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Illinois River BMP Implementation & Phosphorus Management

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ILLINOIS RIVER BMP IMPLEMENTATION 7 PHOSPHORUS MANAGEMENT DEMONSTRATION TASK 5 FINAL REPORT

MSC-304

Submitted to the
Arkansas Soil and Water Conservation Commission

By

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Introduction

In February 1998 the Illinois River BMP Implementation & Phosphorus Management Demonstration was begun. The goal of the project was to implement best management practices (BMPs) on agricultural land that has the highest potential for reduction of nutrient transport, particularly phosphorus, into the Illinois River. Another parallel goal was to demonstrate the effectiveness of BMPs and to educate the public about the aquatic effects of nutrients in lacustrian systems.

In the 1996 Watershed Prioritization report prepared by David G. Parker, Hubert D. Scott, and Rodney Williams, the 37 sub-basins of the Illinois River watershed were prioritized for non-point source activities and ranked (Parker, et al, 1996). A priority ranking for each sub-basin was determined for total phosphorus, total nitrogen, and total suspended solids. Each was ranked high, medium or low priority. Three sub-basins within Washington County, the Upper Illinois, the Muddy Fork, and the Cincinnati were ranked high for total phosphorus. Several programs are currently focused on BMP implementation within the Muddy Fork sub-basin, but the Upper Illinois and the Cincinnati need BMP implementation programs. Therefore, this project used the Upper Illinois and the Cincinnati sub-basins as the general areas for BMP implementation and demonstration.

In the Upper Illinois and Cincinnati sub-basins alone, there are initial estimates of approximately 560 farm ponds. These farm ponds intercept and hold surface runoff. Most of these ponds are located within pastured areas, since their primary function is as a water source for livestock production. The BMPs that were implemented in this project related to pasture management and are considered successful tools for reducing nutrient runoff. These ponds would be first to respond to reductions in nutrient runoff. Therefore, farm ponds were monitored to determine the effectiveness of nutrient BMPs.

The original work plan was divided into eight tasks. Task 1 was to prioritize priority sub-basins within the watershed. Task 2 was to identify and delineate farm ownership and farm type within sub-basins. Task 3 was to interview land owners and collect ground truth. Task 4 was to assess sub-basin and individual farm BMP priorities. Task 5 was to assess pond water quality. Task 6 was to implement selected BMPs. Task 7 was to develop educational and technology transfer materials and Task 8 was the final report. Tasks 1 through 4, part of Task 5, and Tasks 6 through 8 were managed and implemented by the Washington County Soil and Water Conservation District (WCSWCD). The results and deliverables from those tasks have been reported elsewhere.

The original objective of Task 5 was to "quantify the reductions in nutrient transport on farms receiving BMP implementation by monitoring the algae and nutrients in farm ponds. Ponds were selected that are directly associated with BMPs implemented on the pastures in the drainage area. Water quality improvements will be measured as the percent change in pond algal production and nutrient concentrations following BMP implementation."
The Arkansas Water Resources Center (AWRC) was responsible for parts of Task 5. Task 5 was divided into five subtasks. Sub-task 5.1 was the writing the monitoring QAPP. Sub-task 5.2 was the selection of the farm ponds to be monitored. Sub-task 5.3

was the collection of site information. Sub-task 5.4 was the collection of water quality data. Finally, Sub-task 5.5 was to “calculate the percent changes in farm pond productivity following the implementation of BMPs.”

In February 2002 the AWRC submitted a work plan revision for sub-tasks 5.4 and 5.5. AWRC concluded that the original monitoring plan was not collecting adequate data to meet the objectives of task 5. According to the modified work plan, all data collection was stopped and the final report for sub-task 5.5 would detail the data results and discuss the correlations determined as well as make recommendations on pond sampling as a means of determining effectiveness of BMPs. This report is the final report for Task 5.4 and 5.5.

Methods

Five ponds were identified for study as a part of sub-task 5.2. These ponds are listed by farm identification number in table 1 along with watershed area, surface area, latitude and longitude information, and sub-basin 15 digit HUA.

