GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF RESEARCH ADMINISTRATION

RESEARCH PROJECT INITIATION

Date: May 13, 1971

Project Title: Effects of Planned Urban Development on Water Quality at the Macon, Ga. Operation Breakthrough Prototype Site.

Project No: B-628 (E-20-615)

Principal Investigator: Dr. A. W. Hoadley

Sponsor: Macon-Bibb County Planning and Zoning Commission (Subcontract under HUD Prime No. H-1504)

Agreement Period: From October 1, 1970 Until June 30, 1972

Type Agreement: Letter Agreement dated 6 May 1971 (Fixed-Price Contract)

Amount: $6,954 (HUD Funds)
1,100 (GIT Contribution)
$8,054 Total

Reports Required:

Quarterly Progress Reports, Preconstruction Report, Post-Construction Report, Final Report

Sponsor Contact Person (s): Mr. C. C. Connor, Jr., Project Planner
Macon-Bibb County Planning and Zoning Commission
P.O. Box 247
Room 305 - City Hall
Macon, Georgia 31202
Phont: (912) 746-9656

Assigned to: School of Civil Engineering

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RA-3 (2-71)

GEORGIA INSTITUTE OF TECHNOLOGY

OFFICE OF RESEARCH ADMINISTRATION

RESEARCH PROJECT TERMINATION

Date: August 28, 1973

Project Title: Effects of Planned Urban Development on Water Quality at the Macon, Georgia Operation Break-Through Prototype Site

Project No: E-20-615 (Formerly B-628)

Principal Investigator: Dr. A. W. Hoadley

Sponsor: Macon-Bibb County Planning & Zoning Commission (Fixed-Price Subcontract under HUD Prime No. H-1504)

Effective Termination Date: 6/30/73 (Contract Expiration)

Clearance of Accounting Charges: All funds have been exhausted.

Contract Closeout Actions Remaining: Final Invoice
Gov't. Property Disposition (if any)
Final Report of Inventions

School of Civil Engineering

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Terminated Project File No. _____
Other _____

RA-4 (5/70)

dae 8/2/72
THB

E-20-615

February 1, 1971

Pre-Construction Report?

Mr. Craig Lindelow
Operation Breakthrough City Representative
Macon-Bibb County Planning and Zoning Commission
P.O. Box 247
Macon, Georgia 31203

Dear Mr. Lindelow:

In accordance with our proposal entitled "Effects of Planned Urban Development on Water Quality at Macon, Georgia - Operation Breakthrough Site", I am enclosing data obtained for the site on October 24, 1970, prior to initiation of site preparation.

At the time we visited the site there was no flow leaving the lake. It is a very soft water lake. Its condition was typical of highly enriched surface waters of the area. The temperatures in the lake varied from nearly 21° C at the surface to less than 17° C at the bottom, which imparts to the pond a resistance to mixing which is lost as the water temperature drops during winter. The water is highly colored and turbid causing a white disc 20 cm in diameter (the Secchi disc) to disappear at a depth of 30 inches. This is characteristic of an extremely productive lake in the absence of a high silt load.

The above conclusion was supported by the visual observation of large floating masses of algae which were loosely cohesive and fell apart when disturbed. Identification was difficult because of the condition of the algae. Furthermore, the rapid disappearance of oxygen is also characteristic of very rich, productive waters, but not atypical of similar waters in this region. The high ammonia, iron, and manganese concentrations similarly reflect the loss of oxygen and the high concentration of organic matter, The phosphate concentrations are high also, but not unusual for this part of the country.

The data obtained on October 24 provide some idea of the pre-construction condition of the lake. It must be realized that the condition of a lake such as this varies continuously according to a yearly cycle, and a single analysis of this sort cannot be regarded as definitive.

Sincerely yours,

Alfred W. Hoadley
Associate Professor

AWH:bad

ANALYSIS OF POND WATER*, OPERATION

BREAKTHROUGH SITE, MACON, GEORGIA

October 24, 1970

Depth(ft)	Temp. °C	D.O. mg/L	pH	Nitrogen(mg/L-N) NH_3-N	Organic-N	Tot.N	Phosphate(mg/L) Ortho	Poly	Fe(mg/L)	Mn(mg/L)	Ca (Mg/Las$CaCO_3$)
Surface	20.7	9.8	7.71	0	2.4	2.4	0	0	0.5	)0.05	9.3
1	20.7	-	-	-	-	-	-	-	-	-	-
2	20.5	-	-	-	-	-	-	-	-	-	-
2.5	-	9.2	7.33	0	1.9	1.9	0	0	0.79	0.15	8.75
4	20.0	-	-	-	-	-	-	-	-	-	-
5	19.8	2.3	6.62	0	2.2	2.2	0	0	1.05	0.25	9.05
6	19.7	-	-	-	-	-	-	-	-	-	-
7.5	-	0.5	6.42	0	1.5	1.5	.11	.02	0.87	0.30	8.75
8	19.5	-	-	-	-	-	-	-	-	-	-
10	19.3	0.1	6.4	0	1.4	1.4	.23	.05	1.4	0.20	9.05
12	18.6	-	-	-	-	-	-	-	-	-	-
12.5	-	0.0**	6.3	7.7	1.1	8.8	.44	.13	10.1	1.10	12.6
13	17.6	-	-	-	-	-	-	-	-	-	-
14	17.0	-	-	-	-	-	-	-	-	-	-
14.5	-	-	6.3	12.5	1.6	14.1	-	-	13.3	1.20	14
15	16.6	0.0**	-	-	-	-	-	-	-	-	-

*No flow leaving pond
Start at 11:30a.m.
Secchi Disc = 30"
Large floating masses of loosely cohesive algal colonies present in abundance

**H_2S present

aal 8/2/72

E-20-615

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
CIVIL ENGINEERING

TELEPHONE:
(404) 873-4211

AHB

April 8, 1971

Quarterly No. 1 (3)

Mr. C. C. Connor
Macon-Bibb County Planning
and Zoning Commission
Post Office Box 247
Macon, Georgia 31202

Dear Mr. Connor:

I am sorry for the delay in getting this letter off to you, and I hope I can deal with your questions satisfactorily. You must realize, however, that my answers of necessity are based on speculation.

With respect to your first question regarding probable changes in water conditions which will result from construction, I believe the answer is dependent upon several factors. First, the solids entering the lake. Silt carried by runoff into the lake can do a number of things. It can reduce the transparency of the water, in part inhibiting the growth of algae, but at the same time decreasing the attractiveness of the lake, and it can bring nutrients into the lake which could stimulate algal growth, thus decreasing the attractiveness of the lake once again. Of these three effects, the predominent one probably would be the second. However, I believe the silt from a large part of the site would be retained in the upstream portion of the basin. Silt from the road repair and that portion of the site immediately adjacent to the pond might create a problem temporarily, but with reasonable care, to prevent continual runoff into the lake, should be temporary.

The lake presently is quite rich and productive, and potentially a nuissance if it is not protected. Presently the nutrients probably originate largely from the swamp areas surrounding the lake and the bottom sediments in the lake. I think there are several considerations to which I might direct your attention, at this point. First al all, the bottom waters of the lake are stagnant and contain hydrogen sulfide and nutrients. They appear to exist there because the lake is so well protected from the wind that only limited circulation takes place. Odors and increased algal growth easily could result if the outflow were shifted

to the bottom or if circulation were caused in some way. Although I'm not sure how important this is, nutrients entering the lake could be increased as a result of cutting in the watershed. The waters are so rich already, however, that I don't believe this would be of great importance, unless perhaps storm runnoff from roads were allowed into the lake. So I think you are alright on that score. Finally, at the time of our visit, there was no flow from the lake. We will have to base any real judgements on observations at a later time, but we can speculate to some extnet upon this point. If, as I vaguely recall may be the case, a fountain is to be installed in the lake, the quality of the water, particularly the esthetic quality, might be expected to suffer seriously as a result of the resultant circulation of water. On the other hand, the flow through the lake could be increased by adding new water to the lake, for instance via the fountain, the condition of the water undoubtedly could be improved greatly.

I think the above probably answers most of your questions. They represent speculation, but perhaps will help you in viewing more clearly the data which we sent you. With regard to the question of non-detrimental changes, or enhancement of the lake itself, I think the question is a difficult one. I think that enhancement would be primarily a matter of intentional management of the lake for that purpose, specifically mixing of the lake waters accompanied by increased flow of water through the lake.

Finally, I think we would like at this time to make another visit to the Operation Breakthrough site, and to increase the frequency of our analyses. We will be able to collect samples on April 15, and will plan to arrive at the site by 11:00 A.M. on that date unless the weather is too severe or you would prefer that we delay our visit.

Sincerely yours,

A. W. Hoadley
Associate Professor
School of Civil Engineering

AWH:kss

aal 8/2/72

E 20-615

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
CIVIL ENGINEERING

TELEPHONE:
(404) 873-4211

AWH

July 6, 1971

Quarterly No. 2 (3)

Mr. Charles Connor
Macon-Bibb County Planning and Zoning
Commission
City Hall
Macon, Georgia 31202

Dear Mr. Connor:

During the past quarter, the Operation Breakthrough site at Macon has been visited by us on three occasions, April 22, June 3, and June 26. The data obtained are given in Tables I through VII, and are presented graphically in Figures 1 through 13. Data on algal populations are not available for the June 26 date since one of the workers on the project (AWH) has been ill and unable to analyze those samples. Results will be included in the next quarterly report.

The lake on all three sampling dates during the past quarter has been well stratified as a result of the thermal gradient extending from surface to bottom. The highly enriched condition of the lake is reflected in most of the data presented. The very low transparency indicated by the secchi disc readings reflects high algal counts. The slight increases in the readings on successive dates means that photosynthesis can occur at increasing depths, and thus oxygen is present at increasing depths (Fig.2).

The character of the oxygen curves suggests a highly enriched condition and high degree of stability of the stratification The breakdown of organic matter in the deeper water of the lake results in the loss of oxygen, which would prevent fish from living at depths greater than about 3, 4, and 5 feet on the successive dates. The biological activity causing the loss of oxygen in the deeper water also causes the corresponding decrease in pH (Fig.3). High oxygen concentrations (in excess of 100% saturation) result from high photosynthetic activity in the top 2.5 feet on the earlier dates and the top 3.5 feet on June 26. This results also in the relatively high pH observed in the surface waters. The high surface dissolved oxygen is characteristic of highly enriched waters also. The distribution of photosynthetic activity on the two June sampling dates can be seen in Fig.4, which indicates the mg of carbon fixed per cubic meter per hour during photosynthesis (primary production). The curves again are characteristic of highly enriched and productive lakes. The algae present in high concentrations in the surface waters are a primary cause of the low transparency and are the source of the high productivity near the surface. The two blue-green algae, Anabaena sp. and Microcystis aeruginosa are characteristic of highly enriched waters and can cause nuissances.

The disappearance of oxygen from the deeper waters leads to changes in the chemistry of the bottom water. For instance, iron and manganese become soluble (Fig.5 and 6), and hydrogen sulfide is produced (Tables I, III, VI). We understand that consideration has been given to providing a siphon to permit removal of deeper water out of the lake rather than surface water. Considering the highly enriched character of the lake and the quality of the deeper water, this would not appear to be a desirable step, since hydrogen sulfide would be released to the atmosphere causing an odor problem and possibly discoloration of paint. Also, if fish are present in the stream below the lake they could be killed both by hydrogen sulfide and by low dissolved oxygen.

There may be several approaches to controlling the problems associated with excessive algal growths in the lake at the Operation Breakthrough site in Macon. I do not believe treating the lake to kill algae is the answer, since treatment would have to be repeated at fairly frequent intervals, and in killing the algae, it is the symptoms and not the cause of the problem that are treated. Also, the concentration of toxicant builds up in the bottom of the lake and could adversely affect fish breeding in the lake. We would favor approaching the cause of the problem. One approach I have outlined in a previous letter, that is, to provide aeration and circulation of the lake water to prevent stratification and the formation of an oxygen poor zone in the deeper water of the lake. This could be done by aerating or perhaps the use of a fountain taking its water from the bottom of the lake. Other approaches would include dredging to remove bottom sediments which must be an important source of nutrients and biological activity in the lake or dredging plus increasing the flow of water through the lake to remove nutrients and algae continuously. The volume is small enough so that dilution would probably be practical. During the next quarter, studies will be conducted of the bottom deposits to determine the extent to which they must be removed, and the possibility of dilution will be explored further.

A final observation of importance relates to the data on solids presented in Figures 11 through 13. As a rule, the solids concentrations have not been excessive, and silt has not been a factor in water quality at the Operation Breakthrough site. On June 26, however, there were clear visual signs of high silt concentrations in the deeper water of the lake, below the 6 ft. depth, which are reflected particularly in the high nonvolatile solids in the deeper water. Inspection of the shoreline revealed an area at the head of the lake where silt has washed into the lake from the construction site. Stirring up of the sediments in the area revealed the presence of gray silt which has not been present in the past. What the increased flow of silt portends for the future cannot be stated with certainty at this point, but it must increase the rate at which sedimentation takes place in the lake and adversely affect the appearance of the lake. In the past the water in this lake has been free of the muddy appearance of so many lakes in this region. Precautions should be considered to prevent silt-laden runoff from the construction site from reaching the lake.

I hope that the above suffices for you to prepare a quarterly report. If you have any questions, please do not hesitate to contact me.

Sincerely yours,

Alfred W. Hoadley
Associate Professor

AWH:jw

TABLE I. ANALYSIS OF POND WATER, OPERATION BREAKTHROUGH SITE, MACON, GEORGIA
April 22, 1971[1].

Depth (FT)	Temp (°C)	D.O. (mg/l)	pH	H_2S (mg/l)	Nitrogen (mg/l)				Phosphate (mg/l)		Fe (mg/l)	Mn (mg/l)	Mg (mg/l)	Ca (mg/l as $CaCO_3$)	Solids (mg/l)		
					NH_3-N	NO_3-N	Organic-N	Tot-N	Ortho	Poly					Vol	Non-Vol	Total
Surf.	28.2	11.6	9.54	-	2.3	-	-	-	0.06	(0.0) -	0.24	0.06	0.49	1.20	166	67	233
1	25.0	11.4	9.35	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	23.5	11.1	9.5	-	-	-	-	-	-	-	0.27	0.05	0.49	1.20	-	-	-
3	21.5	2.4	8.6	-	-	0.0	-	-	-	-	-	-	-	-	-	-	-
4	18.8	1.2	7.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	17.0	0.4	6.35	-	0.4	0.02	0.5	0.92	0.11	-	0.45	0.11	0.49	1.50	68	47	115
6	15.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	14.1	0.2	6.30	0	0	0.02	0.7	0.72	0.08	(0. -	1.0	0.11	0.49	1.54	23	9	32
8	13.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	12.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	12.0	0.0	6.26	0.2	0	-	0.7	-	0.18	(.15) -	1.35	0.15	0.48	1.55	64	61	125
11	11.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	11.5	0.0	6.46	1.0	0	0.03	0.4	0.43	0.40	-	1.9	0.13	0.49	1.54	63	70	133
13	11.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	11.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

1. Sampled 3:15 - 3:45 p.m.
Slight overcast
Secchi Disc Reading 18"

TABLE II. OPERATION BREAKTHROUGH SITE

April 22, 1971

Depth	*Anabaena* sp. Colonies/ml	*Gonyostomum semen* cells/ml
Surf	1,699	4
1'	2,381	8
2'	1,942	0
3'	427	1,416
4'	176	1,304
5'	13	258
7'	38	547
10'	3	100
12'	2	144

TABLE III. ANALYSIS OF POND WATER, OPERATION BREAKTHROUGH SITE, MACON, GEORGIA
June 3, 1971[1].

Depth (FT)	Temp (°C)	D.O. (mg/l)	pH	Nitrogen (mg/l)			Phosphate (mg/l)		Fe (mg/l)	Mn (mg/l)	Mg (mg/l)	Ca (mg/l as $CaCO_3$)	Solids (mg/l)		
				NH_3-N	Organic-N	Tot-N	Ortho	Poly					Vol	Non-Vol	Total
Surf.	31	9.4	-	0	1.1	1.1	0.08	-	0.39	0.05	0.51	0.94	75	5	80
1	28.5	9.15	-	-	-	-	-	-	-	-	-	-	-	-	-
2	26.0	9.10	-	0	1.8	1.8	-	-	0.45	0.08	0.51	0.94	45	31	76
3	24.5	7.4	-	-	-	-	-	-	-	-	-	-	-	-	-
3.5	-	5.0	-	-	-	-	-	-	-	-	-	-	-	-	-
4	23.0	1.5	-	-	-	-	0.19	-	0.32	0.08	0.50	0.93	58	18	76
5	22.0	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-
6	20.0	0	-	-	-	-	-	-	0.28	0.08	0.50	1.11	24	41	65
7	17.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	15.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	14.5	-	-	0	0.4	0.4	0.07	-	2.5	0.03	0.51	1.98	42	34	76
10	13.6	0	-	-	-	-	-	-	-	-	-	-	-	-	-
11	12.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	12.0	-	-	1.8	0.4	2.2	0.36	-	4.4	0.26	0.53	1.88	30	59	89
13	12.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	11.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.5	-	-	-	3.5	0.3	3.8	0.90	-	5.5	0.23	0.55	1.85	44	64	108

1. Sampled 3:30 - 4:30 p.m.

TABLE IV. PREDOMINANT ALGAE IN OPERATION BREAKTHROUGH SITE

June 3, 1971

Depth	Microcystis aeruginosa colonies/ml	Gonyostomum semen cells/ml	Pediastrum sp. colonies/ml	Scenedesmus sp. colonies/ml
Surf	910	0	0	0
2'	228	0	0	0
4'	70	2,010	0	0
6'	34	142	0	0
9'	20	4	20	18
12'	18	4.5	22	4
14.5'	18	-	30	2

NOTE: BLUE-GREEN ALGAE OF THE ORDER CHROOCOCCALES BELONGING TO GROUP 1B OF STANIER ET AL. (BACTERIOL. REV. 35:171-205, 1971) NUMEROUS AT THE 6' DEPTH AND BELOW. FOR ALL PRACTICAL PURPOSES THESE ARE CONSIDERED OBLIGATE PHOTOTROPHS AND THUS MUST HAVE SETTLED FROM THE SURFACE WATER. THEY WERE PROBABLY TOO NUMEROUS TO HAVE RISEN FROM THE BOTTOM.

TABLE V. PRODUCTIVITY AT OPERATION BREAKTHROUGH SITE

June 3, 1971*.

Depth (FT)	Time (HR)	D.O. (mg/l)					Productivity ($mgC/m^3/hr$)	
		Init.	Light Bottle	Dark Bottle	Gross Incr.	Net Incr.	Gross	Net
Surf	3:21	8.8	9.13	7.9	1.23	.33	114.8	30.8
2'	3:20	8.4	8.95	7.9	1.05	.55	98.6	51.6
4'	3:31	3.9	3.73	3.65	.08	-	7.12	0
6'	3:44	2.6	1.8	1.95	-.15	-	0	0
9'	3:49	2.4	1.5	1.7	-.2	-	0	0
12'	4:03	4.7	4.25	4.58	-.33	-	0	0

*50% Cloud Cover
Secchi Disc Reading 22"

TABLE VI. ANALYSIS OF POND WATER, OPERATION BREAKTHROUGH SITE, MACON, GEORGIA
June 26, 1971

Depth (FT)	Temp (°C)	D.O. (mg/l)	pH	H_2S (mg/l)	Nitrogen (mg/l)			Phosphate (mg/l)		Fe (mg/l)	Mn (mg/l)	Mg (mg/l)	Ca (mg/l as $CaCO_3$)	Zn (mg/l)	Solids (mg/l)		
					NH_3-N	Organic-N	Tot-N	Ortho	Poly						Vol	Non-Vol	Total
Surf.	33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0.5	-	8.3	7.30	N.D.[1]	0.4	2.1	2.5	0.29	-	0.40	0.06	0.51	0.76	0	75	48	123
1.0	31.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.5	-	8.5	7.33	N.D.	1.3	1.2	2.5	0.20	-	0.40	0.07	0.49	0.77	0	36	54	90
2.0	30.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.5	-	8.9	7.5	N.D.	0.4	2.8	3.2	0.30	-	0.42	0.08	0.51	0.76	0	61	16	77
3.0	29.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.5	-	7.7	7.2	N.D.	1.8	1.6	3.4	0.20	-	0.40	0.11	0.50	0.76	0	39	45	84
4.0	28.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.5	-	3.8	6.95	N.D.	0.4	3.2	3.6	0.32	-	0.42	0.20	0.51	0.80	0	52	33	85
5.0	25.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.5	-	0.1	6.2	N.D.	1.8	0.5	2.3	0.4	-	1.55	0.58	0.53	1.27	0	57	82	149
6.0	22.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6.5	-	0.1	6.17	*[2]	0.9	1.5	2.4	-	-	1.75	0.63	0.55	1.30	0	66	95	161
7.0	20.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8.0	19.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8.5	-	0.0	6.3	*	-	-	-	0.4	-	5.8	0.66	0.57	1.98	0.01	92	57	149
9.0	17.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.0	16.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.5	-	0.0	6.4	*	2.6	0.8	3.4	0.48	-	8.3	0.65	0.63	1.90	0.01	71	141	212
11.0	16.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12.0	15.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12.5	-	0.0	6.4	*	3.0	1.7	4.7	0.46	-	10.1	0.75	0.63	1.42	0.02	112	196	308
13.0	15.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.0	15.7	0.0	6.6	*	-	-	-	0.50	-	14.0	1.0	0.63	0.75	0.06	128	642	770
15.0	15.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15.5	15.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

1. N.D. = not detectable
2. * = present

TABLE VII. PRODUCTIVITY AT OPERATION BREAKTHROUGH SITE
June 26, 1971*.

