CR-147910

DISPOSAL OF

HYPERGOLIC PROPELLANTS

(NASA-CR-147910) DISPOSAL OF HYPERGOLIC PROPELLANTS. PHASE 6, TASK 3: PROTOTYPE DISPOSAL POND (Florida Inst. of Tech.) 130 p HC A07/MF A01 CSCL 21D
N77-31333
Unclas
G3/28 48172

Task 3 Report

Prototype Disposal Pond

June 1977

by

Henry E. Sivik Craig N. Wiederhold

Florida Institute of Technology
Melbourne, Florida 32901

prepared for

National Aeronautics and Space Administration
Kennedy Space Center
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130

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PREFACE

This study was conducted by Florida Institute of Technology under contract NAS 10-8399, administered by the National Aeronautics and Space Administration, John F. Kennedy Space Center, Florida. The NASA technical representative for the contract was Mr. Harold H. Franks, DD-MDD, and the alternate technical representative was Mr. Jimmy L. Dobson, DD-MDD. Florida Institute of Technology's study manager was Dr. Thomas E. Bowman, Mechanical Engineering Department.

TABLE OF CONTENTS

1.0 Introduction

1.1 Purpose

The statement of work for Task 3 in NASA Contract NAS 10-8399 reads as follows:

" Design a low cost prototype disposal pond for hypergol waste, to be constructed on KSC property by NASA or another contractor. The design will include a minimal-configuration treatment system for monomethyl hydrazine. Technical expertise will be provided during construction of the pond and treatment system. Florida Institute of Technology will operate the pond and treatment system, on an experimental basis, with hypergol and solvent waste products provided by KSC, to obtain valid operational data. Develop optimized design concepts and operating procedures based on these performance data. All required chemicals and supplies will be provided by KSC, as well as all materials, equipment, and labor required for the construction and fabrication of the pond and treatment system. The Operational phase funded under this amendment will cover the period from completion of the prototype pond and treatment system (estimated to be the end of the fourth month) through the end of the ninth month.

A schematic drawing of the prototype pond, as envisioned by FIT at this time, is presented on the following page. Estimates of the cost of this government furnished equipment are given at the end of the Cost section below.

It is our recommendation that an actual prototype MMH treatment system be funded as a later extension of this work, after the basic prototype pond is operational. In the meantime, we recommend that a very simple drum-based system be used for treatment of MMH for the sake of this testing".

FIT was contracted to operate the PDP on an experimental basis to obtain valid operational data on the destruction of oxidizer waste utilizing water hyacinths. Simultaneously, drum-sized systems were to be used on FIT property to obtain additional data for the treatment of both N_2O_4 and MMH wastes. The program consisted of performing a number of experimental runs which are described in Table 1 and their objectives.

Our general approach to using hyacinths for removing NO_3^-/NO_2^- waste was to introduce (in safe levels) N_2O_4 into the 4½-foot deep pond the surface of which was partly covered with a mat of hyacinth plants. Run numbers 1 and 4 were performed in the PDP.

Likewise, experimental work was conducted in drum-size containers at FIT. The hyacinths were utilized for determining nitrogen absorption rates from dilute solutions of nitrogen-containing substances such as MMH and/or NO_3^-/NO_2^- solutions. These tests are described in Runs #3 and 5.

A private contractor was engaged by NASA to construct the PDP on KSC property based on an FIT design with final drawing specifications prepared by DD-MDD-41 personnel.

1.2 Background

A literature search was made preliminary to initiation of test runs in the Prototype Disposal Pond (at KSC) or at FIT. This had a two-fold purpose:

(1) To acquire a better background on the bioassimilation method for removal of pollutants from water, and

(2) To minimize duplication of effort.

In this section is excerpted information on water hyacinth having a bearing on Task 3 work for Contract NAS 10-8399.

TABLE 1

LIST OF EXPERIMENTAL RUNS (Task 3)

Run #	Description	Site	Volume of Water/Gals.	Objectives
1	N_2O_4/Hyacinth	PDP	8,600	(1) Determine N uptake rate for winter season (2) Study chemical & biological changes
2	Solar conversion of nitrates to N_2O & N_2 in the NH_4Cl-$NaNO_3$ system	FIT	20	Determine effectivenss of system Results appear in Task 4 report June 1977
3	MMH/Hyacinth	FIT	32	Determine N uptake rate and study other changes
4.	N_2O_4/Hyacinth	PDP	11,500	Determine N uptake rate for winter season
5.	MMH/NaOCl	FIT	30	To demonstrate effectiveness of this chemical destructive method (preliminary study)

1.2.1 Approach to Utilizing Water Hyacinths

The approach to utilizing water hyacinth for absorption of oxidizer and fuel wastes is to introduce the diluted wastes into PVC-lined ponds, of proper size and depth, the surface of which is covered with a mat of hyacinth plants. Several favorable characteristics of the hyacinth exist which make it attractive for this purpose. For example, the high absorption capability for nitrogen-containing compounds (rapid depletion of pollutants) its rapid growth rate, ability to withstand relatively high concentrations of the toxic materials mentioned, survive a wide pH range (4 to 10 pH), displays a great potential value that is probably not surpassed by any other common plant.

The pond size requirement is dependent on several factors, the important factors are:

(1) quantity of oxidizer and/or fuel wastes to be disposed of per unit time

(2) degree of pollutant removal required

(3) hyacinth growth rate (seasonal variations)

The first factor is the quantity of each pollutant to be disposed of per unit time. The pond size will be directly proportional to the total amount of hypergolic wastes generated at KSC which have to be treated. It is anticipated that both oxidizer and fuel wastes will be treated in a common pond or series of ponds. The pond size will further depend on maintaining the concentrations of the wastes in the pond water to below the harmful limits of each waste. The "safe" limits for both N_2O_4 and MMH wastes were established by trial runs in 50 gal tanks. An advantage arising by simultaneous treatment of both wastes is one of economy. Less chemicals for pH adjustment is required as a result of the self-neutralizing feature. In very dilute solution no odor problems were observed nor are other problems, as chemical burns, animal deaths, etc., expected.

The second factor, the degree of pollutant removal required, may have a significant effect on pond size. The more stringent the liquid effluent requirement adopted the larger the pond area or the longer detention time will be necessary for reducing pollutant concentration to acceptable limits prior to discharging the pond water to surface water or to ground disposal.

The third factor, hyacinth growth rate, is of lesser importance and is subject to some uncertainty at this time. It is strongly believed this uncertainty can be resolved by the additional runs planned for this summer under Contract #NAS 10-9166. Hyacinth growth rate figures obtained from literature for central Florida have been estimated from a minimum of 10 to as high as 80 tons dry weight per hectare year. Hyacinth growth rate is not uniform the year round. In central Florida a short period during winter may occur in which growth is slow due to air freezing temperature. Figure 1 * indicates the region of applicability of hyacinth for a water purification system. However, growth is not uniform in different seasons and is influenced by several environmental and variable factors. These factors are discussed elsewhere.

*Robinson, A.C., et al. An analysis of the market potential of water hyacinth-based systems for municipal waste water treatment. Batelle Columbus Labs. Interim Report #BCL OA-IR'-76-1, 1976, p.7.

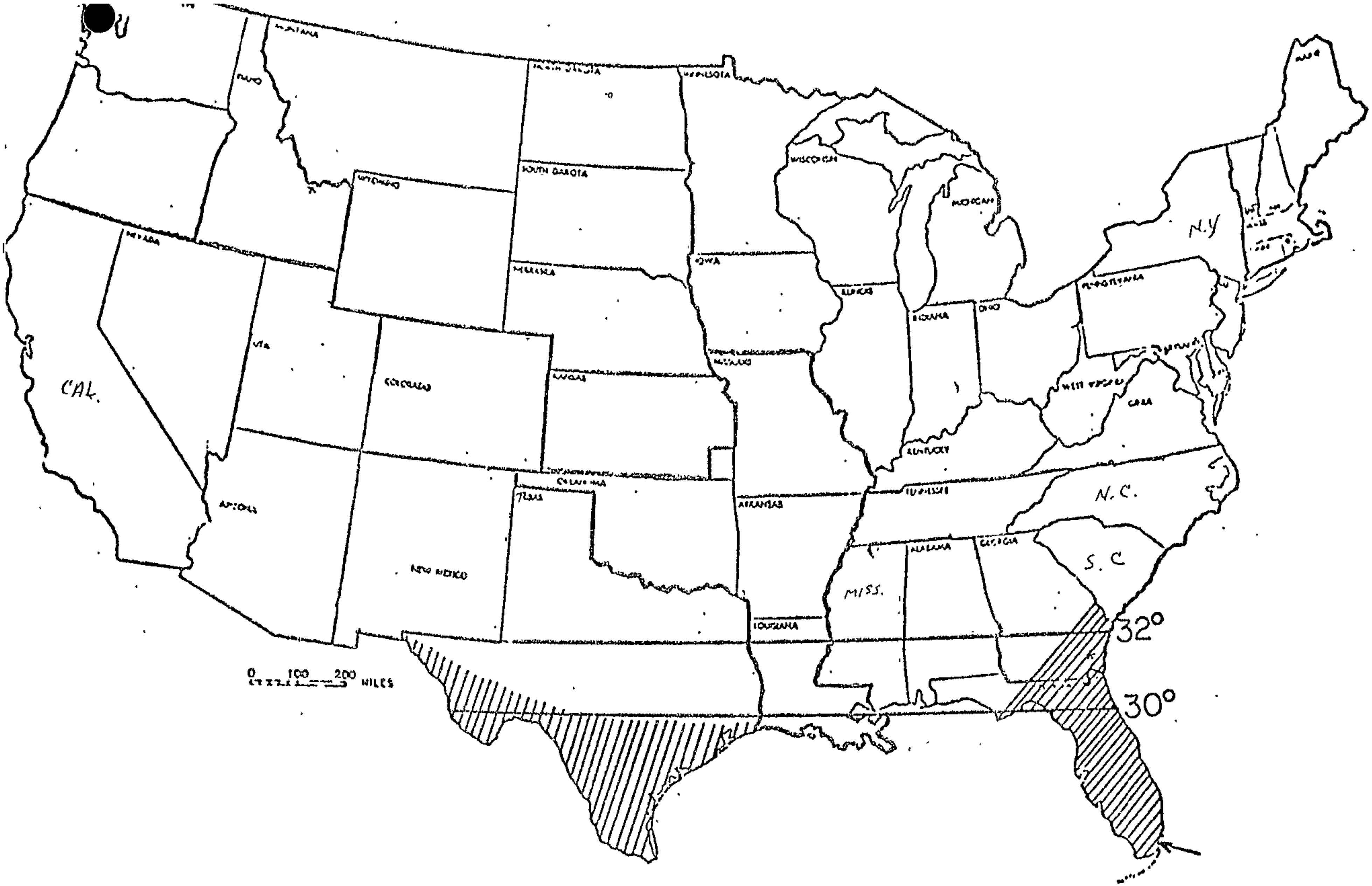


FIGURE 1.. REGION OF APPLICABILITY OF HYACINTH WATER TREATMENT SYSTEMS

Shaded region indicates areas in which hyacinth plants should survive the winter months. Most of the region below the 30th parallel should have year-around growth. Subtropical regions is frost-free more than 360 days/year.

1.2.2 Climatic Effects

Temperature is of paramount importance in the design of a pond system. It affects photosynthetic O_2 production, hyacinth growth rate, as well as other biological reactions. The optimum temperature range for maximum hyacinth growth rate is 22-27^{o}C. Limiting lower and upper values were reported to be 2^{o}C and 35^{o}C, respectively. When water temperatures approach 35^{o}C., the beneficial algal population will be severely curtailed. Such high temperatures were not observed at PDP during the winter or spring months and are not expected during the peak summer months. However, near critical conditions of high temperatures may occur during months when temperatures exceed 30^{o}C (86^{o}F), as shown in Table 2.

Light intensities are relatively high in mid-Florida, even during winter months, as shown in Figure 2 for July and December. Hyacinth growth or development is slowed during winter months and consequently reducing the permissible loading per unit pond surface area at this time. If pond loadings are maintained below critical levels so that algal and hyacinth development and the resultant photosynthetic activity maintains aerobic conditions, then the water stabilization (nitrate removal) can be still effective in winter. The amount of stabilization achieved in winter is expected to drop to 1/3 or less the summer rate in central Florida.

Except for a period of approximately four months in winter, when activity is at its lowest, algal and hyacinth activity is both directly and indirectly responsible for other changes besides oxygenation. The photosynthetic plants are responsible for elevating the pH of the water permitting nitrification, i.e., escape of N_2- compounds as NH_3. All pond systems have an excellent buffering capacity for balancing out excessive peak loads and extreme pH variations. Various nutrients (as phosphates, trace metallic elements as Fe, etc.) are simultaneously embodied in the plant cells. Thus, if the hyacinths are periodically harvested, the NO_3-/ NO_2- content, metallic constituents and nutrients of the water are accordingly reduced. It appears, therefore, that as long as a pond remains aerobic, climatic changes have an effect on water purification.

Nitrogen compound absorption by hyacinth/algae in a pond provides a low cost and efficient means for disposing of N_2O_4/MMH wastes generated at KSC. The hyacinth mats/algal sludges are ultimately disposed of by the low cost sanitary landfilling method rather than harvesting for use as a proteinaceous animal additive. This in large part being due to the very low volume of hyacinth produced in a one, or at most a few, acres of pond surface.

TABLE 2 MONTHLY MINIMUM TEMPERATURE °C FOR FLORIDA *

	January	February	March	April	May	June	July	August	September	October	November	December
Northern Third	4.4	4.4	10.0	10.0	15.6	15.6	21.1	21.1	15.6	10.0	4.4	4.4
Central Third	4.4	4.4	10.0	10.0	15.6	21.1	21.1	21.1	21.1	15.6	10.0	10.0
Southern Third	10.0	10.0	15.6	15.6	15.6	15.6	21.1	21.1	21.1	21.1	15.6	15.6

MONTHLY MAXIMUM TEMPERATURE °C FOR FLORIDA *

	January	February	March	April	May	June	July	August	September	October	November	December
Northern Third	21.1	21.1	26.7	26.7	32.2	37.8	37.8	37.8	32.2	32.2	26.7	21.1
Central Third	26.7	26.7	26.7	32.2	32.2	37.8	37.8	37.8	32.2	32.2	26.7	26.7
Southern Third	26.7	26.7	32.2	32.2	32.2	37.8	37.8	37.8	32.2	32.2	32.2	26.7

MONTHLY SUNSHINE HOURS FOR FLORIDA *

	January	February	March	April	May	June	July	August	September	October	November	December
Northern Third	200	200	240	280	320	300	280	280	240	260	200	180
Central Third	220	220	260	280	300	280	260	260	220	240	200	200
Southern Third	240	240	280	300	280	260	280	280	220	220	220	220

DAILY MEANS OF TOTAL SOLAR RADIATION (Direct & Diffuse)
INCIDENT ON A HORIZONTAL SURFACE, Gm. Cal. Cm^2 Day (Langleys 1 day) **

	January	February	March	April	May	June	July	August	September	October	November	December
Northern Third	300	350	400	550	600	550	550	500	450	400	300	250
Central Third	300	400	450	550	600	550	550	500	450	400	350	300
Southern Third	350	400	500	550	600	550	550	500	450	400	350	300

* The National Atlas of the United States of America, U.S. Dept of the Interior, Geological Survey, Washington D.C.

** LUF, G.O.G., J.A. Duffie & C.O. Smith, 1966, World Distribution of Solar Radiation, Solar Energy Laboratory, U of Wisconson, Madison.

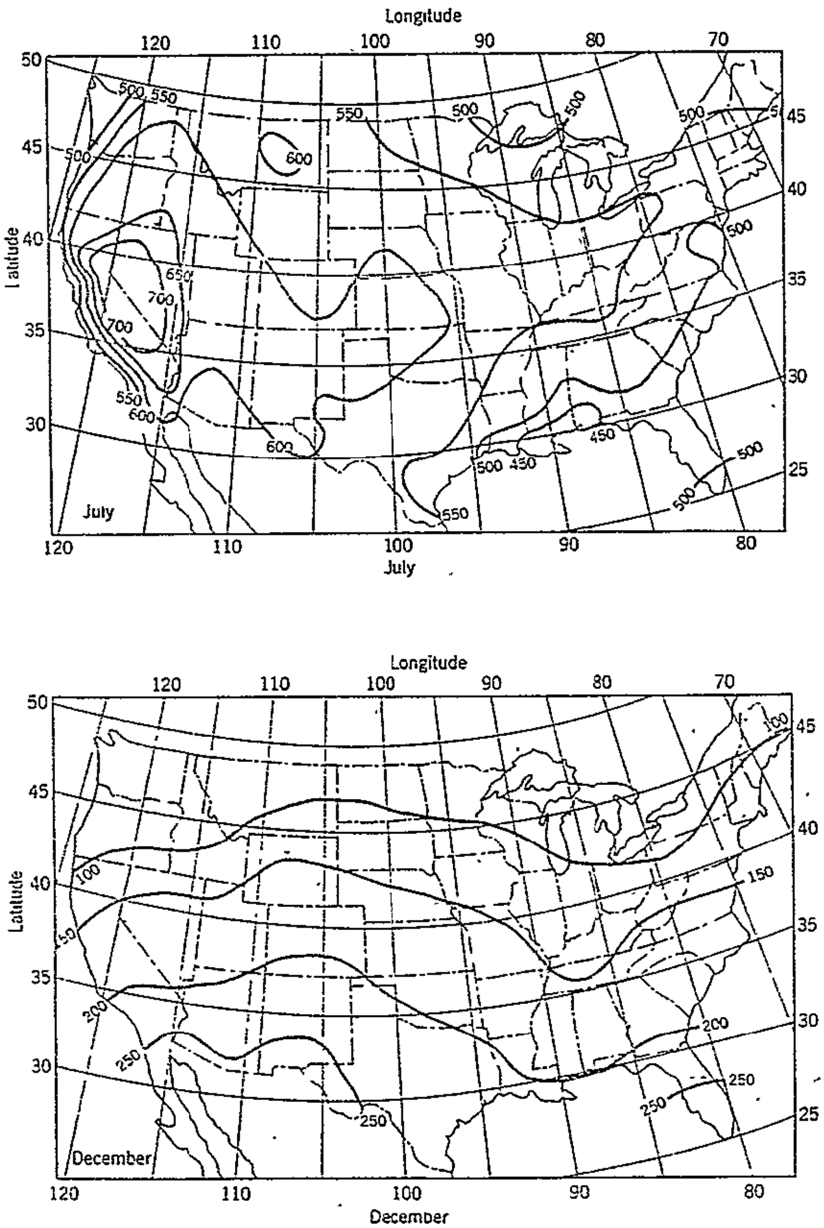


Fig. 2 Isoheliodynamic lines of average solar radiation (calories per square centimeter daily) received on a horizontal surface in the United States during days of average cloudiness in July and December, respectively. [After S. Fritz, Solar Energy on Clear and Cloudy Days, *Scientific Monthly*, 84, 55 (1957).]

1.2.2.1

Temperature Effects on Hyacinths

Temperature is an important factor in determining the h_acinth growth rate. Penfield and Earle * reported the results in Table 3

TABLE 3 . EFFECT OF FREEZING TEMPERATURES ON WATER HYACINTHS

Hours Exposed

Temperature °C	Injury			Resprouting		
	12	24	48	12	24	48
0.6	Blades	Blades	Blades	All	All	All
-2.8	Blades Floats	Leaves Killed	Leaves Killed	All	All	All
-5.0	Leaves	Leaves		All	All	
-6.1	Leaves			Some		

*Penfield, W.T., and T.T. Earle. 1948. The biology of the water hyacinth. Ecol. Mono. 18:447-478.

Hyacinth is highly susceptible to damage or death from freezing temp. Also it is susceptible to excessive heat. It cannot survive air temperature of about 34°C for more than 4 or 5 weeks. During such periods growth usually stops.

1.3 UTILIZATION OF THE HYACINTH

The small volume of hyacinth (maximum pond area not expected to exceed 1-2 hectares) utilized for absorbtion of oxidizer or fuel wastes at KSC will preclude the possibility of economically harvesting the crop as an additive to animal feed. However, as a matter of passing interest, Table 2 shows the seasonal variations of hyacinth as determined by Boyd & Blackburn.*

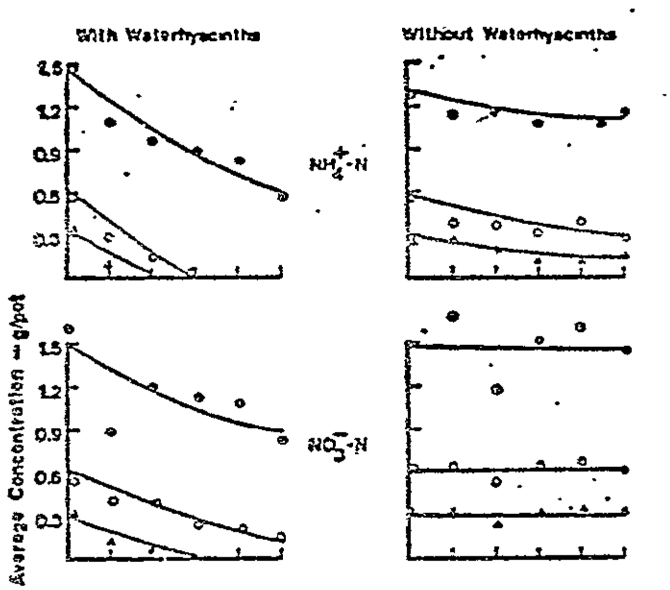
Table 4 Seasonal Changed in the Proximate Composition of Water Hyacinth in Southern Florida, Percent Dry Weight

Time of Collection	Percent Dry Matter	Crude Protein	Ether Extract	Cellulose
April	5.0	22.0	5.29	25.7
May	5.0	23.5	5.60	26.7
June	8.0	18.2	3.75	22.8
July	7.3	15.7	5.11	21.6
August	7.0	19.4	3.84	20.4

*from: Boyd, C.E. and R.D. Blackburn, 1970. Seasonal changes in the proximate composition of some aquatic weeds. Hyacinth Control Journal 8:42-44.

In addition to seasonal changes, the nutrient content of hyacinth varies with location and water quality as shown in Table 5 . In answer to a question raised by an attendee to one of the monthly progress meetings relative to the N_2 content of a PDP hyacinth plant vs. a natural plant the following was found. The Kjeldahl N_2 of plant from PDP vs a control plant was found to be 1.96% vs 1.53%, respectively, based on air dried plants. The N_2 content of the analized plants is within the range shown in the N column of Table 5 and is fairly close to the mean value of 1.61%.

The essential role of the hyacinth is its ability to assimilate the nitrogen compounds. Dunigan, et al*, demonstrated a high removal of NH_4^+ and NO_3^--nitrogen from waters in which hyacinth was growing in the laboratory and in farm ponds. The rate of NO_3^- ion uptake was slower than NH_4^+ ion as shown in Figure 3.*



In 6 liters of water, with and without one water hyacinth plant grown in a greenhouse.

FIG. 3
Uptake of NO_3^- and NH_4^+ by Hyacinth

*Dunigan, E.P., R.A. Phelan and Z.M. Shamsuddin. 1975. Use of water hyacinth to remove nitrogen and phosphorus from eutrophic waters. Hyacinth Control Journal 13:59-61.

TABLE 5 CHEMICAL COMPOSITION BASED ON DRY WEIGHT OF WATER HYACINTHS COLLECTED FROM VARIOUS BODIES OF WATER IN FLORIDA, PERCENT

Origin	Ash	C	N	C/N ratio	P	K	Ca	Mg	Na
Lake Istokpoga (Sebring)	24.4	18.0	1.08	16.7	0.14	1.00	0.73	0.38	0.15
Lake Eden Canal (SR 532)	19.4	28.0	0.86	33.5	0.09	1.95	0.46	0.31	0.23
Lake Thonotosassa	23.0	23.0	1.17	19.7	0.33	3.35	1.49	0.29	0.21
Waverly Creek (SR 60)	25.0	33.1	2.26	14.6	0.56	3.10	1.58	0.50	0.37
Arbuckle Creek	23.4	34.9	1.90	18.4	0.23	3.35	1.06	0.49	0.28
Lake Tohopekaliga (Kissimmee)	21.7	34.0	1.69	20.1	0.60	4.70	1.56	0.71	0.53
Lake Monroe (Sanford)	20.4	32.5	2.86	11.4	0.59	5.55	1.73	0.54	0.83
Duda Canal No. 1 (Belle Glade)	20.3	39.1	1.30	30.1	0.13	3.80	1.99	0.60	0.48
St. Johns River (Astor)	20.1	36.4	2.33	15.6	0.51	6.50	1.43	0.51	0.63
W. R. Grace Landfill (Bartow)	19.0	36.4	1.86	19.6	0.59	2.72	1.99	0.56	1.54
Ponce de Leon Springs	18.5	37.5	1.74	21.5	0.33	5.40	2.34	0.50	0.47
Waverly Creek (SR 540)	18.5	38.1	1.76	21.6	0.32	4.85	1.45	0.55	0.67
Duda Canal No. 2 (Belle Glade)	17.5	37.8	1.66	22.8	0.15	4.70	2.28	0.69	0.57
Lake Alive (N. of Fla.)	17.3	38.6	1.17	33.0	0.40	3.66	2.41	0.69	0.40
Lake Apopka (Montieverde I)	15.8	38.8	1.22	31.8	0.14	4.26	2.07	0.54	0.41
St. Johns River (Palatka)	15.8	38.0	18.2	20.9	0.16	3.44	1.83	0.73	0.86
Lake George	15.4	40.2	1.48	27.1	0.21	3.21	1.91	1.86	1.24
Lake Apopka (Monteverde II)	14.9	39.8	1.36	29.3	0.09	4.08	1.96	0.60	0.21
Lake East Tohopekaliga (St. Cloud)	14.7	37.2	1.08	34.5	0.23	2.90	1.19	0.51	0.53
MEAN	19.2	34.9	1.61	23.3	0.31	3.81	1.66	0.56	0.56
Standard deviation	3.2	5.9	0.50	7.0	0.18	1.30	0.53	0.14	0.36

Source: Parra, J.V. and C.C. Hortenstine. 1974. Plant nutritional content of some Florida water hyacinths and response by pearl millet to incorporation of water hyacinth in three soil types. Hyacinth Control Journal 12: 85-90.

1.4 Absorption of Heavy Metals by Hyacinth

The mineral content of water hyacinth varies with location as shown by Parra * and in Tables 5 and 6 . Of significance is that considerable absorption of some heavy metals, as Fe, Pb, Cr and Cu occurs naturally during the growth of the plant. This fact can be of extreme interest to KSC from the standpoint of providing an alternative means for disposing of the unwanted metallic constituents in plating wastes or miscellaneous chemical wastes. Further, it is believed that simultaneous treatment of hypergolic wastes and heavy-metal containing wastes in a common pond is feasible after suitable dilution.