Table 1. Ponds

Farm ID#	W.S.Area (Ac)	PondArea (Ac)	Latitude	Longitude	HUA
69-106	13	0.37	36:02:15	94:15:11	11110103010030
69-107	8.4	0.34	36:01:09	94:17:25	11110103010030
69-108	15	0.50	36:03:01	94:19:18	11110103010030
71-102	13	0.34	36:01:00	94:27:03	11110103050030
71-111	12	0.52	36:04:02	94:31:52	11110103050030

The pond water quality monitoring schedule was timed to correspond to the spring algal bloom as pond water warmed and spring storms transport nutrients. The original work plan scheduled six samples from each of the five ponds. Samples were to be collected each year for three years: three in the spring, two in the summer, and one in the fall. The actual monitoring consisted of ten grab samples from each pond. The sampling dates for each pond are listed in table 2.

Table 2. Pond sampling dates.

May, 1999	June, 1999	July, 1999	December, 1999	April, 2000
May, 2000	June, 2000	June, 2000	September, 2000	November, 2000

The ponds were sampled within 48 hours following runoff events. The pond water was analyzed for nitrate (NO3-N), total Kjeldahl nitrogen (TKN), phosphate (PO4-P), total phosphorus (TP), total organic carbon (TOC), specific conductance (EC), turbidity (turb), chlorophyll A (CL-A), chlorophyll B (CL-B), chlorophyll C (CL-C), hydrogen ion (pH), and in-situ temperature (TEMP). All samples were collected by a WCSWCD environmental technician and transported immediately to the AWRC Water Quality Lab (WQL) for analysis. The average values for all ten sampling events at the five ponds are listed in table 3. The complete results are provided in appendix I.

Table 3. Average values for water quality sampling results.

	BORCHART	CASELMAN	HERN	HALL	NALL
NO3-N (mg/l)	0.21	0.05	0.10	0.08	0.07
TKN (mg/l)	2.24	2.61	3.58	1.49	1.45
TP(mg/l)	1.13	0.55	0.65	0.35	0.18
PO4-P(mg/l)	0.72	0.18	0.11	0.16	0.02
TOC(mg/l)	17.36	13.60	16.26	10.97	8.33
COND(us/cm)	139.75	159.25	117.33	67.25	116.63
TURB(NTU)	45.80	17.70	124.20	26.10	41.20
CL-A(ug/l)	78.21	87.04	202.11	67.99	36.23
CL-B(ug/l)	52.57	10.67	25.11	18.53	16.51
CL-C(ug/l)	13.22	8.90	21.43	7.94	8.57
PH	7.04	6.72	7.76	7.17	7.30
TEMP(C)	18.90	19.80	18.25	19.85	19.90

In addition to physical and chemical parameters, the water samples collected from the ponds were used to determine algae genera. To ensure a consistent method for collecting pond water samples a Wheaton 12 ft. grab sampling device was used to collect composite pond samples at a distance of 10 ft. from the pond bank. Individual grab samples from each pond were combined into a single composite event sample. Grab samples were collected to represent each 500 $ft.^2$ of pond surface area. Therefore, if a pond has approximately a 2000 $ft.^2$ surface area, four grab samples were collected and combined into a single composite sample. Samples were immediately transferred to the lab where they were preserved with formazin solution and concentrated by sedimentation before being investigated. Each sample was investigated microscopically and all present algae genera were identified but not quantified. If a single genus was noted as dominant, it was identified as such. In most cases, all of the algal genera present were identified. There were a couple of samples that contained unidentifiable genera. The results of these analyses are summarized in Table 4 as the average number of algal genera identified in each of eight major divisions. The complete results are also provided in appendix II.

Table 4. Average Number of Algal Genera Identified in each Division

Division	BORCHART	CASELMAN	HERN	HALL	NALL
Chlorophyta	1.2	5.5	5.4	3.5	1.2
Bacillariophyta	0.1	0.7	0.8	0.3	0.2
Chrysophyta	0	0	0	0.4	0
Synurophyta	0	0.6	0	0.3	0
Cryptophyta	0.7	1.5	0.4	1.1	0.2
Pyrrhophyta	0.1	0.1	0.1	0.4	0.1
Euglenophyta	0.6	0.7	0.4	0.3	0.1
Cyanophyta	0.2	1.1	2.9	0.8	0.9
total #	2.9	10.2	10	7.1	2.7