Depth (FT)	Time (HR)	D.O. (mg/l)					Productivity ($mgC/m^3/hr$)	
		Init.	Light Bottle	Dark Bottle	Gross Incr.	Net Incr.	Gross	Net
Surf	3:22	7.6	7.7	6.75	0.95	0.10	88.1	9.29
2'	3:25	7.6	8.55	6.55	2.00	0.95	183.2	87.0
4'	3:34	3.6	3.65	2.1	1.55	0.05	135.9	4.38
6'	3:41	3.15	2.93	2.95	-0.02	-	0	0

*Clear Sky
Secchi Disc Reading 26"

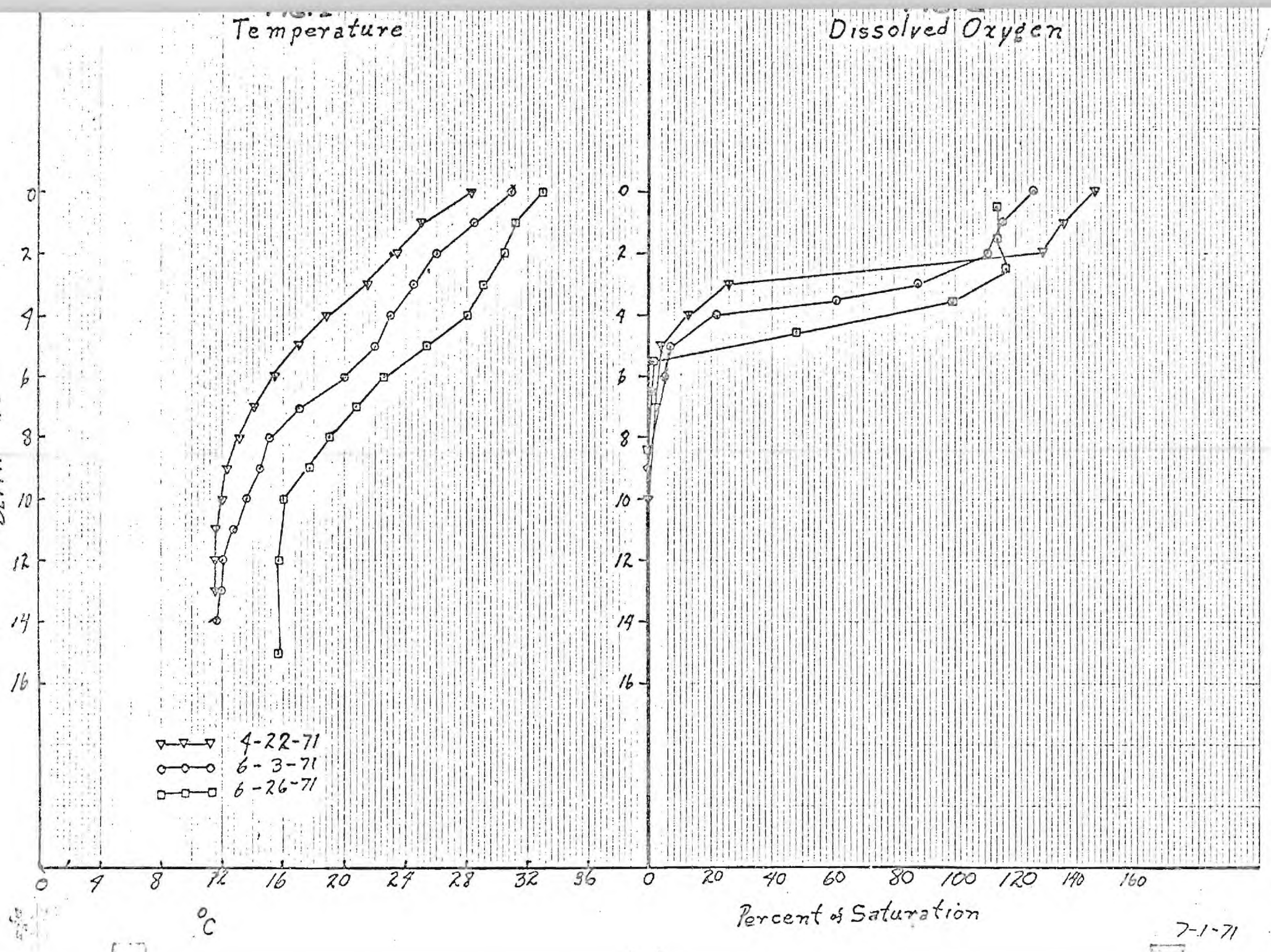

Temperature
Dissolved Oxygen
0
2
4
6
8
10
12
14
16
4-22-71
6-3-71
6-26-71
0
4
8
12
16
20
24
28
32
36
°C
0
20
40
60
80
100
120
140
160
Percent of Saturation
7-1-71

Fig. 3

pH

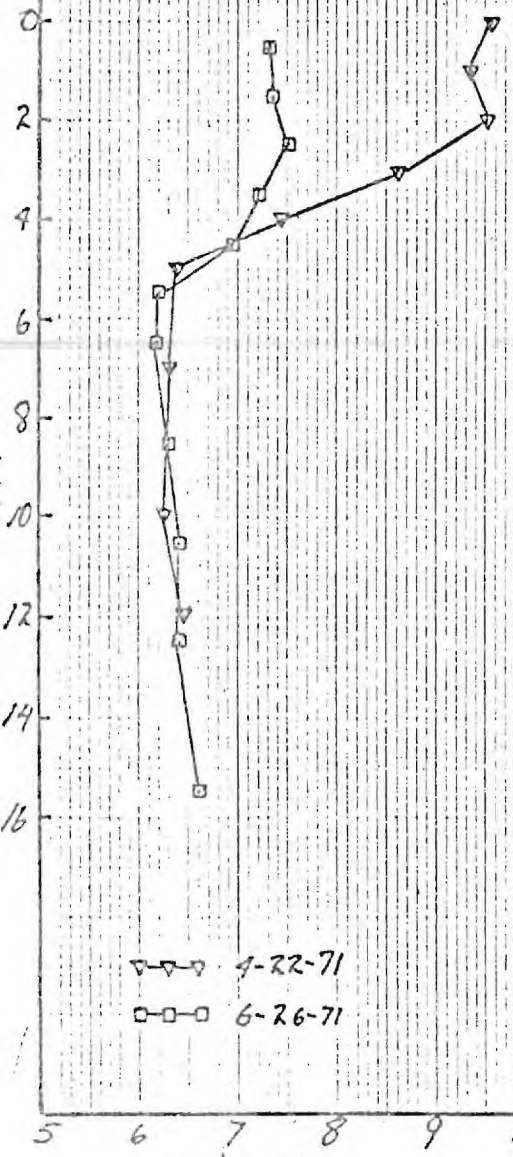
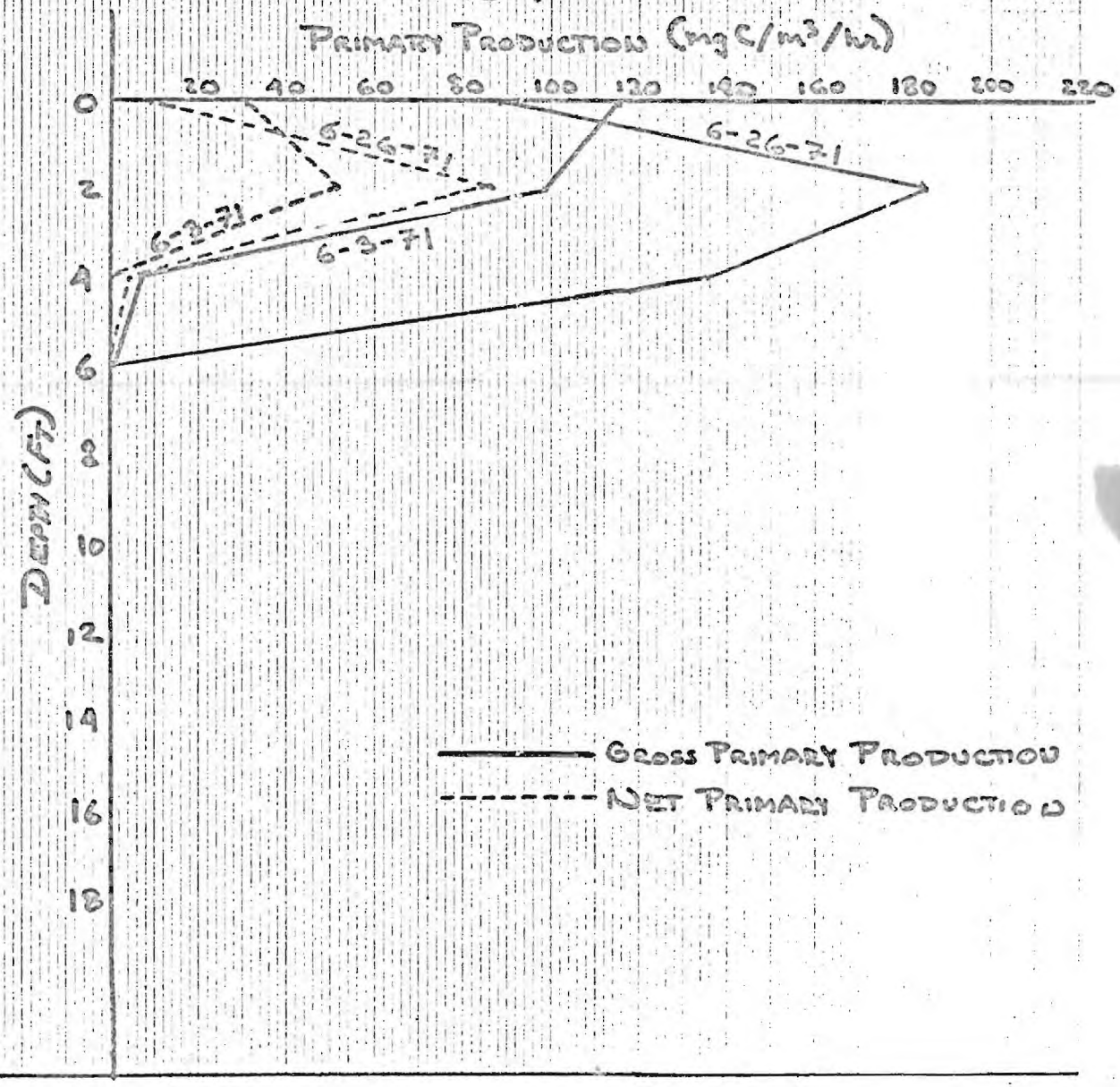


Fig. 4

Primary Production (mg C/m³/hr)



7-1-71

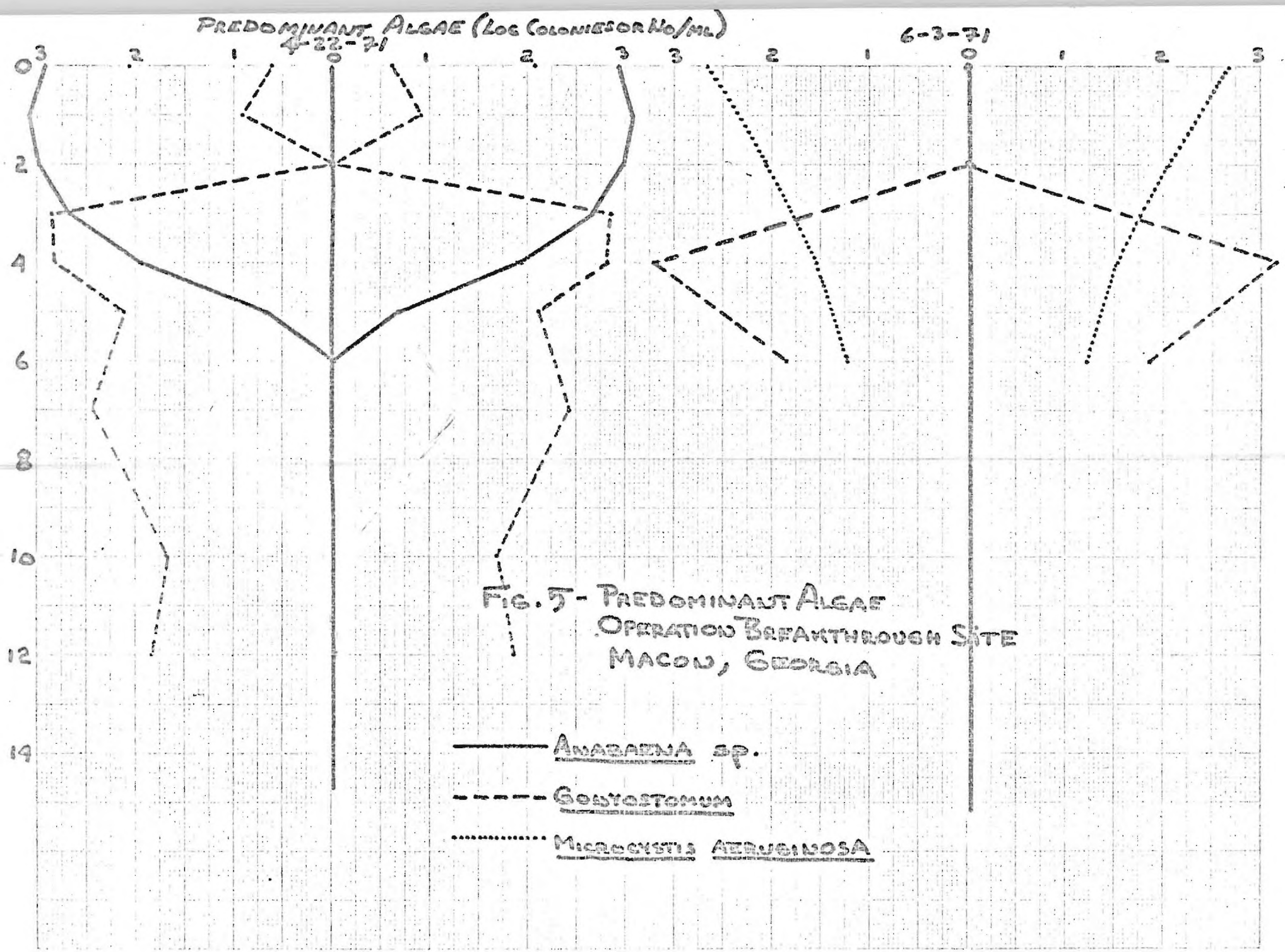
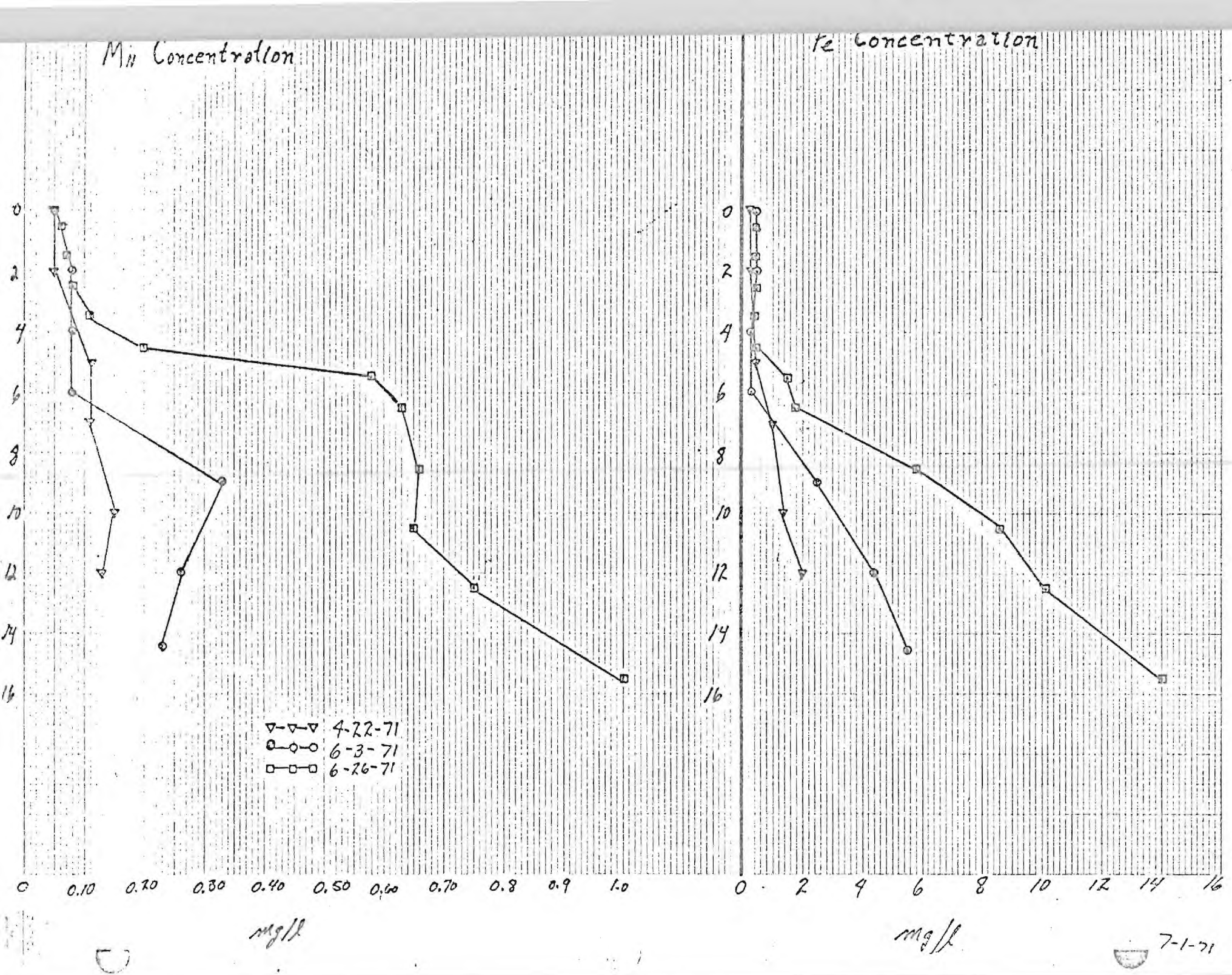
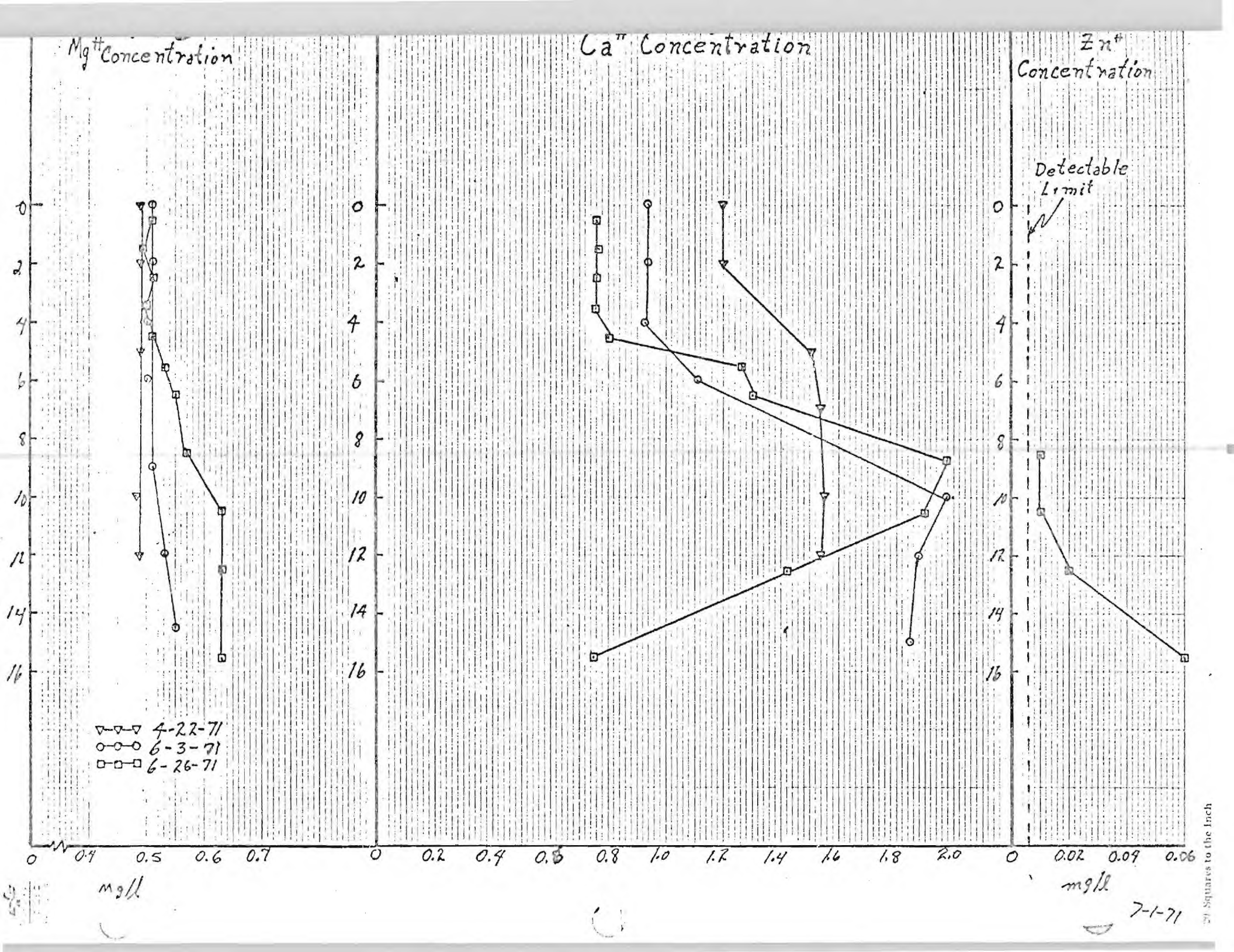
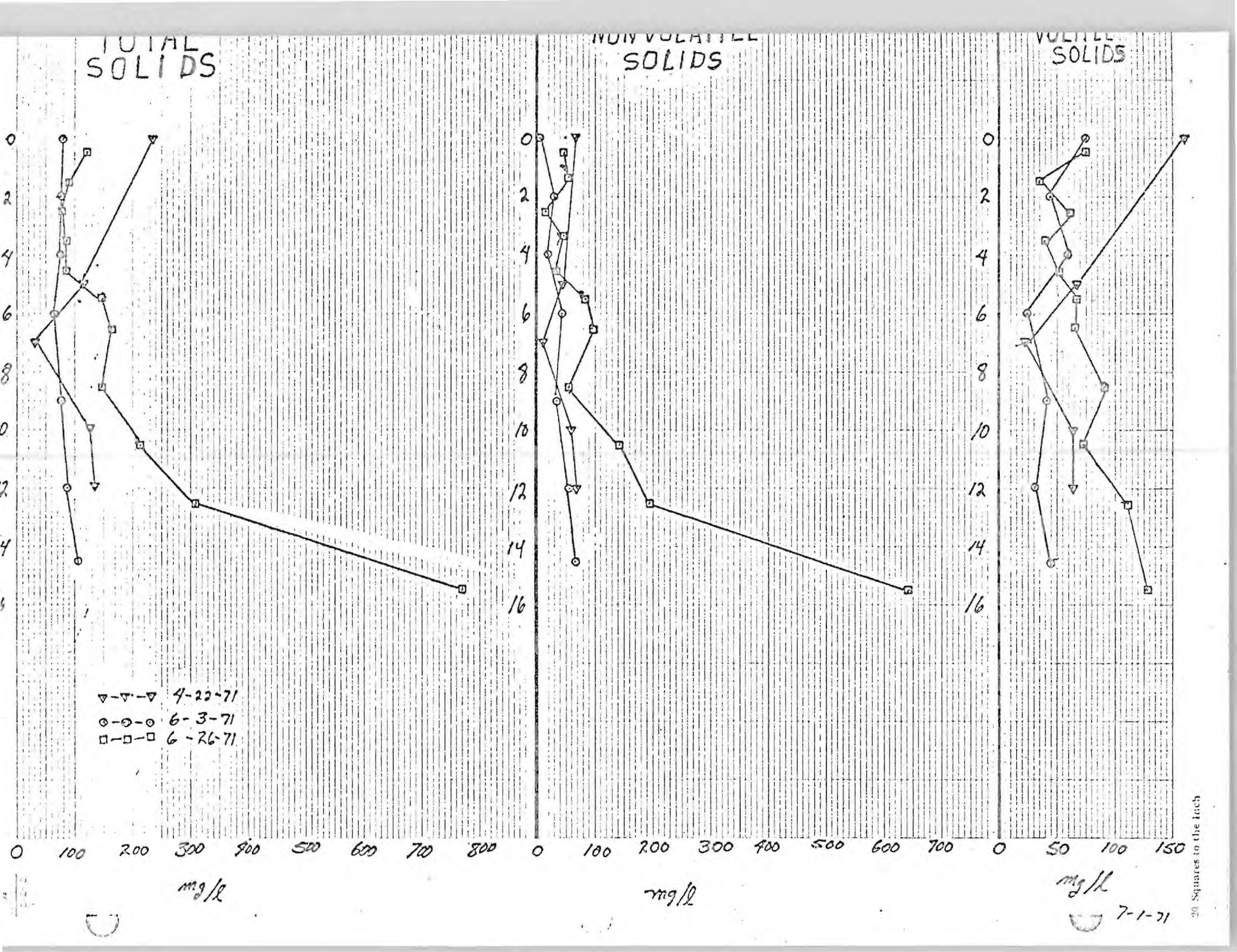


FIG. 5 - PREDOMINANT ALGAE
OPERATION BREAKTHROUGH SITE
MACON, GEORGIA


Mn Concentration
Fe Concentration
0
2
4
6
8
10
12
14
16
0 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.8 0.9 1.0
0 2 4 6 8 10 12 14 16
mg/l
mg/l
4-22-71
6-3-71
6-26-71
7-1-71
20 Squares to the Inch


Mg++ Concentration
Ca++ Concentration
Zn++ Concentration
Detectable Limit
4-22-71
6-3-71
6-26-71
mg/l
mg/l
7-1-71
50 Squares to the Inch


TOTAL SOLIDS
NON VOLATILE SOLIDS
VOLATILE SOLIDS
0
2
4
6
8
10
12
14
16
0 100 200 300 400 500 600 700 800
0 100 200 300 400 500 600 700
0 50 100 150
mg/l
mg/l
mg/l
▽-▽-▽ 4-22-71
⊙-⊙-⊙ 6-3-71
□-□-□ 6-26-71
7-1-71
20 Squares to the Inch

ddl 8/2/72

E-20-615

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
CIVIL ENGINEERING

TELEPHONE:
(404) 873-4211

AHB

November 15, 1971

Quarterly No. 3 (?)