Parra, J. V. and C. C. Hortenstone. 1974. Plant nutritional content of some Florida water hyacinths and response by Pearl Millet to incorporation of water hyacinth in three soil types. Hyacinth Control Journal 12:85-90

TABLE 6 ALUMINUM AND SOME HEAVY METAL CONCENTRATIONS BASED ON DRY WEIGHT OF WATER HYACINTHS COLLECTED FROM BODIES OF WATER IN FLORIDA, PPM

Origin	Al	Cr	Cu	Fe	Pb	Mn	Zn
Lake Istokpoga (Sebring)	6050	35	3	8125	20	408	53
Lake Eden Canal (SR 532)	1850	8	8	3250	ND[a]	295	39
Lake Thonotosassa	1950	5	5	775	10	203	27
Waverly Creek (SR 60)	6750	8	13	5625	ND	238	81
Arbuckle Creek	3250	5	3	2000	ND	225	48
Lake Tohopekaliga (Kissimmee)	6350	10	8	5125	10	560	61
Lake Monroe (Sanford)	2250	5	40	2125	ND	310	192
Duda Canal No. 1 (Belle Glade)	150	ND	5	375	10	115	15
St. Johns River (Astor)	2900	ND	8	525	ND	170	100
W. R. Grace Landfill (Bartow)	9290	10	5	1940	ND	279	18
Ponce de Leon Springs	50	3	3	800	10	615	32
Waverly Creek (SR 540)	3000	3	8	3125	ND	193	45
Duda Canal No. 2 (Belle Glade)	250	ND	8	500	ND	68	26
Lake Alice (U. of Fla.)	853	ND	10	657	10	402	69
Lake Apopka (Monteverde I)	298	ND	5	160	10	122	22
St. Johns River (Palatka)	1181	ND	10	1150	10	464	69
Lake George	904	ND	10	755	10	287	51
Lake Apopka (Monteverde II)	425	ND	5	135	20	219	39
Lake East Tohopekaliga (St. Cloud)	1050	3	8	15500	10	253	107
MEAN	2658	–	9	2772	–	286	58
Standard Deviation	2668	–	8	3765	–	147	42

(a) None detected.

1.5 EFFECT ON THE RECEIVING WATER

It seems reasonable that the pond effluent destined to be discharged on ground or to a receiving body of water should comply with the E.P.A. and state regulations regarding NO_3/NO_2 residuals. The chemical quality of the effluent is affected by the amount of waste hypergols imputed and the method of time and treatment.

As will be discussed later, the total nitrogen content at the end of Run #1 was reduced from 118 ppm to 2.68 ppm. This value is below the Florida Department of Pollution Control Regulation, Chapter 17-3 criterion for an advanced waste water treatment effluent. Thus, it would be permissable to discharge the pond effluent directly to ground or a receiving body of water.

The effect of the residual nitrogen on the receiving body of water would be minimal and no worse than the effect from the discharge of secondary effluent now permitted into streams from typical sewage treatment plants.

1.6 SAFETY HANDLING PROCEDURES

In order to conform to the NASA Safety Requirement, it was necessary to establish five operating procedures. Included were procedures for adding N_2O_4 or MMH to PDP to bring their concentration to the desired operating level, removal of waste water, and a stocking and destocking procedure for hyacinth. A series of meetings were held with pertinent representatives from Safety, So-Lab, Biomedical and DD MDD-41 to satisfy their respective requirements. Table 7 lists the procedures by title. These procedures are included in Appendix III.

TABLE 7

	TITLE	APPROVAL DATE	ITEM
1	Hypergol Handling Procedure for KSC Prototype Disposal Pond (PDP)	12/1/76	N_2O_4
2	Water Hyacinth Stocking Procedure for Prototype Disposal Pond (PDP) at KSC	3/25/77	Hyacinth
3	Disposal of Water Contained in the KSC Prototype Disposal Pond (PDP)	To be approved	H_2O
4	Handling Procedure for KSC Prototype Disposal Pond (PDP)	6/27/77	MMH
5	Disposal of Hyacinth from the KSC Prototype Disposal Pond (PDP)	To be approved	Hyacinth

2.0 Pond Design and Operating Considerations

Preliminary Pond Design and Guidelines were submitted to NASA in the early stages of work on Contract 10-8399, Phase 6 . Based on these criteria NASA personnel drew up the final construction specification drawings. A private contractor was engaged by NASA to construct the PDP on KSC property based on the above final drawings.

Several pond design (and operating) considerations appear in the following sections. Additional design and operating data appear in Appendix IV.

2.1 Aeration System

In the pond, the desirable aerobic conditions in the surface and bottom layers are largely brought about by the photosynthetic activity of the hyacinths and the green algae. In the event that excessive organic debris from decaying plant tissues settles out, an anaerobic environment may exist near the bottom of the pond because of oxygen demand exceeds the local photosynthetic reoxygenation capacity. To preclude this eventuality, the pond was provided with both a water recirculation pump and an air blower. The water pump alone would suffice to prevent the anaerobic condition from developing by an occasional turnover of the bottom water layer so as to keep the organic debris in suspension or accessible to dissolved oxygen. The air blower was installed to provide supplemental O_2 for oxidation of MMH in a preliminary step in a separate pond to below the toxic levels ($\sim$ 50 ppm) needed for hyacinth survival. A small separate pond specially designed for air oxidation of MMH residues in approximately up to 2500 ppm concentration could be an alternative method for reducing the concentration to below this toxic level established elsewhere.

Six jets were provided in the aeration system to help distribute the air from the blower. Two sets of 3 jets each point opposite directions in each half of the pond as shown schematically in Fig. 6 The jets can be used with only the air blower operating or, preferably, simultaneously the water pump and blower operating. In the latter case, a water circulation pattern is established while the air bubbles (now further subdivided) are propelled into a longer path with the water stream resulting in a higher O_2 uptake.

The air distribution and water recirculation piping was made removable to allow line cleaning or overhaul and to facilitate periodic sludge removal should this become necessary after a few years operation. The piping was anchored near the bottom of the pond with sand bags and cement building blocks to prevent whipping during operation. Control of bubble size for most efficient utilization of blower horsepower was not optimized at this time because oxygenation of the water will be provided primarily by the hyacinth/algae.

2.2 Surface Loading and Depth of Pond

As a general guide a loading of approximately 60 pounds N_2O_4 per acre per day can be adopted in a 4-4½ foot deep pond. The surface area exposed to solar radiation is the critical parameter and treatment capacity cannot be substantially increased by merely deepening the pond. The permissible surface loading of the pond increases only slightly with increased pond depth. Therefore, there is very little practical advantage in constructing ponds deeper than 5 feet. Ponds shallower than 3 feet, on the other hand, will be unduly affected by sludge depositon. Anaerobic conditions were not encountered at the bottom of PDP. The lowest D.O. measured was 3.5 ppm occurring only once on Nov. 29, 1976. Consequently no odor nuisances were encountered in Run #1.

Sludge in PDP

Sludge accumulation in the PDP in the six month period was observed to be approximately 2-1/2 inches deep. Most of the sludge settled into the 20x8 foot bottom low of the pond though up to 1/4 - 1/2 inch thick layers also settled along the lower slopes of the slanting sides. This unusually large accumulation is explainable as due to the colder than normal winter. The sludge consists of at least 1-1/2 inches of decaying hyacinth roots and plant tissues resulting from the freeze in January, approximately 1/4 inch of sand, blown into pond by wind and rain swept sand from top of berm, and about 1/2 - 3/4 inch algae and organic debris and insolubles.

In a normal year sludge accumulation is expected not to exceed 2 inches. The sludge pump-out operation would occur at 5-10 year intervals in a 4-1/2 foot pond. A pond with increased depth (say 5 feet) would extend the interval.

The acreage of hyacinths required to absorb a given amount of pollutant (N_2O_4) per unit time is known to an accuracy of about 10% from the field and laboratory work conducted by FIT. The acreage is proportional to the through put rate. Thus, given the weight of pollutant per unit time, the pond area required for a waste disposal system can be determined. For the hyacinth growth rate a value of 10 dry tons per hectare year has been selected for design purposes based on the results of our test runs and the present information available in literature for the central Florida region. This value represents neither the growth under optimum conditions nor maximal growth rate but a reasonable production as would be found in a lightly supervised facility.

It was estimated that the PDP had a maximum resident population of approximately 3760 hyacinth plants at the end of Run #1. The increase from the initial 50% mat coverage to the final 75% coverage after a 6 weeks period was attributed mostly to increase in plant size rather than any substantial increase in the number of new plants.

2.4 Mosquito Control

Mosquitoes have a tremendous nuisance value and should not be allowed to breed freely in ponds. The best control measure is the prevention of breeding by keeping the pond clear of emergent vegetation. Since this is not feasible in a hyacinth pond, an insecticide should be spread in normal quantities around the perimeter of a pond. Certain insect-devouring fish allowed to exist in a pond would also be helpful.

3.0 Preliminary Pond Preparation

Prior to conducting any runs, it was necessary to prepare the pond. The purpose was to provide a suitable chemical and biological environment to ensure adequate growth and health for the hyacinths. The following describes the preparation.

3.1 Procedure

To 8600 Gallons water in PDP, Algae inoculum, nutrients, and trace elements were added. The algae inoculum consisted of two gallons of fresh aerobic digestor sludge from a sewage water treatment plant. In addition to the algae the sludge contained the biota usually found in this material which was necessary for establishing a balanced ecological system. The list of chemical nutrients added appears in Table 8 . The quantity of each additive was sufficient to provide the approximate concentration shown in Column 2.

Table 8

Nutrients & Trace Elements Added
To PDP

Chemical	Desired Element	Approx. Result. Conc. ppm
ISO Propanol	Carbon Source	190
Boric Acid	B	0.2
$CuSO_4 \cdot 5H_2O$	Cu^{++}	0.01
$FeSO_4 . 7H_2O$	Fe^{++}	2.5
$MnSO_4 . 4H_2O$	M_n	0.5
$(NH_4)_6Mo_6O_{24}$	Mo	.01
$ZnSO_4 . 6H_2O$	Zn	2.5
$MgSO_4$	Mg	5.0
$CaCl_2$	Ca	10
$SO_4^=$ (Sufficient from sulfate additions)	S	10-20
50 lbs bag 6-6-6 fertilizer, 50% organic	N	
	K	20
	P	20
Adjust pH to 6.5 - 7.0 with NaOH solution.		

In addition to these elements, trace quantities of other elements may be expected to occur from the impurities of the chemicals as well as from the dissolved and suspended materials naturally present in the water used to fill the pond.

Four days were allowed for pond to come to chemical and biological equilibrium prior to stocking with hyacinths. After stocking, two days were allowed to acclimate the plants to the new surroundings. Run #1 commenced on Nov. 17, 1977 which was 0-day for timing purposes. On this day, first a circulatory motion was established in the pond by means of the jet eductors. Then four liters of N_2O_4 were slowly introduced over a two hour period to minimize local pockets of high NO_3/NO_2 concentrations which could seriously damage the plants.

Water samples were taken and analyzed at frequent intervals for the duration of the run to follow the progress of nitrogen uptake and other changes.

At the outset of test runs, it was unclear which chemical tests would be of greatest significance for interpretating the changes occurring in the pond water, as a result of the hyacinth bioassimilation. Therefore, a large number of tests were selected that frequently are utilized in water pollution studies with the intention of eventually discontinuing tests of minor significance. Table 9 shows a list of the tests originally selected for routine analysis. Later, two of these tests were discontinued, namely, Cl_2 and chemical oxygen demand. However, not all the tests were applied to each water sample obtained. The tests for metals were performed in only a few cases. In Appendix II are found the analytical data forms for recording data.

3.2

TABLE 9

List of Tests Performed on Water Samples

Nitrate, NO_3^-

Nitrite, NO_2^-

Ammonium, NH_4^+

Total Nitrogen TN (Calculated)

Ortho-Phosphate, $O\text{-}PO_4^{\equiv}$

Dissolved Oxygen, D.O.

pH

Suspended Solids, SS

Volatile Suspended Solids, VSS

Turbidity

Apparent and True Color

Temperature (Air & Water)

Monomethyl Hydrazine, MMH

Chloride, Cl^-

Chlorine, Cl_2

Chemical Oxygen Demand, COD

Copper, Cu

Manganese, Mn

Iron, Fe^{++}

Zinc, Zn

4.0 Description of Test Results

4.1 Run #1 (N_2O_4/Hyacinth at PDP)

4.1.1 Objectives of Run #1

Run #1 was performed at the Prototype Disposal Pond (PDP) located on KSC property. The objectives of Run #1 were:

(1) To determine the winter NO_3^-/NO_2^- uptake rate of water hyacinths.

(2) To discover potential problem areas in operating such a pond

(3) To observe the feasiblity of utilizing hyacinth as a method for destroying N_2O_4 wastes.

4.1.2 Description of Procedure

After preparing the pond as described in the previous section, Run #1 was started on November 11, 1976. Water samples were taken at weekly intervals or more frequently. Occasionally, two samples were obtained, one before and one after ½ hour agitation. The sample consisted of an integrated 1 gallon of water collected from 10 equidistant points around the perimeter of the pond, 6 or more inches below the water surface. A clean, labelled polyethylene bottle was used for storing the sample. On the spot analysis of dissolved oxygen was performed on a top and bottom water sample. These results plus other data were recorded on sheet #1 "Pond Water Sampling Data" These data were used in interpreting the results. Analyses on the collected sample was performed at FIT on the same day or the next day. The test methods were as given in "Standard Methods, Water and Waste Water" 13th edition. Samples were stored in a refrigerator at 4°C. (The list of tests performed appears in Table 9) Results of chemical analyses were recorded on sheets #2, 3, 4 and 5. (See appendix II)

After a few weeks into the run, an algal bloom was observed in the pond. It was deemed advisable to obtain a count and identification of algal species. These results appear in Section 4.1.3.2.

4.1.3 Discussion and Results

The analytical data from Run #1 appear in Table 10. Each test is discussed in a separate section.

3.1 NO_3 Uptake Graph 1 shows the NO_3^- uptake by hyacinth in the PDP during the winter period (mid Nov. 76 to mid Jan 77). The solid line represents water samples taken after half hour agitation of pond with the air blower and the water pump, the dotted line water samples taken before agitation. The agitated samples are more representative of the NO_3^- content in the pond. The results show an initial slow decrease in NO_3^- from the 462 ppm peak level to approximately the 280 ppm level in a 50 day period, then a rapid decrease to the 10 ppm level in the succeeding 8 day period, and finally a very slow drop to the 6 ppm level occurring in the next 16 days. At this point the run was terminated. The 10 ppm level was arbitrarily selected as a target to indicate completion of a run. Fluctuations of NO_3^- in or about this level will occur naturally due to the decomposition of proteinaceous materials in the organic detritus. The rapid NO_3^- uptake occurring in the 8 day period was partly attributed to the observed algal bloom. The very slow uptake occurring in the last stage can be accounted for by the after effects of the near freeze and the freeze which caused a die back of the hyacinth plants. The subsequent decomposition of dead plant tissues releases a small amount of NO_3 salts into the pond water.

The dotted curve (unagitated samples) shows a "layering" effect of NO_3^- due to local depletion at the top surface.

The rate of NO_3^- absorption during the winter months in Run #1 was found to be 64.4 lbs. NO_3^- per acre day in a pond containing approximately 3½ feet of water with an average 70% hyacinth coverage in an unusally cold winter for central Florida.

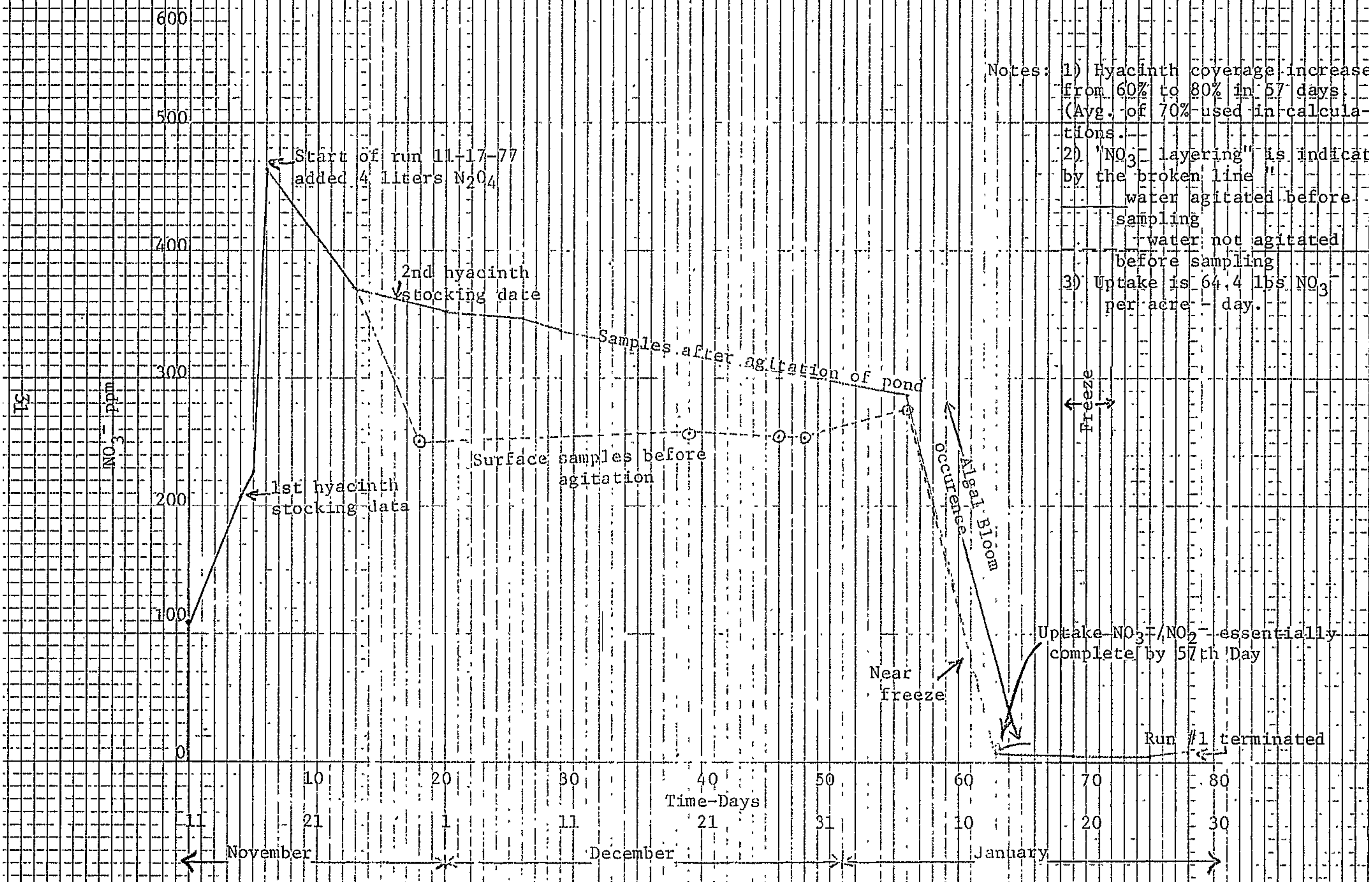
TABLE 10 - Analytical Data for Run #1 FBF

Sample Number	Days	NO_3^- (ppm)	NO_2^- (ppm)	NH_4^+ (ppm)	Total Nitrogen	O-PO_4 (ppm)	D.O. (mg/1)	pH	S.S. (ppm)	V.S.S. (ppm)	Turbidity F.T.U.	True Color	Comments
1	-6	110	0.02	0.98	25.80	0.1	---	7.8	14	14	8	25	
2	-2	116	0.18	1.07	27.20	2.5	9.0	9.5	10	10	18	35	
3	-2	209	0.20	2.07	49.30	2.5	---	9.4	28	26	28	50	
4	-1	229	0.27	0.27	52.30	2.2	T:12.3 B:8.0	9.9	32	26	30	45	
5	0	462	41.25	0.67	118.05	2.9	---	3.6	26	18	25	50	Beginning of Run
6	+6	370	29.70	4.51	96.80	4.4	6.0	6.0	24	22	25	50	
7	+6	369	29.70	4.27	96.40	4.1	6.0	6.2	10	8	19	51	
8	+6	220	0.02	0.41	50.35	0.1	---	9.1	48	48	15	50	Training Area Pond Water
9	+6	62	0.02	1.21	15.00	0.4	---	9.9	0	0	8	0	K.S.C Tap Water
10	+12	392	24.75	4.45	100.15	4.0	T:6.0 B:3.5	9.4	22	20	35	51	
11	+14	352	26.07	4.60	91.70	24.3	---	6.9	8	8	40	70	
12	+20	348	18.98	2.60	86.90	21.3	9.5	7.6	4	4	30	5	
13	+23	339	18.80	2.30	84.60	21.3	T:8.1 B:6.8	7.6	6	6	52	55	
14	+27	312	16.50	1.50	77.20	20.5	T:7.6 B:7.2	7.3	10	10	40	20	
15	+33	260	10.20	0.61	62.60	21.00	T:6.8 B:5.4	6.7	0	0	30	60	
16	+40	255	0.12	0.44	58.40	18.50	T:8.4 B:6.2	6.9	2	2	20	20	
17	+42	253	0.07	0.55	58.00	17.30	T:9.2 B:5.5	7.2	0	0	17	15	

TABLE 10- continued

Sample Number	Days	NO_3^- (ppm)	NO_2^- (ppm)	NH_4^+ (ppm)	Total Nitrogen	$O\text{-}PO_4$ (ppm)	D.O. (mg/1)	pH	S.S. (ppm)	V.S.S. (ppm)	Turbidity F.T.U.	True Color	Comments
18	+50	275	0.83	4.60	66.50	17.50	T:9.4 B:4.2	6.9	2	2	15	35	
19	+50	286	4.50	11.90	76.13	18.30	T:9.4 B:4.2	6.8	0	0	22	5	
20	+57	9	0.03	0.32	2.27	15.50	T:11.4 B:8.6	7.5	8	8	25	5	End of Run
20A	+57	11	0.04	0.29	2.68	14.75	T:11.4 B:8.6	7.5	2	2	25	40	
21	+57	4	0.02	0.33	1.28	17.50	T:12.4 B:8.2	7.0	---	---	30	25	
22	+69	4	0.10	0.61	1.43	18.75	T:11.5 B:8.2	7.0	---	---	23	45	
23	+72	6	0.26	1.16	2.43	18.25	T:8.8 B:7.6	6.8	---	---	23	30	Data Collection Discontinued

GRAPH #1
UPTAKE OF NO_3 vs TIME IN
PROTOTYPE DISPOSAL POND (RUN #1)



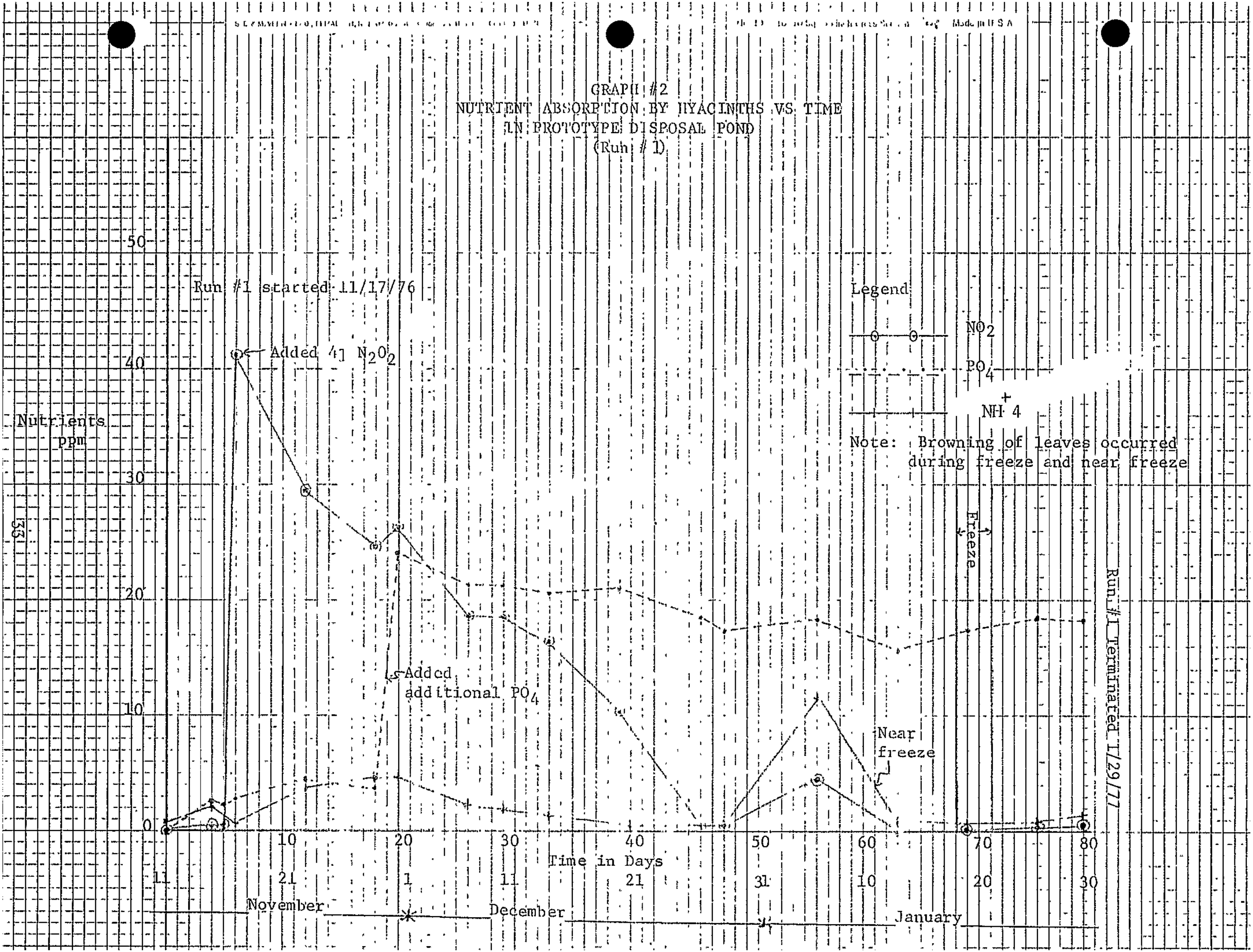
$NO_2/NH_4^+/o\text{-}PO_4$ Uptake

In Graph 2 are plotted the changes in NO_2^-, NH_4^+, and orthophosphate ($o\text{-}PO_4$) concentration as a function of time. It is evident that the NO_2^- was reduced from a peak of 41 ppm to below 1 ppm then rose to 4.5 and dropped to below 1 ppm after 57 days. The NO_2^- was reduced to the low level at about the same time as NO_3^-.