Discussion

Although samples were taken at ten separate times, average values will be used for comparison purposes in this discussion. The original objective may have been to use the discrete measurements to quantify the changes in time. However, several factors make that sort of interpretation very difficult. First of all, each of the samples was taken directly after runoff events. This was done because transport from the fields was assumed to be the primary source of nutrients. However, there was no effort to quantify the runoff event intensity, duration, or quantity. Each of these factors would be expected to have a greater impact on the transport than the time of the year. Thus comparisons between samples taken in June from one year to the next would have little meaning. Second, there was no correlation made between the application of fertilizer in the watersheds and the timing of the runoff events. For comparison between ponds on a single runoff event the most important factor is probably the length of time to the preceding fertilizer application. Third, the timing of the sampling time relative to the timing of the runoff event varied from pond to pond and with each event. Since nutrient uptake or absorption can take place very rapidly, inconsistencies in timing add a great deal of uncertainties. The best way to minimize these and other induced uncertainties is to use the average value of the measured parameters. However, even this approach should be viewed with caution and the understanding that the results may not be representative.

The original work plan for this project stated that the sampling results would be used to “calculate the percent changes in farm pond productivity following the implementation of BMPs.” Farm pond productivity can be estimated using biomass production. Biomass is a quantitative measure of the mass of living organisms in a given volume. The most accurate way to measure biomass is to measure dry weight, ash-free dry weight, or volume of living organisms (20^{th} edition APHA Standard Methods). None of these methods were employed for this project. Some of the indirect methods that can be used include estimating biomass using average percentages of chlorophyll, nitrogen, or carbon. These indirect measurements are subject to interference, non-representative averages, and oversimplification errors. For example, organic nitrogen or organic carbon can be used to estimate biomass but do not differentiate between living or dead biomass. They do not take into account the different percentages between different types or even species of phytoplankton and cannot distinguish between what is growing in the pond versus what was washed of the fields during a runoff event.

Nonetheless, indirect methods are the only ones that can be employed for this project. Table 5 lists the ponds in order of decreasing average values of chlorophyll-a, total Kjeldahl nitrogen, and total organic carbon. Of these rankings, chlorophyll-a is probably the most informative.

Table 5**.** Descending rankings by indirect measures of productivity

BY CL-A	BY TKN	BY TOC
HERN	HERN	BORCHART
CASELMAN	CASELMAN	HERN
BORCHART	BORCHART	CASELMAN
HALL	HALL	HALL
NALL	NALL	NALL

Very little information was gathered about management practices on the pond watersheds. There was little or inconsistent data on slopes, land cover, animal cover, or fertilizer applications. There was no information on BMPs adopted other than the adoption of nutrient management plans (NMP) and fencing around the ponds. There was no information provided about the age of the ponds or past management practices. The two exceptions to this are anecdotal information provided by the WCSWCD technician (Dunnegan, personal communication). According to the technician, the Hall pond "was a new pond from the beginning of the sampling period and it has been under management practices that included grazing animals, fertilizer, etc." Also, "we can't say this for the Nall pond, which had no management of any kind including simple things like mowing."

Perhaps the only useful information available from the pond watersheds was a single soil nutrient test performed when the NMP was adopted. The timing of these soil tests relative to the water sampling is unknown. Nor is there information about additional fertilizer applications that would have affected these numbers. The soil test results are summarized in Table 6. These results are ranked by descending soil test phosphorus (STP) levels.

Table 6**.** Soil test results ranked by descending STP

	P (lb/acre)	K (lb/acre)	N (lb/acre)
CASELMAN	371	213	4
BORCHART	266	636	37
HERN	185	679	15
HALL	157	368	10
NALL	28	168	3

One way to assess the management practices effectiveness is to look at the relation between the soil test nutrients and the total nutrient values in the pond. However, this does not take into account one key element that is probably the controlling factor for nutrient levels in the ponds. That factor is the pond sediments. The quantity of pond sediments, the nutrient concentrations of pond sediments, and other physical/chemical relationships that effect nutrient partitioning from the sediments are extremely important for understanding the nutrient dynamics of ponds. This factor was not taken into account when designing the sampling for this project. This makes it very difficult to make the connection between management practices and pond nutrient levels. Table 7 lists the soil and pond nutrients and N/P ratios.

