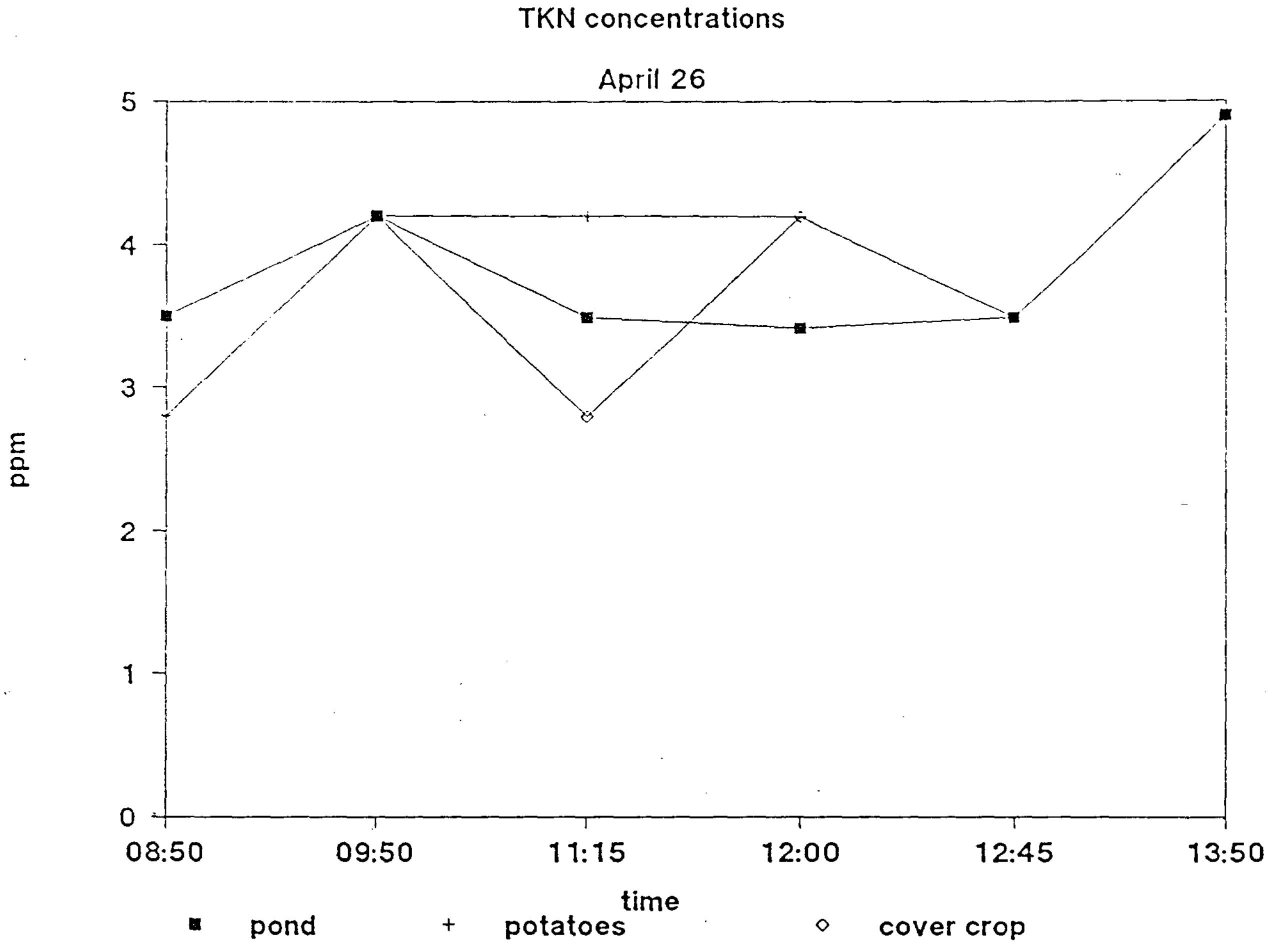


Figure C3. Time distribution of total N (TKN) on April 26, 1988.