A second $o\text{-}PO_4$ addition was made to the pond on 12-2-76 in order to increase the concentration to a preferred level. A slow decrease in $o\text{-}PO_4$ is shown for the duration of the run.

The amount of NH_4^+ was increased from almost nil up to the 4.5 ppm level in about a 6-day period then dropped to below 1 ppm and finally increased to about 12 ppm at the 57th day. This increase is related to the die-back of the hyacinth as a consequence of the cold snap occuring at the same time.

The uncontrolled dumping of N_2O_4 wastes into ecosystems such as holding ponds is likely to create unanticipated changes. Different organisms are adapted to specific levels of materials, excess additions of materials may result in a change in the kinds of organisms able to survive in the changed environment. A near kill of the algal population resulted after the introduction of 4 l N_2O_4 into the pond in order to increase the NO_3^-/NO_2^- concentrations desired from the existing temporary levels of 228 ppm/0.27 ppm to the final desired levels of 462 ppm/ 41 ppm respectively. The hyacinth survived this shock addition with minimal visible effect. After one or two weeks the algal population reappeared in large numbers.


GRAPH #2
NUTRIENT ABSORPTION BY HYACINTHS VS TIME
IN PROTOTYPE DISPOSAL POND
(Run # 1)
Run #1 started 11/17/76
Added 41 N2O2
Added additional PO4
Legend
NO2
PO4
NH+4
Note: Browning of leaves occurred during freeze and near freeze
Freeze
Near freeze
Run #1 Terminated 1/29/77
Nutrients ppm
50
40
30
20
10
0
10
20
30
40
50
60
70
80
Time in Days
11
21
1
11
21
31
10
20
30
November
December
January
33

Water Level in the Pond

At the start of Run #1 the pond was initially filled to contain approximately 8,600 gallons of water. Chloride (Cl^-) picked up by hyacinth is considered to be minimal. Therefore, the Cl^- concentration in the pond water was used to monitor the water level. As is shown in Table 11 , the Cl^- remained essentially the same from start to finish of the run. The small variation shown in considered an experimental error with our method of analysis. Thus, the Cl^- concentration does not shown either a dilution effect that can be attributed to rain or an evaporation effect, i.e. the volume of water was fairly constant during the run.

Tests for Free Chlorine

Table 12 shows the analytical results for free chlorine (Cl_2) using the o-tolidine method of analysis. These results are excessively high due to the known interference that strong oxidizing agents (as HNO_3) have on a chromogenic reagent, as o-tolidine, and should be ignored. Such a high Cl_2 content in water could easily be detected by the sense of smell and none was observed in any of the samples. It is to be noted that in Sample #1, the apparent Cl_2 was .02 ppm when the NO_3^- concentration was 110 ppm. As the NO_3^- was increased to 462 ppm (sample #5) the apparent free Cl_2 rose to above .6 ppm. Then, as NO_3^- decreased to 253 ppm, the apparent Cl_2 decreased to .02 ppm. For this reason the tests for free Cl_2 were discontinued after Sample #17, since they have no significance.

Table 11

Results of Cl^- & Cl_2 Analysis, Run #1, PDP

SAMPLE #	DATE	DAY	Cl^- PPM	Cl_2 PPM	COMMENTS
1	11-11-76	-6	80	.02	
5	11-17-76	0	95	0.4	After adding N_2O_4 Cl^- (interferrence in test
6/7	11-23-76	6	98	.68	Averaged
10	11-29-76	12	92	.58	Added tap water
11	12-1-76	14	90	.78	
12	12-7-76	20	90	.86	
13	12-10-76	23	90	.79	
14	12-14-76	27	90	.86	
15	12-20-76	33	90	.75	
16	12-27-76	40	90	.10	
17	12-29-76	42	90	.02	
18/19	1-6-77	50	95	-	Averaged
20	1-13-77	57	90	-	
21	1-19-77	63	85	-	
22	1-25-77	72	90	-	

TABLE 12

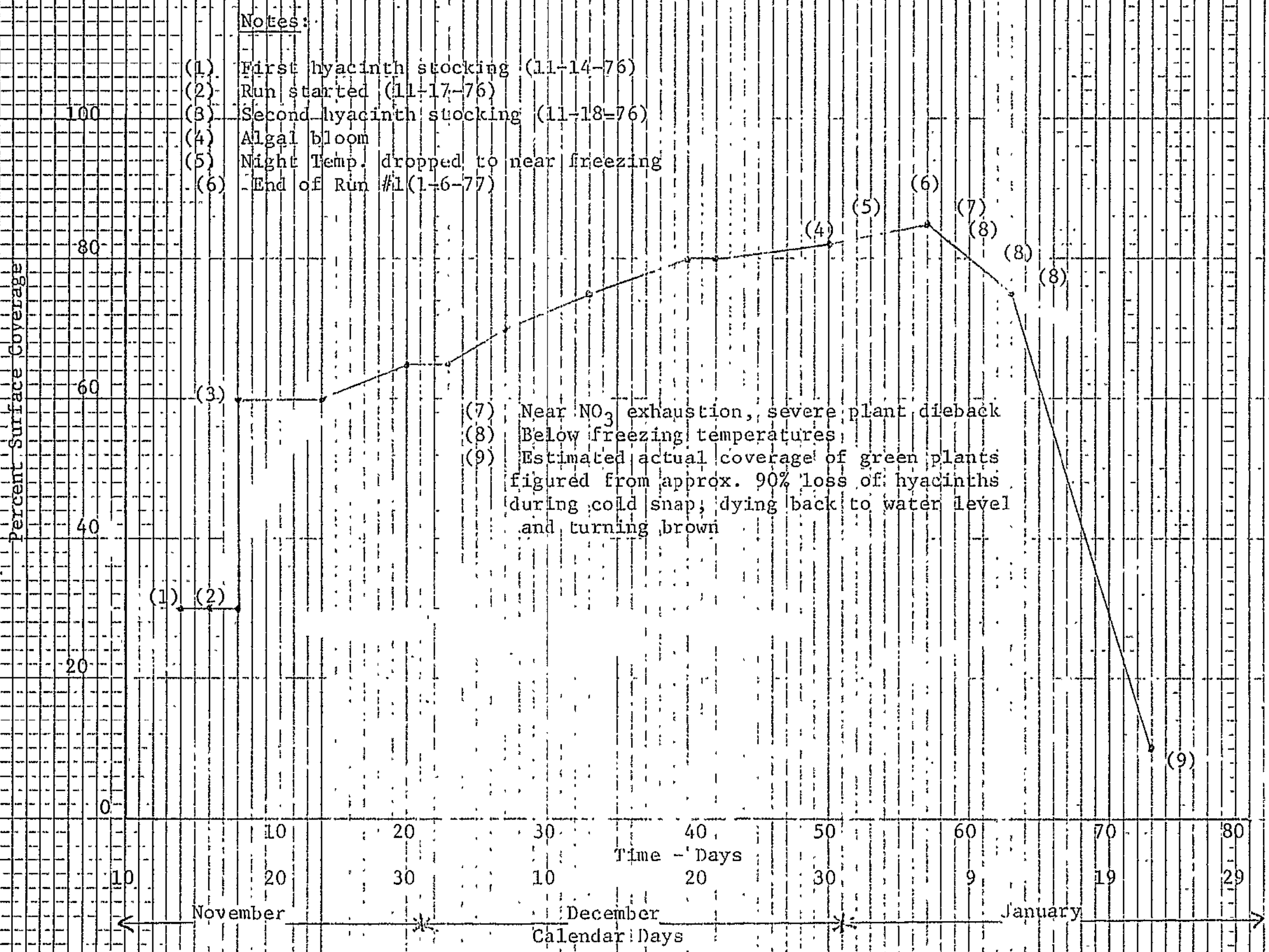
FREE CHLORINE IN RUN #1

Water Sample #	Date Sampled	Free Chlorine ppm	NO_3^- Concentration ppm	Comment
1	11-11-76	.02	110	
2	11-15-76	.04	115	
5	11-17-76	.40	462	After adding 4 1 N_2O_4
6	11-23-76	.68	370	Sample not agitated
10	11-29-76	.58	392	
11	12-1-76	.78	352	
12	12-7-76	.86	347	
13	12-10-76	.79	338	
14	12-14-76	.86	312	
15	12-20-76	.75	260	
16	12-27-76	.10	255	
17	12-29-76	.02	263	Cl_2 test discontinued

Hyacinth Coverage

Graph 3 shows the estimated hyacinth mat coverage during Run #1. Two hyacinth stockings were made, 1st on Nov. 14, 1977, the 2nd Nov. 18, 1976, resulting in 60% coverage. Due to plant growth and a small increase in the number of plants the coverage increased to approx. 85% near the end of the run. The occurrence of freezing weather in the 2nd week of January resulted in severe damage and a die back as shown on the graph. Approx. 90-95% of the exposed parts of the plants turned brown. Patches of ice were observed on the pond surface and the water temp. was at the freezing point. The cold snap coincided roughly with the end of the run on the 57th day. However, data collection was continued until Jan. 21. Hyacinth coverage was difficult to judge but estimated at about 10%.

Additional comments on hyacinth and algae in the PDP appear in Table 13



GRAPH 3
HYACINTH COVERAGE VS TIME
PROTOTYPE DISPOSAL POND
(Run #1)

TABLE 13

Comments on Hyacinth and Algae in Run #1

Sample #	Time in Days	Hyacinth Coverage %	Notes on Algae	Comments
1	-6	0	Considerable algae on sides & bottom of liner	Pond preparation phase - 6 days
2	-2	0		
3	-2	30	No change from above	1st stocking of hyacinth on 11-14-76
4	-1	30		Stabilization Period
5	0	30		Start of run. Added 4L N_2O_4
6/7	6	60	Almost all algae disappeared due to low pH	2nd stocking of hyacinth
10	12	60	Prolific algal growth	Added NaOH to increase pH
11	14	60	Algae very green & lush	Added H_3PO_4 to increase P/N ratio
12	20	65		Turbidity increase rapidly
13	23	65		Turbidity very high
14	27	70		New root growth on hyacinth
15	33	75		
16	40	80		
17	42	80		
18/19	50	85		Algal bloom peaked
20	57	85^+		Absorption of NO_3/NO_2 is essentially complete.
21	63	~70		90-95% of hyacinth turned brown due to freezing weather
22	69	-		
23	72	~10		Run Terminated

Results on MMH Analysis

Table 14 shows the "apparent" results which are considered invalid for the following reasons. Actually, no MMH was added to the pond. The observed values are attributed to the known interference of strong oxidizing agents (HNO_3 or free Cl_2) on the test results. For example, note the correspondance of high NO_3^- with high MMH concentration. As the NO_3^- dropped the MMH value dropped to approximately the original fractional ppm level. A similar occurrence was observed when analyzing for MMH in scrubber liquor effluent containing NaOCl.

Table 14

Results on MMH Analysis, Run #1
Prototype Disposal Pond

Sample #	Days	MMH ppm	NO_3^- ppm	Comments
1	-6	.038	110	
2	-2	.038	116	
3	-2	.047	209	
4	-1	.047	229	
5	0	.352	462	Start of run - added N_2O_4 - sharp increase in MMH
6	6	.332	330	
7	6	.242	370	
10	12	.215	392	
11	14	.210	352	
12	20	.171	348	
13	23	.215	339	
14	27	.178	312	
15	33	.091	260	
16	40	0	255	Algal bloom occurrence
17	42	0	253	
18	50	.026	275	
19	50	.033	286	
20/20d	57	.010/.066	10	Run essentially complete
21	63	.019	4	
22	69	.022	4	
23	72	.019	6	

Chemical Oxygen Demand (COD)

The Chemical Oxygen Demand (COD) determination provides a measure of the oxygen equivalent of that portion of the organic matter in a sample that is susceptible to oxidation by a strong chemical oxidant. It is an important parameter in stream and industrial waste studies.

In Table 15 are presented the results of COD analysis. The change in COD is a slow decrease from about 89 mg/l to 42 mg/l over a 10 week period. Filtered samples were used in the test to remove the large amount of algae present in the pond water. Therefore, the results reflect only that portion of soluble organic or oxidizing matter that was present in the filtrate. Interpretation of these data is inconclusive since a correlation with uptake of any nutrient, hyacinth coverage or other easily observable relationship could not be found. Consequently, COD testing was curtailed after the 12th water sample. An interesting observation is the relatively high figure in sample #8. This sample was taken from the training pond adjacent to PDP into which the apron drains. It was postulated that part of the water used to fill PDP was pumped out of the training pond by the construction contractor.

TABLE 15

COD Results on Filtered Sample
From PDP

Sample #	Days	COD mg/l	Agit/n.Agit	Comments
1	-6	50.2	NA	
2	-2	84.9	NA	
3	-2	73.3	AGIT	
4	-1	88.8	AGIT	Start of Run #1
5	0	69.5	AGIT	
6	6	44.4	NA	
7	6	46.3	AGIT	
8	6	24.3	NA	Large KSC Pond
9	6	19.3	–	KSC Tap H_2O
10	12	38.6	SHORT AGIT	
11	14	42.4	AGIT	
12	20	38.6	NA	
13	23	Not tested	AGIT	

Trace Elements

Seven water samples were analyzed for Fe, Cu, Mn or Zn. Results appear in Table 16 . Fe, required in plant metabolism, was reduced to below the detectable limit (.00 ppm) but Cu or Mn did not change much within the 57 day period.

Table 16

Analytical Data on Trace Elements, Run #1, PDP

Sample #	Days	Cu ppm	Mn ppm	Fe ppm	Zn ppm	Comments
1	-6	.12	.11	-	-	
5	0	.12	.10	-	-	
9	6	.22	-	-	-	Trng.Pond H_2O (Source of Cu)
11	14	.15	.08	.005	-	
14	27	.11	.10	.002	.22	
20	57	-	-	.00	.22	
21	63	.09	.10	-	-	

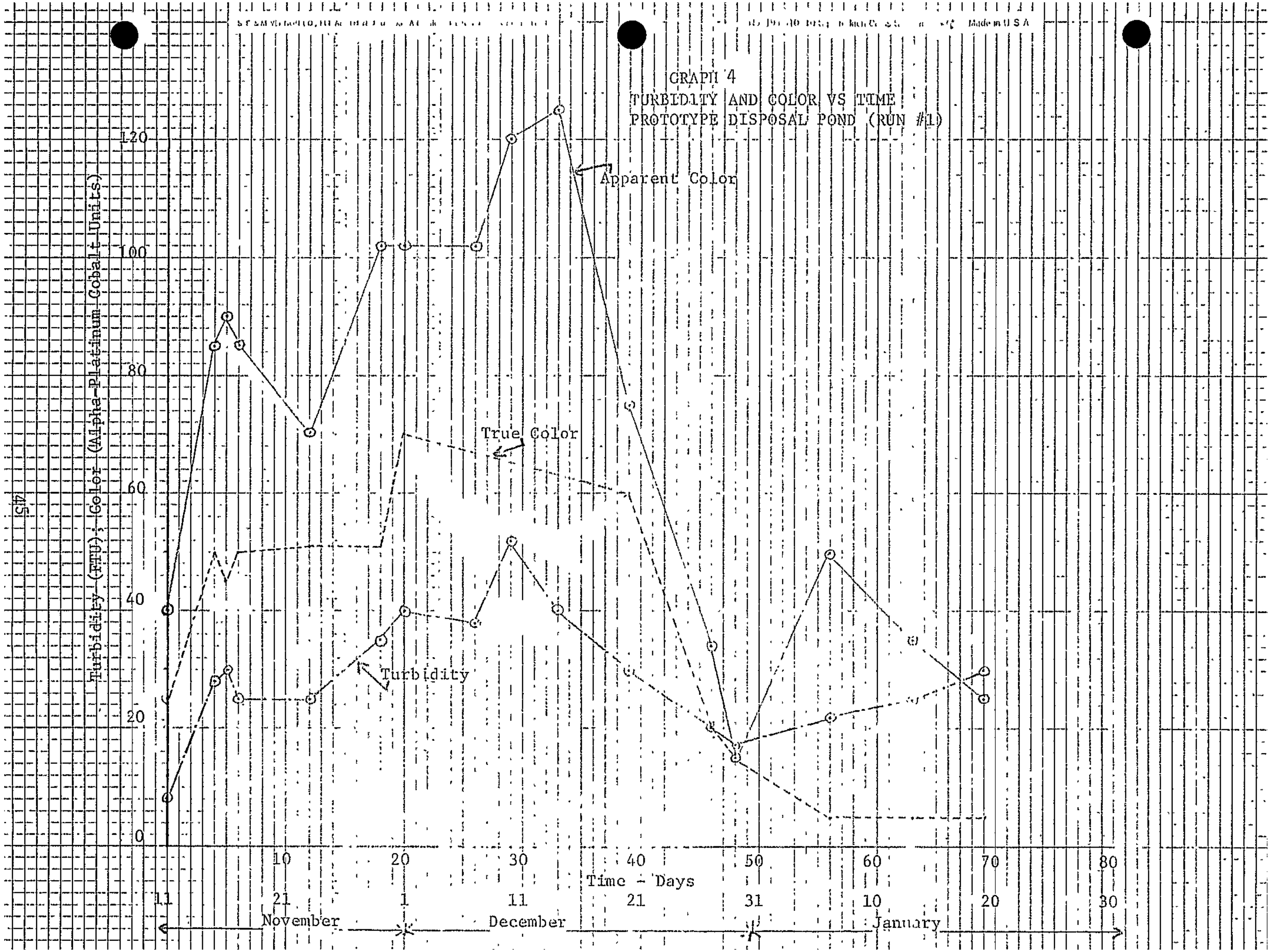
Turbidity Tests

Turbidity in water is caused by the presence of suspended matter, such as clay or inorganic or organic matter. In Graph 4 are plotted the changes in turbidity and color vs time. The increase in turbidity was due almost entirely to the increase in the population of algae rather than from suspended solids. Turbidity increased from 18 FTU (on Nov. 17) to a high of 52 then decreased to 19 on the 57th day. As the nitrogenous compounds were used up, turbidity dropped to about the original level.

The changes in apparent and true color are displayed in this graph. Color in water may result from the presence of humus, plankton, weeds, etc. True color, as used herein is the measurement obtained from the sample from which turbidity has been removed by means of centrifugation. Apparent color is determined on the original sample without any pretreatment. True color fluctuated rather widely. Apparent color reached a peak coinciding with that of turbidity, which then decreased. Both measures decreased toward the end of the run.

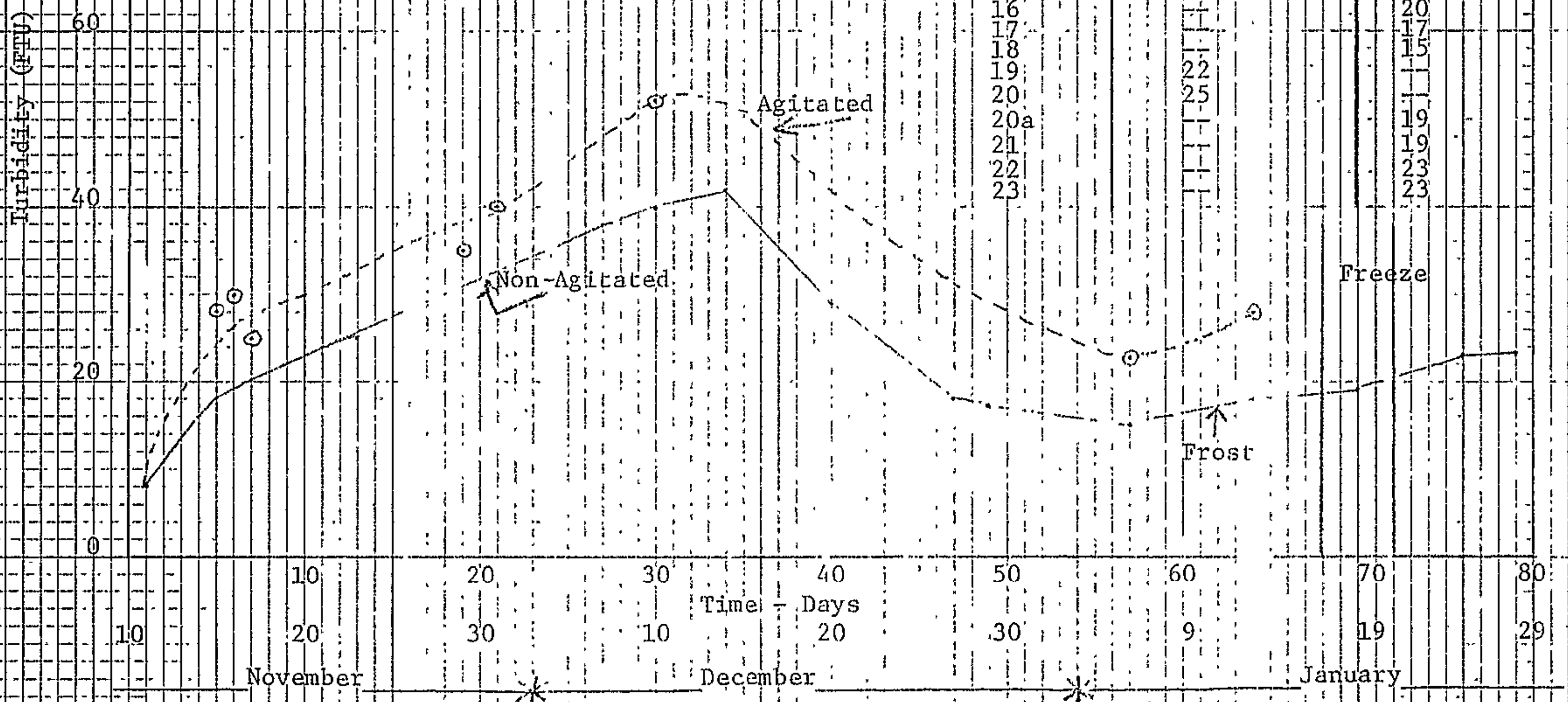
Effect of Agitation on Turbidity Readings

In Graph 5 appear two curves. The dotted curve shows turbidity measurements on agitated samples, the solid curve on non-agitated samples. As expected, turbidity is higher after bottom sediment is stirred up.


GRAPH 4
TURBIDITY AND COLOR VS TIME
PROTOTYPE DISPOSAL POND (RUN #1)
Turbidity (FTU); Color (Alpha-Platinum Cobalt Units)
120
100
80
60
40
20
0
Apparent Color
True Color
Turbidity
10
20
30
40
50
60
70
80
Time - Days
11
21
1
11
21
31
10
20
30
November
December
January

GRAPH 5

AGITATED AND NON-AGITATED
TURBIDITY VS TIME
PROTOTYPE DISPOSAL POND (RUN #1)



Sample #	Turbidity Agitated	Non-Agitated
1	--	8
2	--	18
3	23	--
4	30	--
5	25	--
6	--	25
7	--	19
10	35	--
11	40	--
12	--	38
13	52	--
14	--	40
15	--	29
16	--	20
17	--	17
18	--	15
19	22	--
20	25	--
20a	--	19
21	--	19
22	--	23
23	--	23

Discussion on Suspended Solid and Volatile Suspended Solids

The suspended solids in water constitute that fraction insoluble in water. Estimation of the concentration of suspended solids is useful as a measure for design and evaluation of a treatment. Volatile suspended solids constitute that portion of suspended solids due to organic or volatile constituents.

In Table 17 are shown the changes in suspended solids (SS) and volatile suspended solids (VSS) vs time. At the start of the run SS were 26 ppm and decreased to about the 2 ppm at the end of the run. The SS proved to be volatile and probably all of organic origin as evidenced from the similarity of results in columns: SS & VSS. The trend seems to be for SS to decrease as time progresses. However, the turbidity increases into December, (see graph 7) This was attributed to algal multiplication.

The analysis of SS and VSS was performed on 24 hr. settled and chilled samples to permit deposition of algae and bacteria. Turbidity measurement on the other hand was conducted on thoroughly agitated samples.

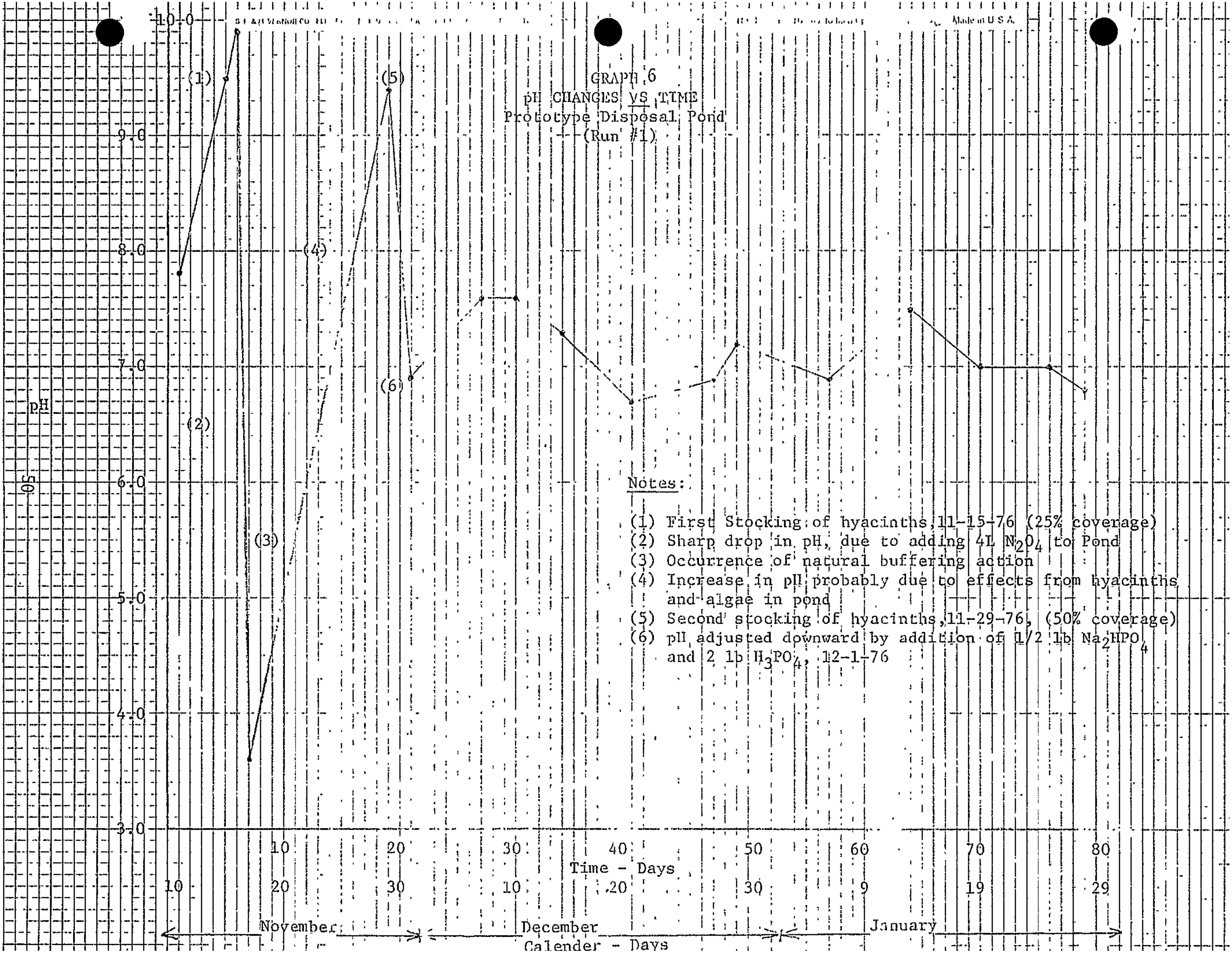
Samples 8 and 9 are not from PDP. Sample #8 is from the draining pond and shows both SS and VSS to be 48 ppm. Sample #9 is from the tap water supply containing neither SS nor VSS.