Table 7. Comparison between soil and pond nutrient values

	Soil P (lb/acre)	Pond P (mg/l)	Soil N (lb/acre)	Pond total N (mg/l)	Soil N/P	Pond N/P
CASELMAN	371	0.55	4	2.66	0.01	5.75
BORCHART	266	1.13	37	2.46	0.14	4.41
HERN	185	0.65	15	3.69	0.08	5.84
HALL	157	0.35	10	1.57	0.06	11.37
NALL	28	0.18	3	1.52	0.11	7.86

One method of assessing pond productivity as a function of management practices is by relating productivity rankings to soil test nutrients. Table 8 lists the descending rankings of productivity and soil test nutrients. Nall has without exception the lowest productivity, the lowest soil nutrients, and the lowest pond nutrients. The other correlations don't hold as well.

Table 8. Descending rankings of productivity and soil test nutrients.

BY CL-A	BY TKN	BY TOC	BY SOIL TEST P	BY SOIL TEST N
HERN	HERN	BORCHART	CASELMAN	BORCHART
CASELMAN	CASELMAN	HERN	BORCHART	HERN
BORCHART	BORCHART	CASELMAN	HERN	HALL
HALL	HALL	HALL	HALL	CASELMAN
NALL	NALL	NALL	NALL	NALL

Productivity is a measure of how much biomass is produced in a pond. From the above information it can be seen that for these ponds productivity is probably related to soil nutrients. However, the effects of management practices, age of the pond (sediment interactions), and induced errors from sampling inconsistencies complicate the relationship. Productivity should be related to nutrient inputs so long as the biological system is in balance and other factors such as space or competition don't become limiting. When nutrients become overabundant excess growth can occur and the system becomes imbalanced or eutrophied. Eutrophication is often signaled by a few species taking advantage of excess nutrients by high growth rates. They in turn out compete other species for limited light, space, or other factors. The end effect is often a large biomass with low diversity as measured by the number of different genera. The ponds measured in this study show increasing productivity with increasing numbers of genera. This is probably indicative that they have not reached advanced eutrophication stages. This may be due to the relatively young age of the ponds or other factors not measured. The Borchart pond is perhaps the exception to this trend and may be in the early stages of eutrophication. The relationship between productivity and number of alga genera identified is shown in Table 9.

Table 9. Descending rankings of nutrients and average number of alga genera identified.

BY SOIL TEST P	BY SOIL TEST N	BY POND P	BY POND TOTAL N	BY AVERAGE # OF GENERA
CASELMAN	BORCHART	BORCHART	HERN	CASELMAN
BORCHART	HERN	HERN	CASELMAN	HERN
HERN	HALL	CASELMAN	BORCHART	HALL
HALL	CASELMAN	HALL	HALL	BORCHART
NALL	NALL	NALL	NALL	NALL

Eutrophication is the process where excess nutrients cause excessive growth. An imbalance of nutrients can cause problems in water bodies as well. Certain genera of algae for instance tend to thrive in waters that have an imbalance of nitrogen and phosphorus. Most plants must rely on nitrogen in the forms of nitrate or ammonia. Blue-green algae or cyanophyta have the ability to fix nitrogen from atmospheric nitrogen. They can thus continue to grow in waters that have low levels of nitrate but sufficient levels of phosphorus. Evidence has shown that waters that have nitrate to phosphate ratios less than 10 tend to favor the growth of blue-green algae (Smith, 1998). Other studies have shown that high rates of animal manure application to fertilize pastureland can result in a build up of soil phosphorus (VanDevender, 2001). Table 10 shows the soil test N to P ratio and the water test N to P ratio. Table 11 shows the inverse relationship between the number of blue-green genera and soil test N to P ratios.

Table 10. The soil test N to P ratio and the water test N to P ratio.

	Soil N/P	Pond N/P
CASELMAN	0.01	5.75
HALL	0.06	11.37
HERN	0.08	5.84
NALL	0.11	7.86
BORCHART	0.14	4.41

Table 11.The inverse relationship between the number of blue-green genera and soil N/P

Decreasing Average # Of Blue-Green Genera	Increasing Soil N/P Ratio
HERN	CASELMAN
CASELMAN	HALL
NALL	HERN
HALL	NALL
BORCHART	BORCHART