Mr. Charles Connor
Macon-Bibb County Planning and
Zoning Commission
City Hall
Macon, Georgia 31202

Dear Mr. Connor:

During the quarter ending Sept. 30, 1971, two trips were made to the Operation Breakthrough site, on July 8 and on August 26. During the summer and fall we have been moving our laboratories to new quarters, and this has seriously hampered our capacity to complete the analysis of water samples from the site, and certain samples being saved for biological examination were destroyed. Sufficient data are available, however, to permit us to make several observations. In general, these are consistent with previous observations.

The most noticable change in water quality attributable to site preparation in the past has been a dramatic increase in non-volatile suspended solids in the bottom water and sediment on the bottom. There has occurred during the past quarter a steady improvement, probably attributable to the control of drainage from the site. Maximum non-volatile suspended solids concentrations have decreased from a value of 642 mg/l on June 26 (previous report) to 401 mg/l on July 8 and 285 mg/l on August 26.

Hydrogen sulfide continues to occur in substantial concentrations in the bottom water with the depletion of oxygen which occurred at the same depth throughout the summer.

Two further observations are of particular interest because they suggest a major role of springs as a source of nutrients entering the pond. The first observation is that of temperatures in the bottom water which remained fairly constant through the summer, suggesting that spring water enters the bottom stratum at about 15.5-16.0 C. The second observation is that of nitrates in the anaerobic zone throughout the summer. If this represents a stagnant zone, the nitrates should have dissappeared early in the summer as a result of denitrification. The presence of NO_3-N in the anaerobic zone suggests a source of nitrate entering the bottom water, such as springs. If this is true, the flow of nutrients into the pond will be hard to control. If the source of springs were ground water originating in the upper portion of the watershed, however, house construction and paving might affect its flow into the pond. At this point little can be said in addition to what was said in the previous report concerning control of poor conditions in the pond.

Although no studies were completed of planktonic algae in the pond, it can be qualitatively stated that the heavy blooms of blue-green algae occurring during the spring were absent, which would be expected. On August 26, however, masses of the blue-green alga Spirulina were observed growing on the surface of a bottom core sample obtained at the upper end of the pond.

During the present quarter we anticipate no changes in our approach. We expect to make 2 or 3 trips to the site and proceed as in the past. No specific further recommendations regarding the protection of the pond can be made at the present time, although it may be concluded that problems of siltation which occurred early in site preparation apparently have been corrected.

Sincerely yours,

Alfred W. Hoadley
Associate Professor

cc: Dr. Mark A. McClanahan

AWH:jw

TABLE I. Analysis of Pond Water, Operation Breakthrough Site, Macon, Georgia, July 8, 1971[1].

Depth (ft)	Temp (°C)	D.O. (mg/l)	pH	H_2S (mg/l)	Nitrogen (mg/l)				Solids (mg/l)		
					NH_3-N	NO_3-N	Organic-N	Total-N	Vol	Non-Vol	Total
Surf.	29.3	8.9	8.35	-	0	1.9	1.0	2.9	62	16	78
1	29.0	8.6	7.68	-	-	1.9	-	-	92	8	100
2	28.7	8.4	7.81	-	0	2.1	1.5	3.6	70	9	79
3	28.0	7.2	7.51	-	-	1.8	-	-	46	54	100
4	26.7	1.6	6.58	-	0	1.9	1.5	3.4	81	0	81
5	24.9	0.5	6.39	0.0	0	2.2	1.5	3.7	67	58	125
6	22.6	0.0	6.15	0.1	-	1.9	1.5	3.4	64	94	158
7	20.8	-	-	-	-	-	-	-	-	-	-
8	19.0	0.0	6.19	2	-	1.9	-	-	83	150	233
9	17.6	-	-	-	-	-	-	-	-	-	-
10	16.9	0.0	6.25	3	3.0	1.7	1.0	5.7	87	229	306
11	16.4	-	-	-	-	-	-	-	-	-	-
12	16.1	0.0	6.22	3	4.0	1.4	0	5.4	89	243	322
13	16.0	-	-	-	-	-	-	-	-	-	-
14	16.0	0.0	6.19	4	5.0	1.6	0.5	7.1	87	401	488
15	16.0	-	-	-	-	-	-	-	-	-	-
16.5	16.0	-	-	-	-	-	-	-	-	-	-

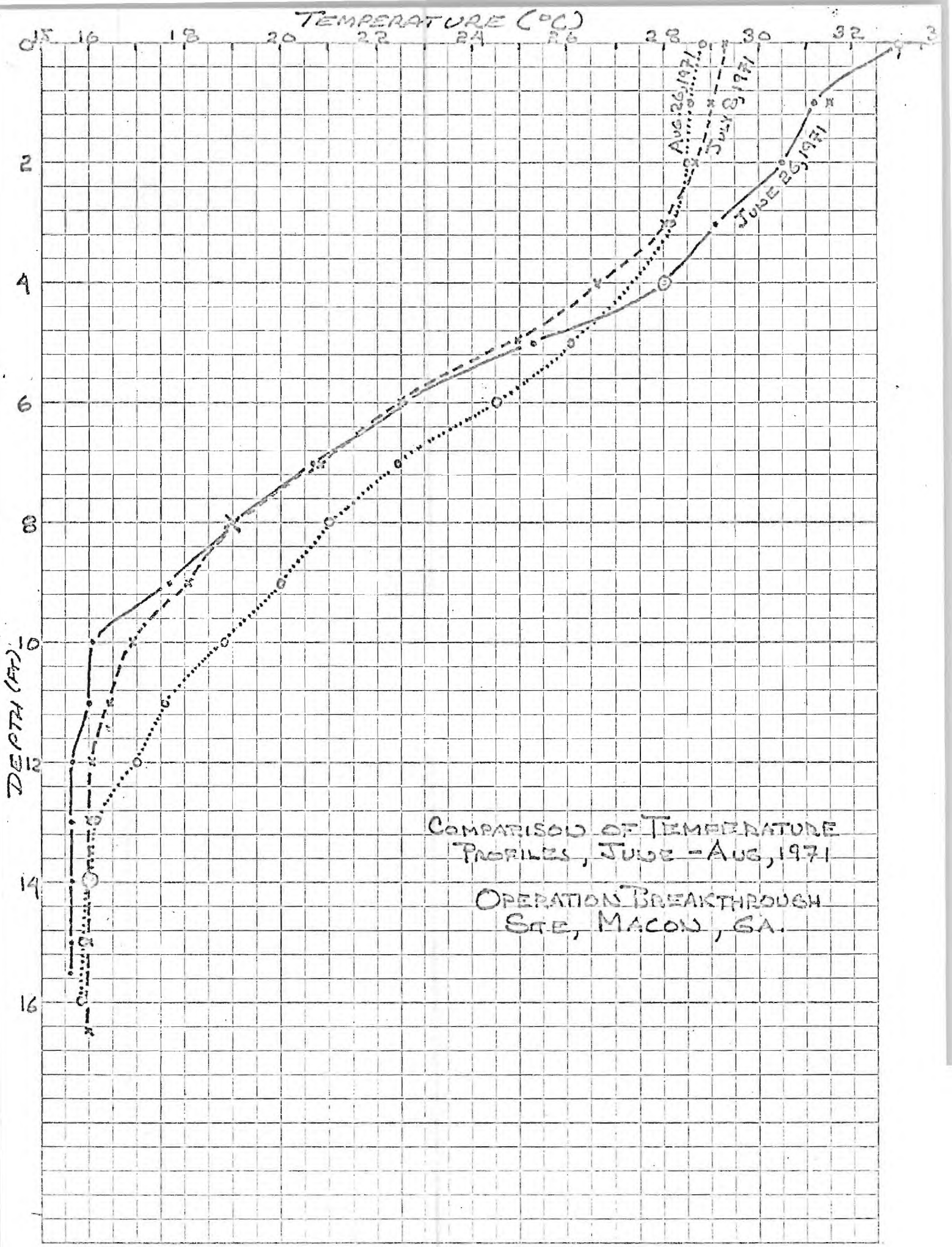
1. Samples taken between 11:15 and 11:45 a.m.
Overcast
Secchi disc reading 23"
Evidence of silt washing into pond at upper end, east side near cleared area
Silt on leaves and bushes to about 1' above water level

TABLE II. Analysis of Pond Water, Operation Breakthrough Site, Macon, Georgia, August 26, 1971[1].

Depth (ft)	Temp (°C)	D.O. (mg/l)	pH	H_2S	Nitrogen (mg/l)				Solids (mg/l)		
					NH_3-N	NO_3-N	Organic-N	Total-N	Vol	Non-Vol	Total
Surf.	28.8	7.0	-		-	-	-	-	-	-	-
1	28.6	6.9	7.4		0	3.2	1.0	4.2	41	47	88
2	28.5	6.9	7.3		0	1.7	1.0	2.7	48	18	66
3	28.2	6.8	7.4		0	2.2	1.0	3.2	57	43	100
4	28.0	6.3	7.4		0	2.2	1.0	3.2	46	53	99
4.5	-	0.6	-		-	-	-	-	-	-	-
5	26.1	0.3	6.64		0	2.8	1.0	3.8	46	90	136
6	24.5	0.1	6.6		-	2.5	-	-	65	59	124
7	22.4	0.0	6.55	+	2.0	1.4	0.0	3.4	58	202	260
8	21.0	0.0	-		-	-	-	-	-	-	-
9	20.0	0.0	6.49	+++	3.0	3.5	0.5	7.0	94	214	308
10	18.8	0.0	-		-	-	-	-	-	-	-
11	17.6	0.0	6.51	+++	5.0	3.3	0.0	8.3	91	236	327
12	17.0	0.0	-		-	-	-	-	-	-	-
13	16.1	0.0	6.53	+++	7.0	2.1	1.0	10.1	116	286	402
14	16.0	0.0	-		-	-	-	-	-	-	-
15	15.9	0.0	6.59	+++	8.5	3.0	0.5	12.0	125	285	410
16	15.8	0.0	-		-	-	-	-	-	-	-

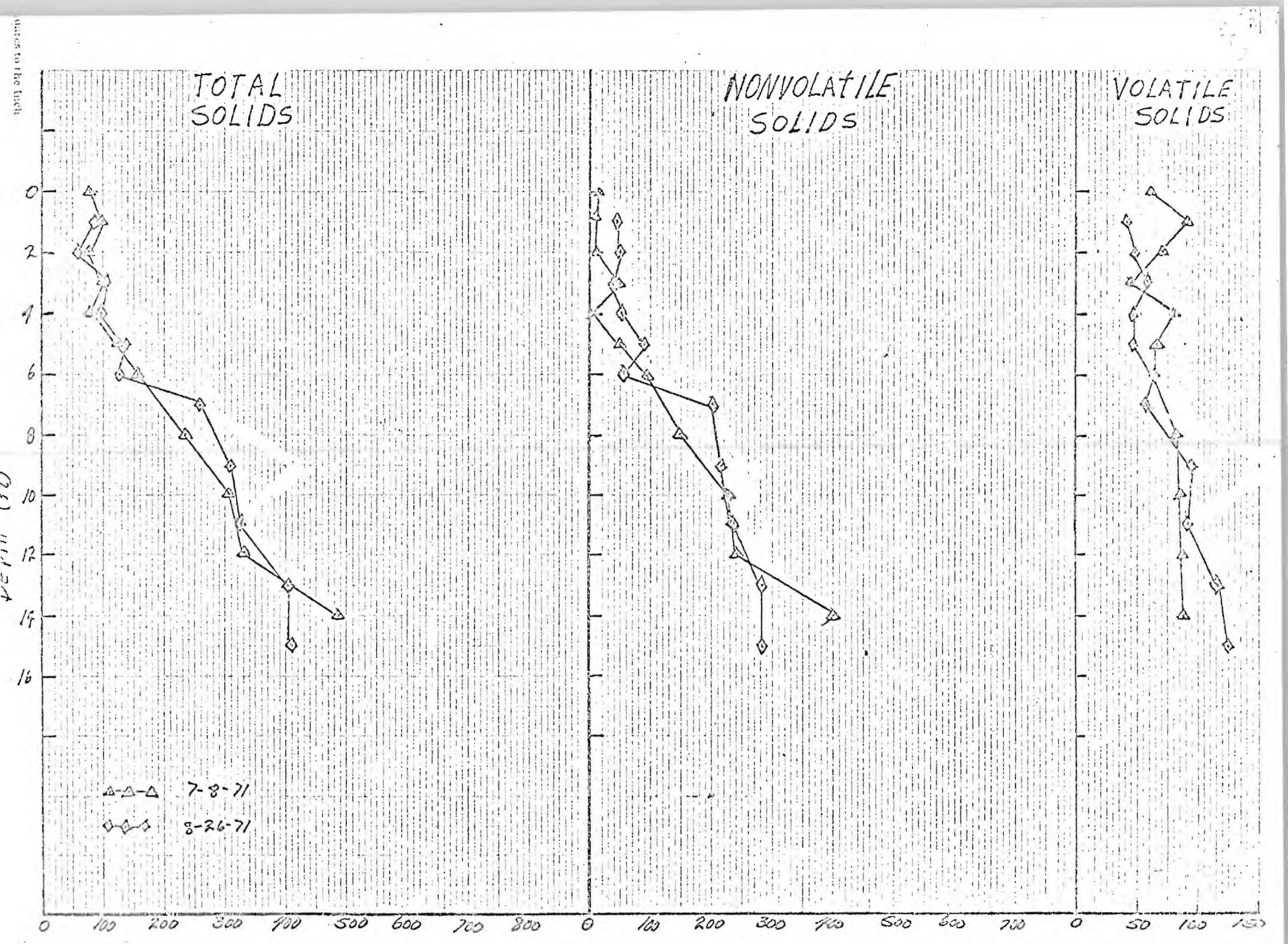
1. Sampled between 11:30 a.m. and 12:00 noon
100% overcast
Secchi disc reading 18"
Evidence of silty runoff entering pond from construction site at upper end, east side
Floating masses of Spirulina

DISSOLVED OXYGEN
Percent Saturation
0 20 40 60 80 100 120 140 160
°C
0 4 8 12 16 20 24 28 32 36
7-8-71
8-26-71
0 2 4 6 8 10 12 14 16 18



COMPARISON OF TEMPERATURE PROFILES, JUNE - AUG, 1971

OPERATION BREAKTHROUGH SITE, MACON, GA.


TOTAL SOLIDS
NONVOLATILE SOLIDS
VOLATILE SOLIDS
0
2
4
6
8
10
12
14
16
0 100 200 300 400 500 600 700 800
0 100 200 300 400 500 600 700
0 50 100 150
7-8-71
8-26-71

rec 8/2/72
AHB

E-20-615

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
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(404) 894-2265

April 4, 1972

Quarterly No. 4 (?)

Mr. John L. Havrilla
Senior Planner
Macon - Bibb County Planning
and Zoning Commission
Post Office Box 247
Macon, Georgia 31202

Dear Mr. Havrilla:

This letter is to report on results obtained during visits to the Operation Breakthrough site on October 29, 1971 and on December 8, 1971.

On October 29, the lake was still thermally stratified, but the temperature at the surface had decreased and was relatively constant to a depth of about 9 ft. The temperature stratification resembled closely that on October 24, 1970. The oxygen and nitrogen profiles, and the occurrence of H_2S in the bottom water were also similar. Substantial non-volatile solids concentrations were present in the bottom waters, although these were less than observed during the summer. Although solids data were not available from the October, 1970 samples, some indication of the probable increase is evident in the iron and manganese concentrations in the bottom waters which increased by a factor of about 2.5. The slight increase in the Secchi disc reading over that of the previous year probably results from a lack of heavy algal growth observed in 1970. The major differences arising between October of 1970 and October of 1971 appear to be related to siltation resulting from disturbance of the surface during construction.

By December 8, 1971, the lake had become completely mixed and unstratified, although some increase in temperature was evident at the surface. Oxygen was present and most chemical species were evenly distributed throughout the depth. Despite the lack of temperature stratification, however, there was evidence of biological activity causing a depletion of oxygen adjacent to the bottom. The Secchi disc reading indicated a severe decrease in transparency on this date.

The major effect of construction on the lake is certainly the initiation of siltation, which was virtually absent before construction began. A change from a highly productive lake, in terms of algae, to one of high turbidity caused by silt and low productivity as a result of limitation on light may be expected. Protection of the appearance of the lake will require control of siltation. Protection of the lake from excessive algal growths has been considered in previous reports.

Sincerely,

A.W. Hoadley

AWH:lb
Enclosures

TABLE I. Analysis of Pond Water, Operation Breakthrough Site, Macon, Georgia, October 29, 1971[1].

Depth (ft)	Temp (°C)	D.O. (mg/l)	pH	H_2S	Nitrogen (mg/l)			Fe (mg/l)	Mn (mg/l)	Mg (mg/l)	Ca (mg/l)	K (mg/l)	Na (mg/l)	Cu, Ni, Zn (mg/l)	Solids (mg/l)		
					NH_3-N	Organic-N	Total-N								Vol	Non-Vol	Total
Surf.	21.5	6.78	6.79	---	0	2.0	2.0	0.9	0.33	0.87	2.6	2.0	---	Absent	114	0	114
1	21.5	6.88	6.70	---	0	1.5	1.5	0.8	0.30	0.87	2.5	1.4	---		73	0	73
2	21.3	6.88	6.62	---	0	1.5	1.5	---	0.31	0.87	2.5	2.0	---		90	9	99
3	21.2	6.88	6.94	---	0	1.5	1.5	0.8	0.30	0.87	2.5	1.7	---		164	11	175
4	21.2	6.88	7.3	---	0	1.5	1.5	0.9	0.30	0.87	2.6	2.0	---		66	3	69
5	21.2	6.57	6.82	---	0	1.8	1.8	0.9	0.35	0.87	2.5	2.0	8.0		52	48	100
6	21.1	6.37	7.3	---	0	1.0	1.0	0.8	0.32	0.87	2.6	1.7	---		58	50	108
7	21.1	4.85	6.78	---	0	1.5	1.5	0.9	0.30	0.87	2.5	1.9	8.0		85	8	93
8	21.0	3.7	7.01	---	0	1.8	1.8	0.9	0.30	0.87	2.5	1.7	8.0		59	1	60
9	20.9	2.8	6.61	0	0	2.0	2.0	1.2	0.38	0.87	2.5	1.7	---		88	4	92
10	20.2	0	6.50	0	1.5	1.5	3.0	3.0	0.9	---	3.04	2.1	---		72	24	96
11	19.7	0	6.52	---	2.5	1.0	3.5	---	1.2	0.94	3.7	2.0	---		173	59	232
12	19.0	0	6.29	<0.5	5.0	2.5	7.5	21.2	2.3	1.36	3.7	2.9	---		110	103	213
13	18.2	0	6.30	---	6.5	3.0	9.5	24	2.5	1.17	3.7	3.2	---		138	125	263
14	17.3	0	6.45	1	8.5	3.0	11.5	25	2.8	1.23	3.8	3.6	---		101	173	274
15	17.0	0	6.35	1	10.0	3.0	13.0	30	2.9	1.54	3.9	3.6	8.0		178	159	337
16	16.5	0	6.40	1	13.0	---	---	32	3.4	1.90	3.9	4.3	---	√	208	237	445

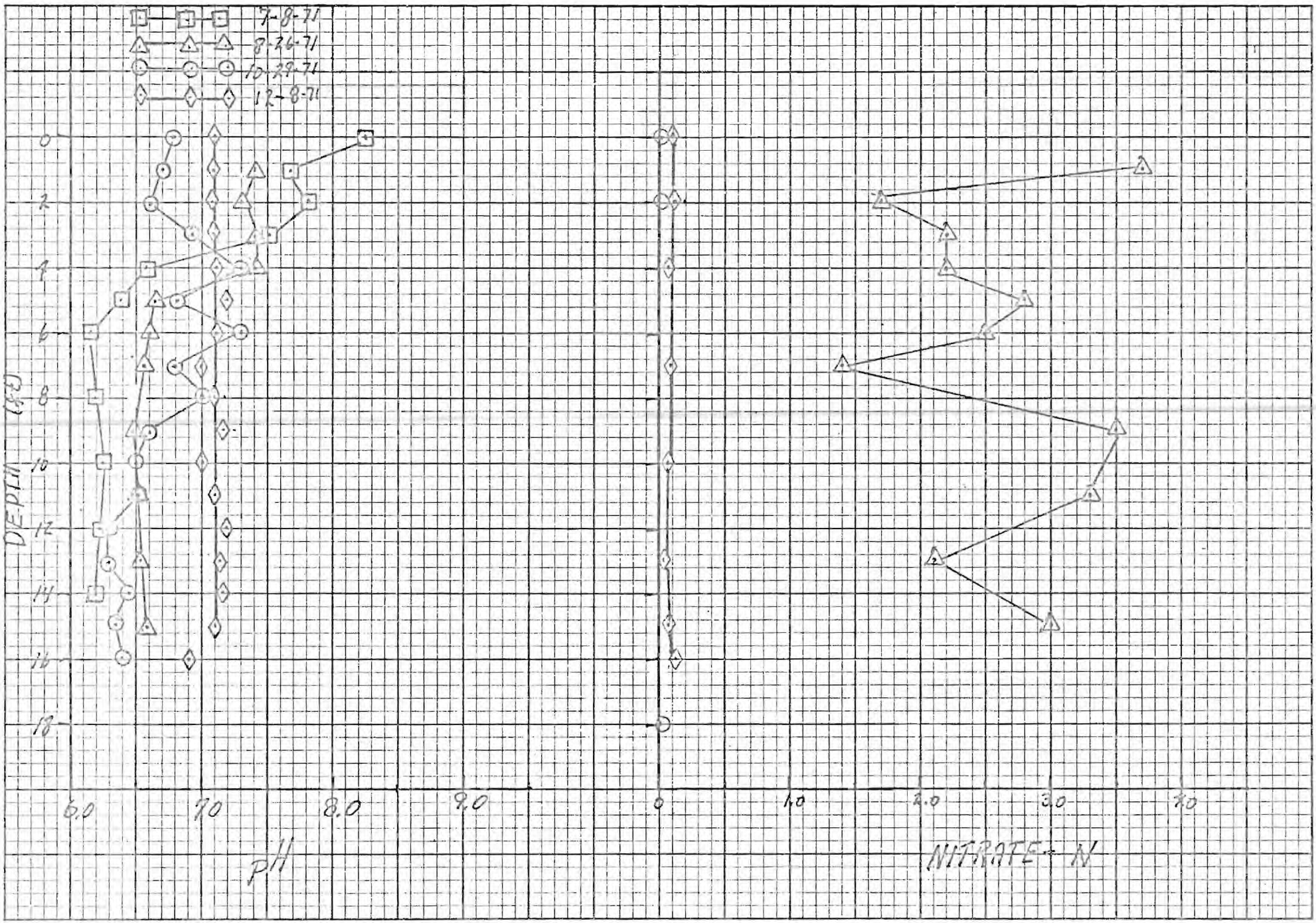
1. Sampled between 10:30 a.m. and 11:30 a.m.
Sunny
Secchi disc reading 36"
Oil slick over most of lake

TABLE II. Analysis of Pond Water, Operation Breakthrough Site, Macon, Georgia, December 8, 1971[1].