TABLE 17

SAMPLE #	DAYS	SS, ppm	VSS, ppm	COMMENTS
1	-6	14	14	
2	-2	10	10	
3	-2	28	26	
4	-1	32	26	
5	0	26	18	Run Started
6	6	24	22	
8	6	48	48	Sample from training pond
9	6	0	0	KSC tap H_2O @ training area
10	12	22	20	
11	14	8	8	
12	20	4	4	
13	23	6	6	
14	27	10	10	
15	33	0	0	
16	40	2	2	
17	42	0	0	
18	50	2	2	
20d	57	2	2	End of Run

pH

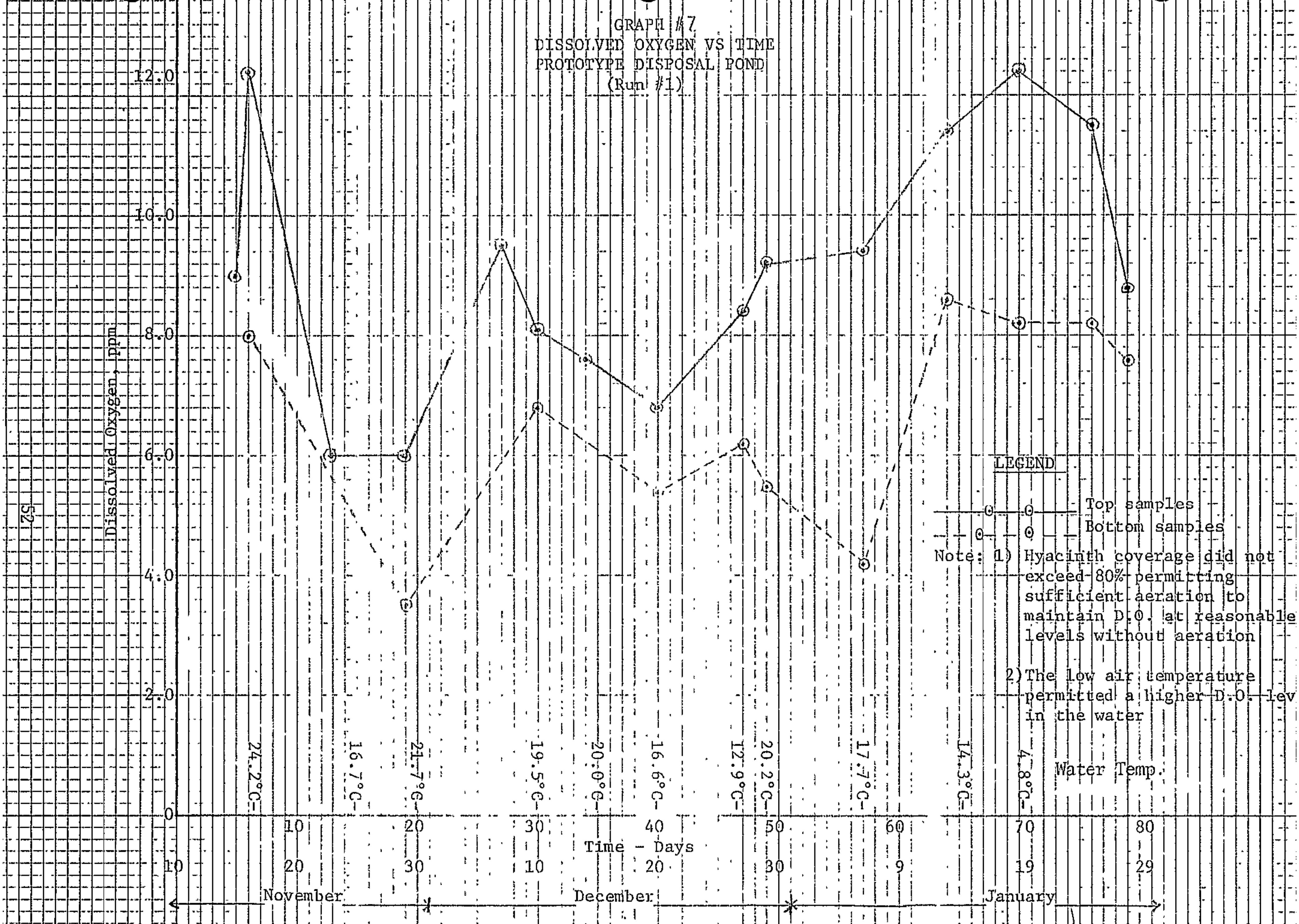
The pH changes occurring in the pond appear in Graph 6 . Prior to adding N_2O_4, pH was 9.9 on Nov. 17, 1976. After addition the pH dropped drastically to 3.6. As a result of this low pH the algae in the pond were severely damaged and practically disappeared in all but isolated pockets. The hyacinth survived this treatment without any visible damage. At the next sampling date a week later, however, the pH had risen to 6.0 as a result of the natural buffering action of the plants in the pond. The algae population started to multiply rapidly. After another week pH had risen to 9.4. At this time a pH adjustment was made by addition of Na_2HPO_4 and H_3PO_4 for two purposes. One, to decrease pH to the more favorable natural level and two, to increase phosphate to approx. the 20 ppm level. Henceforth, pH changes were within several tenths of the neutral point (the pH preferred by hyacinth).


GRAPH 6
pH CHANGES VS TIME
Prototype Disposal Pond
(Run #1)
pH
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
(1)
(2)
(3)
(4)
(5)
(6)
10 20 30 40 50 60 70 80
Time - Days
10 20 30 10 20 30 9 19 29
November
December
January
Calender - Days
Notes:
(1) First Stocking of hyacinths, 11-15-76 (25% coverage)
(2) Sharp drop in pH, due to adding 4L N_2O_4 to Pond
(3) Occurrence of natural buffering action
(4) Increase in pH probably due to effects from hyacinths and algae in pond
(5) Second stocking of hyacinths, 11-29-76, (50% coverage)
(6) pH adjusted downward by addition of 1/2 lb Na_2HPO_4 and 2 lb H_3PO_4, 12-1-76
50

Dissolved Oxygen

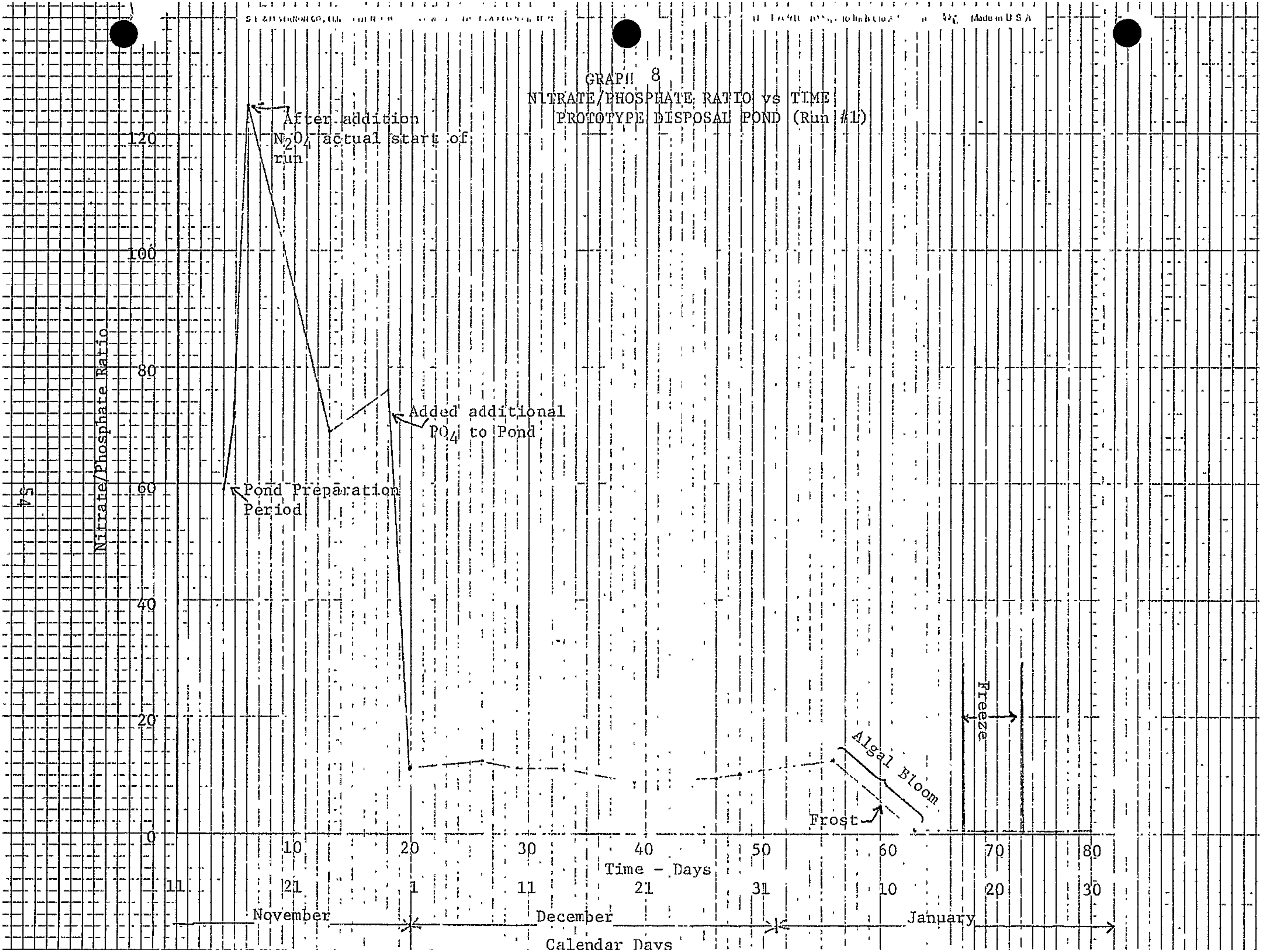
The analysis of dissolved oxygen (DO) is a key test in water pollution control activities. Graph 7 shows the D.O. levels in water samples taken either from four inches below the water surface or from the bottom of the pond. The latter samples were obtained by means of a sampler assembly used for this purpose. Measurements were made on site because of the instability of the samples on storage. The solid line indicates surface samples, the dotted line the bottom samples. Both lines roughly parallel each other. Water temperatures taken for certain samples are indicated. . The lowest bottom reading obtained was 3.5 ppm, the highest top sample reading was 12.1 ppm obtained on Nov. 16, 1976. The lower than normal winter air temperature during Run #1 probably explains the higher than expected D.O. level found in the pond containing a mat coverage of up to 80%.

The D.O. level is an important consideration in maintaining the desired aerobic conditions in the pond. In the hot summer months the D.O. level is expected to decrease sharply, especially with a high density of hyacinth plants or complete coverage.


GRAPH #7
DISSOLVED OXYGEN VS TIME
PROTOTYPE DISPOSAL POND
(Run #1)
Dissolved Oxygen, ppm
12.0
10.0
8.0
6.0
4.0
2.0
0
24.2°C
16.7°C
21.7°C
19.5°C
20.0°C
16.6°C
12.9°C
20.2°C
17.7°C
14.3°C
4.8°C
Water Temp.
10
20
30
40
50
60
70
80
Time - Days
10
20
30
10
20
30
9
19
29
November
December
January
LEGEND
Top samples
Bottom samples
Note: 1) Hyacinth coverage did not exceed 80% permitting sufficient aeration to maintain D.O. at reasonable levels without aeration
2) The low air temperature permitted a higher D.O. lev in the water

N/P Ratio

The Nitrogen-Phosphorus Ratio (N/P) changes vs time appear in Graph 8 The ratio was 125 immediately after adding N_2O_4 to the pond, but within 6 days decreased to 69. An addition of $NaHPO_4$ and H_3PO_4 was made on the 12th day. From the 14th to the 50th day the ratio did not vary greatly. However, the ratio was sharply reduced during the algal bloom period and was decreased to about the .5 level for the duration of the run which extended to the 72nd day. During the algal bloom period the NO_3^- was reduced to the 10 ppm or lower level by the hyacinth-algae.


GRAPH 8
NITRATE/PHOSPHATE RATIO vs TIME
PROTOTYPE DISPOSAL POND (Run #1)
After addition
N_2O_4 actual start of
run
Added additional
PO_4 to Pond
Pond Preparation
Period
Algal Bloom
Frost
Freeze
Nitrate/Phosphate Ratio
120
100
80
60
40
20
0
10
20
30
40
50
60
70
80
Time - Days
11
21
1
11
21
31
10
20
30
November
December
January
Calendar Days

Calculation for NO_3^- & TN Uptake

The following values were used for calculating the N uptake rates.

Surface area of water in pond = 620 sq ft (0.0142 acre)

Run Duration - 57 days

Hyacinth mat coverage 70% (avg of high & low estimates)

Number of plants per sq. yd = 78
or 3760 plants in pond @ 70% cover

Number of hyacinth per acre = 267,000

Volume water in pond = 8,600 gal.

Water depth, 36 inches (avg)

Weights: 14,713 g NO_3^-, 1,335 g NO_2^- or 3,748g TN (8.255 lbs)

The N-uptake calculations were performed on a volume basis. Results appear below:

Volume Basis

$$\text{wt/gal/day} \quad \frac{.1448 \text{ lbs TN/day}}{8600 \text{ gal.}} = 1.683\text{x}10^{-5} \text{ lbs TN/gal-day}$$

or

$$1.683\text{x}10^{-5} \times 9.77\text{x}10^{5} = \frac{16.44 \text{ lbs TN}}{\text{acre day}} \approx \frac{(7464\text{g TN})}{\text{acre day}}$$

Expressed in terms of NO_3^- or NO_2^- the uptake rates on a volume basis are:

$$NO_3^- = 64.4 \text{ lbs/acre day } \left(\frac{29,320 \text{ g}}{\text{acre day}}\right)$$

$$NO_2^- = 5.8 \text{ lbs/acre day } \left(\frac{2662 \text{ g}}{\text{acre day}}\right)$$

The N_2O_4 equivalent is about 64 lbs/acre day.

The results appearing in Run # 4 are lower than above due to the poor condition of the hyacinth from the freeze damage.

4.1.3.2 Identification of Algal Species

Although the initial introduction of 4 liters of N_2O_4 into the pond resulted in destructing a great many algal cells the environment soon stabilized and with the over abundance of required nutrients the algae population came back in force. As the algae population increased total nitrogen began to decrease. When the algae population reached its peak on Dec. 10th there were 39×10^7 algal cells/liter, a good indication of bloom conditions. At this point the algal population had exceeded the carrying capacity of the pond and there was insufficient total nitrogen available to support the population. Again the algal population began to decrease, but as it decreased it rapidly depleted the water of the remaining nitrogen. Analysis of the algae population revealed that the majority, approximately 70% of the algae were of the genus *Scenedesmus*, while 25% were of another green algae genus *Chlamydomonas* and the rest were made up of members of numerous other genera. The above mentioned genera are found in most sewage sludge with which the pond was seeded.

4.1.4 Conclusions

(1) Various forms of soluble nitrogren-containing material in the pond water were bioassimilated by the aquatic biota. The major TN absorbed was attributed to the hyacinth because of their larger biomass.

(2) The winter uptake rate was 64.4 lbs NO_3-/acre-day or 16.4 lbs TN/acre-day. The winter rate will probably be the limiting rate.

(3) The feasibility of moving soluble N_2- compounds (up to 460 ppm NO_3-) from water by hyacinth was demonstrated.

Recommendation

It is recommended that additional runs be performed at PDP to establish TN uptake rates for each season of the year.

Run #3 (MMH/Hyacinth)

.1 Objectives - Run #3

Objectives of Run #3 were (1) to observe the capability of hyacinth to utilize MMH (or its hydrolized products) as a source of nitrogen, (2) to determine the MMH uptake rate, (3) to observe side effects, and (4) to discover potential problem areas. Such information could not be found in the literature.

Two runs (3A and 3B) were performed at FIT in drums as preliminary trials prior to conducting a full scale run at PDP. A description of this effort and the results are presented in the following sections.

4.2.2 Test Set Up

Initially, a 50 gallon drum was filled with about 32 gals water containing the necessary nutrients and trace elements, in order to provide the proper nutritional requirements for rapid growth, as described for Run #1. Sufficient MMH was added to bring the concentration up to about 20 ppm. Analysis for MMH was performed immediately after mixing to minimize hydrolysis and possible reaction with organic and inorganic constituents present in the water. Then, a supplementary source of nitrogen, in the form of HNO_3, was added to attain approximately a 50 ppm NO_3^- concentration. In the past it was observed that considerable reaction occurs between MMH and HNO_3 even in dilute solution. Fresh hyacinth recently gathered from the St. Johns River were placed in the drum to start the run. Samples of water and observations were taken periodically. The results of chemical analyses appear in Table 17 .

Run 3B was set up, identical to 3A, after a stretch of cold and freezing weather damaged the hyacinth in the drum within three days from the start. The amount of HNO_3 added, however, was less. It was desired to determine the rate of MMH depletion at the low ppm range as well as to check the time for complete exhaustion of MMH.

Table 17
Analytical Data for Runs 3A and 3B

Run #	SAMPLE NO.	DAYS	NO_3^- PPM	NO_2^- PPM	NH_4^+ PPM	Total NITREEN	o-PO_4 PPM	MMH PPM	pH	Turbidity F.T.U.	COMMENTS
3A	1	0	56	0.01	50.3	54.05	.62	21.50	8.0	5	
	1A	1	--	--	--	--	--	6.00	--	--	
	1B	2	--	--	--	--	--	3.00	--	--	Jan 18-21 -water temp. below 5°C. Hyacinths turned brown due to cold
	2	6	1	0.09	1.7	1.73	.25	1.40	6.6	18	Ice found on surface every morning
	3	9	2	0.08	5.2	4.77	.24	1.00	7.4	18	Hyacinths changed 1-24-77 because of freeze damage
	4	14	1	0.03	2.9	2.56	.18	0.46	6.7	58	
	5	16	-	--	--	--	--	0.00	--	--	
3B	1	0	3	.02	79.3	65.6	1.40	22.00	6.8	42	
	2	6	2	.08	20.7	17.5	0.25	0.70	6.2	100	
	3	8	1	.03	28.8	23.8	0.20	0.20	6.7	300	

4.2.3 Discussion & Results - Run #3

The results of MMH uptake vs time in runs 3A and 3B are presented in Graph 9. It is seen that in both runs the initial MMH concentration in excess of 20 ppm was reduced within 5 days to below the 2 or 3 ppm level. On the third day during Run 3A cold weather damaged the hyacinth to an extent that the rate of MMH pickup was decreased. After 16 days MMH concentration was reduced to a non-detectable level and the run was completed. However, in Run 3B, without cold damage, the MMH reduction was essentially completed in 8 days (MMH = 0.2 ppm).

MMH hydrolyzes in water forming derivatives. One of the products shows up as NH_4^+. The NH_4^+ concentration, as shown in Table 17, initially 50.3 ppm was reduced to 2.87 ppm in Run 3A. In Run 3B, NH_4^+ changed from 79.3 to 28.8 ppm.

The NO_3^- concentration in both runs did not exceed 0.09 and varies slightly in each time period.

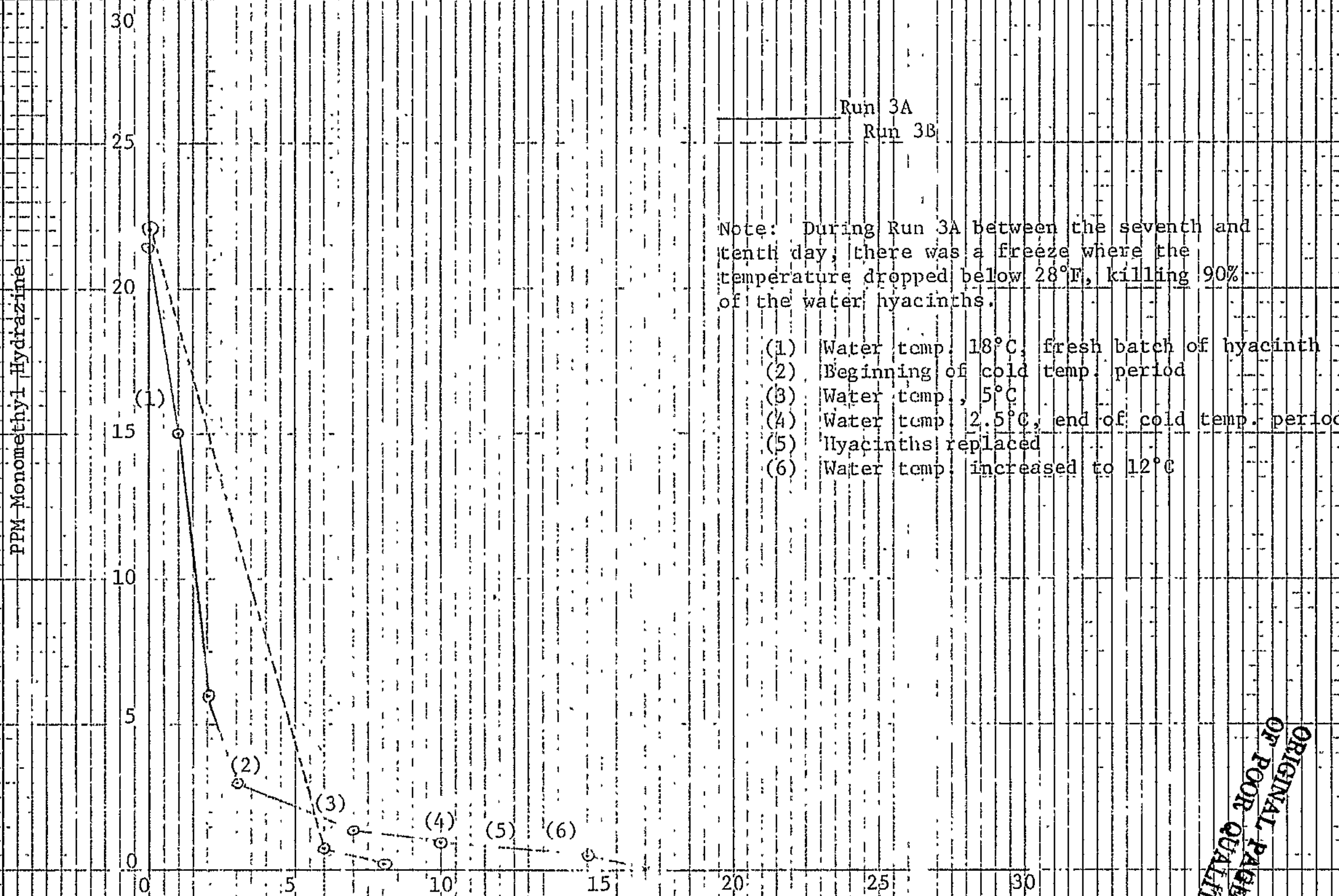
The uptake rates vs time for the nitrates and nitrites in Runs 3A and 3B are shown in graphs 10 and 11 respectively. In graph 12 are shown the changes in true color and turbidity for run 3A.

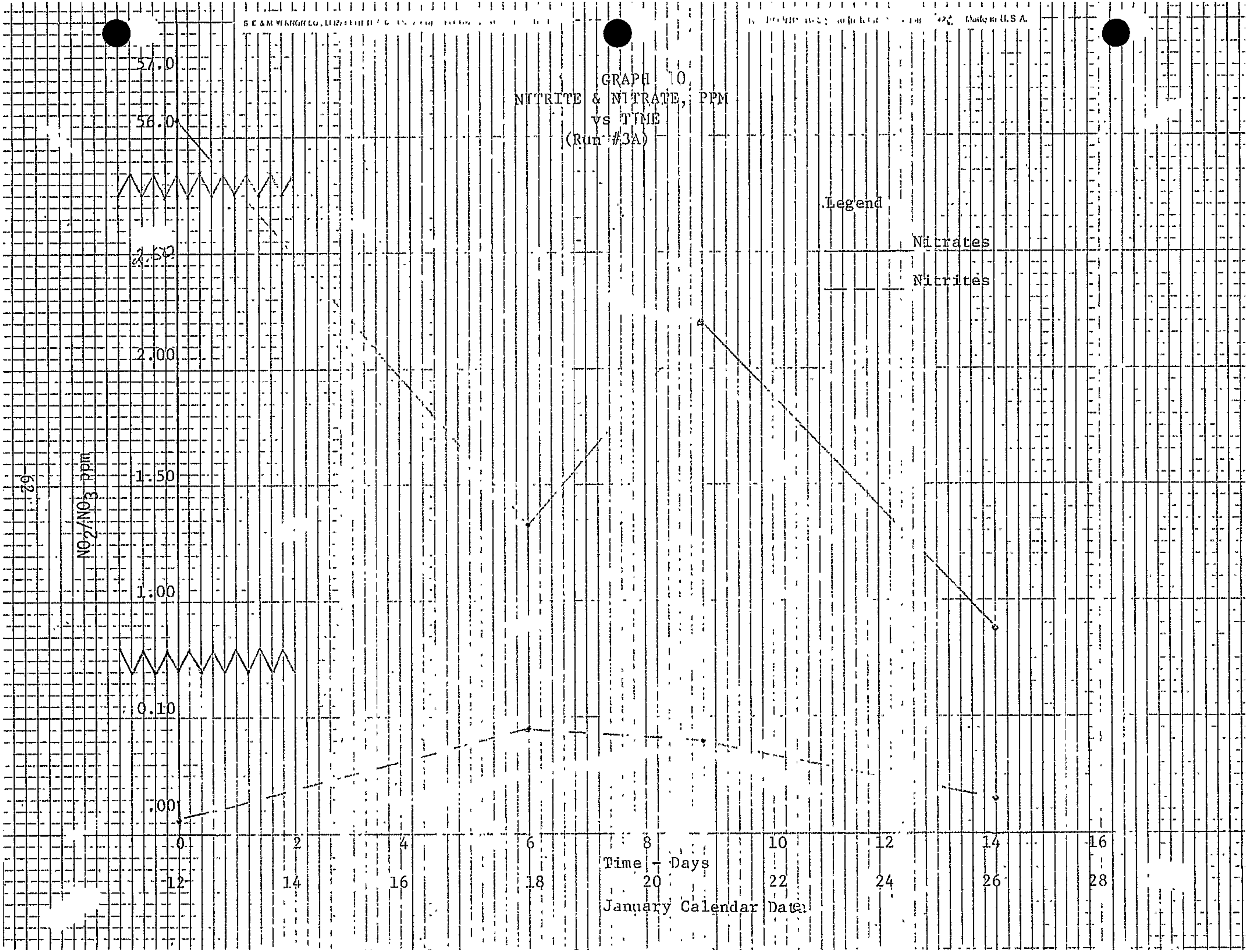
In Table 18 appear in summary form the results of runs 3A and 3B. Calculations show that MMH uptake was 0.005 and 0.01125g per gallon per day for Run #3A and 3B respectively. Expressed in other units the results are 10.77 and 24.22 lbs/acre-day for runs 3A and 3B respectively.