Blue-green algae blooms are becoming more and more of a problem across this country. Blue-greens can be responsible for taste and odor problems in drinking water supplies. They are also responsible for dense surface mats of algal blooms that make recreational waters unusable. Perhaps the most significant impact from blue-green algae has been from toxic algal blooms. Certain species of blue-greens can create powerful nerve or hepatic (liver) toxins. They have been responsible for marine killer tides such as the infamous red tides that cause massive fish kills. They have been shown to cause marine mammal die kills. An emerging phenomenon is toxic algal blooms in estuaries and fresh waters. Phiesteria is a blue-green that has caused massive fish kills and some human health problems in the Carolinas. Other genera such as Microcystis, Aphanizomenon and Anabaena have been known to cause livestock deaths from drinking pond waters. In the past the incidence of problems has been low, but widespread. The incidences are increasing in number as the levels of P in surface waters are increasing. New findings have shown that the problem is a greater threat than it has been considered in the past. Studies have indicated that low levels of these toxins are present in nearly all of surface water impoundments (Carmichael, 2000). Other studies have shown that low levels of these toxins ingested over long periods of time can cause severe health problems and especially liver cancers (Codd, 2001; Kuiper-Goodman, 1999). These studies are generating increased interest in studying the effects of phosphorus and nitrogen/ phosphorus imbalances on the preferential growth of blue-green algae.

This study identified the predominant algae genera in each water sample. In two ponds, (Hern and Castleman) several samples showed the dominant genera was either Microcystis or Anabaena. Both of these are genera known to produce toxins in the right situation. These toxins may not have been present in high enough concentrations to cause livestock or fish deaths, but could still contribute to their poor health.

Conclusions

This project has shown some relationships do exist between nutrients in soils, management practices, and the health of the farm ponds. However, the relationship of farm ponds to on-farm management practices is very complex. A project that attempts to determine the effectiveness of BMPs on pond water quality must take into account many factors and must use sufficient samples to characterize the natural variability of the system.

Perhaps the most important information from this project is that toxin forming blue-green algae are found in our farm ponds and may be linked to the use of animal manure fertilizers. These toxins may be causing health effects in farm livestock that are not being attributed to the pond water. If farm ponds are an indicator of the effects of management practices in our watersheds, these results may be pointing to a problem in our surface drinking water sources.