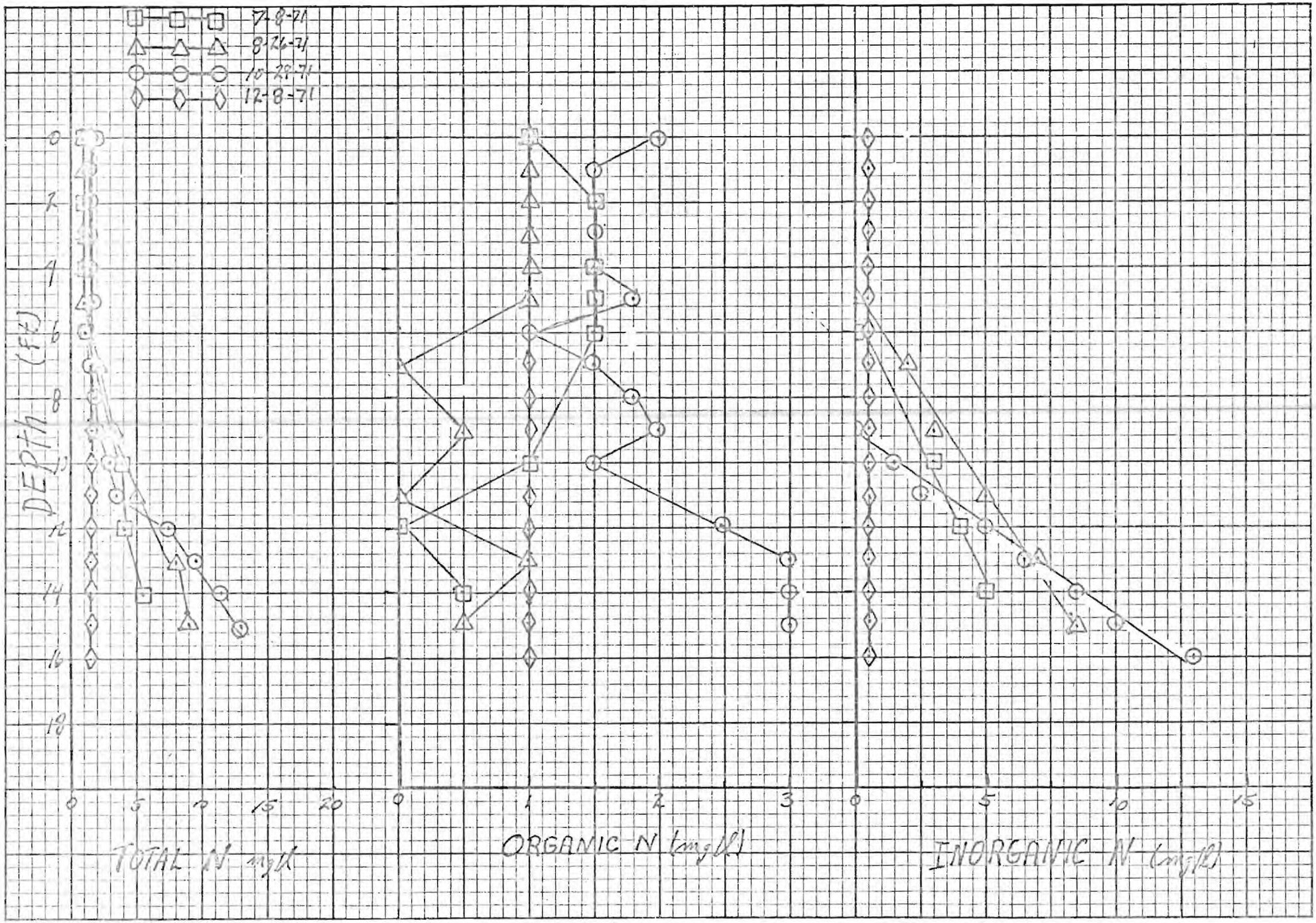
Depth (ft)	Temp (°C)	D.O. (mg/l)	pH	H_2S (mg/l)	Nitrogen (mg/l)				Fe (mg/l)	Mg (mg/l)	Mn (mg/l)	Ca (mg/l)	K (mg/l)	Na (mg/l)	Solids (mg/l)		
					NH_3-N	Organic-N	NO_3-N	Total-N							Vol	Non-Vol	Total
Surf.	13	8.5	7.1	Absent	0.5	1.0	0.10	1.6	3.85	0.76	0.26	1.3	2.0	---	111	101	212
1	12.5	8.3	7.09				---	---	3.3	0.76	0.28	1.3		6.8	130	73	203
2	12	7.9	7.07				0.12	1.62	4.0	0.76	0.28	1.3		7.0	105	167	272
3	10.2	7.9	7.12				0.06	1.56	3.4	0.76	0.28	1.4		---	133	86	219
4	9.8	7.6	7.10				0.06	1.56	3.5	0.76	0.28	1.4		---	55	135	190
5	9.7	7.6	7.19				---	---	3.4	0.76	0.28	1.3		---	87	103	190
6	9.5	7.7	7.12				---	---	4.1	0.76	0.28	1.4		---	14	136	150
7	9.4	7.6	6.98				0.08	1.58	3.3	0.76	0.28	1.4		6.4	87	121	208
8	9.3	7.6	7.08				---	---	3.8	0.76	0.28	1.4		---	86	122	208
9	9.2	7.8	7.16				---	---	3.3	0.76	0.28	1.3		---	195	36	231
10	9.1	7.8	7.0				0.06	1.56	3.5	0.76	0.28	1.3		---	97	84	181
11	9.1	7.8	7.10				---	---	3.4	0.76	0.28	1.3		---	96	72	168
12	9.0	7.8	7.19				---	---	3.5	0.76	0.28	1.4		---	38	121	159
13	9.1	7.6	7.12				0.03	1.53	3.5	0.76	0.28	1.3		---	102	121	223
14	9.9	6.7	7.16				---	---	---	0.76	0.28	1.4		7.0	80	198	278
15	9.9	6.5	7.10				0.06	1.56	---	0.76	0.28	1.4		---	113	161	274
16	10.0	4.5	6.8				0.12	1.62	5.1	0.66	0.40	1.2	3.2	6.0	103	334	437
Siphon	---	---	7.06	---	---	---	---	---	3.4	0.76		1.35	---	---	52	120	172

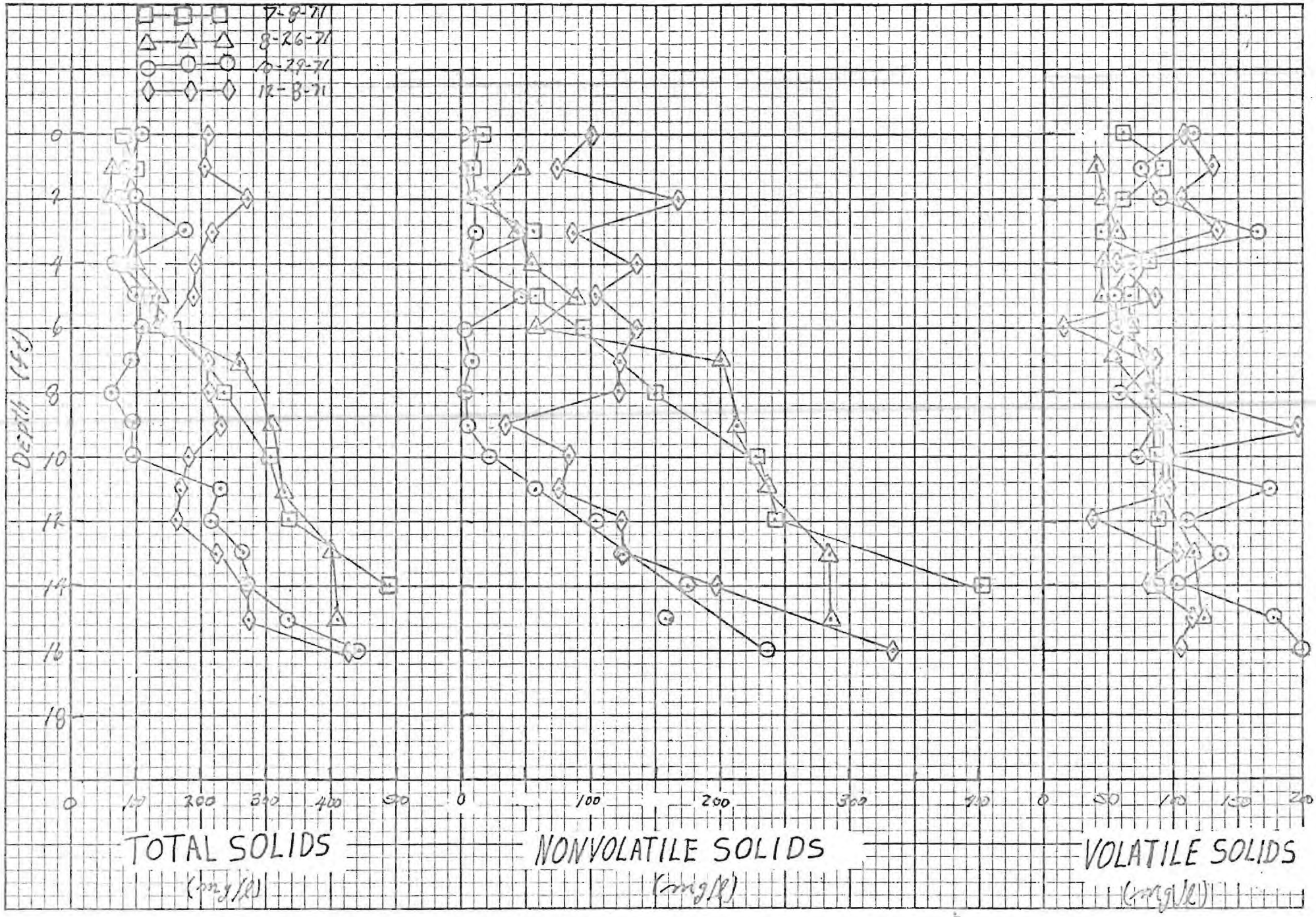
1. Overcast
   Secchi disc reading 10"
   6" siphon accross dam

Macon Lake


7-8-71
8-26-71
10-29-71
12-8-71
0
2
4
6
8
10
12
14
16
18
DEPTH (ft)
6.0
7.0
8.0
9.0
0
1.0
2.0
3.0
4.0
pH
NITRATE - N

1


7-8-71
8-26-71
10-29-71
12-8-71
DEPTH (FT)
0
2
4
6
8
10
12
14
16
18
0
5
10
15
20
TOTAL N mg/l
0
1
2
3
ORGANIC N (mg/l)
0
5
10
15
INORGANIC N (mg/l)


7-8-71
8-26-71
10-29-71
12-8-71
DEPTH (ft)
0
2
4
6
8
10
12
14
16
18
0
100
200
300
400
500
0
100
200
300
400
0
50
100
150
200
TOTAL SOLIDS
(mg/l)
NONVOLATILE SOLIDS
(mg/l)
VOLATILE SOLIDS
(mg/l)

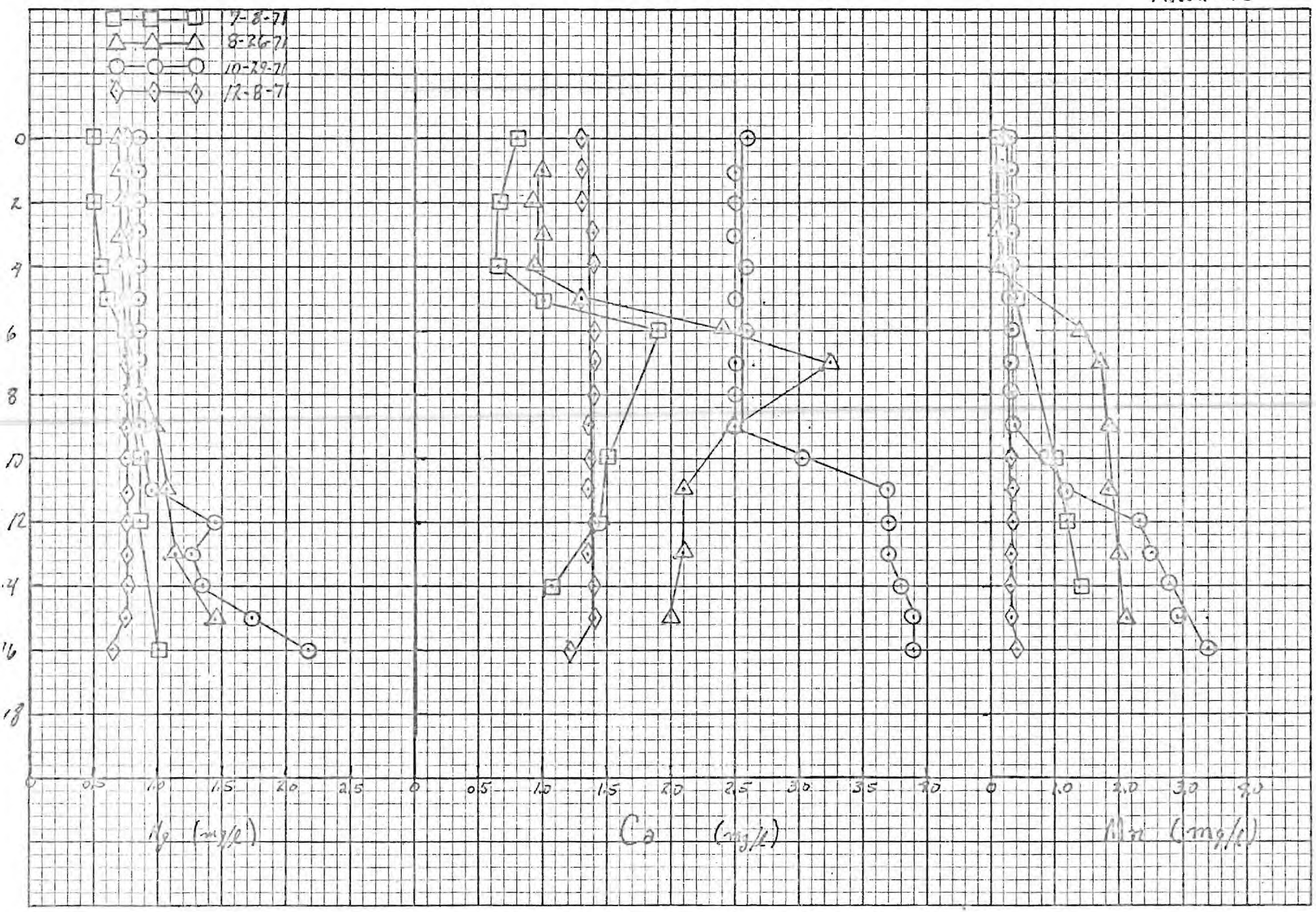
Macon Lake


7-8-71
8-26-71
10-22-71
12-8-71
Depth (ft)
0
2
4
6
8
10
12
14
16
18
0
5
10
15
20
25
30
35
°C
0
20
40
60
80
100
120
140
D.O. % Saturation

Macon Lake


7-6-71
8-16-71
10-29-71
12-8-71
0
2
4
6
8
10
12
14
16
18
0
10
20
30
40
Fe (mg/l)
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
K mg/l

Macon Lake


7-8-71
8-26-71
10-29-71
12-8-71
0
2
4
6
8
10
12
14
16
18
0
0.5
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1.5
2.0
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0
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1.0
1.5
2.0
2.5
3.0
3.5
4.0
0
1.0
2.0
3.0
4.0
Fe (mg/l)
Co (mg/l)
Mn (mg/l)

Nelson (dupe)
File

E-20-615
Hoadley

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
VIL ENGINEERING

TELEPHONE:
(404) 894-2265

August 23, 1972

Mr. John L. Havrilla
Senior Planner
Macon - Bibb County Planning
and Zoning Commission
Post Office Box 247
Macon, Georgia 31202

Quarterly Reports #5, 6 + 7 11 00

Dear Mr. Havrilla:

Attached are the data obtained by us at the Operation Breakthrough Site in Macon during the first three quarters of this calendar year. Although at least one further ~~visit will~~ be made to the site before the end of September, the data probably will not be available by the end of the third quarter. The sampling dates covered by the present report are March 21, April 7, May 25, July 6, July 7, and August 2, 1972.

The data obtained during the current year are of considerable interest since the lake water was of greatly improved quality in late March and early April in terms of the solids, reflecting the silt load in the pond. The solids were higher than, but comparable to, those observed at the same time in 1971. The solids observed on May 25, July 6 and August 2, while lower than during the previous year, were relatively high compared with values obtained prior to June, 1971.

Of particular interest was a marked improvement in the clarity of the water observed on May 25 and July 6. The secchi disc readings on these two dates were 5' and 4', far greater than observed on any previous occasion. Furthermore, oxygen was present to a greater depth on April 7, May 25, and July 6, also suggesting improvement in the quality of the water. The productivity curve obtained on May 25 indicate a similar reduction in photosynthesis and the occurrence of photosynthesis at much greater depths than during 1971. We can only speculate regarding the reason. It is possible that the silt load to the lake was greatly reduced during the period in question, and that the silt previously suspended in the water settled, carrying with it nutrients which at other times have been available to support the growth of algae. This view is not supported by nitrogen data for May 25, however, or phosphate data; although lower concentrations during the previous year could have resulted from utilization by algae. By July 6, algae in the lake had apparently removed essentially all nitrate nitrogen. The improvement in water quality was a temporary one, however. By July 6, the productivity had increased indicating that photosynthesis was greater than that observed during the previous year. By August of 1972, the secchi disc reading had decreased to 2.25 ft and the profile of dissolved oxygen resembled that of the previous year, although the silt load remained vastly improved. The lower nitrate levels on August 2 can be attributed to utilization by algae. These concentrations were lower than during the previous year (July 8 and August 26, 1971), again, probably as a result of increased algal production.

Thus, although improvement in water quality was evident during the Spring of 1972, this change was temporary, and algal productivity now appears to at least equal that of the previous year. A judgment regarding whether this will continue must await further sampling. There has been a substantial reduction in the sediment load to the lake over that early in construction, although the solids are still substantially greater than those present prior to construction. It should be noted that such suspended materials may harm the bottom for the spauning of fish. Also, while we have no quantitative data in support of the statement, we have observed that fish nests are very much less in evidence this year than last.

Sincerely yours,

Alfred W. Hoadley

AWH:lb
Enclosures

Table I. Analysis of Pond Water, Operation Breakthrough Site, Macon, Georgia, March 21, 1972[1]

Depth (ft)	Temp (°C)	D.O. (mg/L)	pH	Fe (mg/L)	Mn (mg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Zn (mg/L)	Solids (mg/L)		
											Vol	Non-vol	Total
Surf	18.5	7.2	7.3	2.7	.043	1.7	.73	1.6	-	.0007	70	62	132
1	18.0	7.1	7.3	2.7	.043	1.7	.73	1.6	-	.0002	64	24	98
2	17.1	7.3	7.3	2.9	.07	1.7	.73	1.6	-	.001	65	35	100
3	15.0	6.0	7.15	2.8	.043	1.7	.73	1.6	-	.0007	62	23	85
4	14.0	5.3	7.0	3.1	.043	1.6	.73	1.6	8.0	0	78	59	137
5	13.2	3.8	6.9	3.1	.07	1.6	.70	1.6	8.0	.001	37	113	150
6	11.9	2.6	6.8	3.2	.043	1.5	.70	1.6	-	-	64	48	112
7	11.0	2.5	6.7	3.2	.043	1.6	.70	1.6	-	-	61	23	84
8	10.8	1.6	6.7	3.2	.043	1.4	.70	1.6	-	.001	83	50	143
9	10.5	1.4	6.65	3.7	.113	1.4	.70	1.6	-	.001	93	21	114
10	10.2	1.3	6.7	3.7	.113	1.4	.70	1.6	-	.002	90	25	115
11	10.1	1.2	6.7	3.7	.27	1.4	.70	1.6	8.0	-	76	39	115
12	10.0	1.1	6.65	3.8	.23	1.4	.70	1.6	8.0	.007	76	44	120
13	10.0	1.3	6.7	3.7	.14	1.4	.70	1.6	-	0	82	36	118
14	10.0	1.2	6.6	3.8	.13	1.3	.70	1.6	-	.0007	70	23	93
14.5	10.0	-	-	-	-	-	-	-	-	-			

[1]Sampled between 9:30 and 10:30 a.m. Overcast Secchi Disc Reading 1'

Site, Macon, Georgia, April 7, 1972[1]

Depth (ft)	Temp (°C)	D.O. (mg/L)	pH	Fe (mg/L)	Mn (mg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Zn (mg/L)	Solids (mg/L)		
											Vol	Non-vol	Total
Surf	28.0	10.2	7.2	2.3	.043	2.6	.81	1.6	-	.004	63	84	147
0.5	23	-	-	-	-	-	-	-	-	-	-	-	-
1	20	10.4	7.2	2.4	.029	2.5	.81	1.6	-	.003	56	41	97
2	18	11.2	7.8	2.3	.113	2.4	.81	1.6	-	.003	59	39	98
3	15.5	11.1	7.35	2.3	.057	2.4	.77	1.6	-	.003	32	108	140
4	14.8	10.6	7.21	2.4	.07	2.5	.81	1.6	-	.03	46	51	97
5	14.0	7.2	6.83	2.5	.07	2.5	.81	1.6	8.0	.003	70	84	154
6	13.0	3.4	6.75	2.6	.07	2.5	.81	1.6	-	.002	77	35	112
7	12.9	1.0	6.68	3.1	.113	2.4	.77	1.6	-	-	83	86	169
8	11.9	0.3	6.9	-	-	-	-	-	-	-	-	-	-
9	11.9	0.3	6.68	3.4	.29	2.2	.77	1.6	-	.002	106	32	138
10	11.4	0.3	6.72	4.0	.33	1.9	.81	1.6	8.0	.002	96	60	156
11	11.0	-	6.6	4.0	.32	1.9	.77	1.6	-	.003	102	33	135
12	10.9	0.3	6.82	4.1	.36	1.8	.77	1.6	-	.005	84	63	147
13	10.9	0.3	6.78	4.2	.39	1.7	.81	1.6	8.0	.003	91	50	141
14	10.9	0.2	6.8	5.1	.46	1.8	.81	1.6	-	.003	100	47	147
15	-	0.1	6.72	5.2	.49	1.9	.85	1.6	-	.003	96	67	163
16	-	0.05	6.75	5.2	.51	1.9	.85	1.6	8.0	.003	110	106	216

[1] Sunny, clear to hazy Secchi Disc Reading 1' sampled 3:00 to 4:00 p.m.