TABLE 18

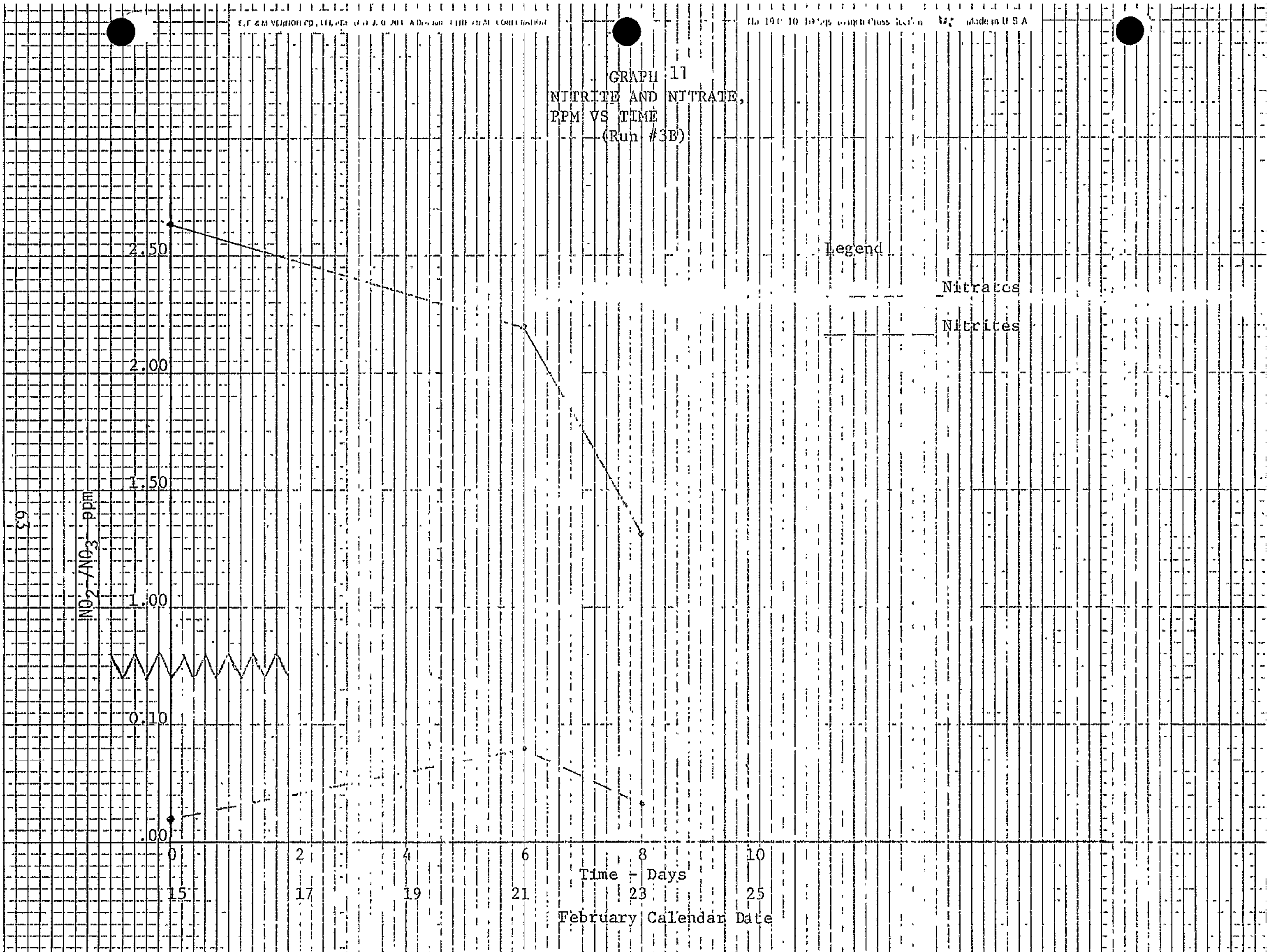
Run #	Grams MMH Start/Finish		Lenth of Run - Days	MMH Uptake g/day	g/gal day	lbs/acre day	Comments
3A	2.59	.00	16	.16	.005	10.77	freeze on 3d day
3B	2.89	.02	8	.36	.01125	24.22	

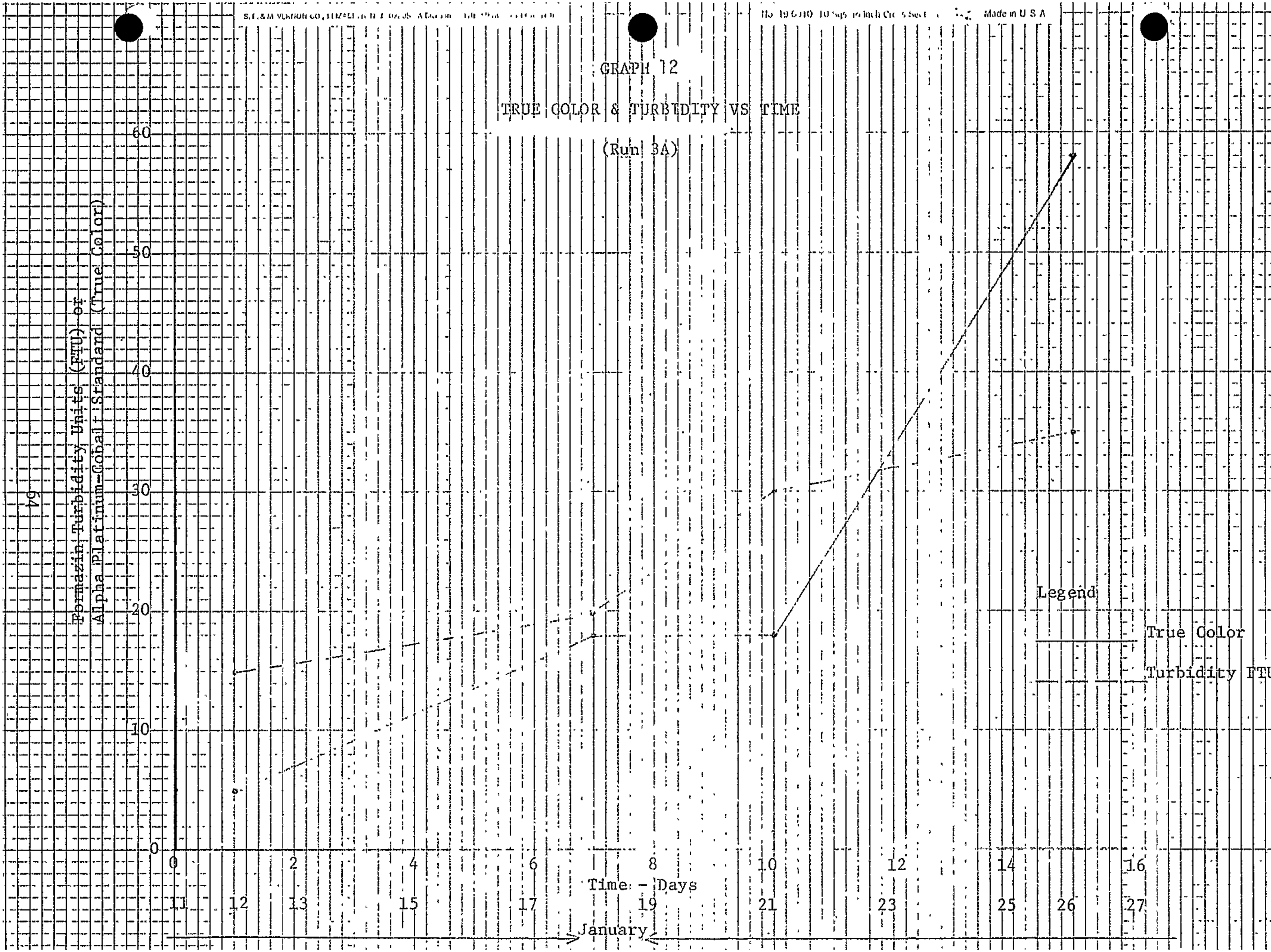
GRAPH 9
MMH UPTAKE BY WATER HYACINTHS VS TIME





GRAPH 10
NITRITE & NITRATE, PPM
vs TIME
(Run #3A)


GRAPH 11
NITRITE AND NITRATE,
PPM VS TIME
(Run #3B)
Legend
Nitrates
Nitrites
NO_2^-/NO_3^- ppm
2.50
2.00
1.50
1.00
0.10
.00
0
2
4
6
8
10
Time - Days
15
17
19
21
23
25
February Calendar Date



GRAPH 12
TRUE COLOR & TURBIDITY VS TIME
(Run 3A)
Formazin Turbidity Units (FTU) or
Alpha Platinum-Cobalt Standard (True Color)
0
10
20
30
40
50
60
0
2
4
6
8
10
12
14
16
Time - Days
11
12
13
15
17
19
21
23
25
26
27
January
Legend
True Color
Turbidity FTU

4.2.4 Conclusions

(1) The winter MMH uptake rate by hyacinth was about 24 lbs MMH/acre-day in Run 3B, where no frost damage occurred, and about 10 lbs MMH/acre-day in Run 3A, where frost damage occurred on the third day.

(2) This test demonstrates the feasibility of the hyacinth-pond-system as a potential method for MMH disposal in concentrations up to up to 20 ppm MMH.

(3) Freezing weather severely damages hyacinth creating secondary problems.

Recommendation

It is recommended that similar MMH runs be performed in the PDP in order to obtain data under actual field conditions and on a larger scale.

4.3 Run #4 (N_2O_4/Hyacinth)

4.3.1 Objectives

PDP Run #4 was set up and performed with objectives similar to Run #1 except the ratio of NO_2^- to NO_3^- was considerably higher than in Run #1, and the volume of water was greater. The sampling and analytical procedures utilized were similar to those described for Run #1. The purpose of Run #4 was to try to duplicate the previous results obtained for midwinter. A second purpose was to observe the effect of a high NO_2^- concentration on hyacinths. the pH was maintained above 6.0 during addition of the N_2O_4 by adjustment with NaOH solution.

The condition of the hyacinth in the pond at initiation of Run #4 was fair to poor. The plants were recovering from the effects of the freeze which occurred a few weeks ago. No new plants were available for restocking because the freeze affected the whole county.

4.3.2 Discussion and Results

Six water samples were taken during the run. The analytical results appear in Table 19. For purposes of calculating the nitrogen uptake rate, run duration was set at 35 days though data were collected for 40 days. A freeze or near freeze occurred on Feb. 17, 1977 causing severe damage to the hyacinth.

In Table 19 is shown that NO_3^-/NO_2^- are reduced from the 135/33 ppm to the 17/.11 ppm levels, respectively. Graph 13 displays the changes of NO_3^-, NO_2^- and TN as a function of time.

TABLE 19

Analytical Data for Run 4, PDP

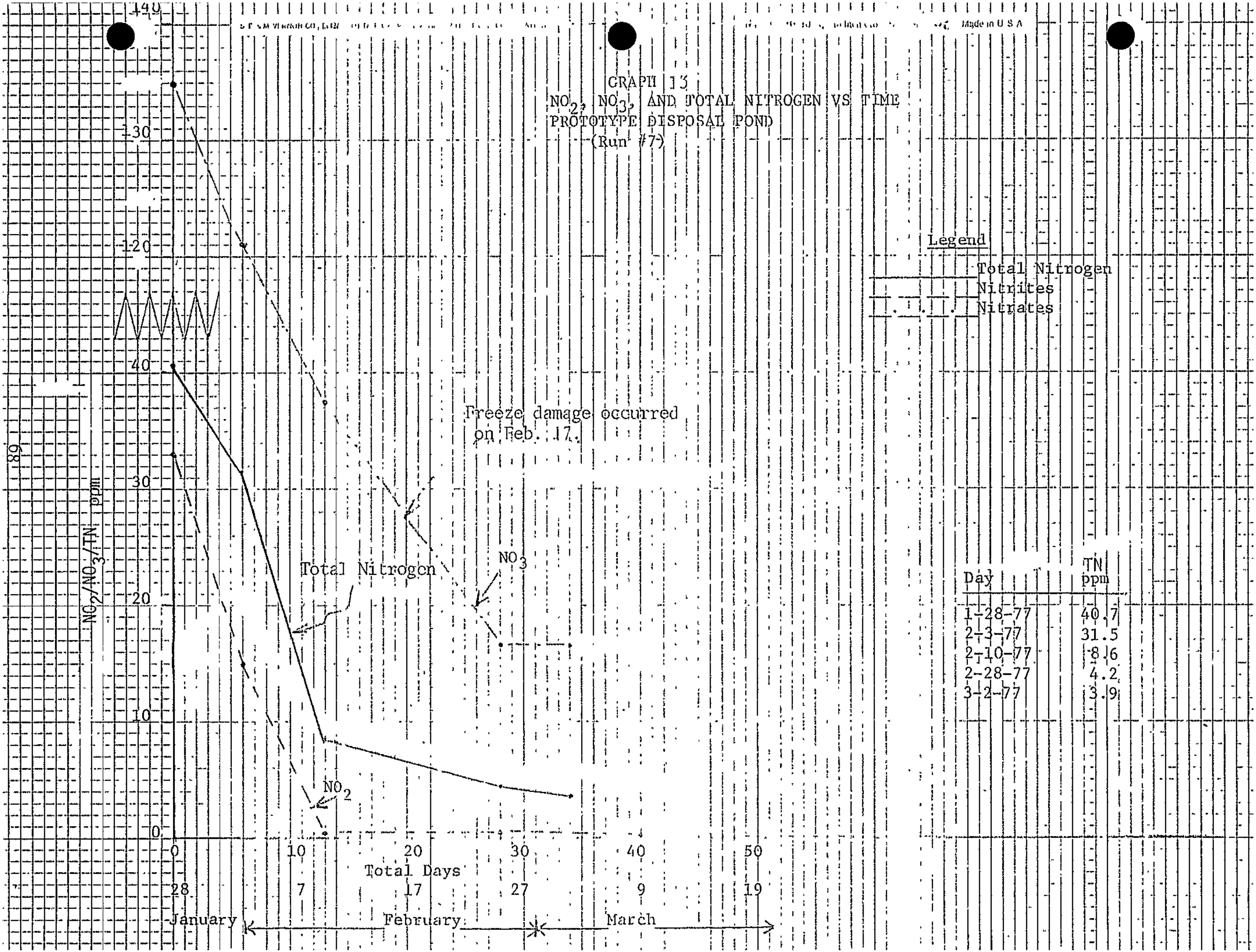
Sample #	Days	NO_3^- ppm	NO_2^- ppm	NH_4^+ ppm	Total Nitrogen	O-PO_4 ppm	pH	Turbidity F.T.U.
24	0	135	33.00	1.16	40.7	19.3	6.3	28
25	5	121	13.20	1.34	31.5	18.5	6.7	32
26	13	37	0.17	1.34	8.6	18.5	6.5	40
27	27	16	0.40	1.65	4.2	16.5	6.8	30
28	33	16	0.15	2.20	3.8	18.0	7.2	28
29	40	17	0.11	1.71	3.6	-	7.0	-

Table 19 -continued

Sample #	Days	Apparent Color	True Color	Dissolved Oxygen	N/P Ratio
24	0	75	30	--	2.6:1
25	5	100	75	* T:12.6 B:4.2	5.1:1
26	13	150	75	T:7.4 B:4.0	1.6:1
27	27	102	100	T:6.4 B:2.5	1.0:1
28	33	104	100	T:11.4 B:2.8	1.0:1
29	40	--	--	T:9.25 B:4.75	--

* T = Top sample (4" under surface)

B = Bottom sample


GRAPH 13
NO2, NO3, AND TOTAL NITROGEN VS TIME
PROTOTYPE DISPOSAL POND
(Run #7)
Legend
Total Nitrogen
Nitrites
Nitrates
Freeze damage occurred on Feb. 17.
Total Nitrogen
NO3
NO2
NO2/NO3/TN ppm
Total Days
January
February
March
Day
TN ppm
1-28-77 40.7
2-3-77 31.5
2-10-77 8.6
2-28-77 4.2
3-2-77 3.9

In Graph 14 are shown the changes in TN, turbidity and $O-PO_4$. TN is reduced from 40.7 to the 3.6 ppm level; $O-PO_4$ decreases slowly with time. Turbidity increases from 28 to 40 then decreases to 28 FTU.

In Graph 15 is shown the hyacinth mat coverage. The cover of live plants was reduced to about 10% after the freeze of Feb. 17 due to the poor initial condition of the plants combined with adverse cold weather periods the rate of nitrogen absorption from the pond was greatly reduced.

The comments made in Run #1 apply as well to Run #4 for the following tests: pH, Cl^-, MMH, color, and D.O. The differences are those of degree and of not too much consequence.

Effect of High NO_2^-

The NO_2^- concentration in Run #4 was 33 ppm compared to 41 ppm in run #1. . No pronounced toxicity effects, at least easily observable effects, were noted on the hyacinth due to the high NO_2^-/NO_3^- ratio. The algae may have suffered a slight decrease immediately after N_2O_4 addition, but at the next sampling period, a week later, the algae appeared to be unaffected.

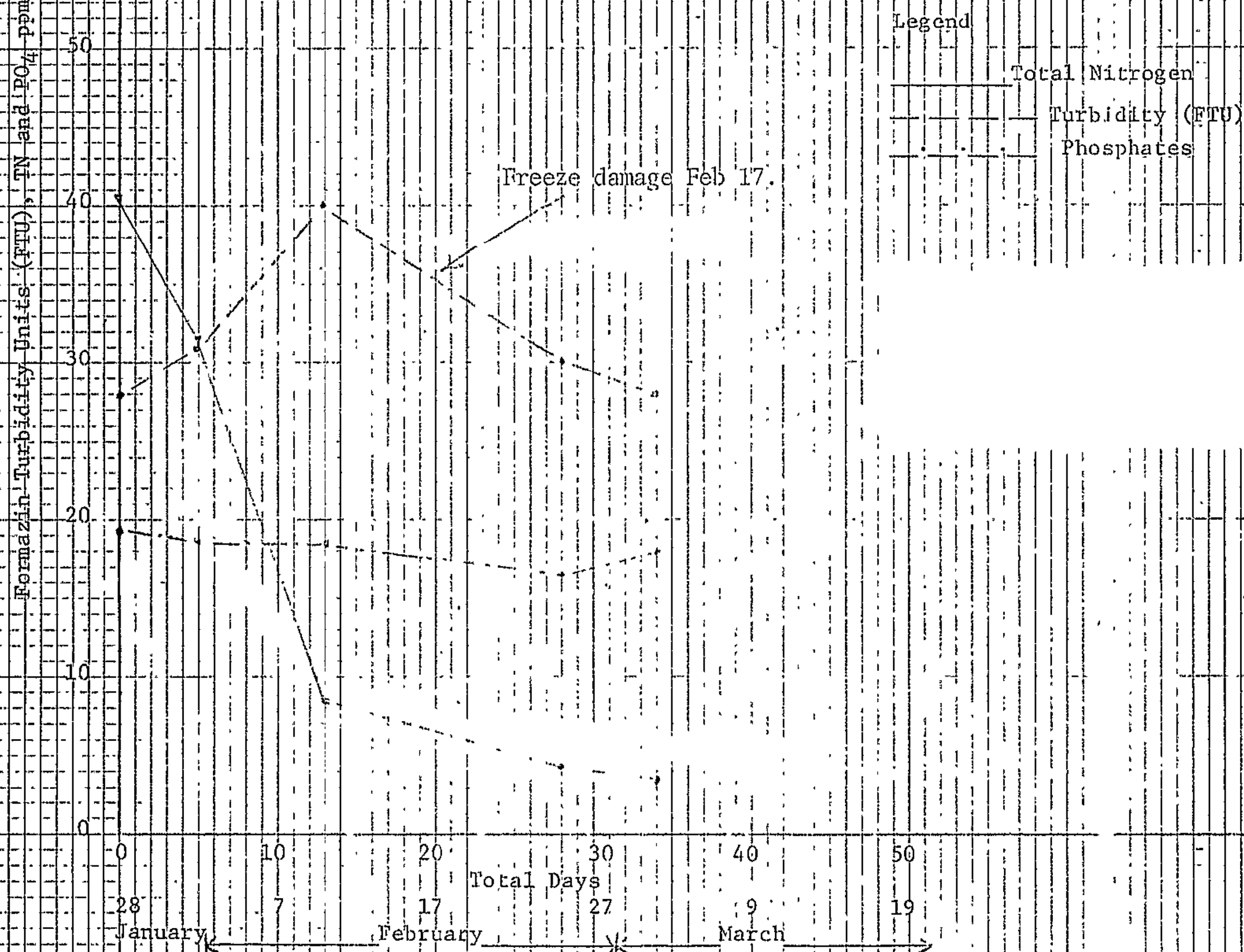
TN Uptake Rate

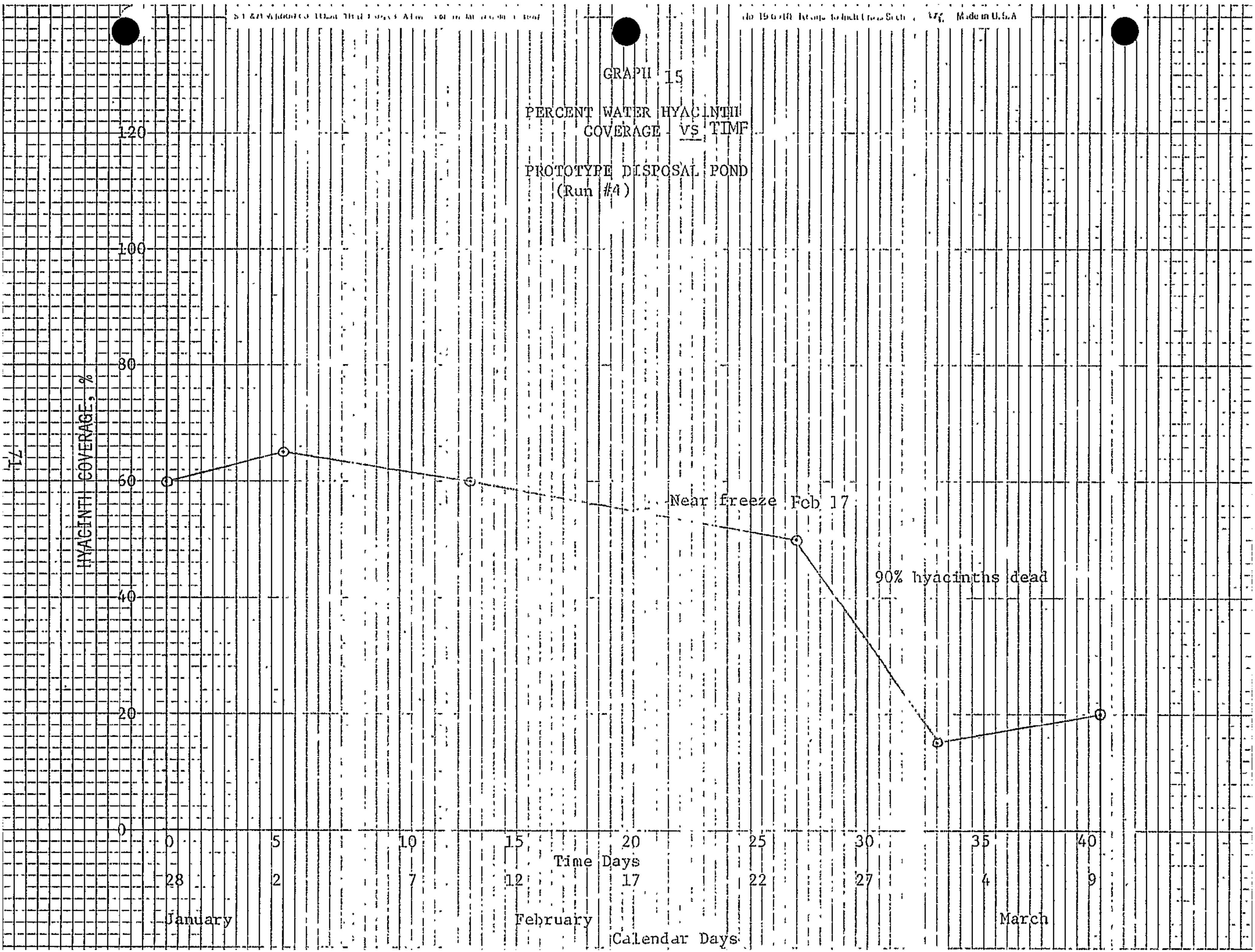
Due to the cold temperature during Run #4, damage occurred in the 3d week into the run, resulting in low nitrogen uptake. The TN uptake rate was calculated to be 46.3 grams of TN - per day. Equivalent rates are:

TN: 9.76 lbs/acre - day

N_2O_4: 35.2 lbs/acre - day

GRAPH 14
Turbidity, Total Nitrogen, and PO_4 PPM VS TIME
PROTOTYPE DISPOSAL POND
(RUN #7)




GRAPH 15
PERCENT WATER HYACINTH COVERAGE vs TIME
PROTOTYPE DISPOSAL POND
(Run #4)
HYACINTH COVERAGE, %
120
100
80
60
40
20
0
Near freeze Feb 17
90% hyacinths dead
0
5
10
15
20
25
30
35
40
Time Days
28
2
7
12
17
22
27
4
9
January
February
March
Calendar Days

Thus, the TN uptake rate was lower in run #4 than in run #1 in which a rate of 16.6 lbs/acre-day was obtained.