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APPENDIX I

	DATE	no3-n	TKN	TP	PO4-P	TOC	COND	TURB	CL-A	CL-B	CL-C	PH	TEMP	tkn+no3/tp	no3/po4
BORCH	5/14/1999	0.4	1.14	0.18	0.009	8.67	.	47	12.14	6.777	9.974	7.2	22	6.7	44.4
BORCH	6/17/1999	0	.	2.715	2.14	24.12	170	5	8.175	3.909	3.571	6.8	24		0.0
BORCH	7/1/1999	1.231	3.69	2.73	2.475	36.85	210	5	164.5	58.59	22.22	7.1	23	2.6	0.5
BORCH	12/6/1999	0.021	1.7	0.28	0.048	18.57	220	32	28.39	4.703	0.141	7.4	6	6.1	0.4
BORCH	4/17/2000	0.068	2.19	1.06	0.244	10.6	.	93	238	63	12	7.1	14	2.1	0.3
BORCH	5/1/2000	0.02	2.45	1.02	0.089	11.4	105	118	80	34	37	7	19	2.4	0.2
BORCH	6/12/2000	0.003	1.67	0.46	0.073	8.91	75	73	20.64	275.8	.	7	24	3.6	0.0
BORCH	6/22/2000	0.191	2.27	2.04	2	22.82	92	8	12.15	4.524	1.528	7.1	23	1.3	0.1
BORCH	9/25/2000	0.006	1.68	0.18	0.029	18.48	136	19	21.67	3.426	2.489	6.8	17	9.3	0.2
BORCH	11/6/2000	0.2	3.4	0.65	0.125	13.17	110	58	196.4	70.99	30.05	6.9	17	5.4	1.6
BORCH	ave	0.214	2.243	1.132	0.7232	17.36	139.8	45.8	78.21	52.57	13.22	7.04	18.9	4.4	4.8
CASEL	5/14/1999	0	2.02	0.545	0.205	13.21	.	18	13.09	5.298	6.956	7.2	25	3.7	0.0
CASEL	6/17/1999	0	.	0.535	0.154	10.93	700	10	26.4	16.37	1.762	6.7	25		0.0
CASEL	7/1/1999	0.28	1.68	0.825	0.483	13.1	57	9	25.47	12.69	14.43	6.8	23	2.3	0.6
CASEL	12/6/1999	0.026	2.99	0.385	0.111	14.59	110	16	43.39	8.581	2.653	6.6	9	7.8	0.2
CASEL	4/17/2000	0.004	2.67	0.42	0.045	14.5	.	17	80	9	10	7.5	15	6.4	0.1
CASEL	5/1/2000	0.008	2.58	0.6	0.025	14.6	80	27	87	13	13	6	19	4.3	0.3
CASEL	6/12/2000	0.007	4.48	0.55	0.057	18.79	95	29	400.9	.	14.14	7.3	24	8.2	0.1
CASEL	6/22/2000	0.126	1.93	1.08	0.668	11.59	67	14	58.35	9.069	4.843	7.1	23	1.9	0.2
CASEL	9/25/2000	0.026	2.27	0.27	0.004	12.12	88	14	87.4	9.538	11.85	6	17	8.4	6.5
CASEL	11/6/2000	0.007	2.89	0.33	0.006	12.57	77	23	48.44	12.53	9.39	6	18	8.8	1.2
CASEL	ave	0.048	2.612	0.554	0.1758	13.6	159.3	17.7	87.04	10.67	8.901	6.72	19.8	5.7	0.9
HERN	05/14/99	0	0.94	0.15	0.031	12.52	.	31	18.32	8.88	13.78	7.6	22	6.3	0.0
HERN	06/17/99	0	.	0.7	0.11	12.34	550	54	336.9	39.94	19.08	7.8	22		0.0
HERN	07/01/99	0	3.13	0.69	0.121	8.4	35	52	155.9	60.31	68.67	6.6	25	4.5	0.0
HERN	12/06/99	0.15	3.04	1.11	0.187	22.41	75	64	.	.	.	6.5	5	2.9	0.8
HERN	04/17/00	0.837	5.7	0.7	0.052	17.5	25	869	138	26	5		17	9.0	16.1