Table III. Analysis of Pond Water, Operation Breakthrough Site, Macon, Georgia, May 25, 1972[1]

Depth (ft)	Temp (°C)	D.O. (mg/L)	pH	H_2S	Nitrogen (mg/L)				PO_4 (mg/L)	Fe (mg/L)	Mn (mg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Zn (mg/L)	Solids (mg/L)		
					NH_3-N	Organic-N	NO_3-N	Total-N									Vol	Non-vol	Total
Surf	31	9.5	*	-	0	0	1.37		.3	0.4	0.25	2.8	0.85	1.2	10.5	*	34	63	97
1	30	9.6		-	0	0	1.42		.3	0.3	0.0	2.8	0.85	1.2	8.0		32	106	138
2	29.5	9.6		-	0	1.0	1.55		.4	0.4	0.0	2.8	0.85	1.2	8.2		48	110	158
3	29	9.9		-	0	-	1.50		.5	0.3	0.0	2.8	0.85	1.2	8.2		69	94	163
4	28.7	10.0		-	0	0	1.37		.2	0.3	0.0	2.8	0.85	1.2			10	106	116
5	28.1	10.5		-	0	0	1.98		.3	0.3	0.0	2.8	0.85	1.2			23	21	44
6	27.0	10.1		-	0	0	1.15		.2	0.3	0.0	2.8	0.85	1.2			26	60	86
7	25.6	4.7		-	0	0	0.66		.4	0.3	0.15	2.8	0.85	1.2	8.0		72	74	146
8	24.0	2.1		-	0	1.0	0.35		.4	0.4	0.30	2.8	0.85	1.2	10.5		52	88	140
9	22.0	1.2		-	0	0	0.0		.8	0.4	0.55	2.6	0.85	1.2	6.5		49	48	97
10	19.2	0.9		-	0	1.0	0.0		-	0.4	1.0	2.5	0.85	1.2			65	18	83
11	18.0	0.0		+	0	2.0	0.0		.4	3.5	1.25	2.4	0.92	1.5			42	101	143
12	17.4	0.0		+	0	2.0	0.0		.5	4.8	1.1	2.3	0.92	1.2			74	146	220
13	17.0	0.0		+	0	2.0	0.0		.5	5.0	0.8	2.3	0.92	1.2	7.2		67	115	182
14	16.6	0.0		+	2.0		0.0		.1	6.9	1.0	2.2	0.92	1.5	8.0		58	139	197
14.5	16.5	0.0		+	-	-	-			-	-	-	-	-	-				

[1]Partly cloudy Secchi Disc Reading 5' sampled 1:15 to 2:15 floating masses of Oedogonium present
*Not performed

Table IV. Analysis of Pond Water, Operation Breakthrough Site, Macon, Georgia, July 6, 1972[1]

Depth (ft)	Temp (°C)	D.O. (mg/L)	pH	Nitrogen (mg/L)			PO_4 (mg/L)	Fe (mg/L)	Mn (mg/L)	Ca (mg/L)	Mg (mg/L)	Solids (mg/L)		
				NH_3-N	Organic-N	NO_3-N						Vol	Non-vol	Total
Surf	*	8.0	**	0.0	0.0	0.09	0.4	-	-	3.5	1.06	60	23	83
1		8.0		0.0	0.0	0.0	0.3	-	-	3.5	1.07	104	9	113
2		8.0		0.0	1.0	0.0	0.2	0.1	-	3.5	1.05	60	12	72
3		8.1		0.0	-	0.0	-	-	-	3.5	-	-	-	-
4		8.0		0.0	1.0	0.0	0.4	-	-	3.5	1.11	54	42	96
5		8.0		0.0	1.0	0.0	0.4	0.1	-	3.5	1.07	90	6	96
6		8.0		0.0	0.0	0.0	0.3	0.1	-	3.4	1.07	80	5	85
7		4.7		0.0	1.0	0.0	0.4	0.25	-	2.7	1.11	27	8	35
8		1.8		0.0	1.0	0.0	0.3	0.25	0.35	3.25	1.13	63	97	160
9		1.0		0.0	1.0	0.0	0.5	0.60	0.5	4.4	1.16	58	40	98
10		0.0		0.0	1.0	0.04	0.7	1.85	1.4	5.8	1.26	68	117	185
11		0.0		0.0	0.0	0.0	1.1	2.2	1.7	5.6	1.27	57	134	191
12		0.0		3.0	3.0	0.04	0.6	5.2	2.1	6.3	1.36	107	119	226
13		0.0		3.0	3.0	0.27	0.6	6.1	1.9	5.9	1.35	95	133	228
14		0.0		5.0	2.0	0.0	0.5	14.2	1.09	4.5	1.40	120	120	240
15		0.0		4.0	4.0	0.0	0.7	14.6	2.1	4.5	1.40	128	122	250
16	↓	0.0	↓	7.0	6.0	0.0	0.6	15.0	2.2	4.5	1.44	128	111	239

[1]Sunny Secchi Disc Reading 4' sampled 12:15 to 1:15
*Probe not operating - see data for July 7, 1972
**Not performed

Table V. Analysis of Pond Water, Operation Breakthrough Site, Macon, Georgia July 7, 1972[1].

Depth (Ft)	Temp. (°C)	D. O. (Mg/L)
Surf.	28.0	8.9
1	28.2	9.0
2	28.2	9.0
3	28.1	8.9
4	28.1	8.1
5	28.1	7.6
6	28.0	5.7
7	27.0	1.2
8	26.1	0.05
9	24.8	0.0
10	22.5	0.0
11	20.5	0.0
12	19.0	0.0
13	17.3	0.0
14	16.8	0.0
15	15.2	0.0
16	15.0	0.0
17	14.5	0.0

1. Sunny
Secchi Disc Reading 3' - 9"
Sampled 10:00 A.M.

Table V-a

ANALYSIS OF POND WATER, OPERATION BREAKTHROUGH SITE, MACON, GEORGIA *
August 2, 1972

Depth (Ft)	Temp (°C)	D.O. (mg/l)	Nitrogen (mg/l)			Nitrate (mg/l)	Phosphate (mg/l)		Fe (mg/l)	Mn (mg/l)	Mg (mg/l)	Ca (mg/l)	Solids (mg/l)		
			NH_3-N	Organic-N	Total-N		Ortho	Poly					Vol	Non Vol	Total
0	29.9	8.9	0	1.0	1.0	0	0.3	---	----	----	1.04	2.30	38	33	71
1	29.8	8.8	0	1.0	1.0	0.180	0.4	---	----	----	----	----	---	--	--
2	29.8	8.1	0	1.0	1.0	0.222	0.4	---	----	----	----	----	132	56	188
3	29.7	7.4	0	1.0	1.0	0.220	0.3	---	----	----	----	----	57	23	81
4	29.4	6.4	0	1.5	1.5	0.266	0.2	---	----	----	----	----	109	6	115
5	29.0	3.8	0	1.5	1.5	0.266	0.3	---	0.65	----	1.05	2.6	50	43	93
6	28.7	0.5	0	1.0	1.0	0	0.2	---	0.30	0.25	1.18	2.85	89	55	144
7	27.8	0	0	---	---	0.355	---	---	----	----	----	----	86	9	95
8	26.7	0	0	1.0	1.0	0.266	0.6	---	----	----	----	----	132	126	258
9	25.4	0	0	---	---	0.532	0.7	---	----	----	----	----	106	146	252
10	23.8	0	0	2.0	2.0	0	0.4	---	2.78	1.15	1.20	5.25	126	133	259
11	21.9	0	2	1.5	3.5	0.576	0.2	---	8.10	2.20	1.25	5.90	97	157	254
12	20.4	0	---	---	---	0.487	0.3	---	----	----	----	----	142	183	325
13	18.5	0	2.5	0.5	3.0	0.665	0.3	---	11.1	2.25	1.25	6.50	131	81	222
14	17.3	0	3	1.0	4.0	0.532	0.2	---	16.75	2.60	1.43	6.30	133	141	274
15	16.7	0	4	1.0	5.0	0.620	0.6	---	----	----	----	----	144	105	249
16	16.2	0	---	---	---	-----	---	---	----	----	----	----	---	---	---

*Secchi disc reading 2.25
Sunny
Sampled 9:30-10:30 A.M.

Table VI. Productivity at Operation Breakthrough Site May 25, 1972[1].

Depth (Ft.)	Time (Hr)	D. O. (mg/l)					Productivity (mg C/m^3/hr)	
		Init.	Light Bottle	Dark Bottle	Gross Increase	Net Increase	Gross	Net
1'	2:50	9.3	9.25	9.1	0.15	-	16.7	---
2'	2:56	9.6	9.65	9.45	0.20	0.05	21.2	5.3
3'	3:03	9.7	9.45	9.4	0.05	-	5.0	---
5'	3:08	10.1	10.0	9.8	0.20	-	20.0	---
7'	3:27	9.1	9.35	8.85	0.50	0.15	45.4	13.6
9'	3:39	3.7	3.2	2.85	0.35	-	30.0	---

1. Partly Cloudy

Table VII. Productivity at Operation Breakthrough Site July 6, 1972[1].

Depth (Ft.)	Time (Hr)						Productivity (mg C/m^3/hr)	
		Init.	Light Bottle	Dark Bottle	Gross Increase	Net Increase	Gross	Net
0.5'	3:42	7.6	7.9	7.45	0.45	0.3	38	25.3
1.5'	3:51	7.6	8.275	7.6	0.675	0.675	54.9	54.9
2.5'	3:57	7.6	8.1	7.5	0.60	0.50	47.5	39.6
4.5'	4:06	7.6	8.2	7.5	0.70	0.60	53.4	45.8
6.5'	4:12	7.3	8.0	7.4	0.60	0.70	44.7	----
8.5'	4:18	3.7	3.75	3.7	0.05	0.05	3.6	3.6

1. Sunny

E-20-615

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
CIVIL ENGINEERING

TELEPHONE:
(404) 894-

August 22, 1973

Ms. Marcia Oder
Macon-Bibb County Planning
and Zoning Commission
P. O. Box 247
Macon, Georgia 31202

Dear Ms. Oder:

Attached are three copies of the final report on the studies conducted by the School of Civil Engineering at Georgia Tech on the Effects of Planned Urban Development on Water Quality at the Operation Breakthrough Site at Macon, Georgia. The Site was visited on sixteen occasions between October, 1970 and July, 1973, spanning Pre-construction, Construction, and Post-construction periods. The attached report covers that period.

If you have any questions regarding our report, please let me know.

Sincerely yours,

cl

Alfred W. Hoadley
Associate Professor

AWH/cl
Enclosures

A STUDY OF WATER QUALITY AT THE MACON, GEORGIA, OPERATION BREAKTHROUGH SITE

BY

Alfred W. Hoadley and Mark A. McClanahan

FINAL REPORT

HUD Contract H-1504

Initiated: October 1, 1970
Terminated: June 30, 1973

SCHOOL OF CIVIL ENGINEERING
GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

INTRODUCTION

A ubiquitous problem in urban development is that of determining the effects of development on environmental quality. Generally, attempts to determine these effects have taken place after the fact. The study of water quality at the Macon, Georgia, Operation Breakthrough Site was undertaken in an attempt to assess variations in water quality in a small lake located on an essentially undeveloped site scheduled for full development. The study was to have covered the pre-construction, construction and post-construction phases of the project. The study was undertaken to "determine the causes for changes in water quality and where possible, remedies shall be recommended to alleviate contamination and to prevent future entry of undesirable elements (contaminants) into the water body."

The site of the Water Quality Study was a small lake of 6 acres area located on a site of about 50 acres. The lake was fed by surface drainage from the construction site entering through an alluvial area at the northeast end of of the lake and a small brook entering at the northwest side of the lake. Based upon results of early studies during the planning stages of the Operation Breakthrough Project, the lake is believed to be spring-fed. The probable source of water feeding the springs is the high portion of the Breakthrough Site which lies to the north and northeast.

The lake has a surface area of about six acres, having a volume of 12.72 million gallons, a maximum depth of about 15.5 feet and a mean depth of 4.2 feet. The lake is formed by an earth dam across the drainage from the watershed. A drain was at one time located at the deep point in the lake. There apparently is no drainage from this point at the present time, and the level of the lake is determined by a weir located at the western end of the dam. Midway in the study a siphon was installed to carry water over the dam. Water carried by the siphon originated from the bottom waters of the lake, although it is not known when the siphon was in operation. The bottom of the lake consists of about 1 foot of muck underlaid with clay. An important feature of the lake from a limnological point of view is its relative protection from the wind afforded by its surrounding slopes and trees.

Before turning to the results of the study of water quality, it is important to understand certain circumstances which limit the interpretations which may

be made of the results of the study. Some of these circumstances might be avoided in future studies, others were unavoidable.

A major limitation of the study was one of time and of resources. To determine properly the pre-construction condition of a body of water, studies must be conducted over at least a full year's time. This would permit an understanding of normal seasonal variations which cannot be taken into account in the present study. In addition, more thorough investigation of the factors affecting biological production in the lake should have been undertaken. These should include studies of biomass, limiting nutrients, and more thorough studies of algal populations. The resources available did not permit the inclusion of such analyses in the present study.

The last point leads to a further matter of concern. This is a question of purpose. Characteristically, concern for water quality in a lake in a residential area is with the appearance of the lake. Clear water free of unsightly masses of algae and free of odors, is ordinarily considered desirable. It has been our assumption that these represented appropriate goals. A point has come to our attention since completing this study which raises questions concerning goals. Prior to July, 1971, the lake was fertilized extensively to increase fish production. Thus nitrogen and phosphorus were added to the lake. The effect is to increase the production of algae and as a consequence, to increase that of fish. Apparently some fertilization was practiced in July, 1972, but the amount of nutrients added to the lake was minimal. However, it is our understanding that between April and mid-July, 1973, some 1200 pounds of fertilizer have been added to the lake. The consequences of doing this are in direct conflict with the aims of certain proposals made during the study, (see letter from A. W. Hoadley to Mr. Charles Connor, Appendix III). Knowledge of when fertilization has been carried out goes far to explain results of the study which have been a mystery so far. Indeed, the way in which fertilization has been carried out precludes many conclusions relating to the impacts of construction on water quality and reduces substantially the value of the study for the purposes intended.

RESULTS OF THE STUDY:

Before data relating to water quality can be interpreted, it is essential to understand the degree to which stratification occurs, and as a result, the degree of stability of the lake under study. Classically, if one starts with a lake in winter, the temperature throughout is fairly constant and mixing takes place throughout. Under these circumstances, nutrients and other constituents of the water are relatively evenly distributed throughout the water column. As the air temperature rises and as the days lengthen in the spring, the temperature of the water rises at the surface. If the water is not significantly disturbed, there will be little mixing and the difference between the surface water temperature and the temperature of the bottom water will increase, and the water will become stratified. Ordinarily, in Georgian lakes, mixing of the warm surface waters of lakes occurs to depths considerably in excess of the depth of Crystal Lake at the Operation Breakthrough Site in Macon. At the Operation Breakthrough Site, however, a very sharp temperature stratification develops early in the spring as is evident in Figures I and II. This occurs because the slopes and trees surrounding the lake protect it from wind which in a more open location would cause mixing throughout, although springs may also supply cool waters to the bottom of the lake.

The result of temperature stratification such as that evident in Crystal Lake is great stability of the water. The surface water, being warm, is less dense than the cold bottom water and as a result it floats on the cold water. The effect is a reduction in the amount of circulation occuring between bottom water and surface water, and the virtual isolation of the bottom water during the summer months. In the fall, however, as the surface

waters cool, circulation extends ever deeper until, when the surface temperature equals that of the bottom waters, and circulation is possible throughout the water column.

The processes described are very well illustrated in Figures I and II, and must be born in mind in the discussion which follows. An important difference is evident between the summers of 1971 and 1972 represented in Figures I and II, respectively. During the summer of 1971 (Figure I) stratification begins at, or very near the surface. During the summer of 1972 (FigureII) on the other hand, stratification begins at a depth of about 6 feet. In other words, mixing of the surface waters occurs to a depth of at least 6 feet.

The reasons for the differences between the temperature stratification during 1971 and 1972 are not clear. Probably the most plausible explanation would be that wind disturbance of the surface of the lake was greater during the summer of 1972. Whether the increased circulation during the summer of 1972 was or was not an unusual occurence cannot be answered without having data from previous summers. Such an increase could result from reduced protection of the lake as a consequence of the cutting of trees. The effect on the lake was a beneficial one, since the increased circulation carried oxygen to a greater depth (see Figures III and IV).

The most obvious consequence of temperature stratification in a rich lake such as Crystal Lake and the resulting isolation of the deep waters is a depletion of the oxygen content in the deep water. Algae growing in the surface waters of the lake sink and die then decompose. The decomposition of the algae and organic bottom sediments cause a depletion of oxygen in the isolated bottom waters. The depletion of oxygen in the bottom waters

of Crystal Lake is evident in Figures III and IV. During the summer of 1971 (Figure III), oxygen was always absent below a depth of 5 feet. During the summer of 1972 (Figure IV), however, oxygen was always present to a depth of 6 to 7 feet, and was often present to greater depths. The causes and consequences of oxygen depletion in the bottom waters are matters of concern in the context of the present report.

The cause of oxygen depletion in the deep waters is the enrichment of the lake with plant nutrients (nitrogen, phosphorus, and other trace elements). The nutrients stimulate the massive growths of algae which sink and decompose or form an organic mud which itself decomposes. Such growths of algae would not occur if nitrogen and phosphorus were kept out of the lake initially. Once bottom sediments accumulate, however, they remain as sources of nutrients even if nutrients are not permitted to enter the lake. Nutrients in the form of fertilizers have been added to Crystal Lake apparently for years, and substantial bottom deposits have accumulated. Thus if nutrients were no longer added, there would be an internal source which would continue to stimulate growth of algae. Very high levels of nitrogen and phosphorus were present through most of the study (see Tables in Appendix I). It is generally assumed that 0.1 mg of orthophosphate or more will result in excessive algal production. Phosphate concentrations were always well in excess of this value. Elimination of algae would require dredging of sediments, use of an algicide, such as copper sulfate, or increasing the flow of water through the lake. Elimination of the oxygen free bottom zone could also be accomplished by aeration or forced circulation, which might or might not reduce the production of algae.

The desires of the residents of the site may be partially at variance with

the objectives implicit in the above discussion, however, since it is our understanding that some 1200 pounds of fertilizer had been added to the lake between April and mid-July of 1973. The object clearly is to increase fish production in the lake.

Before such a practice is continued, however, it is important to review the consequences of adding fertilizer to the lake, especially in excessive quantities. It should be noted that although this discussion is directed towards the lake at the Operation Breakthrough Site, fertilizer in the effluent from the lake may cause nuissance conditions in the stream receiving the effluent or in downstream lakes. The effects on Crystal Lake itself and the surrounding Operation Breakthrough community may not be desirable. Floating masses of algae have been observed in the lake on a number of occasions. Characteristically, but not always, the floating masses and the suspended algae have been blue-green algae indicative of highly enriched waters (for instance see Figure V and Tables XXIII and XXIV). If such growths become excessive, undesirable odor problems could result upon death of the organisms. Furthermore, hydrogen sulfide produced in the oxygen free bottom muds and bottom waters may become a problem. The presence of hydrogen sulfide in the bottom waters has been recorded in Tables II, IV - VII, and XI, sometimes in substantial concentrations. If hydrogen sulfide reaches the surface waters of the lake it can kill the fish, and if it escapes to the surrounding area, unpleasant odors and possibly blackening of lead base paints can occur. If bottom water is siphoned over the dam when high hydrogen sulfide concentrations are present, the substance can become a problem, and care should be exercised in the future management of the lake. Depletion of oxygen affects fish more directly by limiting the depth to which the fish can survive. Furthermore, if excessive growths of algae die and decompose

in the surface waters, oxygen depletion can result in the death of fish. The lack of oxygen may be a concern also if water is released from the bottom of the lake to the receiving stream, since kills of fish downstream can result from discharge of such waters.

The effect of excessive fertilization is evident in the profiles of net primary production (see Tables in XVIII to XXII and Figure VI). Net primary production represents photosynthetic activity in excess of decomposition. The values depicted in Figure VI represent hourly figures approximately at mid-day. The curves of June 3 and June 26, 1971 represent net primary production at the end of fertilization. Production was low on June 3 since the day was cloudy. June 26 was a clear sunny day, and the effect on photosynthesis is evident, and the photosynthetic rate was high. During July, 1972 the photosynthetic rates were lower and occurred to greater depths (indicating greater water clarity). This would indicate an improvement in water quality during the construction period. This was attributed in earlier reports to removal of nutrients by adsorption on silt. However, it now appears that witholding of fertilizer is the probable cause of improvement. Net primary production increased substantially during July, 1973 following addition of excessive quantities of fertilizer to the lake. The data depicted in Figure VI confirm previously discussed results and conclusions regarding the possible consequences of fertilization. Fertilization of the lake has obscured completely effects of construction on probably the most important aspect of water quality investigated during this study.

Included in the Tables of Appendix I are concentrations of iron, manganese, calcium, magnesium, zinc, and on a few occasions sodium and potassium. Concentrations of these metals are of more academic than practical interest in

in the present study. The low calcium and magnesium concentrations are characteristic of extremely soft waters. The concentrations of iron and manganese illustrate the effects of oxygen depletion in the bottom waters. In the absence of oxygen, these elements are reduced and become soluble in water. Thus, during stratification when the oxygen concentration drops to zero in the bottom waters of the lake, iron concentrations in those waters rise, sometimes to very high levels, as do manganese concentrations. Such concentrations would be highly detrimental in a water supply, but in Crystal Lake they probably are of little consequence. If, however, water is released to the effluent from the bottom,rust-colored iron oxide could be deposited on the bottom of the stream below the dam.

Two further measurements of a purely physical nature demonstrate changes occurring in Crystal Lake during the course of the present investigation. The first is a simple measurement of water clarity. A white disc 20cm in diameter known as a Secchi disc, is lowered into the water until it disappears. The depth at which the Secchi disc disappears is recorded. Secchi disc readings depicted in Figure VII illustrate substantial changes during the course of construction at the Operation Breakthrough Site. Since there exist few data from the pre-construction period, interpretation is not clearcut. However, readings were very low during 1971 as a result of dense algal populations and probably the occurrence of silt in the lake which washed into the lake as a result of clearing of land during construction (see discussion of solids below). During 1972, the clarity of the water increased substantially (although it must be stressed that the lake even in 1972 was by no means a clear lake). The increased clarity reflects primarily the decrease in algal production caused by cessation of fertilization. It should be noted that Secchi disc readings afford a simple a simple but

useful measure of long term trends in the quality of lake waters which might be followed at Crystal Lake.

The major variations in water quality in Crystal Lake which can be attributed to construction on the Operation Breakthrough Site is the very great increase in the rate of siltation which resulted, particularly during 1971. Lacking data for a full year previous to construction, the pre-construction silt loads are unavailable, however during clearing of land and laying of sewers, a heavy load of silt entered the lake forming deltas running into the lake, covering the bottom, and increasing the silt load in the water (see Tables of Appendix I and Figure VIII). High silt loads in the water were temporary, but on the northwestern littoral zone of the lake, nesting areas of fish were obliterated and substantially changed in character. Sandy bottom was covered with silt, but lacking sufficient long-term follow-up the effects on fish production cannot be estimated. The ability of fish to breed may have been seriously interrupted, however.

SUMMARY AND CONCLUSIONS:

1. Substantial variations in water quality occurred in Crystal Lake during construction at the Macon, Georgia, Operation Breakthrough Site.
2. Because of variations in fertilization practices, effects of construction on the levels of nutrients and the production of algae which might cause nuisance conditions were obliterated.
3. The major effect of construction was greatly increased siltation which altered fish spawning areas, the consequences of which cannot

be determined at present.

4. There should be established goals for water quality in Crystal Lake. One possible objective is a lake of high quality free of nuisance algae. An alternative objective is a highly productive fishing lake. The two are not necessarily incompatible.

5. If fertilization is to continue, it must be done with care, for nuisance conditions, no more suitable to the needs of fish than to the senses of area residents could result from excessive fertilization. Conditions could approach those in a waste stabilization pond. It is doubtful whether fertilization will increase fish production.

6. If a more clear, esthetically more pleasant lake is desired, several approaches are available to accomplish that goal.

APPENDIX I - TABLES

IA - Physical - Chemical Analyses

IB - Productivity

IC - Algae

APPENDIX IA - PHYSICAL - CHEMICAL ANALYSES

TABLE I

ANALYSIS OF POND WATER*, OPERATION

BREAKTHROUGH SITE, MACON, GEORGIA

October 24, 1970

Depth(ft)	Temp. °C	D.O. mg/L	pH	Nitrogen(mg/L-N) NH_3-N	Organic-N	Tot.N	Phosphate(mg/L) Ortho	Poly	Fe(mg/L)	Mn(mg/L)	Ca ($Mg/LasCaCO_3$)
Surface	20.7	9.8	7.71	0	2.4	2.4	0	0	0.5	>0.05	9.3
1	20.7	-	-	-	-	-	-	-	-	-	-
2	20.5	-	-	-	-	-	-	-	-	-	-
2.5	-	9.2	7.33	0	1.9	1.9	0	0	0.79	0.15	8.75
4	20.0	-	-	-	-	-	-	-	-	-	-
5	19.8	2.3	6.62	0	2.2	2.2	0	0	1.05	0.25	9.05
6	19.7	-	-	-	-	-	-	-	-	-	-
7.5	-	0.5	6.42	0	1.5	1.5	.11	.02	0.87	0.30	8.75
8	19.5	-	-	-	-	-	-	-	-	-	-
10	19.3	0.1	6.4	0	1.4	1.4	.23	.05	1.4	0.20	9.05
12	18.6	-	-	-	-	-	-	-	-	-	-
12.5	-	0.0**	6.3	7.7	1.1	8.8	.44	.13	10.1	1.10	12.6
13	17.6	-	-	-	-	-	-	-	-	-	-
14	17.0	-	-	-	-	-	-	-	-	-	-
14.5	-	-	6.3	12.5	1.6	14.1	-	-	13.3	1.20	14
15	16.6	0.0**	-	-	-	-	-	-	-	-	-

*No flow leaving pond
Start at 11:30a.m.
Secchi Disc = 30"
Large floating masses of loosely cohesive algal colonies present in abundance

**H_2S present

TABLE II

ANALYSIS OF POND WATER, OPERATION BREAKTHROUGH SITE, MACON, GEORGIA
April 22, 1971[1].