The experiences with Runs 1 and 4 provides useful design information. Also, one is able to predict that a hyacinth recovery period of several weeks may be necessary for new growth and damage repair in winter months. In the event of a hard freeze in central Florida (unlikely), it is conceivable for extensive irreparable damage to occur, necessitating hyacinth restocking.

4.3.3 Conclusions

The winter rate of TN uptake is strongly dependent on air temperature. A rate of about 10 lbs/acre-day may be expected in the event of a mild freeze that damages the leaves of the hyacinth; or considerably less if both leaves and roots are damaged.

Recommendation

The freeze factor must be incorporated into the design equations for a hyacinth pond-disposal system.

4.4 Run #5 (MMH/NaOCl)

Objectives of #5

Run #5 performed at FIT had two objectives:

(1) To provide an alternative method for destroying residual MMH in PDP in the eventuality of hyacinth failure or alternately to be able to empty the water from PDP on short notice.

(2) To demonstrate the NaOCl method for destroying MMH in dilute solution on a larger scale than the lab scale work performed in Phase 5 of NAS 10-8399.

The NaOCl method is applicable to solutions containing up to 1% MMH (10,000 ppm) or as little as 1 ppm or less. The restriction for the high concentration is to prevent thermal runaway and excessive pressures due to the rapid reaction and copious gas evolution. Thus, off-specification MMH ca be diluted to 1% or less and then treated. At the other extreme, should it be desired to destroy very dilute MMH this method is applicable also.

4.4.2 Procedure

The set up for performing the MMH/NaOCl test is shown in Fig. 4. Thirty gallons of water and 130 ml MMH were added to the drum and immediately a sample was analyzed for MMH (Sample #1) utilizing the p-DAB method. The stoichiometric quantity plus 5% excess NaOCl was then introduced into the drum, requiring approx. 3 min. Timing started from this point. Sample #2 was taken after 5 minutes and immediately analyzed for MMH. After 10 minutes a 3rd sample was taken and analyzed, as above. Two additional samples were taken after 60 minutes and 24 hours. The results appear in Table 20.

SCHEMATIC FOR MMH/NaOCl REACTOR

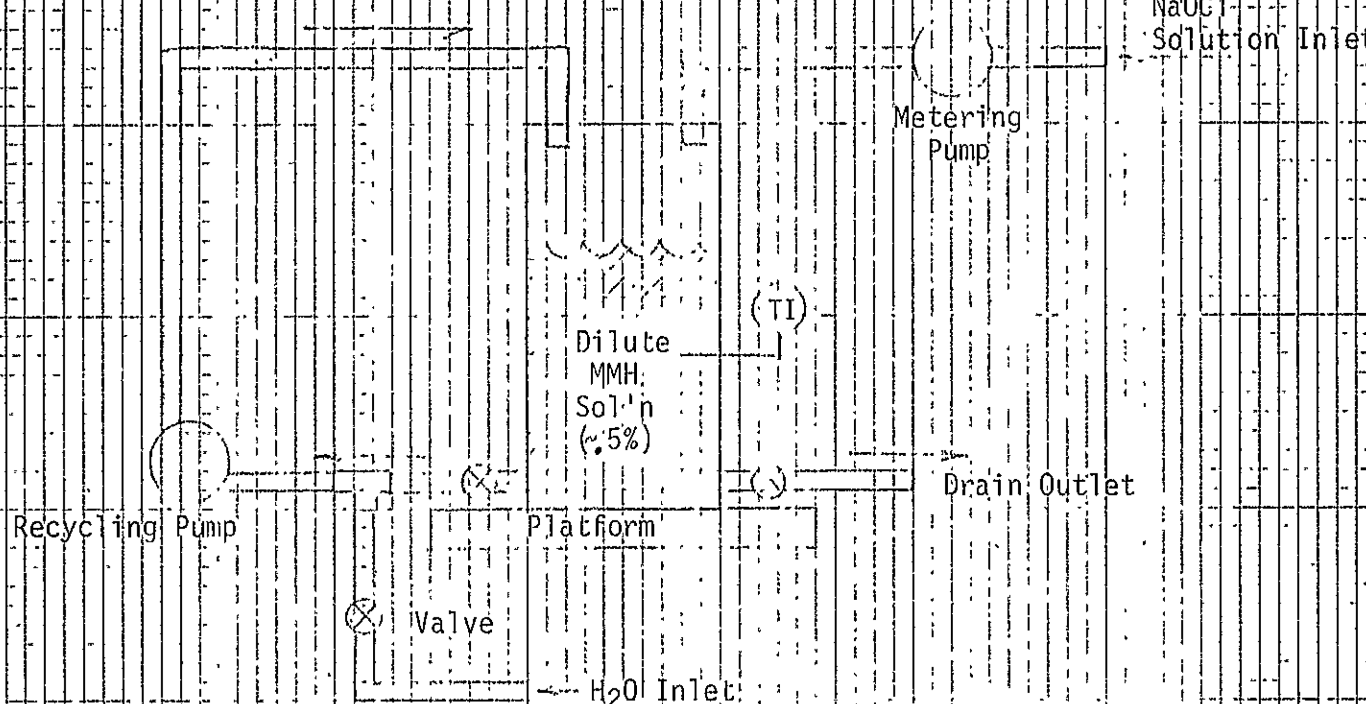


Figure 4

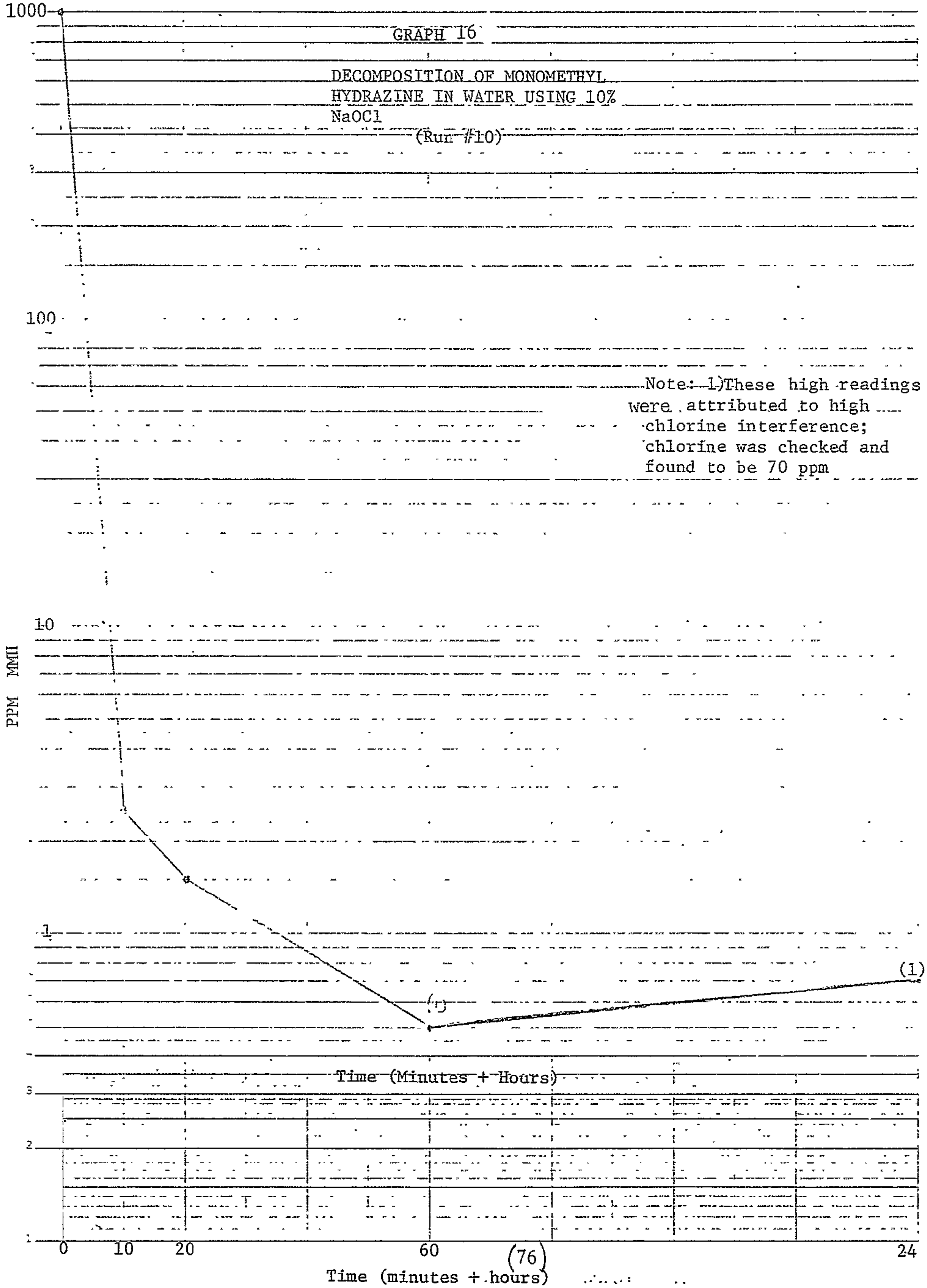
Table 20

Sample #	Water Sample Taken	MMH, ppm	Temp °C	Comment
1	Initial	1350	22.3	130 ml MMH/30 gal H_2O
2	After 5 min.	2.5	26.8	
3	After 10 min	1.5		
4	After 60 min	0.5		Chlorine Interference
5	After 24 hrs	0.7		" "
6	Control	0.2		No MMH, approx 70 ppm free chlorine

4.4.3 DISCUSSION & RESULTS

The addition of the NaOCl to the dilute MMH solution was accompanied by copious gas evolution and a 4.5°C temperature rise. Table 20 and Graph 16 show that the initial 0.1% MMH concentration was reduced to below the 1 ppm level within an hour. However, the free chlorine in the sample causes interference in the pDAB method, as explained elsewhere. The MMH concentration was probably approaching zero after 1 hour. To check the Cl_2 interference a test was performed on a solution containing only 25 ppm free Cl_2. The analysis showed 0.2 ppm MMH or about the same as in samples 4 & 5. This confirmed the Cl_2 interference.

The following test was performed to determine what effect the resulting solution would have on hyacinth. Two hyacinths were placed in the drum.


GRAPH 16
DECOMPOSITION OF MONOMETHYL HYDRAZINE IN WATER USING 10% NaOCl
(Run #10)
1000
100
10
1
PPM MMH
Note: 1) These high readings were attributed to high chlorine interference; chlorine was checked and found to be 70 ppm
(1)
(1)
Time (Minutes + Hours)
0
10
20
60
24
Time (minutes + hours)

containing approximately 4500 ppm chloride and 70 ppm free chlorine. Observations were made on the plants with the following results:

In the first 4 hours - no apparent change in color or other visible effect. On the next day - leaves beginning to droop and curl at edges. On the 3d day - advanced epinasty, most leaves at water level. On the 6th day - all leaves withered and brown.

Water hyacinths are salt intolerate. Batelle labs have established a maximum salt tolerance at 315 ppm Chloride.

4.4.4 Conclusions

Based on the results of this test, it was concluded that:

(1) Use of NaOCl is a simple and effective way for destroying residual MMH in concentrations up to 1350 ppm and may be applied to PDP.

(2) No regard was taken on the effect the NaOCl may have on the hyacinth or other biota in the pond. At sufficiently high free-Cl_2 levels the biota would be killed.

(3) The method appears to be satisfactory for drum size operations up to 1350 ppm MMH after inclusion of suitable safety procedures as apply for working with strong chemicals.

Recommendations

It is recommended that further investigations be conducted at PDP on utilizing NaOCl as a destructive agent for highly diluted solutions of MMH.

4.5 Overall Conclusions and Recommendations

Based on the above study the following overall conclusions were drawn:

(1) Water hyacinth readily assimilate from a dilute solution soluble nitrogen - containing compounds, including N_2O_4, MMH and/or their hydrolysis and/or other reaction products.

(2) The feasibility of the hyacinth pond concept as one method for destroying N_2O_4 or MMH wastes was fully demonstrated by this investigation in spite of the freezing problems encountered during three of the runs.

(3) Follow up work is necessary to optimize the operating procedures for both N_2O_4 and MMH for application at KSC.

Based on the above the following recommendations are made:

(1) Continue PDP runs in order to determine total nitrogen uptake rates in the spring, summer and fall seasons.

(2) Continue investigations on chemical methods of hypergol destruction, intially on drum scale to be followed on full scale (PDP) on promising methods.

(3) Establish new investigations on utilizing the hyacinth pond concept on the following suggested wastes

a. N_2O_4 vapor scrubber liquor (Na_2SO_3, NaOH solutions, etc)

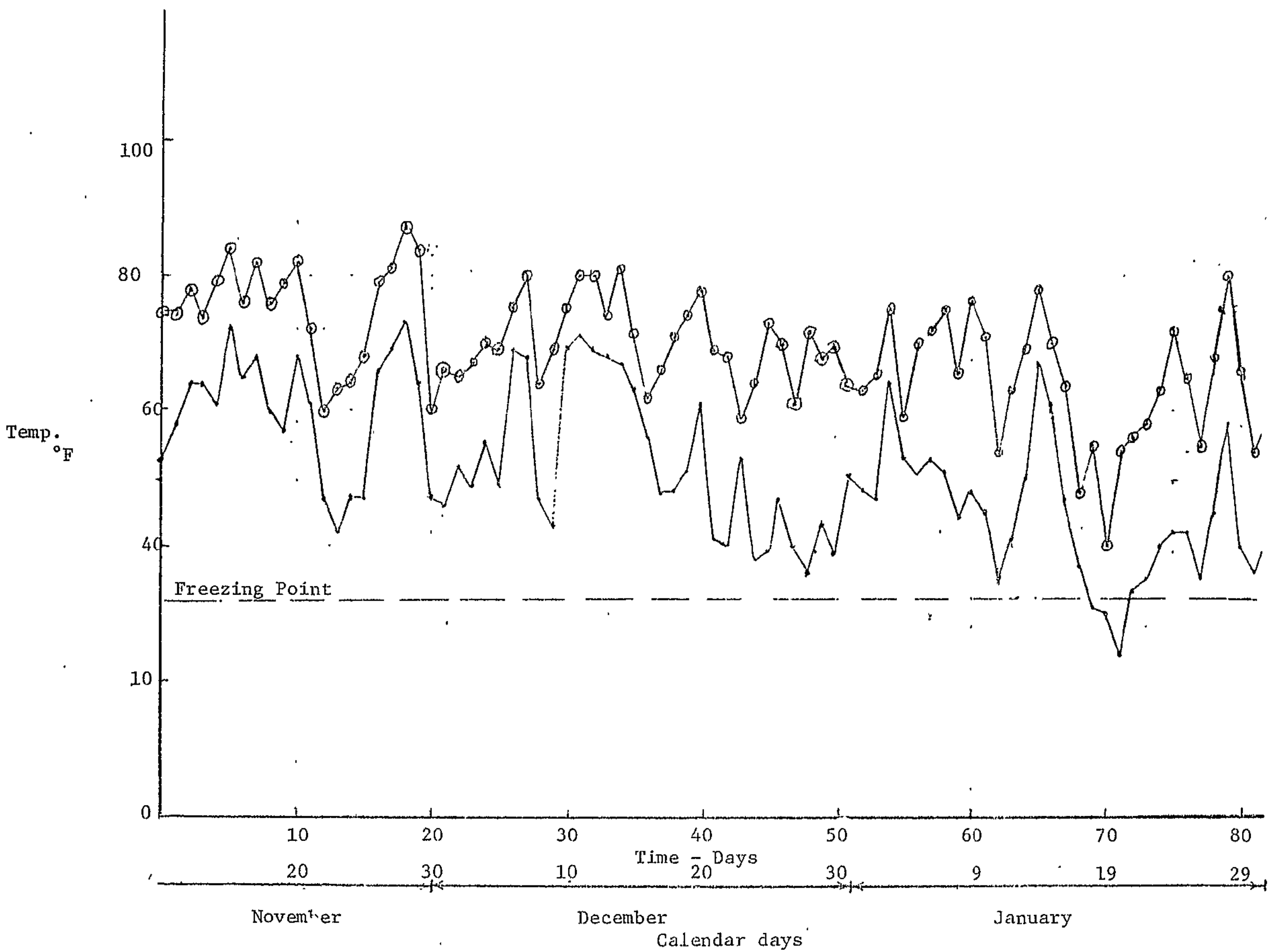
b. MMH vapor scrubber liquor (NaOCl, solutions, etc)

c. Non-halogenated solvents (MEK, IPA, E.G.)

d. Solutions containing heavy metals (plating solutions, Cd Cr, Cu, Zn)

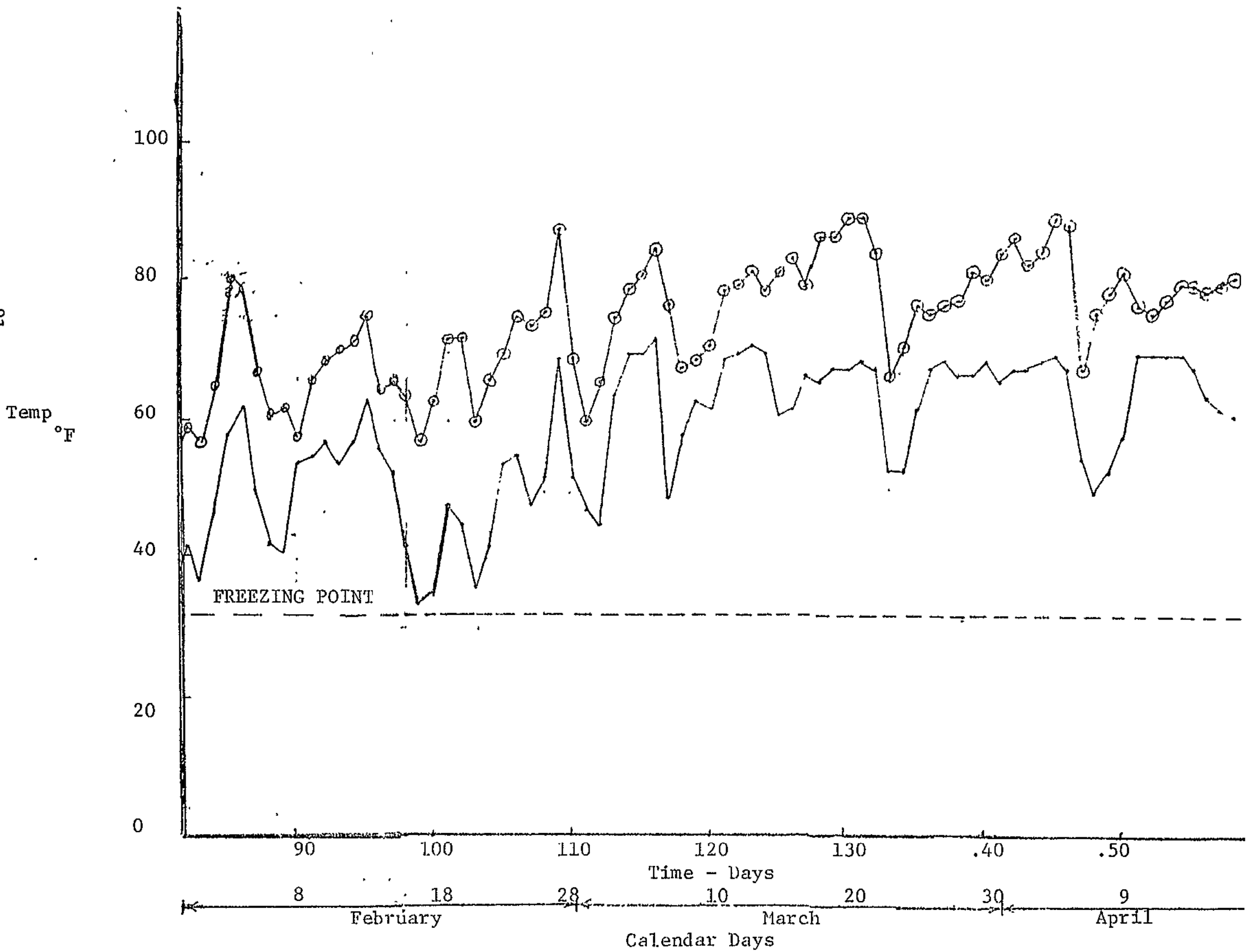
e. Miscellaneous chemicals (acids, bases, HNO_3, H_3PO_4, Battery acid, etc.)

GRAPH 17
HIGH AND LOW TEMPERATURES
RECORDED AT MELBOURNE AIRPORT



GRAPH 17 (continued)

HIGH AND LOW TEMPERATURES
RECORDED AT MELBOURNE AIRPORT



APPENDIX I (cont)

APPENDIX II

POND WATER SAMPLING DATA (Sheet #1)

Run #________________ Sample #________________

Water sampled by____________ date__________ time__________

H_2O Temp: (avg of 3 readings)____________

Weather conditions:

Air temp__________ Cloud cover__________

Rain (24 hr period)________ Wind____________

D.O. (on site):

YSI method 1.______ppm

2.______ppm

Avg______ppm

Winkler method:

	Sample size	D.F.	ml Titrant	D.O. ppm
1.				
2.				
Avg				

[illegible]:

Color: (Brief description)

Appearance of Hyacinths:

Notes/Comments:

Action required:

POND TEST DATE (Sheet #2)

H_2O Sample #	Date Tested	Color		D.O.		pH	$\frac{N}{P}$ Ratio	Turbidity F.T.U.	Analyst Initials
		Apparent	true	ppm	H_2O Temp.				

POND CHEMICAL TEST DATA (SHEET #3)

H_2O Sample # ____________ Date sampled ____________ Date tested ____________

Analyst ____________________ Approved by ______________________

Suspended solids test: Sample size __________ ml

Wt of tare & solids

Tare wt of Gooch

g solids

$$\frac{\text{g solids} \times 10^6}{\text{ml sample}} = \text{\_\_\_\_\_\_\_\_\_\_ ppm total SS}$$

VSS Test: $\frac{\text{Wt of loss on ignition} \times 10^6}{\text{ml sample}} =$ __________ ppm volatile suspended solids

COD Test:

	Size sample	Reflux Time. min	Standard-Titrant,ml	COD ppm
Blank				
Sample				

I.P.A. Test (glc)

Concentration of IPA __________ mg/1

POND CHEMICAL TEST DATA (SHEET #4)

H_2O Sample # ______________ Date sampled ____________ Date tested ____________

Analyst ______________________ Approved by __________________________

Suspended solids test: Sample size __________ ml

Wt of tare & solids

Tare wt of Gooch

g solids

$$\frac{\text{g solids} \times 10^6}{\text{ml sample}} = \text{\_\_\_\_\_\_\_\_\_\_ ppm total SS}$$

VSS Test: $\frac{\text{Wt of loss on ignition} \times 10^6}{\text{ml sample}}$ = ____________ ppm volatile suspended solids

COD Test:	Size sample	Reflux Time. min	Standard-Titrant,ml	COD ppm
Blank				
Sample				

I.P.A. Test (glc)

Concentration of IPA ____________ mg/l

APPENDIX II (continued)

TRACE ELEMENT DATA (Sheet #5)

Run # __________ H_2O Sample # __________ Date sampled __________

Analyst __________ Date Tested __________

Element	Method	Sample ml	D.F.	READING	ELEMENT PPM	COMMENTS
B						
Cu						
Fe++						
Mn						
Zn						

5.3 APPENDIX III

SAFETY HANDLING PROCEDURES

HYPERGOL HANDLING PROCEDURE

FOR

KSC PROTOTYPE DISPOSAL POND (PDP)

Submitted:

H Sivik 12-1-76

H. Sivik, F.I.T.
Contract NAS 10-8399

Approved:

R.E. Woods 12-1-76

R.E. Woods, SF-SOO-31

S.E. Churchwell 12-1-76

S.E. Churchwell, SO-LAB-31

H.H. Franks 12-1-76

H.H. Franks, DD-MDD-31

TABLE OF CONTENTS

1.0 SCOPE

This procedure covers hypergol (raw and diluted) deliveries to the Prototype Disposal Pond (PDP) and subsequent handling at the PDP.

2.0 APPLICABLE DOCUMENTS : K-V-053, Vol 1, Rev 5, SOP-6 and SOP-7

3.0 REQUIREMENTS

3.1 Hypergol Deliveries to PDP:- All deliveries of safety equipment and raw or diluted hypergols to the PDP will be accomplished by SO-LAB/MSI.

3.1.1 Scheduling:- FIT (Mr. Sivik) will call one of the following to arrange deliveries (allow 10 working days for delivery):

S.E. Churchwell, SO-LAB-31, 867-2330

R. Samples, MSI, 867-2337

3.1.2 Safety Notification: Notify SF-SOO-31, 867-3617, prior to PDP operations.

3.2 Hypergol Handling at PDP:

3.2.1 Training:- Personnel handling raw or diluted hypergols must have had the KSC "Propellant Hazards Qualification Course."

3.2.2 Protective Clothing:- Personnel handling raw or diluted hypergols must wear the KSC "Splash" suit type of protective clothing and gas mask. Personnel not wearing "Splash" and gas mask must be at least 50 feet upwind of handling activity.

3.2.3 Buddy System:- A minimum of two trained, "Splash"-suited personnel shall be utilized to conduct any handling of raw or diluted hypergols at the PDP. Oneof these shall be Mr. Sivik.

3.2.4 Spills:- If a spill should occur, flush skin immediately with copious quantity of water, then report to KSC medical facility.

3.2.5 N_2O_4 Transfer to PDP:

A. Designate two handlers as "Operator" and "Helper." The Operator will direct the operation and will handle the propellant. The Helper will stand by to provide operational and safety assistance, as required.

B. One bottle of N_2O_4 at a time will be brought to the perimeter of the pond, by the Operator. It will be his duty to empty the bottle into the water.

C. The Helper will take up a position by the water hose. His duty will be two-fold.

1. To give safety assistance, as required, and
2. to help the Operator in his task (hand tools). He will stand by in readiness at all times.

D. The Operator will then take a ¼" nylon rope, approximately 25 feet long and tie one end to a valve on the N_2O_4 bottle with 2 or 3 knots. The other rope end will be fastened to the PVC pipe or a suitable anchor.