HERN	05/01/00	0	4.48	0.74	0.132	21.6	120	38	6	7	12	9.1	20	6.1	0.0
HERN	06/12/00	0	5.38	0.7	0.051	17.62	115	44	264.3	36.78	13.75	8.3	24.5	7.7	0.0
HERN	06/22/00	0.055	1.23	0.39	0.338	10.99	28	13	26.5	5.709	2.369	7.8	23	3.2	0.2
HERN	09/25/00	0	5.28	0.85	0.05	24.69	56	48	722.9	23.25	44.37	7.8	14	6.2	0.0
HERN	11/07/00	0	3.08	0.46	0.008	14.51	52	29	150.2	18.16	13.84	8.3	10	6.7	0.0
HERN	ave	0.104	3.584	0.649	0.108	16.26	117.3	124.2	202.1	25.11	21.43	7.756	18.25	5.8	1.7
JHALL	5/14/1999	0.46	2.62	1.895	1.113	17.07	.	27	27.4	15.54	13.27	8.1	24	1.8	0.4
JHALL	6/17/1999	0	.	0.17	0.06	5.98	300	32	32.51	5.981	3.82	6.6	25		0.0
JHALL	7/1/1999	0.071	0.87	0.385	0.239	8.6	32	16	22.66	4.073	3.81	6.7	24.5	2.3	0.3
JHALL	12/6/1999	0.003	1.55	0.14	0.003	9.65	30	45	128.4	20.04	7.89	7	8	11.1	1.0
JHALL	4/17/2000	0.002	1.98	0.21	0.024	17.6	.	36	197	57	17	7.3	15	9.4	0.1
JHALL	5/1/2000	0.002	2.13	0.3	0.014	17.4	40	51	129	46	20	7.3	19	7.1	0.1
JHALL	6/12/2000	0.003	1.38	0.09	0.006	11.68	35	16	57.38	10.9	6.391	7.2	25	15.3	0.5
JHALL	6/22/2000	0.031	0.78	0.021	0.139	8.47	34	6	16.62	5.128	1.518	7.3	23	37.2	0.2
JHALL	9/25/2000	0.128	1.26	0.18	0.003	8.2	36	21	34.52	11.12	3.347	7.3	17	7.1	42.7
JHALL	11/6/2000	0.05	0.87	0.08	0.003	5.07	31	11	34.38	9.541	2.327	6.9	18	10.9	16.7
JHALL	ave	0.075	1.493	0.347	0.1604	10.97	67.25	26.1	67.99	18.53	7.937	7.17	19.85	11.4	6.2
NALL	5/14/1999	.	3.32	0.54	0.103	13.53	.	47	78.27	18.61	14.03	9.3	25		
NALL	6/17/1999	0.007	.	0.06	0.013	10.81	510	12	12.38	4.764	2.456	7.1	27		0.5
NALL	7/1/1999	0.067	0.63	0.115	0.006	7.51	42	24	10.1	2.588	7.303	6.7	24	5.5	11.2
NALL	12/6/1999	0.141	0.88	0.165	0.008	10.17	80	96	.	.	.	6.6	8	5.5	17.6
NALL	4/17/2000	0.003	1.16	0.1	0.002	10.4	.	13	130	80	17	7.3	15	11.6	1.5
NALL	5/1/2000	0.133	1.16	0.22	0.004	11.9	80	64	25	13	16	7.2	19	5.4	33.3
NALL	6/12/2000	0.086	1.23	0.16	0.007	4.68	65	42	24.33	4.351	2.062	7.1	24	7.8	12.3
NALL	6/22/2000	0.045	0.72	0.12	0.025	7.97	45	27	4.309	14.93	.	7.4	23	6.0	1.8
NALL	9/25/2000	0.072	3.31	0.25	0.058	4.32	66	55	36.63	8.532	7.445	7.4	16	13.3	1.2
NALL	11/6/2000	0.091	0.61	0.08	0.01	2	45	32	5.026	1.802	2.231	6.9	18	7.7	9.1
NALL		0.072	1.447	0.181	0.0236	8.329	116.6	41.2	36.23	16.51	8.565	7.3	19.9	7.9	9.8