Depth (FT)	Temp (°C)	D.O. (mg/l)	pH	H_2S (mg/l)	Nitrogen (mg/l)				Phosphate (mg/l)		Fe (mg/l)	Mn (mg/l)	Mg (mg/l)	Ca (mg/l as $CaCO_3$)	Solids (mg/l)		
					NH_3-N	NO_3-N	Organic-N	Tot-N	Ortho	Poly					Vol	Non-Vol	Total
Surf.	28.2	11.6	9.54	-	2.3	-	-	-	0.06	(0.0) -	0.24	0.06	0.49	1.20	166	67	233
1	25.0	11.4	9.35	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	23.5	11.1	9.5	-	-	-	-	-	-	-	0.27	0.05	0.49	1.20	-	-	-
3	21.5	2.4	8.6	-	-	0.0	-	-	-	-	-	-	-	-	-	-	-
4	18.8	1.2	7.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	17.0	0.4	6.35	-	0.4	0.02	0.5	0.92	0.11	-	0.45	0.11	0.49	1.50	68	47	115
6	15.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	14.1	0.2	6.30	0	0	0.02	0.7	0.72	0.08	(0. -	1.0	0.11	0.49	1.54	23	9	32
8	13.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	12.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	12.0	0.0	6.26	0.2	0	-	0.7	-	0.18	(.15) -	1.35	0.15	0.48	1.55	64	61	125
11	11.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	11.5	0.0	6.46	1.0	0	0.03	0.4	0.43	0.40	-	1.9	0.13	0.49	1.54	63	70	133
13	11.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	11.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

1. Sampled 3:15 - 3:45 p.m.
   Slight overcast
   Secchi Disc Reading 18"

TABLE III. ANALYSIS OF POND WATER, OPERATION BREAKTHROUGH SITE, MACON, GEORGIA
June 3, 1971[1].

Depth (FT)	Temp (°C)	D.O. (mg/l)	pH	Nitrogen (mg/l)			Phosphate (mg/l)		Fe (mg/l)	Mn (mg/l)	Mg (mg/l)	Ca (mg/l as $CaCO_3$)	Solids (mg/l)		
				NH_3-N	Organic-N	Tot-N	Ortho	Poly					Vol	Non-Vol	Total
Surf.	31	9.4	-	0	1.1	1.1	0.08	-	0.39	0.05	0.51	0.94	75	5	80
1	28.5	9.15	-	-	-	-	-	-	-	-	-	-	-	-	-
2	26.0	9.10	-	0	1.8	1.8	-	-	0.45	0.08	0.51	0.94	45	31	76
3	24.5	7.4	-	-	-	-	-	-	-	-	-	-	-	-	-
3.5	-	5.0	-	-	-	-	-	-	-	-	-	-	-	-	-
4	23.0	1.5	-	-	-	-	0.19	-	0.32	0.08	0.50	0.93	58	18	76
5	22.0	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-
6	20.0	0	-	-	-	-	-	-	0.28	0.08	0.50	1.11	24	41	65
7	17.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	15.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	14.5	-	-	0	0.4	0.4	0.07	-	2.5	0.03	0.51	1.98	42	34	76
10	13.6	0	-	-	-	-	-	-	-	-	-	-	-	-	-
11	12.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	12.0	-	-	1.8	0.4	2.2	0.36	-	4.4	0.26	0.53	1.88	30	59	89
13	12.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	11.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.5	-	-	-	3.5	0.3	3.8	0.90	-	5.5	0.23	0.55	1.85	44	64	108

1. Sampled 3:30 - 4:30 p.m.

TABLE IV

ANALYSIS OF POND WATER, OPERATION BREAKTHROUGH SITE, MACON, GEORGIA
June 26, 1971

Depth (FT)	Temp (°C)	D.O. (mg/l)	pH	H_2S (mg/l)	Nitrogen (mg/l)			Phosphate (mg/l)		Fe (mg/l)	Mn (mg/l)	Mg (mg/l)	Ca (mg/l as $CaCO_3$)	Zn (mg/l)	Solids (mg/l)		
					NH_3-N	Organic-N	Tot-N	Ortho	Poly						Vol	Non-Vol	Total
Surf.	33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0.5	-	8.3	7.30	N.D.[1]	0.4	2.1	2.5	0.29	-	0.40	0.06	0.51	0.76	0	75	48	123
1.0	31.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.5	-	8.5	7.33	N.D.	1.3	1.2	2.5	0.20	-	0.40	0.07	0.49	0.77	0	36	54	90
2.0	30.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.5	-	8.9	7.5	N.D.	0.4	2.8	3.2	0.30	-	0.42	0.08	0.51	0.76	0	61	16	77
3.0	29.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.5	-	7.7	7.2	N.D.	1.8	1.6	3.4	0.20	-	0.40	0.11	0.50	0.76	0	39	45	84
4.0	28.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.5	-	3.8	6.95	N.D.	0.4	3.2	3.6	0.32	-	0.42	0.20	0.51	0.80	0	52	33	85
5.0	25.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.5	-	0.1	6.2	N.D.	1.8	0.5	2.3	0.4	-	1.55	0.58	0.53	1.27	0	57	82	149
6.0	22.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6.5	-	0.1	6.17	*[2]	0.9	1.5	2.4	-	-	1.75	0.63	0.55	1.30	0	66	95	161
7.0	20.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8.0	19.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8.5	-	0.0	6.3	*	-	-	-	0.4	-	5.8	0.66	0.57	1.98	0.01	92	57	149
9.0	17.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.0	16.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.5	-	0.0	6.4	*	2.6	0.8	3.4	0.48	-	8.3	0.65	0.63	1.90	0.01	71	141	212
11.0	16.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12.0	15.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12.5	-	0.0	6.4	*	3.0	1.7	4.7	0.46	-	10.1	0.75	0.63	1.42	0.02	112	196	308
13.0	15.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.0	15.7	0.0	6.6	*	-	-	-	0.50	-	14.0	1.0	0.63	0.75	0.06	128	642	770
15.0	15.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15.5	15.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

1. N.D. = not detectable
2. * = present

TABLE V

Analysis of Pond Water, Operation Breakthrough Site, Macon, Georgia, July 8, 1971[1].

Depth (ft)	Temp (°C)	D.O. (mg/l)	pH	H_2S (mg/l)	Nitrogen (mg/l)				Solids (mg/l)		
					NH_3-N	NO_3-N	Organic-N	Total-N	Vol	Non-Vol	Total
Surf.	29.3	8.9	8.35	-	0	1.9	1.0	2.9	62	16	78
1	29.0	8.6	7.68	-	-	1.9	-	-	92	8	100
2	28.7	8.4	7.81	-	0	2.1	1.5	3.6	70	9	79
3	28.0	7.2	7.51	-	-	1.8	-	-	46	54	100
4	26.7	1.6	6.58	-	0	1.9	1.5	3.4	81	0	81
5	24.9	0.5	6.39	0.0	0	2.2	1.5	3.7	67	58	125
6	22.6	0.0	6.15	0.1	-	1.9	1.5	3.4	64	94	158
7	20.8	-	-	-	-	-	-	-	-	-	-
8	19.0	0.0	6.19	2	-	1.9	-	-	83	150	233
9	17.6	-	-	-	-	-	-	-	-	-	-
10	16.9	0.0	6.25	3	3.0	1.7	1.0	5.7	87	229	306
11	16.4	-	-	-	-	-	-	-	-	-	-
12	16.1	0.0	6.22	3	4.0	1.4	0	5.4	89	243	322
13	16.0	-	-	-	-	-	-	-	-	-	-
14	16.0	0.0	6.19	4	5.0	1.6	0.5	7.1	87	401	488
15	16.0	-	-	-	-	-	-	-	-	-	-
16.5	16.0	-	-	-	-	-	-	-	-	-	-

1. Samples taken between 11:15 and 11:45 a.m.
   Overcast
   Secchi disc reading 23"
   Evidence of silt washing into pond at upper end, east side near cleared area
   Silt on leaves and bushes to about 1' above water level

TABLE VI

Analysis of Pond Water, Operation Breakthrough Site, Macon, Georgia, August 26, 1971[1].

Depth (ft)	Temp (°C)	D.O. (mg/l)	pH	H_2S	Nitrogen (mg/l)				Solids (mg/l)		
					NH_3-N	NO_3-N	Organic-N	Total-N	Vol	Non-Vol	Total
Surf.	28.8	7.0	-		-	-	-	-	-	-	-
1	28.6	6.9	7.4		0	3.2	1.0	4.2	41	47	88
2	28.5	6.9	7.3		0	1.7	1.0	2.7	48	18	66
3	28.2	6.8	7.4		0	2.2	1.0	3.2	57	43	100
4	28.0	6.3	7.4		0	2.2	1.0	3.2	46	53	99
4.5	-	0.6	-		-	-	-	-	-	-	-
5	26.1	0.3	6.64		0	2.8	1.0	3.8	46	90	136
6	24.5	0.1	6.6		-	2.5	-	-	65	59	124
7	22.4	0.0	6.55	+	2.0	1.4	0.0	3.4	58	202	260
8	21.0	0.0	-		-	-	-	-	-	-	-
9	20.0	0.0	6.49	+++	3.0	3.5	0.5	7.0	94	214	308
10	18.8	0.0	-		-	-	-	-	-	-	-
11	17.6	0.0	6.51	+++	5.0	3.3	0.0	8.3	91	236	327
12	17.0	0.0	-		-	-	-	-	-	-	-
13	16.1	0.0	6.53	+++	7.0	2.1	1.0	10.1	116	286	402
14	16.0	0.0	-		-	-	-	-	-	-	-
15	15.9	0.0	6.59	+++	8.5	3.0	0.5	12.0	125	285	410
16	15.8	0.0	-		-	-	-	-	-	-	-

1. Sampled between 11:30 a.m. and 12:00 noon
100% overcast
Secchi disc reading 18"
Evidence of silty runoff entering pond from construction site at upper end, east side
Floating masses of Spirulina

TABLE VII

Analysis of Pond Water, Operation Breakthrough Site, Macon, Georgia, October 29, 1971[1].

Depth (ft)	Temp (°C)	D.O. (mg/l)	pH	H_2S	Nitrogen (mg/l)			Fe (mg/l)	Mn (mg/l)	Mg (mg/l)	Ca (mg/l)	K (mg/l)	Na (mg/l)	Cu. Ni. Zn (mg/l)	Solids (mg/l)		
					NH_3-N	Organic-N	Total-N								Vol	Non-Vol	Total
Surf.	21.5	6.78	6.79	---	0	2.0	2.0	0.9	0.33	0.87	2.6	2.0	---	Absent	114	0	114
1	21.5	6.88	6.70	---	0	1.5	1.5	0.8	0.30	0.87	2.5	1.4	---		73	0	73
2	21.3	6.88	6.62	---	0	1.5	1.5	---	0.31	0.87	2.5	2.0	---		90	9	99
3	21.2	6.88	6.94	---	0	1.5	1.5	0.8	0.30	0.87	2.5	1.7	---		164	11	175
4	21.2	6.88	7.3	---	0	1.5	1.5	0.9	0.30	0.87	2.6	2.0	---		66	3	69
5	21.2	6.57	6.82	---	0	1.8	1.8	0.9	0.35	0.87	2.5	2.0	8.0		52	48	100
6	21.1	6.37	7.3	---	0	1.0	1.0	0.8	0.32	0.87	2.6	1.7	---		58	50	108
7	21.1	4.85	6.78	---	0	1.5	1.5	0.9	0.30	0.87	2.5	1.9	8.0		85	8	93
8	21.0	3.7	7.01	---	0	1.8	1.8	0.9	0.30	0.87	2.5	1.7	8.0		59	1	60
9	20.9	2.8	6.61	0	0	2.0	2.0	1.2	0.38	0.87	2.5	1.7	---		88	4	92
10	20.2	0	6.50	0	1.5	1.5	3.0	3.0	0.9	---	3.04	2.1	---		72	24	96
11	19.7	0	6.52	---	2.5	1.0	3.5	---	1.2	0.94	3.7	2.0	---		173	59	232
12	19.0	0	6.29	<0.5	5.0	2.5	7.5	21.2	2.3	1.36	3.7	2.9	---		110	103	213
13	18.2	0	6.30	---	6.5	3.0	9.5	24	2.5	1.17	3.7	3.2	---		138	125	263
14	17.3	0	6.45	1	8.5	3.0	11.5	25	2.8	1.23	3.8	3.6	---		101	173	274
15	17.0	0	6.35	1	10.0	3.0	13.0	30	2.9	1.54	3.9	3.6	8.0		178	159	337
16	16.5	0	6.40	1	13.0	---	---	32	3.4	1.90	3.9	4.3	---		208	237	445

1. Sampled between 10:30 a.m. and 11:30 a.m.
   Sunny
   Secchi disc reading 36"
   Oil slick over most of lake

TABLE VIII

Analysis of Pond Water, Operation Breakthrough Site, Macon, Georgia, December 8, 1971[1].

Depth (ft)	Temp (°C)	D.O. (mg/l)	pH	H_2S (mg/l)	Nitrogen (mg/l)				Fe (mg/l)	Mg (mg/l)	Mn (mg/l)	Ca (mg/l)	K (mg/l)	Na (mg/l)	Solids (mg/l)		
					NH_3-N	Organic-N	NO_3-N	Total-N							Vol	Non-Vol	Total
Surf.	13	8.5	7.1	Absent	0.5	1.0	0.10	1.6	3.85	0.76	0.26	1.3	2.0	---	111	101	212
1	12.5	8.3	7.09				---	---	3.3	0.76	0.28	1.3		6.8	130	73	203
2	12	7.9	7.07				0.12	1.62	4.0	0.76	0.28	1.3		7.0	105	167	272
3	10.2	7.9	7.12				0.06	1.56	3.4	0.76	0.28	1.4		---	133	86	219
4	9.8	7.6	7.10				0.06	1.56	3.5	0.76	0.28	1.4		---	55	135	190
5	9.7	7.6	7.19				---	---	3.4	0.76	0.28	1.3		---	87	103	190
6	9.5	7.7	7.12				---	---	4.1	0.76	0.28	1.4		---	14	136	150
7	9.4	7.6	6.98				0.08	1.58	3.3	0.76	0.28	1.4		6.4	87	121	208
8	9.3	7.6	7.08				---	---	3.8	0.76	0.28	1.4		---	86	122	208
9	9.2	7.8	7.16				---	---	3.3	0.76	0.28	1.3		---	195	36	231
10	9.1	7.8	7.0				0.06	1.56	3.5	0.76	0.28	1.3		---	97	84	181
11	9.1	7.8	7.10				---	---	3.4	0.76	0.28	1.3		---	96	72	168
12	9.0	7.8	7.19				---	---	3.5	0.76	0.28	1.4		---	38	121	159
13	9.1	7.6	7.12				0.03	1.53	3.5	0.76	0.28	1.3		---	102	121	223
14	9.9	6.7	7.16				---	---	---	0.76	0.28	1.4		7.0	80	198	278
15	9.9	6.5	7.10				0.06	1.56	---	0.76	0.28	1.4		---	113	161	274
16	10.0	4.5	6.8				0.12	1.62	5.1	0.66	0.40	1.2	3.2	6.0	103	334	437
Siphon	---	---	7.06	---	---	---	---	---	3.4	0.76		1.35	---	---	52	120	172

1. Overcast
   Secchi disc reading 10"
   6" siphon accross dam

Analysis of Pond Water, Operation Breakthrough Site, Macon, Georgia, March 21, 1972[1]

Depth (ft)	Temp (°C)	D.O. (mg/L)	pH	Fe (mg/L)	Mn (mg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Zn (mg/L)	Solids (mg/L)		
											Vol	Non-vol	Total
Surf	18.5	7.2	7.3	2.7	.043	1.7	.73	1.6	-	.0007	70	62	132
1	18.0	7.1	7.3	2.7	.043	1.7	.73	1.6	-	.0002	64	24	98
2	17.1	7.3	7.3	2.9	.07	1.7	.73	1.6	-	.001	65	35	100
3	15.0	6.0	7.15	2.8	.043	1.7	.73	1.6	-	.0007	62	23	85
4	14.0	5.3	7.0	3.1	.043	1.6	.73	1.6	8.0	0	78	59	137
5	13.2	3.8	6.9	3.1	.07	1.6	.70	1.6	8.0	.001	37	113	150
6	11.9	2.6	6.8	3.2	.043	1.5	.70	1.6	-	-	64	48	112
7	11.0	2.5	6.7	3.2	.043	1.6	.70	1.6	-	-	61	23	84
8	10.8	1.6	6.7	3.2	.043	1.4	.70	1.6	-	.001	83	50	143
9	10.5	1.4	6.65	3.7	.113	1.4	.70	1.6	-	.001	93	21	114
10	10.2	1.3	6.7	3.7	.113	1.4	.70	1.6	-	.002	90	25	115
11	10.1	1.2	6.7	3.7	.27	1.4	.70	1.6	8.0	-	76	39	115
12	10.0	1.1	6.65	3.8	.23	1.4	.70	1.6	8.0	.007	76	44	120
13	10.0	1.3	6.7	3.7	.14	1.4	.70	1.6	-	0	82	36	118
14	10.0	1.2	6.6	3.8	.13	1.3	.70	1.6	-	.0007	70	23	93
14.5	10.0	-	-	-	-	-	-	-	-	-			

[1]Sampled between 9:30 and 10:30 a.m. Overcast Secchi Disc Reading 1'

Site, Macon, Georgia, April 7, 1972[1]

Depth (ft)	Temp (°C)	D.O. (mg/L)	pH	Fe (mg/L)	Mn (mg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Zn (mg/L)	Solids (mg/L)		
											Vol	Non-vol	Total
Surf	28.0	10.2	7.2	2.3	.043	2.6	.81	1.6	-	.004	63	84	147
0.5	23	-	-	-	-	-	-	-	-	-	-	-	-
1	20	10.4	7.2	2.4	.029	2.5	.81	1.6	-	.003	56	41	97
2	18	11.2	7.8	2.3	.113	2.4	.81	1.6	-	.003	59	39	98
3	15.5	11.1	7.35	2.3	.057	2.4	.77	1.6	-	.003	32	108	140
4	14.8	10.6	7.21	2.4	.07	2.5	.81	1.6	-	.03	46	51	97
5	14.0	7.2	6.83	2.5	.07	2.5	.81	1.6	8.0	.003	70	84	154
6	13.0	3.4	6.75	2.6	.07	2.5	.81	1.6	-	.002	77	35	112
7	12.9	1.0	6.68	3.1	.113	2.4	.77	1.6	-	-	83	86	169
8	11.9	0.3	6.9	-	-	-	-	-	-	-	-	-	-
9	11.9	0.3	6.68	3.4	.29	2.2	.77	1.6	-	.002	106	32	138
10	11.4	0.3	6.72	4.0	.33	1.9	.81	1.6	8.0	.002	96	60	156
11	11.0	-	6.6	4.0	.32	1.9	.77	1.6	-	.003	102	33	135
12	10.9	0.3	6.82	4.1	.36	1.8	.77	1.6	-	.005	84	63	147
13	10.9	0.3	6.78	4.2	.39	1.7	.81	1.6	8.0	.003	91	50	141
14	10.9	0.2	6.8	5.1	.46	1.8	.81	1.6	-	.003	100	47	147
15	-	0.1	6.72	5.2	.49	1.9	.85	1.6	-	.003	96	67	163
16	-	0.05	6.75	5.2	.51	1.9	.85	1.6	8.0	.003	110	106	216

[1] Sunny, clear to hazy Secchi Disc Reading 1' sampled 3:00 to 4:00 p.m.

TABLE XI

Analysis of Pond Water, Operation Breakthrough
Site, Macon, Georgia, May 25, 1972[1]

Depth (ft)	Temp (°C)	D.O. (mg/L)	pH	H_2S	Nitrogen (mg/L)				PO_4 (mg/L)	Fe (mg/L)	Mn (mg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Zn (mg/L)	Solids (mg/L)		
					NH_3-N	Organic-N	NO_3-N	Total-N									Vol	Non-vol	Total
Surf	31	9.5	*	-	0	0	1.37		.3	0.4	0.25	2.8	0.85	1.2	10.5	*	34	63	97
1	30	9.6		-	0	0	1.42		.3	0.3	0.0	2.8	0.85	1.2	8.0		32	106	138
2	29.5	9.6		-	0	1.0	1.55		.4	0.4	0.0	2.8	0.85	1.2	8.2		48	110	158
3	29	9.9		-	0	-	1.50		.5	0.3	0.0	2.8	0.85	1.2	8.2		69	94	163
4	28.7	10.0		-	0	0	1.37		.2	0.3	0.0	2.8	0.85	1.2			10	106	116
5	28.1	10.5		-	0	0	1.98		.3	0.3	0.0	2.8	0.85	1.2			23	21	44
6	27.0	10.1		-	0	0	1.15		.2	0.3	0.0	2.8	0.85	1.2			26	60	86
7	25.6	4.7		-	0	0	0.66		.4	0.3	0.15	2.8	0.85	1.2	8.0		72	74	146
8	24.0	2.1		-	0	1.0	0.35		.4	0.4	0.30	2.8	0.85	1.2	10.5		52	88	140
9	22.0	1.2		-	0	0	0.0		.8	0.4	0.55	2.6	0.85	1.2	6.5		49	48	97
10	19.2	0.9		-	0	1.0	0.0		-	0.4	1.0	2.5	0.85	1.2			65	18	83
11	18.0	0.0		+	0	2.0	0.0		.4	3.5	1.25	2.4	0.92	1.5			42	101	143
12	17.4	0.0		+	0	2.0	0.0		.5	4.8	1.1	2.3	0.92	1.2			74	146	220
13	17.0	0.0		+	0	2.0	0.0		.5	5.0	0.8	2.3	0.92	1.2	7.2		67	115	182
14	16.6	0.0		+	2.0		0.0		.1	6.9	1.0	2.2	0.92	1.5	8.0		58	139	197
14.5	16.5	0.0		+	-	-	-			-	-	-	-	-	-				

[1] Partly cloudy Secchi Disc Reading 5' sampled 1:15 to 2:15 floating masses of Oedogonium present
*Not performed

Analysis of Pond Water, Operation Breakthrough Site, Macon, Georgia, July 6, 1972[1]

Depth (ft)	Temp (°C)	D.O. (mg/L)	pH	Nitrogen (mg/L)			PO_4 (mg/L)	Fe (mg/L)	Mn (mg/L)	Ca (mg/L)	Mg (mg/L)	Solids (mg/L)		
				NH_3-N	Organic-N	NO_3-N						Vol	Non-vol	Total
Surf	*	8.0	**	0.0	0.0	0.09	0.4	-	-	3.5	1.06	60	23	83
1		8.0		0.0	0.0	0.0	0.3	-	-	3.5	1.07	104	9	113
2		8.0		0.0	1.0	0.0	0.2	0.1	-	3.5	1.05	60	12	72
3		8.1		0.0	-	0.0	-	-	-	3.5	-	-	-	-
4		8.0		0.0	1.0	0.0	0.4	-	-	3.5	1.11	54	42	96
5		8.0		0.0	1.0	0.0	0.4	0.1	-	3.5	1.07	90	6	96
6		8.0		0.0	0.0	0.0	0.3	0.1	-	3.4	1.07	80	5	85
7		4.7		0.0	1.0	0.0	0.4	0.25	-	2.7	1.11	27	8	35
8		1.8		0.0	1.0	0.0	0.3	0.25	0.35	3.25	1.13	63	97	160
9		1.0		0.0	1.0	0.0	0.5	0.60	0.5	4.4	1.16	58	40	98
10		0.0		0.0	1.0	0.04	0.7	1.85	1.4	5.8	1.26	68	117	185
11		0.0		0.0	0.0	0.0	1.1	2.2	1.7	5.6	1.27	57	134	191
12		0.0		3.0	3.0	0.04	0.6	5.2	2.1	6.3	1.36	107	119	226
13		0.0		3.0	3.0	0.27	0.6	6.1	1.9	5.9	1.35	95	133	228
14		0.0		5.0	2.0	0.0	0.5	14.2	1.09	4.5	1.40	120	120	240
15		0.0		4.0	4.0	0.0	0.7	14.6	2.1	4.5	1.40	128	122	250
16	↓	0.0	↓	7.0	6.0	0.0	0.6	15.0	2.2	4.5	1.44	128	111	239

[1]Sunny Secchi Disc Reading 4' sampled 12:15 to 1:15
*Probe not operating - see data for July 7, 1972
**Not performed

TABLE XIII

Analysis of Pond Water, Operation Breakthrough Site, Macon, Georgia July 7, 1972[1].