E. The Operator will then grasp the bottle with one hand and with the other hand loosen the safety plug with a cresent wrench, at the opposite end of the nylon rope knots, and unscrew the plug from the bottle. He will then:

1. Lay the cresent wrench and safety plug down.
2. Lay the bottle down on the inclined edge of the pond liner.
3. Helper will turn on the water pump.
4. While firmly holding the nylon rope and bottle with one hand, the Operator with the other hand will turn the valve handle (1/8 to ¼ turn) until a small stream of brówn vapors of N_2O_4 are issuing forth.

5. Immediately submerge the bottle under water by gently sliding it down the incline about 10 feet until it comes to rest in the direct path of the water stream from the pump outlet.
6. Allow approximately 20-30 minutes for emptying the bottle.
7. During this period, both handlers will stay upwind of the prevailing wind and be on the lookout for brown fumes. The gas mask need not be worn but must be kept in readiness for immediate use.

   NOTE: No escaping brown fumes above the water surface are expected at this slow outflow from the bottle since all the vapors should be rapidly dissolved in the water.

8. After 20-30 minutes, the Operator will re-don the gas mask and then carefully drag the bottle to near the surface of the water to observe if gas is still issuing from the bottle.
9. If the bottle is not empty, reposition the bottle as in step 5 and allow an additional 10 minutes.
10. Repeat steps 8 and 9 if necessary.
11. If contents of bottle was exhausted, as evidenced by no brown fumes, pull bottle out of the water, shut off valve and replace safety plug.

F. If required, proceed with another full N_2O_4 bottle as above, until the desired concentration of NO_3 is reached in the pond water.

G. After all the predetermined amount of N_2O_4 was added to the pond, the Operator can remove gas mask (but not protective clothing).

H. Rinse the empty N_2O_4 bottles with water from the hose.

I. Remove safety equipment.

J. Clean work area.

K. Turn over empty N_2O_4 bottles and safety equipment to MSI.

DISPOSAL OF HYAÇINTHS

FROM

PROTOTYPE DISPOSAL POND

Submitted by:

S. E. Churchwell, SO-LAB-3[illegible]
March 2, 1977

Approved:

KSC Safety

W. H. Lee, MD-B

H. H. Franks, DD-MDD-31

DISPOSAL OF HYACINTHS FROM PROTOTYPE DISPOSAL POND

1.0 SCOPE

Hyacinths plants used in the Prototype Disposal Pond (PDP) for studies require disposal. The disposal of these plants from the PDP, located in the Fire Suppression Training area off Static Test Road, shall be performed as outlined herein.

2.0 SCHEDULING

It is desired that the hyacinths be removed not later than March 15, 1977. S. E. Churchwell, SO-LAB-31, (867-2330) shall serve as the technical contact to coordinate the hyacinths removal. KSC Safety (867-3617) shall be notified at least 24 hours prior to the scheduled removal of the hyacinths.

3.0 REQUIREMENTS

3.1 Protective Clothing

Elbow length rubber gloves are required when handling the hyacinths.

3.2 Transportation Vehicles

A dump truck and a Gradall vehicle equipped with a weed bucket will be used to remove the hyacinths.

3.3 Hand Tools

Rakes or equivalent

4.0 COLLECTION

The hyacinths will be collected and then transported to the disposal site.

CAUTION

Exercise care to prevent puncture of the pond lining with Gradall or hand tools.

NOTE

To expedite collection of the hyacinths in the middle of the pond the blower and/or the water pump may be turned on so as to sweep them toward the shore.

4.1 While operating from the shoreline of the pond, skim the hyacinths from the water surface with the Gradall weed bucket. Use hand rake or equivalent, if necessary, to remove residual plant debris.

4.2 Allow the hyacinths to drain thoroughly and dump into the bed of the dump truck.

4.3 Remove the entire mat of hyacinths from the pond

4.4 Turn off the pond circulation system, if used.

5.0 DISPOSAL

The hyacinths are to be disposed of at the land fill site located off Swartz Road.

5.1 Transport the collected hyacinths immediately to the land fill site.

5.2 Dump the hyacinths in a location designated by the land fill supervisor or operator.

NOTE

The hyacinths may be earth covered by the land fill operator, if desired.

5.3 Return the vehicles to the garage and the tools to their respective storage areas.

DISPOSAL OF WATER CONTAINED IN

THE KSC PROTOTYPE POND

SUBMITTED:

H. Sivik, F.I.T.
Contract NAS 10-8399

APPROVED:

B.P. Willis, SF-SOO-31

S.E. Churchwell, SO-LAB-31

W.H. Lee, MD-B

H.H. Franks, DD-MDD-31

TABLE OF CONTENTS

1.0 SCOPE

This procedure gives instructions for pumping out the water contained in the prototype disposal pond (PDP). A preliminary analysis for hydrazine is performed and the residual hydrazine is destroyed by adding NaOCl solution prior to pumping.

2.0 APPLICABLE DOCUMENTS

3.0 REQUIREMENTS

3.1 SCHEDULING

F.I.T. (Mr. Sivik) will call one of the following to arrange for emptying the PDP at least 5 working days in advance:

S.E. Churchwell, SO-LAB-31	867-2330
R. Samples, MSI	867-2337

3.1.2 SAFETY NOTIFICATION:

Notify SF-SOO-31 prior to PDP operations (867-3613).

3.2 TRAINING:

3.2.1 PROTECTIVE CLOTHING:

None required.

3.3 ANALYSIS AND HYDRAZINE DESTRUCTION PROCEDURE:

A. Prior to emptying the water in pond, a representative sample must be obtained and analyzed for hydrazine (or hydrazine derivatives, i.e., MMH, UDMH) by an authorized analytical procedure : D-DAB or equivalent.

B. In the event hydrazine or hydrazine-like products are present in excess of 0.2 ppm, a sufficient volume of a 10% solution of NaOCl (bleach) must be added to destroy it.

C. After addition of NaOCl agitate the pond by turning on the water pump and air blower for one-half hour or until reaction is complete.

D. A second water sample is taken and the steps A through D repeated until the residual hydrazine is 0.2 ppm or less.

NOTE: The presence of strong oxidizing agents (as NaOCl or NO_3) in the water will interfere with the hydrazine test. Run a blank sample containing an equivalent concentration of the oxidizing agents and subtract the "oxidizer" interference reading from the analytical value found on the sample water.

E. When the hydrazine is reduced below the 0.2 ppm level, the water is ready to be pumped, proceed as below.

3.4 WATER PUMPING PROCEDURE:

A. The operator will shut off valve #1 (in schematic) and open valve #2.

B. Attach PVC pipe into female fitting on the cross with the exit end of pipe projecting into the 100x100 foot pond (large pond).

C. Plug extension cord into proper receptacle on the electric panel.

D. Throw to "on" position the main power level on square D box.

E. Flip water pump switch on terminal box to "on" position.

F. Allow water pump to empty pond. Pump capacity is 30 gpm so it will require about 6 hours to pump out 8000-9000 gallons of water.

G. When most of the water is removed, it may be necessary to move the suction pipe to the low point in the pond.

NOTE: Do not allow roots or solid debris on the pond bottom to enter the pump as damage or plugging may occur. In the event much debris is accumulated on the bottom, it may be advisable to shovel out the debris and convey it to a sanitary landfill.

H. When the pond is emptied, shut off the pump and turn off the electric power at the main box.

I. Remove the PVC pipe and store on ground in an out-of-the-way location to prevent damage.

J. Notify your supervisor that work is complete.

4.0 HYPERGOLS ANALYSIS

If required by safety, environmental health (Pan Am) will perform the water sampling and analysis for the MMH or N_2O_4 residuals present in the pond water, as required.

4.1 METHODS FOR ANALYSIS OF MMH RESIDUALS

Analysis of MMH residuals will be performed either with the G.L.C. or wet method by the procedure below

MONOMETHYL HYDRAZINE (MMH) ASSAY

Reagents

(1) p-Dimethylaminobenzaldehyde (DAB) solution
Must be prepared fresh each day
2.0g. DAB, 90 ml. Methanol, and
10 ml. of concentrated HCl

(2) Standard MMH Solution
1.00g. MMH is diluted to 1.0 liter with
H_2O - stock solution

1 ml. of above stock solution is diluted with H_2O to 100 ml. - working solution

Procedure - Standard Curve

Into six 10.ml. volumetric flasks, pipet 5 ml. DAB reagent. In order, pipet 1, 2, 3, 4, 5 ml. of working MMH standard and to the sixth flask add 5 ml. H_2O (reagent blank).

Dilute these solutions as needed to 10 ml. with H_2O, mix well and let stand 30 minutes. Determine absorbance on a suitable spectrophotometer at 485 mm.

For sample determination, prepare appropriate dilution to obtain a final concentration in 10 ml. flask of 1.5 micrograms/ml. Use 5 ml. of this solution and 5 ml. of the DAB solution.

4.2 METHODS FOR ANALYSIS OF N_2O_4 RESIDUALS

Analysis of N_2O_4 residuals will be performed utilizing procedures given in "Standard Methods for the Examination of Water and Wastewater," 14th edition.

THIS PROCEDURE CONTAINS HAZARDOUS OPERATIONS

MMH

HANDLING PROCEDURE

FOR

KSC PROTOTYPE DISPOSAL POND (PDP)

Submitted:

H. Sivik, F.I.T.
Contract NAS

Approved:

J. T. McGough SF-SOO-3

S. E. Churchwell SO-LAB-31

W. H. Lee MD-B

H. H. Franks DD-MDD-31 6-28-77

TABLE OF CONTENTS

1.0 Scope

This procedure covers diluted MMH (5%) deliveries to the Prototype Disposal Pond (PDP) and subsequent handling at the PDP.

2.0 Related Documents

K-V-053, Volume 1, Revision 5, SOP-6 and SOP-7.

3.0 Requirements

3.1 Hypergol Deliveries to PDP

All deliveries of safety equipment and diluted hypergols to the PDP will be accomplished by SO-LAB/MSI.

3.1.1 Scheduling

FIT (Mr. Sivik) will call one of the following to arrange deliveries (allow 10 working days for delivery).

S. E. Churchwell, SO-LAB-31, 867-2330

R. Samples, MSI, 867-2337

3.1.2 Safety Notification

Notify SF-SOO-31, 867-3617, prior to PDP operations.

3.2 Hypergol Handling at PDP

3.2.1 Training

Personnel handling diluted hypergols must have had the KSC "Propellant Hazards Qualification Course."

3.2.2 Protective Clothing

Personnel handling diluted hypergols must wear splash suits with Scott Air Packs, boots, gloves and face shields. Personnel not wearing protective clothing must be at least 50 feet upwind of handling activity.

3.2.3 Buddy System

A minimum of two trained personnel shall be utilized to conduct any handling of diluted hypergols at the PDP.

3.2.4 Spills

If a spill should occur, flush skin immediately with copious amount of water, then report to KSC medical facility.

4.0 MMH Transfer to PDP

A. Designate two handlers as "Operator" and "Helper." The Operator will direct the operation and will handle the MMH. The Helper will stand by to provide operational and safety assistance, as required.

B. The container(s) of 5% MMH (previously prepared by MSI) will be brought to the perimeter of the pond by the Operator. It will be his duty to empty the container(s) into the water.

C. The Helper will take up a position by the water hose. His duty will be two-fold.

   1. To give safety assistance, as required, and
   2. To help the Operator in his task. He will stand by in readiness at all times.

D. The Helper will turn on both the water pump and the air blower to start circulation in the pond.

E. The Operator will pick up the MMH container one at a time and unscrew the cap. Then, while holding it just above the surface of the water, pour the contents into the pond. It may help to distribute the material if the Operator also walks around the dike while pouring. Exercise care NOT to spill any MMH directly on the hyacinth plants. If necessary, shove plants away from the spill area.

F. Repeat Step E for additional containers, as required.

G. After all the predetermined amount of MMH is added to the pond, allow an additional 15-20 minutes agitation time to mix the material.

H. Rinse the emptied containers with 3 or 4 changes of water, about 1 or 2 quarts each time, and dump the washings into the pond. Replace the cap.

I. Thoroughly rinse operator's protective clothing with water from the hose.

J. Remove safety equipment.

K. Clean work area.

L. Turn over the empty container(s) and safety equipment to MSI.

5.4 Miscellaneous Pond Design and Operating Data

DESIGN CRITERIA FOR POND CONSTRUCION

ORIGINAL PAGE IS OF POOR QUALITY

SITE:

The pond shall be constructed within the fenced confines of the fire suppression training area located off Static Test Road on KSC property. In Figure 5 are indicated several likely locations within this area. The selected site should not be in path of rain wash-off nor in a low spot. It should be situated conveniently with respect to supply of water and electrical power for operating pumps and air blowers and far enough away from the concrete pad, the Hypergolic storage tanks and the existing pond, so as not to interfere with the training programs.

Exact siting is not specified. Final site selection is left to the disgression of the proper KSC personnel.

POND DESCRIPTION:

The pond is to contain from approximately 0 to 20,000 ppm of either/or both MMH and HNO_3/HNO_2 mixture plus some treating chemicals.

The contents of pond is to be neutralized with caustic or aerated during treatment and mildly chlorinated prior to dishcarge or short storage.

Generally pH will be in the 6-9 range; extremes of pH from 2 to 11 units for periods not to exceed 48 hours. Highest Cl_2 level is 40-100 ppm.

Temperature expected not to exceed 100°F. Useful life of pond for experimental work is estimated less than 2 years.

Dimensions of pond: Approximately 24 x 36 feet. (See Fig. 2).

Depth: 3½ to 4½ feet at center.

Volume at operating level - approximately 9,000 gallons.

Volume at Brim - approximately 13,500 gallons.

2.

Pond Description continued:

Sides sloped 2:1 (approximately)

A berm approximatley 18 inches above ground level to keep out rain run-off; width of berm determined by amount of excavated material.

SITE PREPARATION:

The area to be lined should be away from flood areas. Bottom of pit is sloped to allow draining. Provide at least two (2) inches of clean sand cover if subsoil contains sharp objects or rocks. Chemically treat ground under liner to prevent growth of trees or other vegetation.

An anchor trench in the outer perimeter (1 or 2 feet away from inner perimeter) of the dike approximately 10 inches square is back-filled with dirt after installing liner.

To monitor for leakage a slightly sloped 2" PVC perforated pipe is buried in a 10" x 8" deep pit and covered with pea gravel. This pipe also functions as a vent to relieve gas pressure. Figure 6 shows this pipe laid lengthwise but it may run width-wise.

The berm can be of width resulting from the excavated dirt, with outside slope of convenient angle.

LINER:

A suitable 20-30 Mil nominal liner (unreinforced) shall be installed in the graded excavated hole. The line material can be one of several, for example:

3.

LINER, Continued:

1. HYPALON (DuPont de Nemours & Company)
(Elastomer Chemicals Dept.)
(7527 Nemours Bldg.)
(Wilmingon, Del. 19898)

   See Sales Offices - Display 4

2. FLEXSEAL HN, Non-reinforced (Gulf Seal Corp.)
(510 Anna Avenue)
(Clearwater, Florida 33515)
(813/447-0897)

   See Display 5

3. PVC Lining (Watersaver Co., Inc.)
(3600 Wynkoop Street)
(Denver, CO 80216)
(303/623-4111)

4. PVC & HYPALON (Staff Industries)
See Display 6

5. OTHER EQUIPMENT SUPPLIES (See inclosures)

   a. Pond Liner Div.

   b. Misco United Supply Inc.

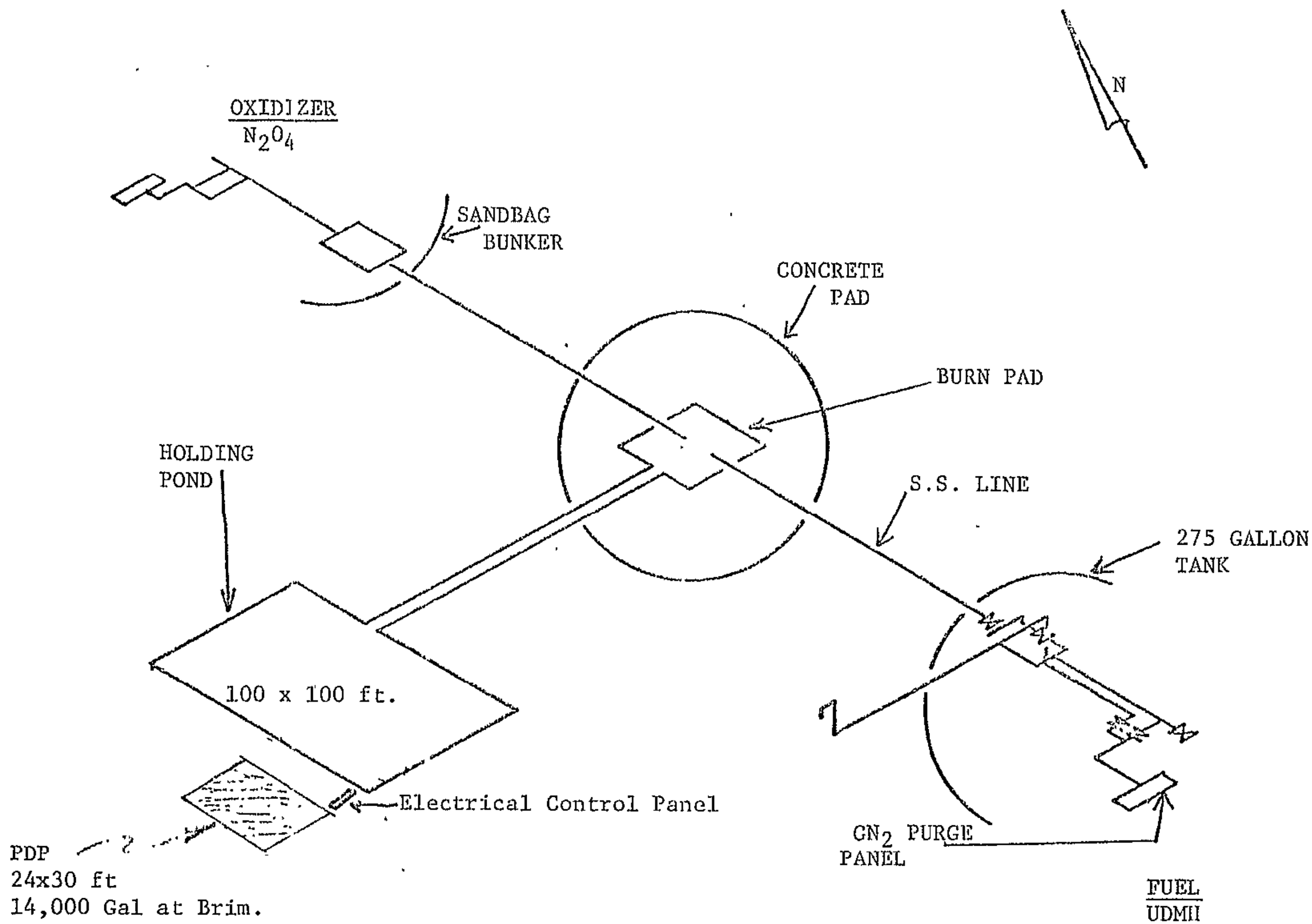
   c. Others

MISCELLANEOUS INFORMATION:

Target Dates:

The design work on pond should proceed immediately; construction to start Mid-April. Completed construction of pond including installation of equipment (pumps/blowers) is not later than June 1st.

Specifications for procuring or "scrounging" the necessary equipment will be forthcoming before April 15.



FIGURE

FIRE SUPPRESSION TRAINING AREA LAYOUT

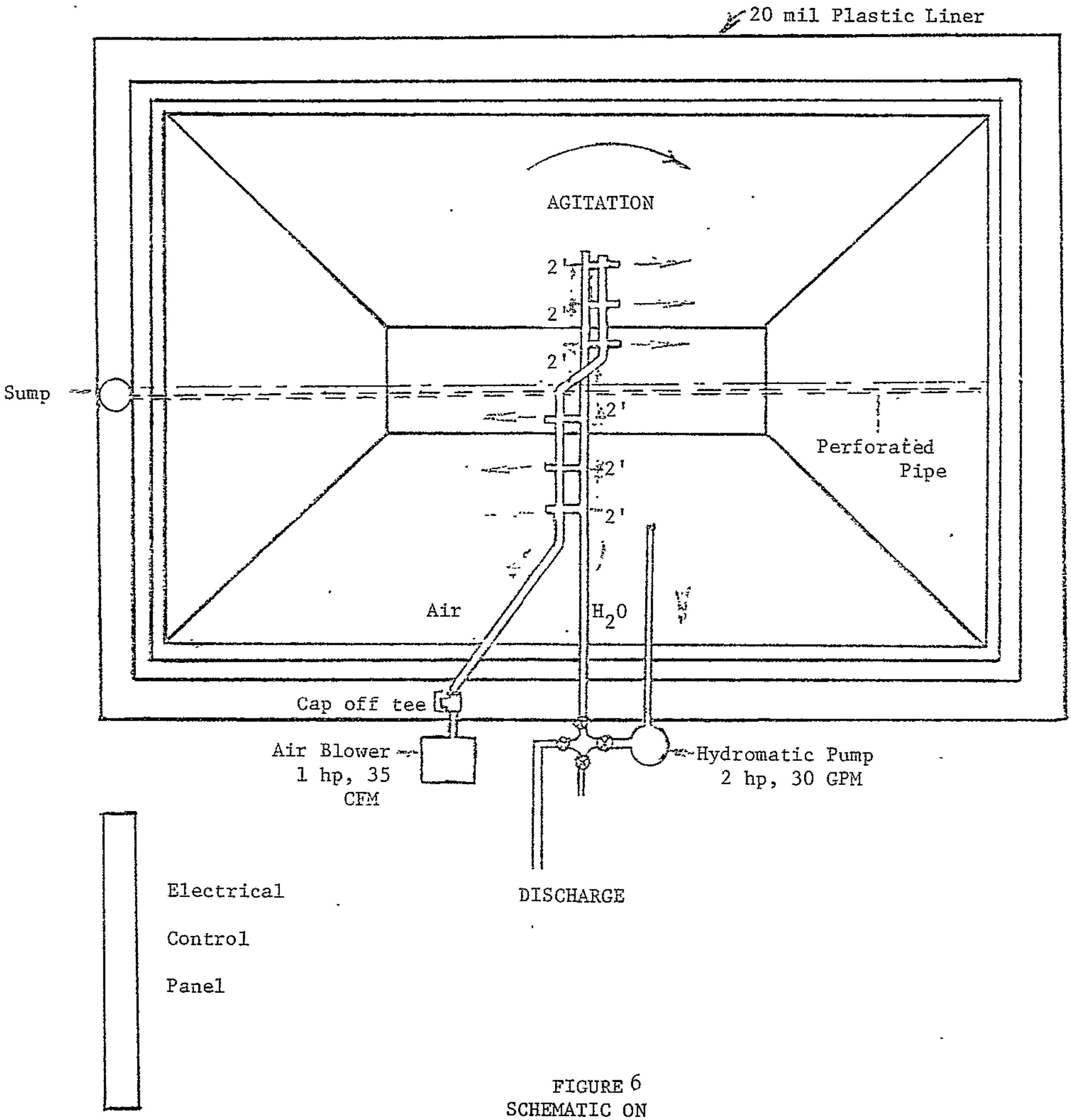


FIGURE 6
SCHEMATIC ON
AIR AND WATER LINES AND FLUID PUMPS

COST SUMMARY

PROTOTYPE POND

Volume at Operating Level	9,000 Gal.
Volume at Brim	13,500 Gal.
Enclosed Work Area, Approx. 3,500 sq. ft.	(70'x50') Min.

CONSTRUCTION COST ESTIMATE

Engineering	$ 2,000.
Excavation	2,000.
Liner, Approax.1400 sq. ft. @ $.55/sq. ft.	510
Liner, Installation, 3 Man Days	300.
Submersible Pumps, 2 Req'd, 30 Gpm. min. @ 300 ea.	600.
Water Pump, 30 Gpm min.	400.
Chlorinator, Complete	1,600.
Blowers, 1 hp., 15 cfm., 2 req'd @ $350.	700.
Piping, Fittings, Pump Installation	1,500.
Miscellaneous	1,200.
TOTAL	$10,810

MMH Reactor & Auxillary Equipment	$ 650.
NTO Neutralizer	350.
	$ 1,000.

Display 3

MISCELLANEOUS INFORMATION ON POND

Drawings and Pond Description

A set of drawings describing the PDP was prepared by personnel in DD-MDD-41. The drawing number and titles are:

Sheet No.	Drawing No.	Title
1	79K07616	Title Map and Index
2	"	Parts List
3	"	Site Location
4	"	Pond Layout & Details
5	"	Elect. & Mechanical Layout & Details
6.	"	Electrical Details

The PDP is located in the Fire Suppression Training Area off Static Test Road. It is adjacent (shaded area) to the 100 x 100 ft. dilution holding pond as shown in Figure 5 .

The size is approximately 28 x 36 ft. with 3:1 sloping slides, 4½ ft. deep and contains approx. 13,500 gallons of water when brim full. Operating level is approx. 9,000 gals. to prevent overflow during periods of heavy rainfall. A foot and one-half berm was constructed from the excavated material. Table 21 and Graph 18 show the depth in inches vs gallons and volume of water vs depth respectively.

Description of Piping Diagrams

The piping arrangement and equipment location is shown schematically in Fig. 6 . The water jet eductors are made from PVC as shown in Schutte & Koerting drawing No. 71G-X074J, Fig. 7 .

Aeration and agitation in the pond is provided by a 35 CFM Blower and a 2 HP Hydromatic Water Pump with their discharges flowing through six (6) eductors arranged in sets of three (3) pointing in opposite directions.