	AVERAGE	no3-n	TKN	TP	PO4-P	TOC	COND	TURB	CL-A	CL-B	CL-C	PH	TEMP	No3+tkn/t	No3/po4
NALL		0.07	1.45	0.18	0.02	8.33	116.63	41.20	36.23	16.51	8.57	7.30	19.90	7.86	9.83
JHALL		0.08	1.49	0.35	0.16	10.97	67.25	26.10	67.99	18.53	7.94	7.17	19.85	11.37	6.20
BORCH		0.21	2.24	1.13	0.72	17.36	139.75	45.80	78.21	52.57	13.22	7.04	18.90	4.41	4.78
HERN		0.10	3.58	0.65	0.11	16.26	117.33	124.20	202.11	25.11	21.43	7.76	18.25	5.84	1.71
CASEL		0.05	2.61	0.55	0.18	13.60	159.25	17.70	87.04	10.67	8.90	6.72	19.80	5.75	0.92

APPENDIX II

Number of Genera in each division

			Chlorophyta	Bacillariophyta	Chrysophyta	Synurophyta	Cryptophyta	Pyrrhophyta	Euglenophyta	Cyanophyta	total #	Dominant genus
borchart	15-May-99	99-2835	1	0	0	0	2	0	0	0	3	
borch	17-Jun-99	99-3211	2	0	0	0	0	0	1	0	3	
borch	01-Jul-99	00-014	1	0	0	0	1	0	1	1	4	
borch	06-Dec-99	826-01	0	0	0	0	0	0	0	0	0	
borch	17-Apr-00	1143-01	0	0	0	0	0	0	0	0	0	
borch	01-May-00	1194-01	2	1	0	0	0	0	1	0	4	
borch	12-Jun-00	1320-03	2	0	0	0	1	0	0	0	3	Chroomonas
borch	22-Jun-00	1375-02	0	0	0	0	0	1	1	0	2	
borch	25-Sep-00	10216-04	2	0	0	0	2	0	2	1	7	
borch	06-Nov-00	10289-01	2	0	0	0	1	0	0	0	3	Cryptomonas
ave			1.2	0.1	0	0	0.7	0.1	0.6	0.2	2.9	
castleman	16-May-99	99-2836	8	0	0	1	1	0	0	1	11	Cryptomonas
castleman	17-Jun-99	99-3212	6	0	0	1	2	0	1	1	11	Cryptomonas
castleman	01-Jul-99	00-015	5	2	0	1	1	0	0	2	11	
castleman	06-Dec-99	826-04	1	1	0	0	2	0	1	0	5	
castleman	17-Apr-00	1143-03	5	1	0	1	2	1	0	0	10	2: Mallomonas, Chroomonas
castleman	01-May-00	1194-04	1	0	0	0	2	0	1	0	4	Cryptomonas
castleman	12-Jun-00	1320-02	8	2	0	1	2	0	0	2	15	Anabaena
castleman	22-Jun-00	1375-05	5	0	0	0	2	0	3	3	13	Anabaena
castleman	25-Sep-00	10216-01	12	1	0	1	1	0	1	2	18	
castleman	06-Nov-00	10289-03	4	0	0	0	0	0	0	0	4	
ave			5.5	0.7	0	0.6	1.5	0.1	0.7	1.1	10.2	
hern	18-May-99	99-2838	1	0	0	0	1	1	0	0	3	unknown green
hern	17-Jun-99	99-3214	3	1	0	0	0	0	0	2	6	Microcystis
hern	01-Jul-99	00-016	12	1	0	0	0	0	2	3	18	Scenedesmus
hern	06-Dec-99	826-03	4	1	0	0	0	0	0	3	8	Microcystis
hern	17-Apr-00	1143-05	8	2	0	0	1	0	0	3	14	
hern	12-Jun-00	1320-04	9	1	0	0	0	0	1	2	13	Scenedesmus
hern	01-May-00	1196-01	3	0	0	0	0	0	0	2	5	Scenedesmus
hern	22-Jun-00	1375-01	5	1	0	0	1	0	1	3	11	Scenedesmus
hern	25-Sep-00	10216-05	3	0	0	0	1	0	0	6	10	
hern	07-Nov-00	10291-01	6	1	0	0	0	0	0	5	12	Scenedesmus
ave			5.4	0.8	0	0	0.4	0.1	0.4	2.9	10	
hall	17-May-99	99-2837	2	0	0	0	1	0	1	0	4	volvox
hall	17-Jun-99	99-3213	2	0	1	1	2	0	0	0	6	Mallomonas,Strauastrum
hall	01-Jul-99	00-013	3	0	1	1	2	0	0	0	7	Cryptomonas
hall	06-Dec-99	826-05	4	1	0	0	0	0	0	0	5	unknown green
hall	17-Apr-00	1143-04	8	2	0	0	1	1	0	5	17	Tetraedron
hall	01-May-00	1194-02	2	0	0	0	0	0	0	0	2	Tetraedon
hall	12-Jun-00	1320-05	6	0	1	1	1	2	1	1	13	
hall	22-Jun-00	1375-03	1	0	1	0	2	1	1	0	6	
hall	25-Sep-00	10216-03	4	0	0	0	1	0	0	1	6	Gomphosphera
hall	06-Nov-00	10289-04	3	0	0	0	1	0	0	1	5	Scenedesmus
ave			3.5	0.3	0.4	0.3	1.1	0.4	0.3	0.8	7.1	
nall	14-May-99	99-2834	9	2	0	0	1	0	0	5	17	Scenedesmus
nall	17-Jun-99	99-3210	1	0	0	0	0	0	1	1	3	Chroococcus
nall	01-Jul-99	00-012	0	0	0	0	0	1	0	0	1	
nall	06-Dec-99	826-02	0	0	0	0	0	0	0	0	0	
nall	17-Apr-00	1143-02	1	0	0	0	0	0	0	0	1	
nall	01-May-00	1194-03	0	0	0	0	0	0	0	0	0	
nall	12-Jun-00	1320-01	0	0	0	0	0	0	0	2	2	Blue Green Colony very small
nall	22-Jun-00	1375-04	0	0	0	0	1	0	0	1	2	
nall	25-Sep-00	10216-02	1	0	0	0	0	0	0	0	1	
nall	06-Nov-00	10289-02	0	0	0	0	0	0	0	0	0	
ave			1.2	0.2	0	0	0.2	0.1	0.1	0.9	2.7	

		Chlorophyta	Bacillariophyta	Chrysophyta	Synurophyta	Cryptophyta	Pyrrhophyta	Euglenophyta	Cyanophyta	total #	Dominant genus
AVERAGE											
	NALL	1.2	0.2	0	0	0.2	0.1	0.1	0.9	2.7	
	JHALL	3.5	0.3	0.4	0.3	1.1	0.4	0.3	0.8	7.1	
	BORCH	1.2	0.1	0	0	0.7	0.1	0.6	0.2	2.9	
	HERN	5.4	0.8	0	0	0.4	0.1	0.4	2.9	10	
	CASEL	5.5	0.7	0	0.6	1.5	0.1	0.7	1.1	10.2	