Depth (Ft)	Temp. (°C)	D. O. (Mg/L)
Surf.	28.0	8.9
1	28.2	9.0
2	28.2	9.0
3	28.1	8.9
4	28.1	8.1
5	28.1	7.6
6	28.0	5.7
7	27.0	1.2
8	26.1	0.05
9	24.8	0.0
10	22.5	0.0
11	20.5	0.0
12	19.0	0.0
13	17.3	0.0
14	16.8	0.0
15	15.2	0.0
16	15.0	0.0
17	14.5	0.0

1. Sunny
Secchi Disc Reading 3' - 9"
Sampled 10:00 A.M.

TABLE XIV

ANALYSIS OF POND WATER, OPERATION BREAKTHROUGH SITE, MACON, GEORGIA *
August 2, 1972

Depth (Ft)	Temp (°C)	D.O. (mg/l)	Nitrogen (mg/l)			Nitrate (mg/l)	Phosphate (mg/l)		Fe (mg/l)	Mn (mg/l)	Mg (mg/l)	Ca (mg/l)	Solids (mg/l)		
			NH_3-N	Organic-N	Total-N		Ortho	Poly					Vol	Non Vol	Total
0	29.9	8.9	0	1.0	1.0	0	0.3	---	----	----	1.04	2.30	38	33	71
1	29.8	8.8	0	1.0	1.0	0.180	0.4	---	----	----	----	----	---	--	--
2	29.8	8.1	0	1.0	1.0	0.222	0.4	---	----	----	----	----	132	56	188
3	29.7	7.4	0	1.0	1.0	0.220	0.3	---	----	----	----	----	57	23	81
4	29.4	6.4	0	1.5	1.5	0.266	0.2	---	----	----	----	----	109	6	115
5	29.0	3.8	0	1.5	1.5	0.266	0.3	---	0.65	----	1.05	2.6	50	43	93
6	28.7	0.5	0	1.0	1.0	0	0.2	---	0.30	0.25	1.18	2.85	89	55	144
7	27.8	0	0	---	---	0.355	---	---	----	----	----	----	86	9	95
8	26.7	0	0	1.0	1.0	0.266	0.6	---	----	----	----	----	132	126	258
9	25.4	0	0	---	---	0.532	0.7	---	----	----	----	----	106	146	252
10	23.8	0	0	2.0	2.0	0	0.4	---	2.78	1.15	1.20	5.25	126	133	259
11	21.9	0	2	1.5	3.5	0.576	0.2	---	8.10	2.20	1.25	5.90	97	157	254
12	20.4	0	---	---	---	0.487	0.3	---	----	----	----	----	142	183	325
13	18.5	0	2.5	0.5	3.0	0.665	0.3	---	11.1	2.25	1.25	6.50	131	81	222
14	17.3	0	3	1.0	4.0	0.532	0.2	---	16.75	2.60	1.43	6.30	133	141	274
15	16.7	0	4	1.0	5.0	0.620	0.6	---	----	----	----	----	144	105	249
16	16.2	0	---	---	---	----	---	---	----	----	----	----	---	---	---

*Secchi disc reading 2.25
Sunny
Sampled 9:30-10:30 A.M.

TABLE XV

Analysis of Pond Water, Operation Breakthrough Site, Macon, Georgia, Sept. 23, 1972[1].

Depth (ft)	Temp (°C)	D.O. (mg/l)	Fe (mg/l)	Mn (mg/l)	Ca^{++} (mg/l)	Mg^{++} (mg/l)	K (mg/l)
0	29.6	8.4	0.20	0.08	2.9	1.15	1.8
1	29.2	8.4	0.15	0.08	2.6	1.15	1.8
2	28.9	8.1	0.15	0.08	2.9	1.15	1.8
3	28.6	8.0	0.15	0.08	2.9	1.15	1.8
4	28.4	7.4	0.15	0.08	2.9	1.15	1.8
5	28.3	7.0	0.15	0.08	2.9	1.15	1.8
6	28.1	6.3	0.11	0.08	2.9	1.15	1.8
7	28.0	5.8	0.15	0.08	2.9	1.15	1.8
8	26.8	0.0	0.28	0.10	2.9	1.15	1.8
9	25.3	0.0	0.25	0.40	2.9	1.15	1.8
10	23.5	0.0	0.32	1.5	3.3	1.15	1.9
11	21.9	---	7.0	2.9	5.7	1.5	2.5
12	20.2	---	20.8	4.0	7.9	1.7	2.7
13	18.8	---	24.0	4.1	7.5	1.9	2.9
14	18.3	---	27.0	4.1	6.7	1.9	2.9

1. Sampled at 1:00 p.m.
   Secchi disc reading 3' 3"

TABLE XVI

Analysis of Pond Water, Operation Breakthrough Site, Macon, Georgia, November 24, 1972[1].

Depth (ft.)	Temp (°C)	D.O. (mg/l)	Fe (mg/l)	Mn (mg/l)	Ca++ (mg/l)	Mg++ (mg/l)	Tot-N (mg/l)	Solids Vol (mg/l)	Solids Non-Vol (mg/l)	Solids Total (mg/l)
0	14	5.0	1.05	0.14	4.0	1.1	1.0	61	45	106
1	13.9	4.8								
2	13.4	4.6								
3	13.2	4.6	0.99	0.14	4.0	1.1	1.0	60	73	133
4	13.1	4.5								
5	13.0	4.5								
6	13.0	4.5	0.99	0.14	4.0	1.1	1.0	41	52	93
7	13.0	4.4								
8	13.0	4.4								
9	13.0	4.4	1.05	0.14	4.0	1.1	1.0	46	95	141
10	12.9	4.4								
11	12.8	4.4								
12	12.7	4.4	1.11	0.15	4.0	1.1	1.0	62	66	128
13	12.5	4.4								
14	12.3	4.4								
15	12.3	4.4	1.11	0.16	4.0	1.1	1.0	63	78	140

1. Sampled at 11:30 - 12:30 p.m., Secchi disc reading 2'6".

APPENDIX IB - PRODUCTIVITY

TABLE XVII

ANALYSIS OF POND WATER,
OPERATION BREAKTHROUGH SITE,
MACON, GEORGIA, July 11, 1973

DEPTH (Ft)	TEMP. (°C)	D.O. (mg/l)
Surface	29.7	10.6
1	29.7	10.6
2	29.5	10.6
3	29.3	10.9
4	29.0	8.3
5	28.0	4.2
6	27.0	0.7
7	25.0	0.5
8	23.5	
9	21.8	
10	18.9	0.0
11	16.7	
12	15.2	
13	14.2	0.0
14	13.8	
15	13.2	
16	13.2	0.0
17	12.8	

SAMPLED 11:00 A.M. to 12:00 NOON

SUNNY

SECCHI DISC READING 215[1]

TABLE XVIII

PRODUCTIVITY AT OPERATION BREAKTHROUGH SITE

June 3, 1971*.

Depth (FT)	Time (HR)	D.O. (mg/l)					Productivity ($mgC/m^3/hr$)	
		Init.	Light Bottle	Dark Bottle	Gross Incr.	Net Incr.	Gross	Net
Surf	3:21	8.8	9.13	7.9	1.23	.33	114.8	30.8
2'	3:20	8.4	8.95	7.9	1.05	.55	98.6	51.6
4'	3:31	3.9	3.73	3.65	.08	-	7.12	0
6'	3:44	2.6	1.8	1.95	-.15	-	0	0
9'	3:49	2.4	1.5	1.7	-.2	-	0	0
12'	4:03	4.7	4.25	4.58	-.33	-	0	0

*50% Cloud Cover
Secchi Disc Reading 22"

TABLE XIX

PRODUCTIVITY AT OPERATION BREAKTHROUGH SITE
June 26, 1971*.

Depth (FT)	Time (HR)	D.O. (mg/l)					Productivity ($mgC/m^3/hr$)	
		Init.	Light Bottle	Dark Bottle	Gross Incr.	Net Incr.	Gross	Net
Surf	3:22	7.6	7.7	6.75	0.95	0.10	88.1	9.29
2'	3:25	7.6	8.55	6.55	2.00	0.95	183.2	87.0
4'	3:34	3.6	3.65	2.1	1.55	0.05	135.9	4.38
6'	3:41	3.15	2.93	2.95	-0.02	-	0	0

*Clear Sky
Secchi Disc Reading 26"

TABLE XXI

Productivity at Operation Breakthrough Site
July 6, 1972[1].

Depth (Ft.)	Time (Hr)						Productivity (mg C/m^3/hr)	
		Init.	Light Bottle	Dark Bottle	Gross Increase	Net Increase	Gross	Net
0.5'	3:42	7.6	7.9	7.45	0.45	0.3	38	25.3
1.5'	3:51	7.6	8.275	7.6	0.675	0.675	54.9	54.9
2.5'	3:57	7.6	8.1	7.5	0.60	0.50	47.5	39.6
4.5'	4:06	7.6	8.2	7.5	0.70	0.60	53.4	45.8
6.5'	4:12	7.3	8.0	7.4	0.60	0.70	44.7	----
8.5'	4:18	3.7	3.75	3.7	0.05	0.05	3.6	3.6

1. Sunny

TABLE XX

Productivity at Operation Breakthrough Site
May 25, 1972[1].

Depth (Ft.)	Time (Hr)	D. O. (mg/l)					Productivity (mg C/m^3/hr)	
		Init.	Light Bottle	Dark Bottle	Gross Increase	Net Increase	Gross	Net
1'	2:50	9.3	9.25	9.1	0.15	-	16.7	---
2'	2:56	9.6	9.65	9.45	0.20	0.05	21.2	5.3
3'	3:03	9.7	9.45	9.4	0.05	-	5.0	---
5'	3:08	10.1	10.0	9.8	0.20	-	20.0	---
7'	3:27	9.1	9.35	8.85	0.50	0.15	45.4	13.6
9'	3:39	3.7	3.2	2.85	0.35	-	30.0	---

1. Partly Cloudy

TABLE XXII

PRODUCTIVITY AT OPERATION BREAKTHROUGH SITE
July 11, 1973[1]

Depth (Ft.)	Time (Hr)	D.O. (mg/l) Init.	Light Bottle	Dark Bottle	Gross Incr.	Net Incr.	Productivity ($mgC/m^3/hr$) Gross	Net
Surf.	4:15	9.63	10.15	9.45	0.7	0.52	51.5	38.2
1	4:00	9.85	10.85	9.92	0.93	1.00	72.6	78.2
2	3:57	9.51	10.85	9.22	1.63	1.34	129.0	106.0
3	3:52	9.85	10.43	9.51	0.92	0.58	74.3	46.9
4	3:52	9.16	9.28	8.58	0.70	0.12	56.5	9.69
5	3:38	8.12	8.7	7.95	0.75	0.58	64.8	50.1

1. Sunny

APPENDIX IC - ALGAE

TABLE XXIII

OPERATION BREAKTHROUGH SITE

April 22, 1971

Depth	*Anabaena* sp. Colonies/ml	*Gonyostomum semen* cells/ml
Surf	1,699	4
1'	2,381	8
2'	1,942	0
3'	427	1,416
4'	176	1,304
5'	13	258
7'	38	547
10'	3	100
12'	2	144

TABLE XXV

PREDOMINANT ALGAE IN OPERATION BREAKTHROUGH SITE

June 3, 1971

Depth	Microcystis aeruginosa colonies/ml	Gonyostomum semen cells/ml	Pediostrum sp. colonies/ml	Scenedesmus sp. colonies/ml
Surf	910	0	0	0
2'	228	0	0	0
4'	70	2,010	0	0
6'	34	142	0	0
9'	20	4	20	18
12'	18	4.5	22	4
14.5'	18	-	30	2