TABLE 21

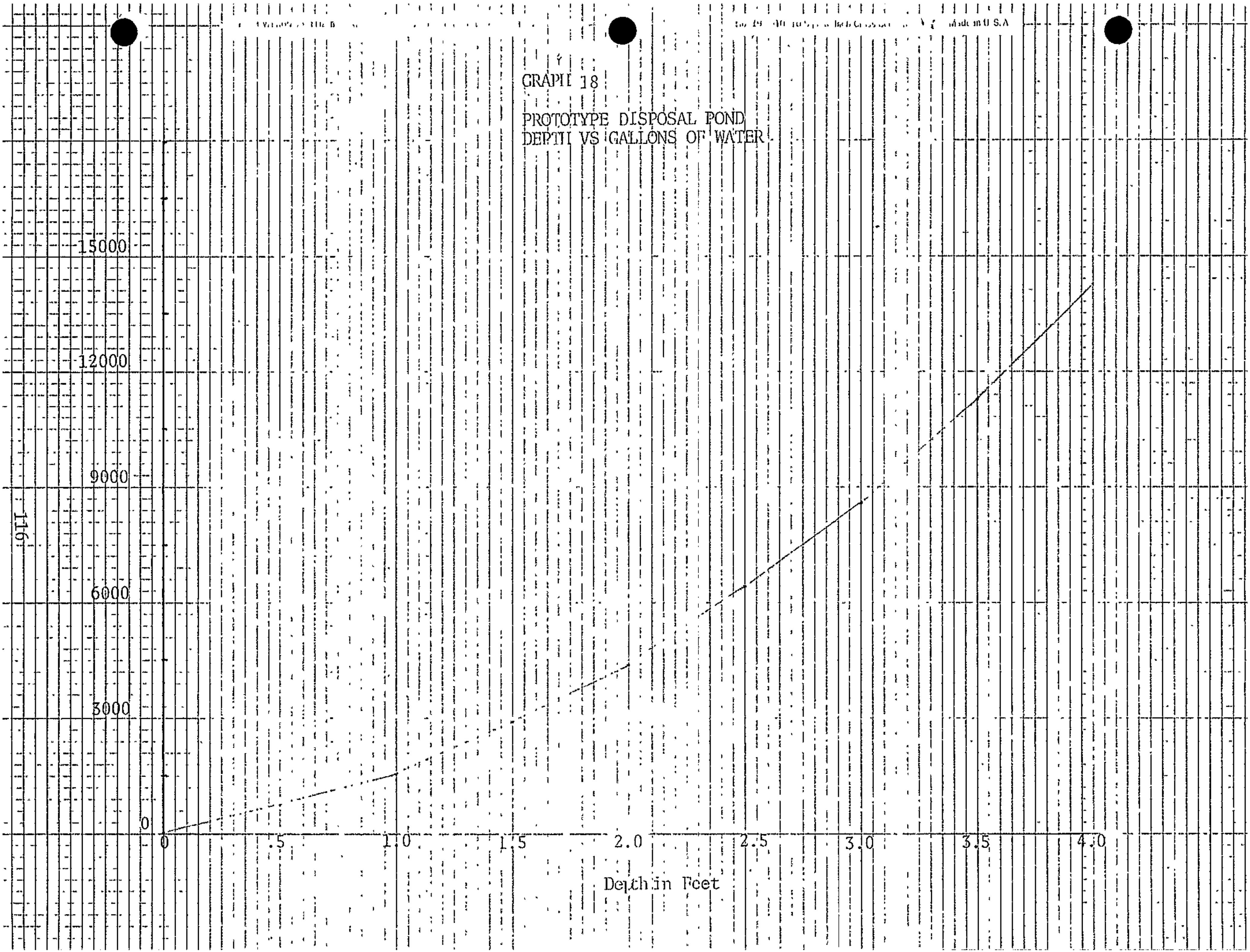
H_2O LEVEL IN PDP

Prototype Disposal Pond: Depth vs Gallons

0	1 x 100 x 244 = 106			1 x 196 x 340 = 289	
	1 x 104 x 248 = 112			1 x 200 x 344 = 298	
	1 x 108 x 252 = 118			1 x 204 x 348 = 307	
	1 x 112 x 256 = 124			1 x 208 x 352 = 317	
	1 x 116 x 260 = 131			1 x 212 x 356 = 327	
6"	1 x 120 x 264 = 137	-Sub total = 728	30"	1 x 216 x 360 = 337	- Sub Tot. 6356
	1 x 124 x 268 = 144			1 x 220 x 364 = 347	
	1 x 128 x 272 = 151			1 x 224 x 368 = 357	
	1 x 132 x 276 = 158			1 x 228 x 372 = 367	
	1 x 136 x 280 = 165			1 x 232 x 376 = 378	
	1 x 140 x 284 = 172			1 x 236 x 380 = 388	
12"	1 x 144 x 288 = 180	-Sub total = 1698	36"	1 x 240 x 384 = 399	-Sub Tot. 8592
	1 x 148 x 292 = 187			1 x 244 x 388 = 410	
	1 x 152 x 296 = 195			1 x 248 x 392 = 421	
	1 x 156 x 300 = 203		39"	1 x 252 x 396 = 432	
	1 x 160 x 304 = 211			1 x 256 x 400 = 443	
	1 x 164 x 308 = 219			1 x 260 x 404 = 455	
18"	1 x 168 x 312 = 227	-Sub total= 2940	42"	1 x 264 x 408 = 466	-Sub Tot. 11,219
	1 x 172 x 316 - 235			1 x 268 x 412 = 478	
	1 x 176 x 320 = 244			1 x 272 x 416 = 490	
	1 x 180 x 324 = 252			1 x 276 x 420 = 502	
	1 x 184 x 328 = 261			1 x 280 x 424 = 514	
	1 x 188 x 332 = 270			1 x 284 x 428 = 526	
24"	1 x 192 x 336 = 279	-Sub. Total 4481.	48"	1 x 288 x 432 = 539	- Total 14,268

Conversion Factors: convert Cu. in. to gallons. multiply by .0043290
There are 231 cu. in. to 1 gallon

For every increase in height of one inch from the bottom, both the length and the width increase by 4 inches.



GRAPH 18

PROTOTYPE DISPOSAL POND
DEPTH VS GALLONS OF WATER

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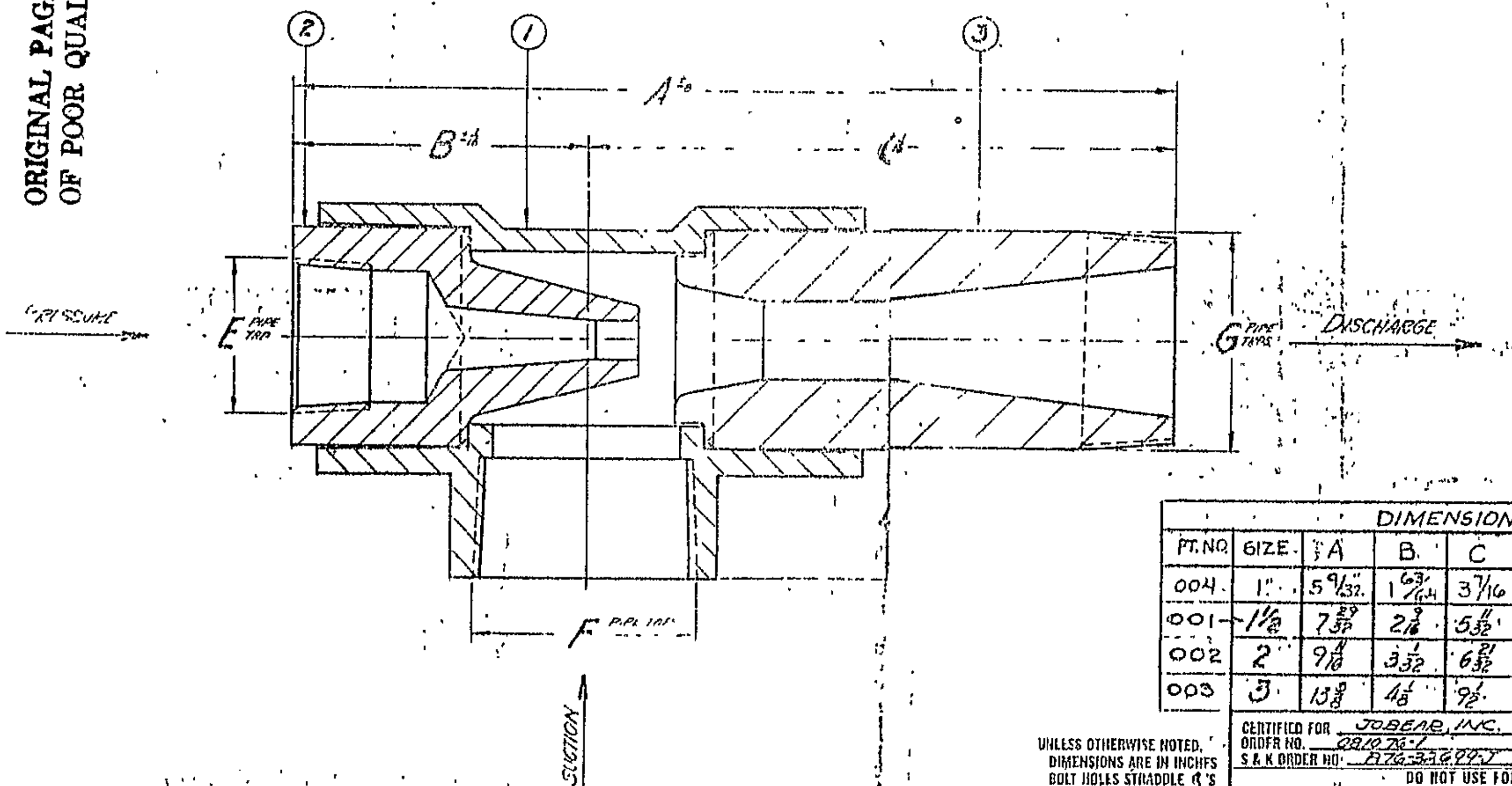
FIGURE 7

PARTS LIST 71XG-0074J

MK.	NO. REQ.	DESCRIPTION	MATERIAL
1	1	BODY	P.V.C. HIGH IMPACT
2	1	NOZZLE	P.V.C. HIGH IMPACT
3	1	TAIL	P.V.C. HIGH IMPACT



DIMENSIONS

PT. NO.	SIZE	A	B	C	D	E	F	G
004	1"	5 9/32"	1 63/64	3 7/16	1 7/8	3/4"	1"	1"
001	1 1/2	7 29/32	2 9/16	5 11/32	2 1/16	1"	1 1/2	1 1/2
002	2	9 11/16	3 1/32	6 21/32	2 5/16	1 1/4	2	2
003	3	13 3/8	4 1/8	9 1/2	3 7/8	2	3	3

UNLESS OTHERWISE NOTED, DIMENSIONS ARE IN INCHES
BOLT HOLES STRADDLE ℄'S

CERTIFIED FOR JOBEAR, INC.
ORDER NO. 081076-1 DATE 8-26-76
S & K ORDER NO. R76-31699-J BY R. SIMONELLI
DO NOT USE FOR CONSTRUCTION UNLESS CERTIFIED FOR A SPECIFIC ORDER

REVISIONS | DATE

OUTLINE ASSEMBLY DWG
WATER JET EDUCTOR
STANDARD P.V.C.

FIG NO 26A
B/M 71-384-J
P.O.
DRAWN dp 5-11-71
CHECKED
SCALE NONE
MADE FROM

SCHUTTE & KOERTING CO.
MANUFACTURING ENGINEERS
CORNWELLS HEIGHTS BUCKS COUNTY, PENNA

71G-X074J REV 1

Air Line

The Air Blower is located just off the berm and approximately equidistant from both ends of the pond and conveniently close to the Water Pump.

The air piping starts with a 3" diam. PVC discharge line leading to the first set of three eductors and is then reduced to 2" diam. PVC pipe to the second set of eductors located and spaced about two feet apart as shown in Fig. 6. The lines are reduced and connected to the 1½" diameter suction side of the eductors with the discharge end pointing in the given direction.

A TEE is included just upstream of the Blower discharge line and capped off for possible future use. Several properly placed sand bags on top of the air (and water) line serve to anchor it on the pond bottom and thereby prevent lateral movement.

Water Line

The Water Pump intake and discharge are fitted with 2" diameter PVC pipe after mounting the pump near the berm approximately equal distance from both ends of the pond.

A 2" PVC pipe approx. 20 feet long is connected to the pump intake. PVC piping is installed to accomodate elevation changes and anchored on bottom of pond with sand bags.

Alternately, an inexpensive angle iron frame may be constructed and painted with a resistant coating. The air and water lines may be fastened with U-bolts or in other ways to minimize lateral movement.

Sump

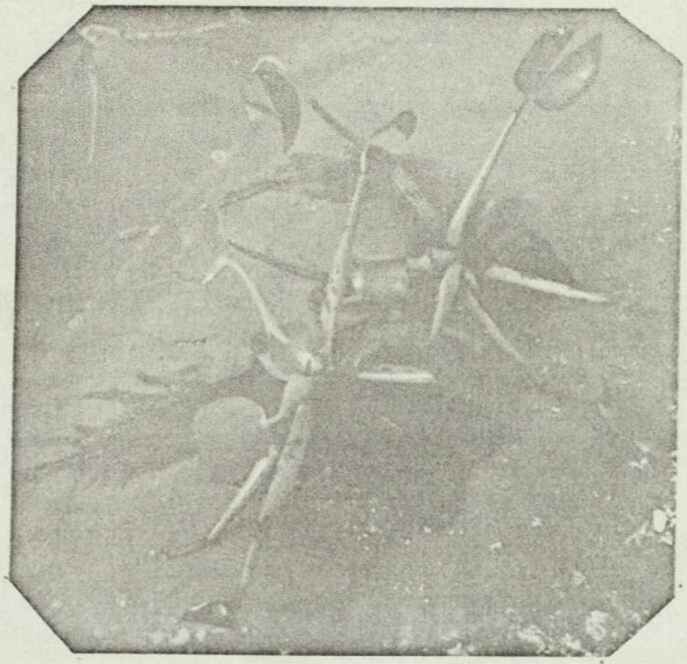
A six foot deep sump is located at one end of the pond. Thus, in order to monitor the liner for leakage, an inclined perforated PVC pipe is installed underneath the liner in a 1x1 ft trough containing pea gravel which connects to the sump.

An access road (not shown in Fig. 5) exists several yards to the west of PDP.

5.5 APPENDIX V

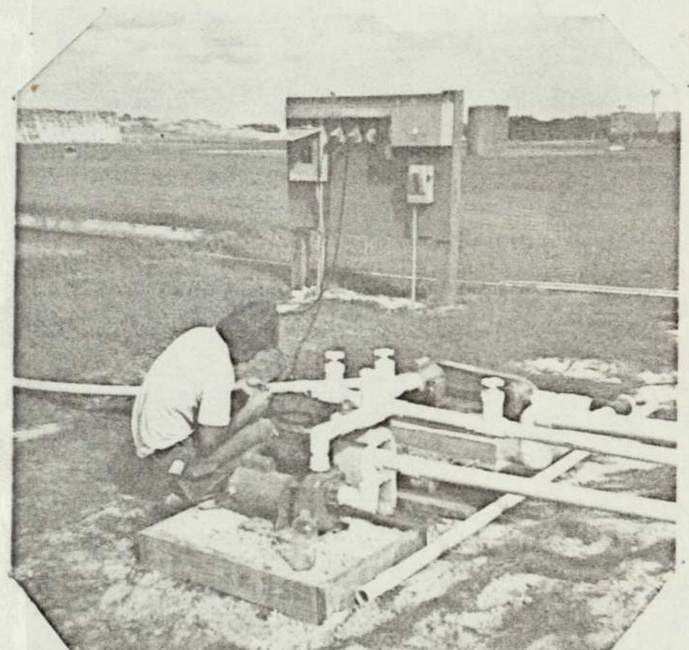
PHOTOGRAPHS TAKEN AT VARIOUS
STAGES AT PDP DURING RUNS #1 & 4

During the runs at the Prototype Disposal Pond a photographic log was kept. Below are photographs with captions to illustrate certain facets of pond operation and to show pictorially certain events during each run;

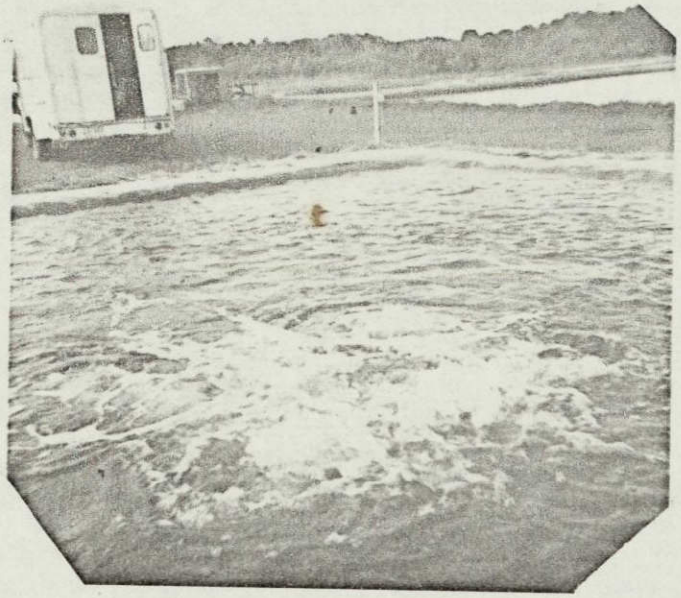
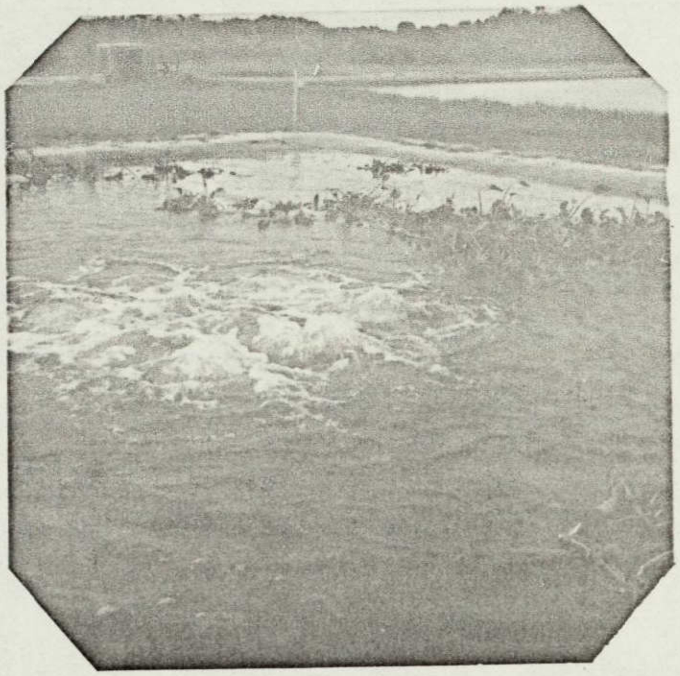


Photograph 1 is a close-up of a typical water hyacinth plant showing leaves, floats and root structures. Note damaged leaves due to handling in transfer.

Photograph 2 shows the electrical control panel which activates the water pump and air blower used for agitating the pond.

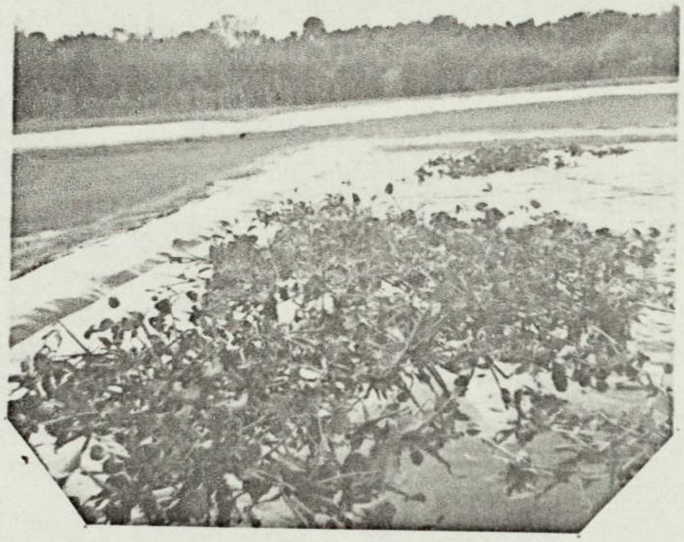


Photograph 3 is a view of the water pump (foreground) and air blower (center) with the electrical panel in the background

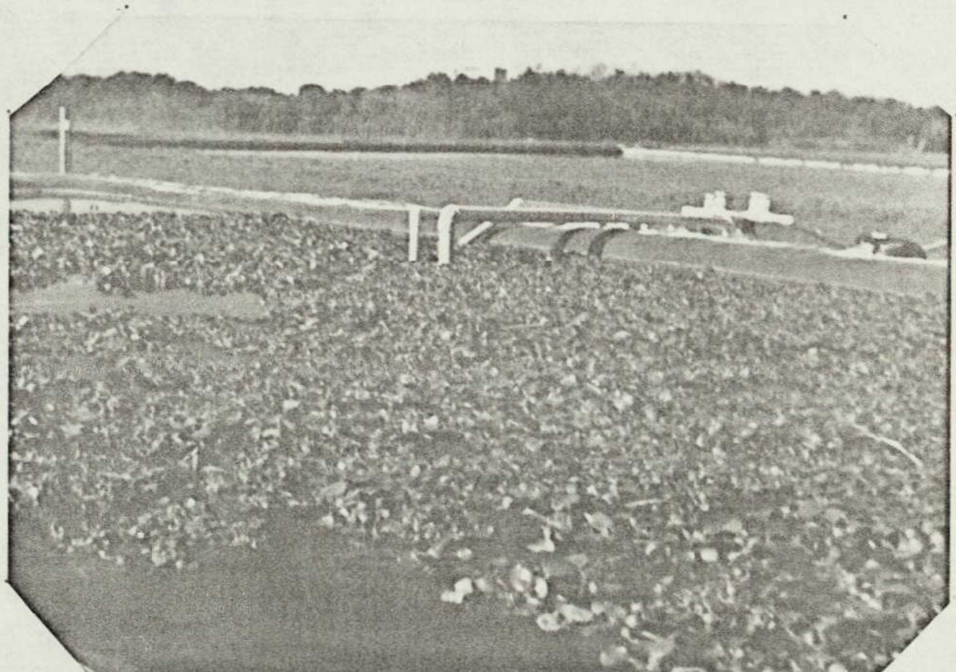
Photographs #4 and 5 illustrate the turbulence caused by the air blower (water pump not in operation). The van in the background of photo #4 was used for transporting hyacinths to the pond.

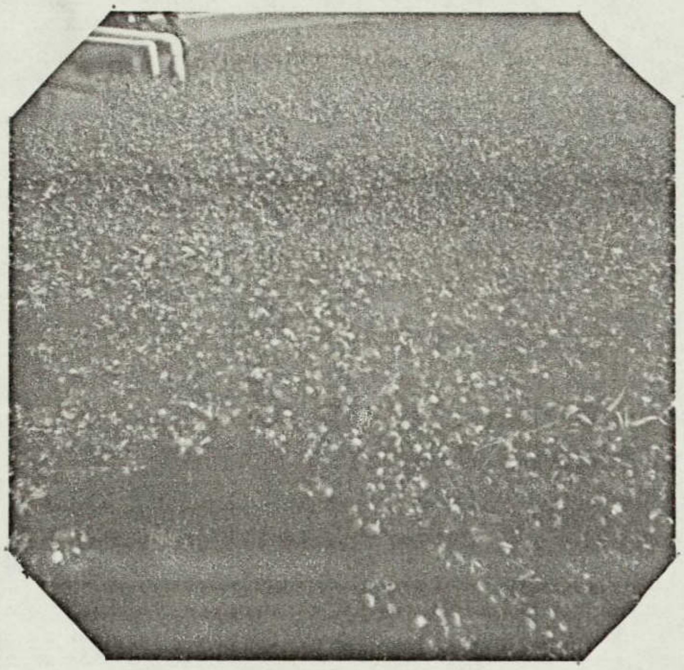
Photograph #6 shows the hyacinths in PDP after first stocking for run #1 on November 15, 1976



Photograph #7 - view of the hyacinths after two weeks growth in run #1. Note increase in size of leaves.

Photograph #8
View of hyacinth in PDP in the middle of run #1. Note the increase in plant coverage and the greenness of the leaves.





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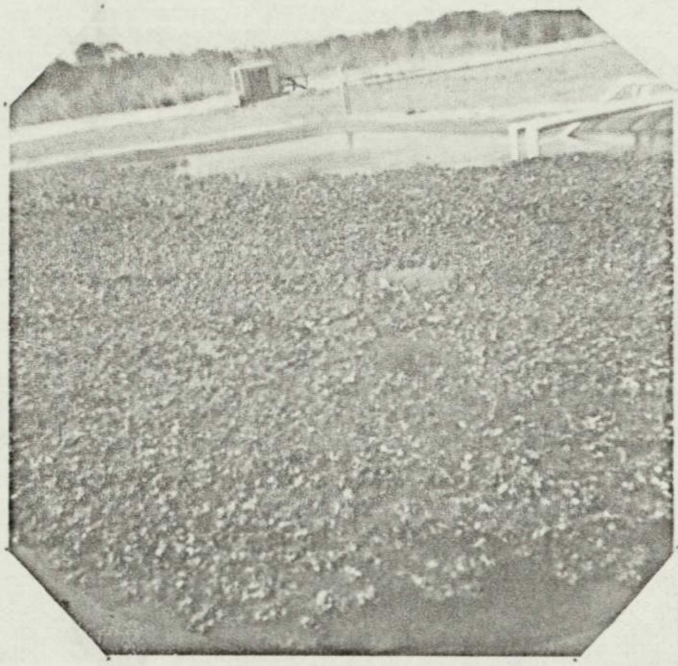
#9

Photographs 9 and 10 - illustrate the effect of the freeze on the hyacinths in the PDP. Photograph 10 is a closeup of a hyacinth plant. Note the difference between the plant and the plant in Photograph #1

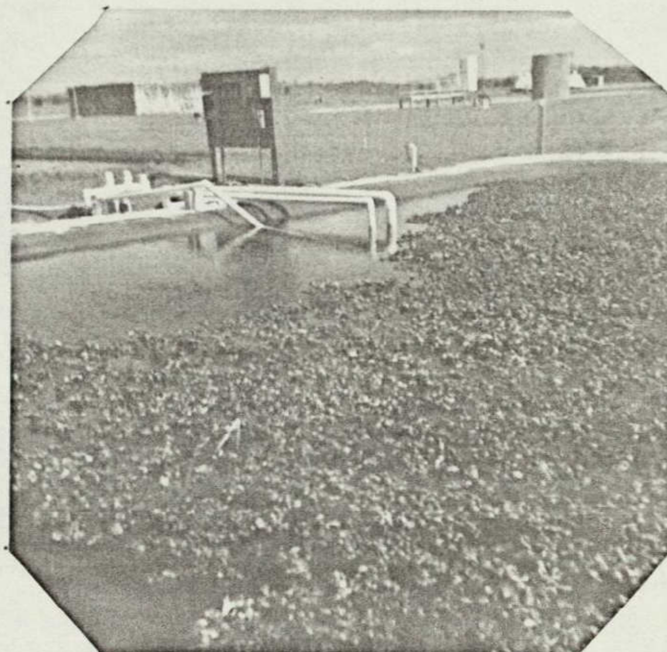
#10



#11

Photographs 11 and 12. Condition of the hyacinth plants before the start of run #4. Note the difference between these hyacinths and those in photograph #8

#12



#13 - Condition of the hyacinths after the freeze on February 18, 1977 during run #4.