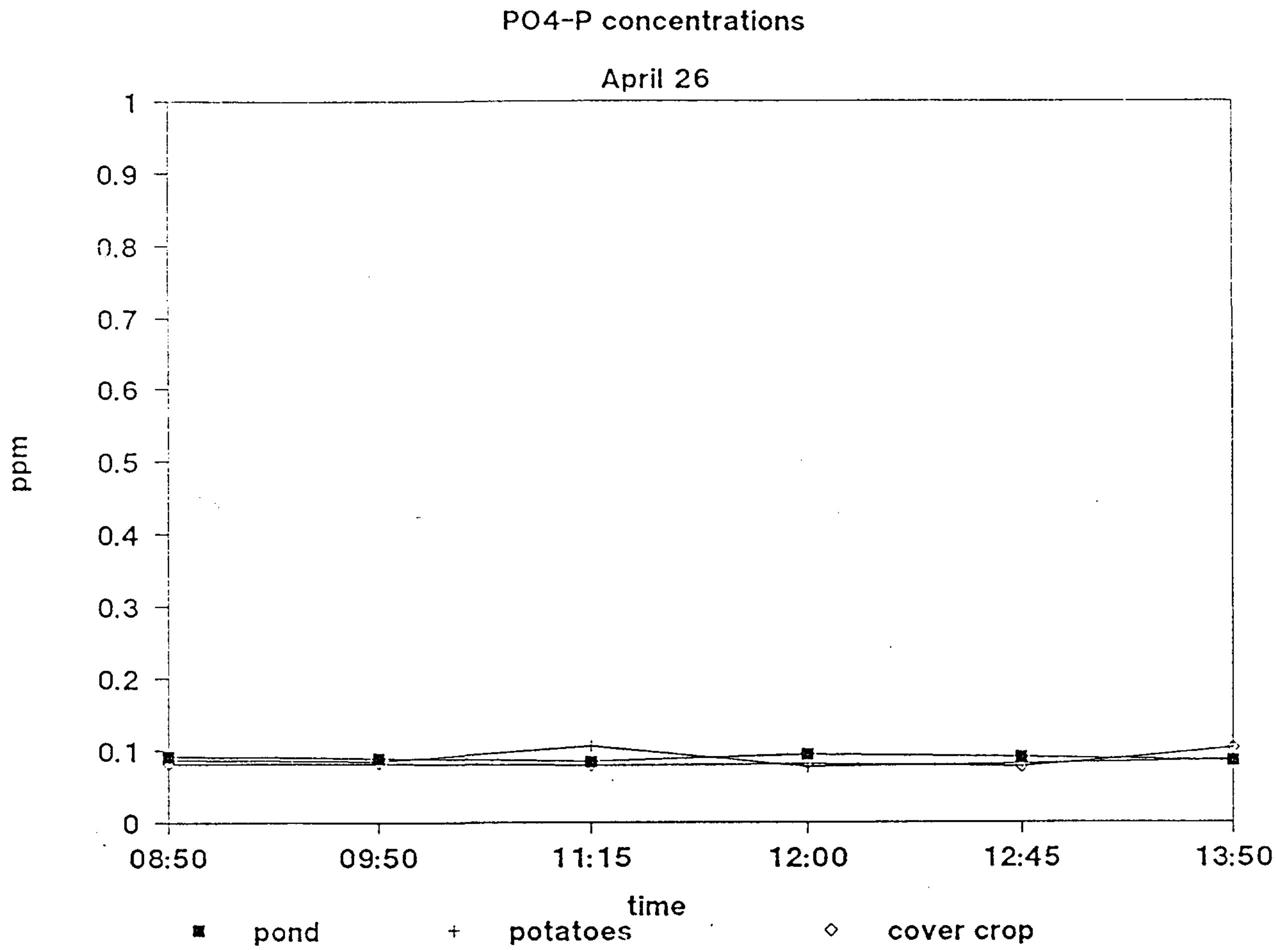


Figure C4. Time distribution of phosphate on April 26, 1988.