APPENDIX II - FIGURES

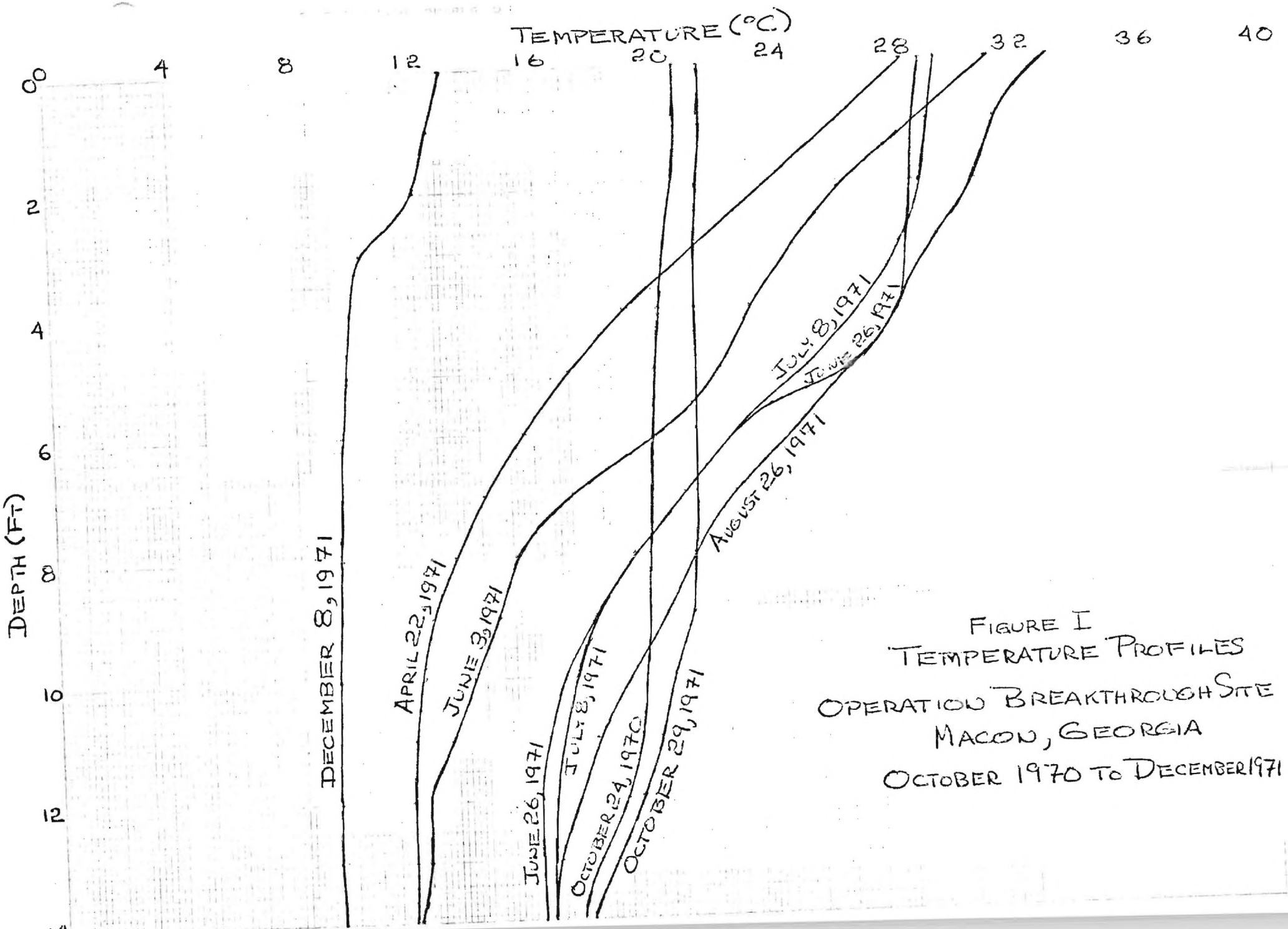

FIGURE I
TEMPERATURE PROFILES
OPERATION BREAKTHROUGH SITE
MACON, GEORGIA
OCTOBER 1970 TO DECEMBER 1971

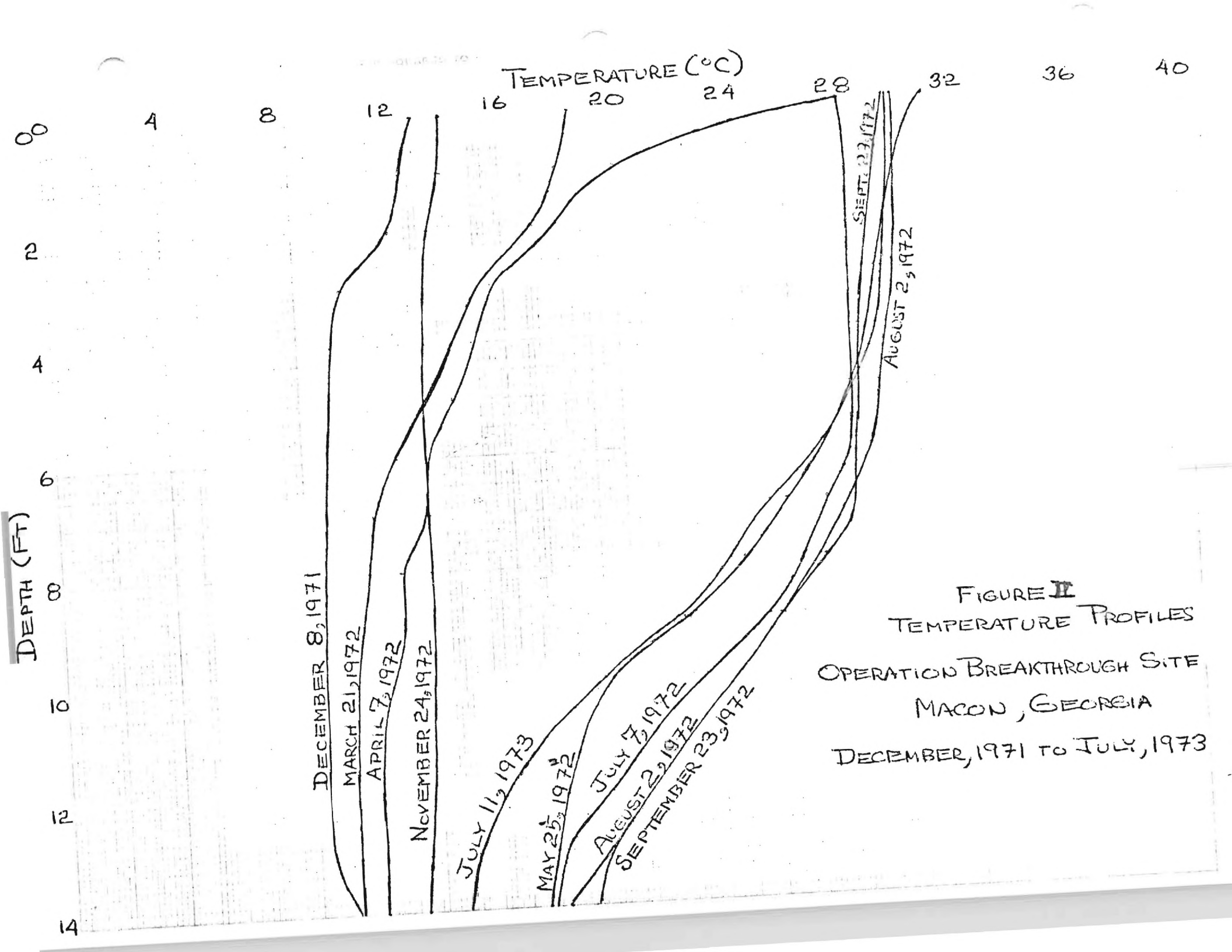

FIGURE II
TEMPERATURE PROFILES
OPERATION BREAKTHROUGH SITE
MACON, GEORGIA
DECEMBER, 1971 TO JULY, 1973

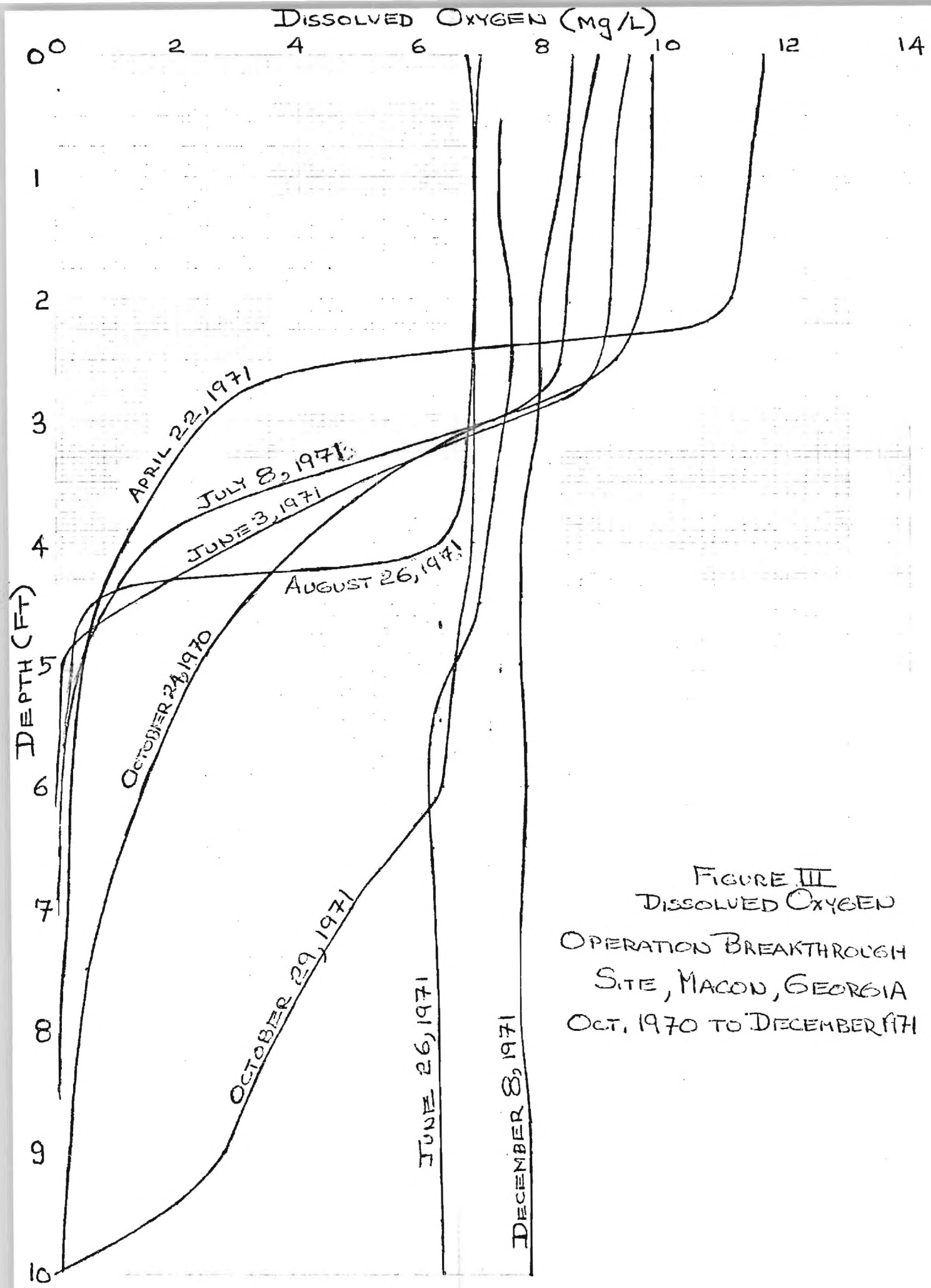

FIGURE III
DISSOLVED OXYGEN
OPERATION BREAKTHROUGH
SITE, MACON, GEORGIA
OCT. 1970 TO DECEMBER 1971

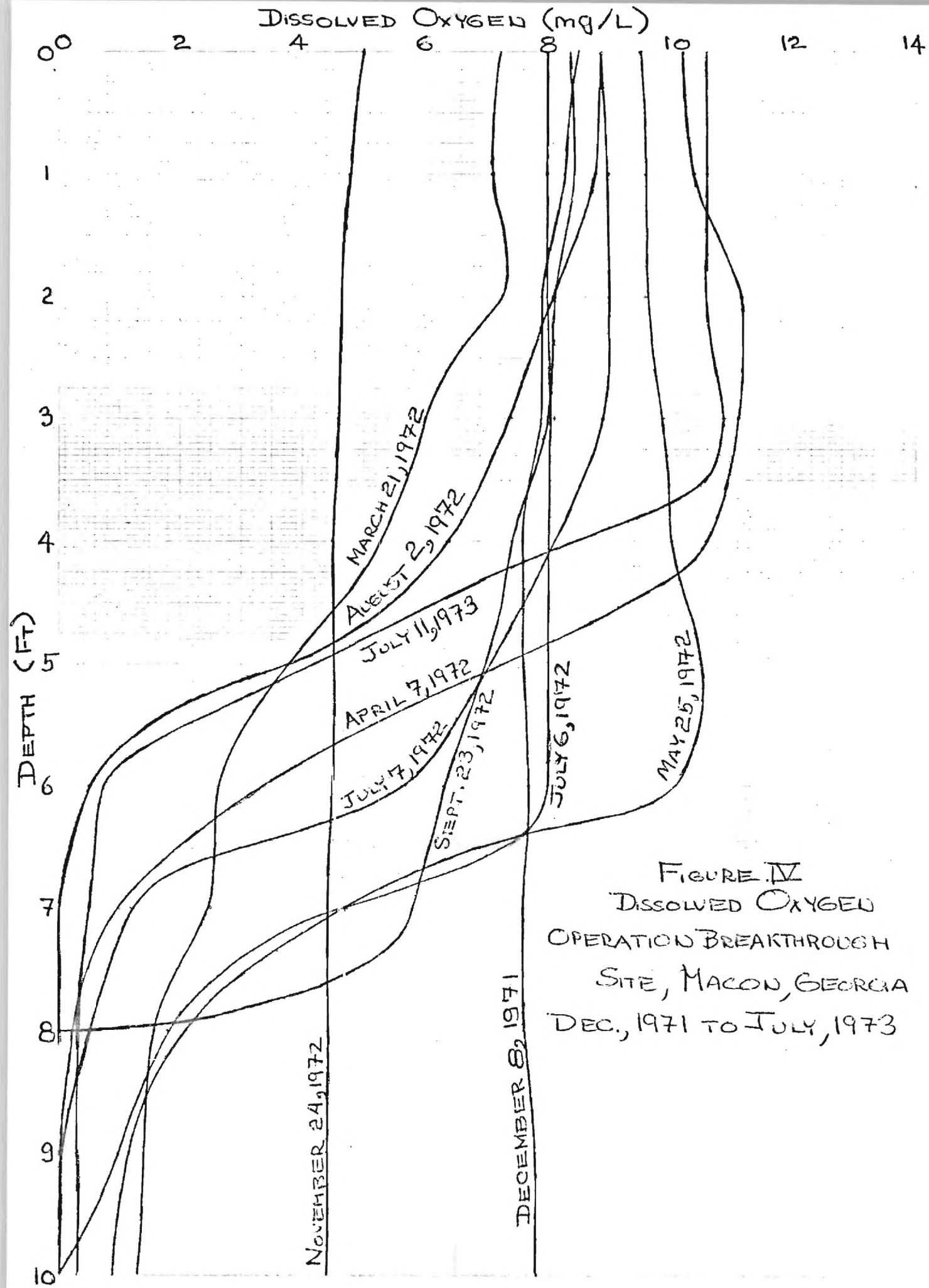

FIGURE IV
DISSOLVED OXYGEN
OPERATION BREAKTHROUGH
SITE, MACON, GEORGIA
DEC., 1971 TO JULY, 1973

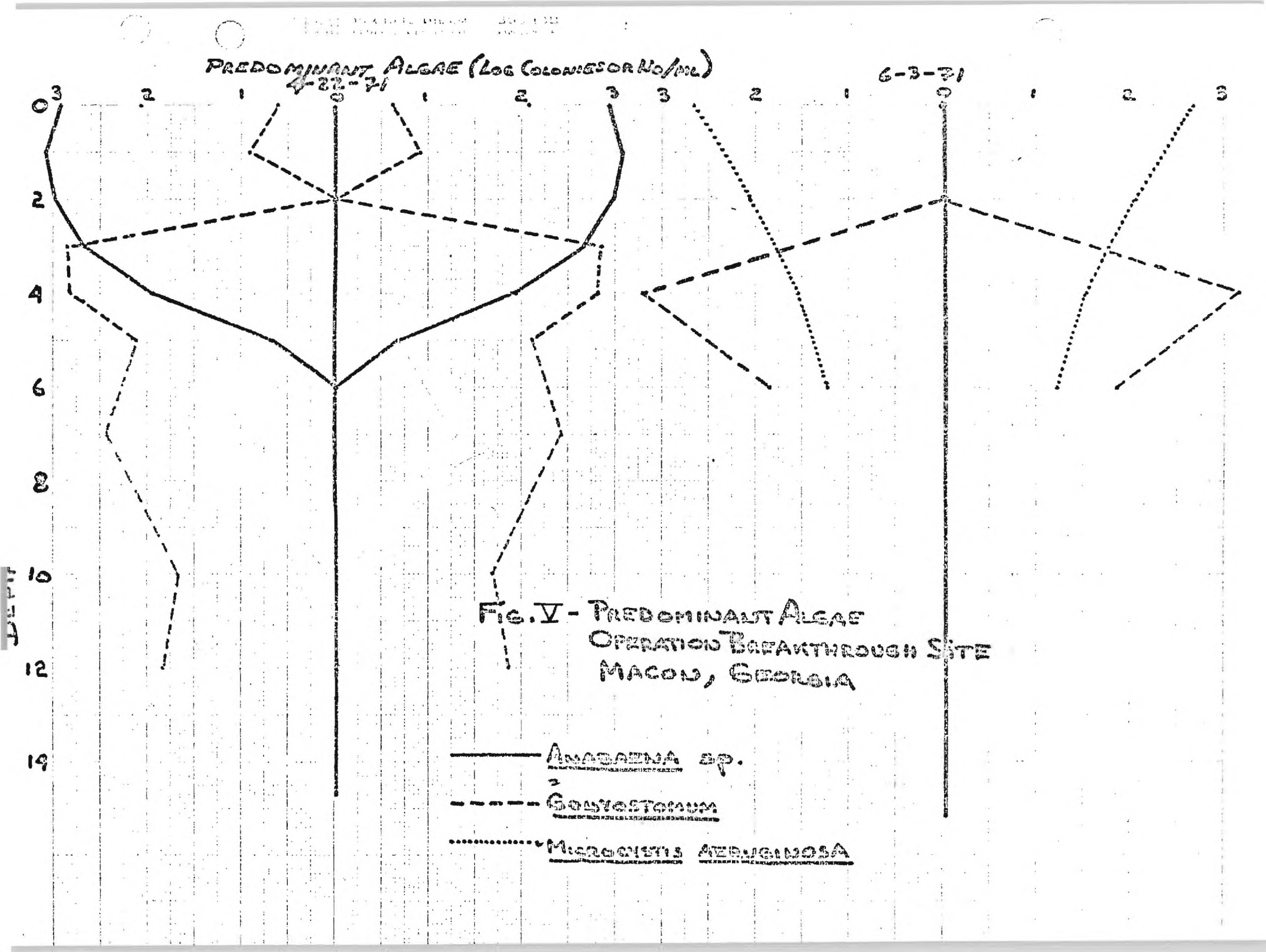

FIG. V - PREDOMINANT ALGAE
OPERATION BREAKTHROUGH SITE
MACON, GEORGIA

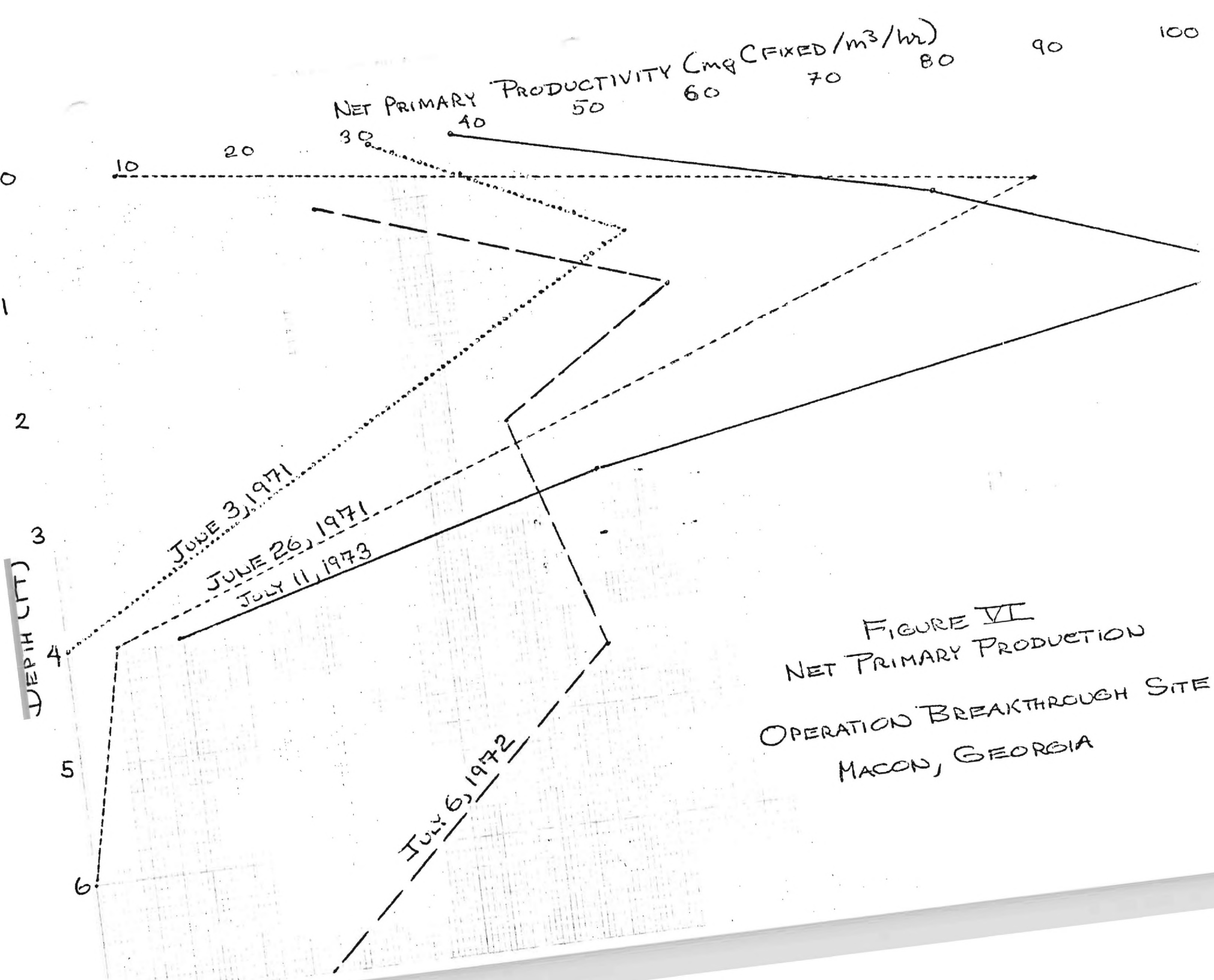

FIGURE VI
NET PRIMARY PRODUCTION
OPERATION BREAKTHROUGH SITE
MACON, GEORGIA

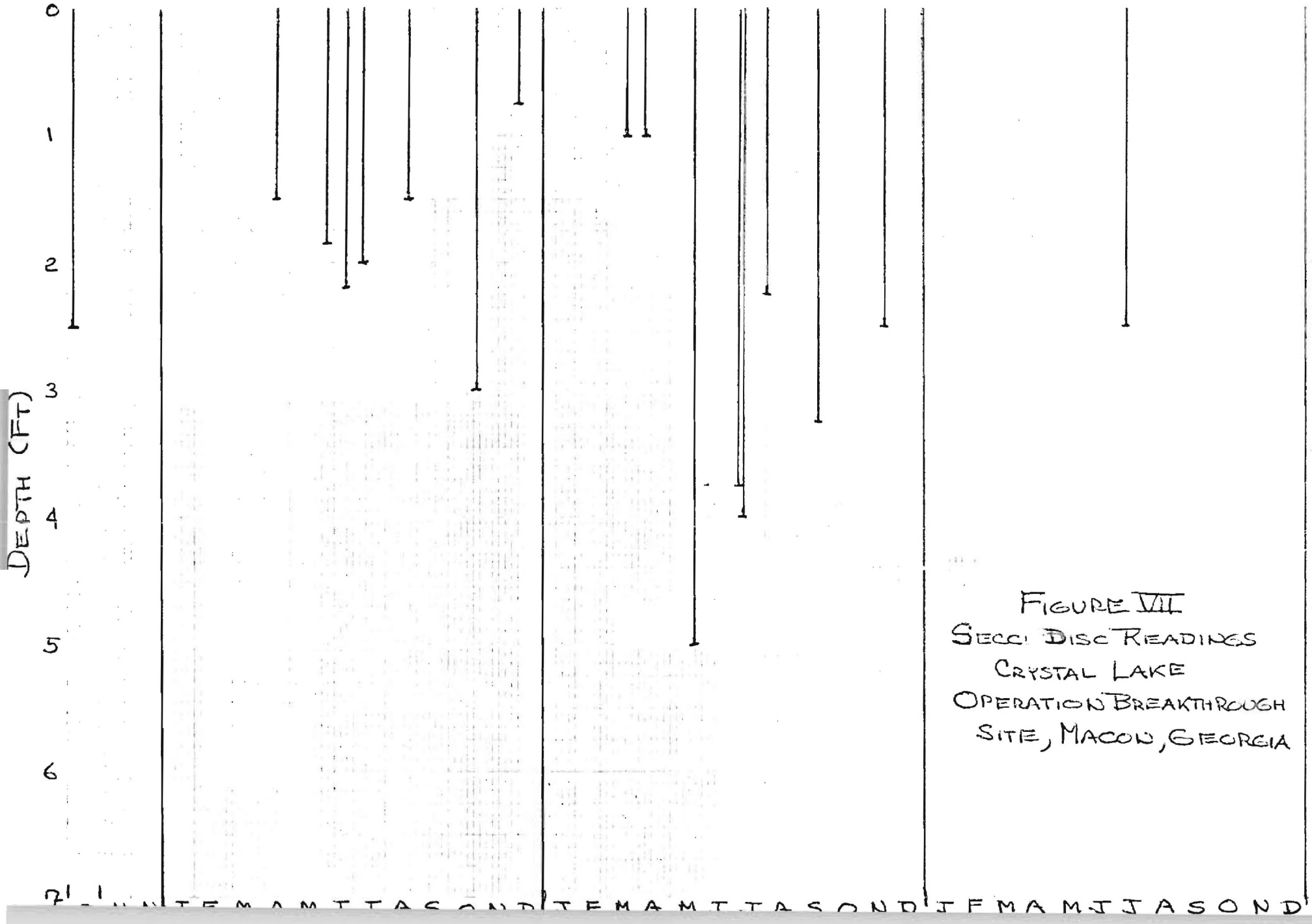

FIGURE VII
SECCI DISC READINGS
CRYSTAL LAKE
OPERATION BREAKTHROUGH
SITE, MACON, GEORGIA

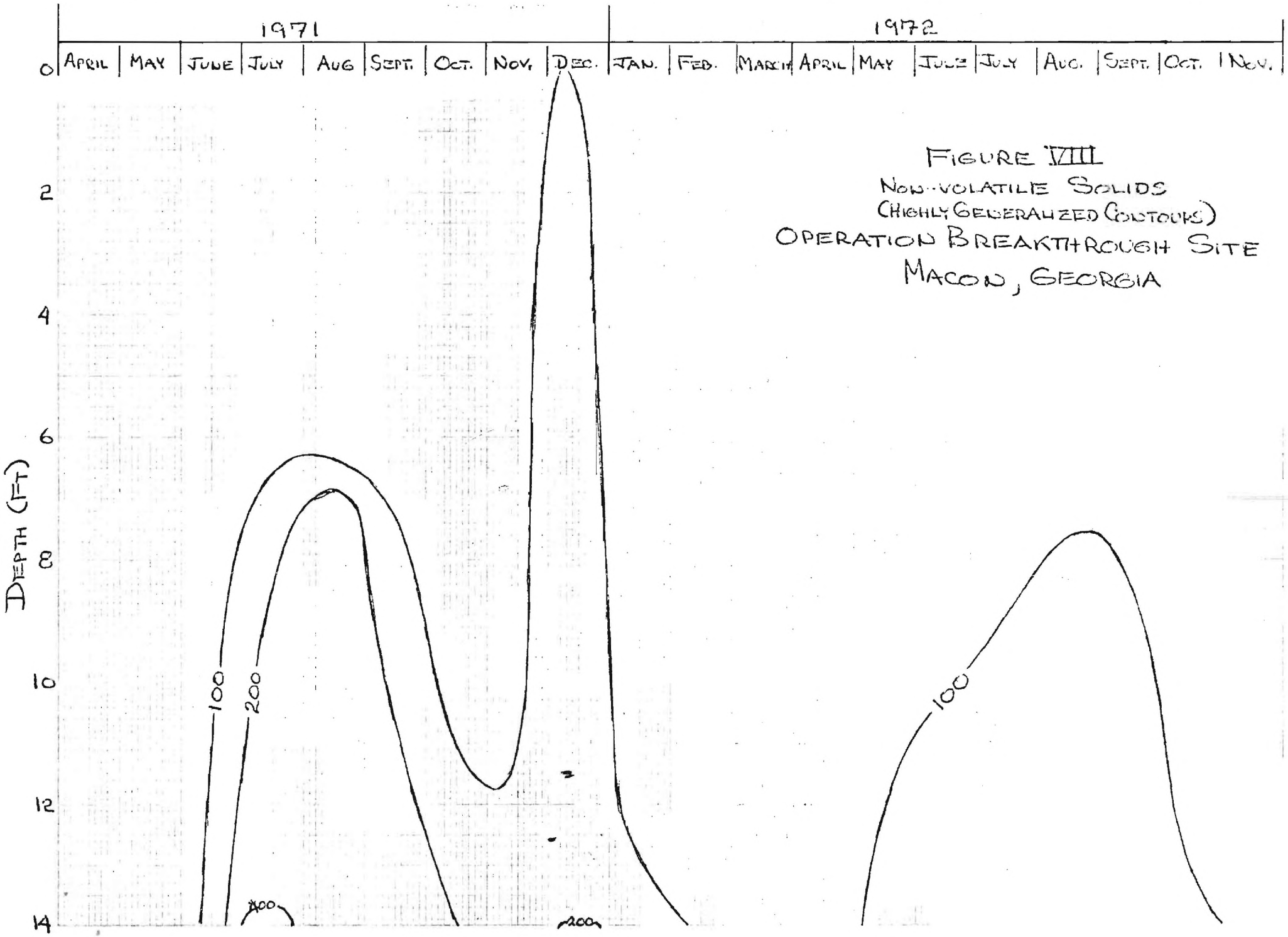

FIGURE VIII

NON-VOLATILE SOLIDS

(HIGHLY GENERALIZED CONTOURS)

OPERATION BREAKTHROUGH SITE

MACON, GEORGIA

APPENDIX III - LETTER FROM
A. W. HOADLEY TO
CHARLES CONNOR

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
CIVIL ENGINEERING

TELEPHONE:
(404) 873-4211

July 6, 1971

Mr. Charles Connor
Macon-Bibb County Planning and Zoning
Commission
City Hall
Macon, Georgia 31202

Dear Mr. Connor:

During the past quarter, the Operation Breakthrough site at Macon has been visited by us on three occasions, April 22, June 3, and June 26. The data obtained are given in Tables I through VII, and are presented graphically in Figures 1 through 13. Data on algal populations are not available for the June 26 date since one of the workers on the project (AWH) has been ill and unable to analyze those samples. Results will be included in the next quarterly report.

The lake on all three sampling dates during the past quarter has been well stratified as a result of the thermal gradient extending from surface to bottom. The highly enriched condition of the lake is reflected in most of the data presented. The very low transparency indicated by the secchi disc readings reflects high algal counts. The slight increases in the readings on successive dates means that photosynthesis can occur at increasing depths, and thus oxygen is present at increasing depths (Fig.2).

The character of the oxygen curves suggests a highly enriched condition and high degree of stability of the stratification The breakdown of organic matter in the deeper water of the lake results in the loss of oxygen, which would prevent fish from living at depths greater than about 3, 4, and 5 feet on the successive dates. The biological activity causing the loss of oxygen in the deeper water also causes the corresponding decrease in pH (Fig.3). High oxygen concentrations (in excess of 100% saturation) result from high photosynthetic activity in the top 2.5 feet on the earlier dates and the top 3.5 feet on June 26. This results also in the relatively high pH observed in the surface waters. The high surface dissolved oxygen is characteristic of highly enriched waters also. The distribution of photosynthetic activity on the two June sampling dates can be seen in Fig.4, which indicates the mg of carbon fixed per cubic meter per hour during photosynthesis (primary production). The curves again are characteristic of highly enriched and productive lakes. The algae present in high concentrations in the surface waters are a primary cause of the low transparency and are the source of the high productivity near the surface. The two blue-green algae, Anabaena sp. and Microcystis aeruginosa are characteristic of highly enriched waters and can cause nuissances.

The disappearance of oxygen from the deeper waters leads to changes in the chemistry of the bottom water. For instance, iron and manganese become soluble (Fig.5 and 6), and hydrogen sulfide is produced (Tables I, III, VI). We understand that consideration has been given to providing a siphon to permit removal of deeper water out of the lake rather than surface water. Considering the highly enriched character of the lake and the quality of the deeper water, this would not appear to be a desirable step, since hydrogen sulfide would be released to the atmosphere causing an odor problem and possibly discoloration of paint. Also, if fish are present in the stream below the lake they could be killed both by hydrogen sulfide and by low dissolved oxygen.

There may be several approaches to controlling the problems associated with excessive algal growths in the lake at the Operation Breakthrough site in Macon. I do not believe treating the lake to kill algae is the answer, since treatment would have to be repeated at fairly frequent intervals, and in killing the algae, it is the symptoms and not the cause of the problem that are treated. Also, the concentration of toxicant builds up in the bottom of the lake and could adversely affect fish breeding in the lake. We would favor approaching the cause of the problem. One approach I have outlined in a previous letter, that is, to provide aeration and circulation of the lake water to prevent stratification and the formation of an oxygen poor zone in the deeper water of the lake. This could be done by aerating or perhaps the use of a fountain taking its water from the bottom of the lake. Other approaches would include dredging to remove bottom sediments which must be an important source of nutrients and biological activity in the lake or dredging plus increasing the flow of water through the lake to remove nutrients and algae continuously. The volume is small enough so that dilution would probably be practical. During the next quarter, studies will be conducted of the bottom deposits to determine the extent to which they must be removed, and the possibility of dilution will be explored further.

A final observation of importance relates to the data on solids presented in Figures 11 through 13. As a rule, the solids concentrations have not been excessive, and silt has not been a factor in water quality at the Operation Breakthrough site. On June 26, however, there were clear visual signs of high silt concentrations in the deeper water of the lake, below the 6 ft. depth, which are reflected particularly in the high nonvolatile solids in the deeper water. Inspection of the shoreline revealed an area at the head of the lake where silt has washed into the lake from the construction site. Stirring up of the sediments in the area revealed the presence of gray silt which has not been present in the past. What the increased flow of silt portends for the future cannot be stated with certainty at this point, but it must increase the rate at which sedimentation takes place in the lake and adversely affect the appearance of the lake. In the past the water in this lake has been free of the muddy appearance of so many lakes in this region. Precautions should be considered to prevent silt-laden runoff from the construction site from reaching the lake.

I hope that the above suffices for you to prepare a quarterly report. If you have any questions, please do not hesitate to contact me.

Sincerely yours,

Alfred W. Hoadley

Alfred W. Hoadley
Associate Professor

AWH:jw