NPS Report file Pictured Rocks

A PRELIMINARY SURVEY OF THE ENVIRONMENTAL QUALITY OF THE PICTURED ROCKS NATIONAL LAKESHORE AND RECREATIONAL AREA ALGER COUNTY, MICHIGAN

LIMNETICS, INC.

environmental research and engineering

A PRELIMINARY SURVEY OF THE ENVIRONMENTAL QUALITY OF THE PICTURED ROCKS NATIONAL LAKESHORE AND RECREATIONAL AREA ALGER COUNTY, MICHIGAN

conducted for

UNITED STATES DEPARTMENT OF THE INTERIOR

NATIONAL PARK SERVICE

DECEMBER 1970

by

LIMNETICS, INC.

Environmental Research and Engineering

Milwaukee, Wisconsin

LIMNETICS, INC. A SUBSIDIARY OF ECOTONICS, LTD.
environmental research and engineering

LETTER OF TRANSMITTAL

Mr. Garland Moore
Office of Water Resources
and Land Acquisition
Eastern Service Center
National Park Service
U. S. Department of Interior
Washington, D. C. 20242

January 18, 1971

Dear Sir:

We are pleased to submit our report:

"A Preliminary Survey of the Environmental Quality of the Pictured Rocks National Lakeshore and Recreational Area".

This report is in accordance with the requirements of contract number 14-10-6: 990-042, dated 19 June, 1970, administered by your office.

Respectfully,

R. V. Harmsworth, PhD.
Vice President

B. J. Gallagher, P.E.
President

6132 West Fond du Lac Avenue, Milwaukee, Wisconsin 53218 • Telephone 414/461-9500

PREFACE

This report is the result of a comprehensive study conducted for the National Park Service, U. S. Department of Interior, on the environmental quality of the Pictured Rocks National Lakeshore and Recreational area, Alger County, Michigan.

The environmental survey was conducted during the summer and fall of 1970 under contract No. 14-10-6:990-042, administered by the Office of Water Resources and Land Acquisition, Eastern Service Center, National Park Service, Washington, D. C.

Environmental data was collected during this project and is documented in this report concerning the Pictured Rocks National Lakeshore water resources quality; fish analyses; air quality; pesticide residues; rain analyses; noise environment and soils, leaves, and grass analyses.

ACKNOWLEDGEMENTS

We wish to express our thanks to the National Park Service and to all agencies and persons who cooperated in performing this unique environmental survey. We would like to especially acknowledge the following: Mr. Garland Moore, National Park Service Engineer; Mr. Norman Davidson (and Staff), Park Management Assistant; Messrs. David Spencer, John Reidy, and Karl Tomaro of the U. S. Coast Guard Station, Munising, and their Commanding Officers, who assisted in the Lake Superior water sample collection; Mr. John Bjork, commercial fisherman, who collected the representative Lake Superior fish samples; Mr. Lee Anderson, Michigan Department of Natural Resources, who contributed the fish assay information; Mr. John Byrnes, Vice President, Michigan Consolidated Gas Company, for entrance and use of their property; and Mr. Tom Feldhusen, Station WGON, Munising, for public announcements.

The following personnel took part in this survey and in the preparation of this report: Miss Marjorie Staats, Secretary; Mrs. Sandra Harmsworth, Typist; Mrs. Deanna Gallagher, Typist; Mr. Richard Wehland, Biologist; Mr. Neil Johansen, Chemist; Mrs. Karen Donohoo, Assistant Chemist; Mr. David Lange, Assistant Chemist; Mr. Anthony Kuhry, Chemical Technician; Mr. Don Lange, Instrument Technician; Mr. Richard Arrington, Instrument Engineer; Professor R. J. Wold, Consulting Geophysicist; Dr. Rodney Harmsworth, Limnologist and Vice President of Limnetics, Inc. and Mr. Brian Gallagher, Environmental Engineer and President, Limnetics, Inc.

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SUMMARY AND GENERAL CONCLUSIONS

1. A preliminary survey was conducted on the environmental quality of Pictured Rocks National Lakeshore and Recreational Area during the summer and early fall of 1970. The survey consisted of measuring the water, air and noise quality. Water sites included eight stations along the shoreline in Lake Superior and eight lakes and thirteen streams within the park. The air and noise quality were measured at fourteen sites in the park.

2. The portion of Lake Superior along the park shoreline indicated a high quality environment but Munising Bay showed some early signs of eutrophication. This situation is probably due to waste discharges and should be carefully monitored.

3. The inland lakes of the park varied greatly in quality and were generally productive brown-water lakes with a wide variety of planktonic life. Many of the inland lakes indicated an advanced state of eutrophication and should be carefully monitored.

4. The inland streams are brown-water streams with a varied biota and water quality. In general, the streams contained high concentrations of nutrients. The nutrients appear to be naturally draining from swamps and heavily forested areas.

5. A representative 30 day water quality recording of one stream showed little changes other than normal diurnal or seasonal fluctuations. The gross changes that did occur were due to inherent limitations of the equipment. Long term water quality monitoring of some limited parameters is possible but periodic

maintenance of the equipment is definitely required. The more important parameters such as the nutrients, phosphorous and nitrogen cannot be adequately monitored by automated instruments at this time.

6. Pesticide residues were not detected in the water resources. However, small quantities of pesticides were found in the soil, leaf, and grass samples from the campgrounds. Traces of pesticide residues were found in 5 different species of fish obtained from Lake Superior. No detectable traces of mercury or arsenic were found in the fish.

7. The air quality is good with very low amounts of both particulate matter and sulfur oxides. Much longer air monitoring is required to accurately establish the very low concentrations of air pollutants. Continuous long term monitoring equipment is available to perform this task provided adequate power can be supplied.

8. The noise levels in the park are presently very low in general with several exceptions. Natural sounds, such as wind and water, were high in intensities but are not annoying to the human ear. Long term noise measurements suitable for correlation with observed wildlife and camper activity should be investigated. Integrated noise recordings might be applicable for this task, but much more research is needed to establish standards and methods suitable for monitoring environmental noise to assist in park management.

9. This report has demonstrated that environmental monitoring of an ecologically fragile environment is feasible and indeed necessary for the optimum development and protection of our public lands.

CHAPTER I

INTRODUCTION

The Pictured Rocks National Lakeshore area is located on the southern shore of Lake Superior in the beautiful wilderness of Michigan's upper peninsula. The Pictured Rocks National Lakeshore was authorized by Congressional act on October 15, 1966 and is now in the process of being developed by the National Park Service. The area extends from the Town of Munising on the west to the Town of Grand Marais on the east. The area is approximately 80 kilometers* (50 miles) long east and west and extends south from Lake Superior approximately 8 kilometers (5 miles) to the picturesque "Adams Trail" road. Figure 1.1 is a map of the area which will be referred to as the "park" in this report.

The natural resources of the park are rich in quantity, quality and diversity. Among other resources, the park contains many lakes, streams, waterfalls, sand dunes, forests, plains, beaches and the colored rock formations along Lake Superior's shoreline which give the park its name.

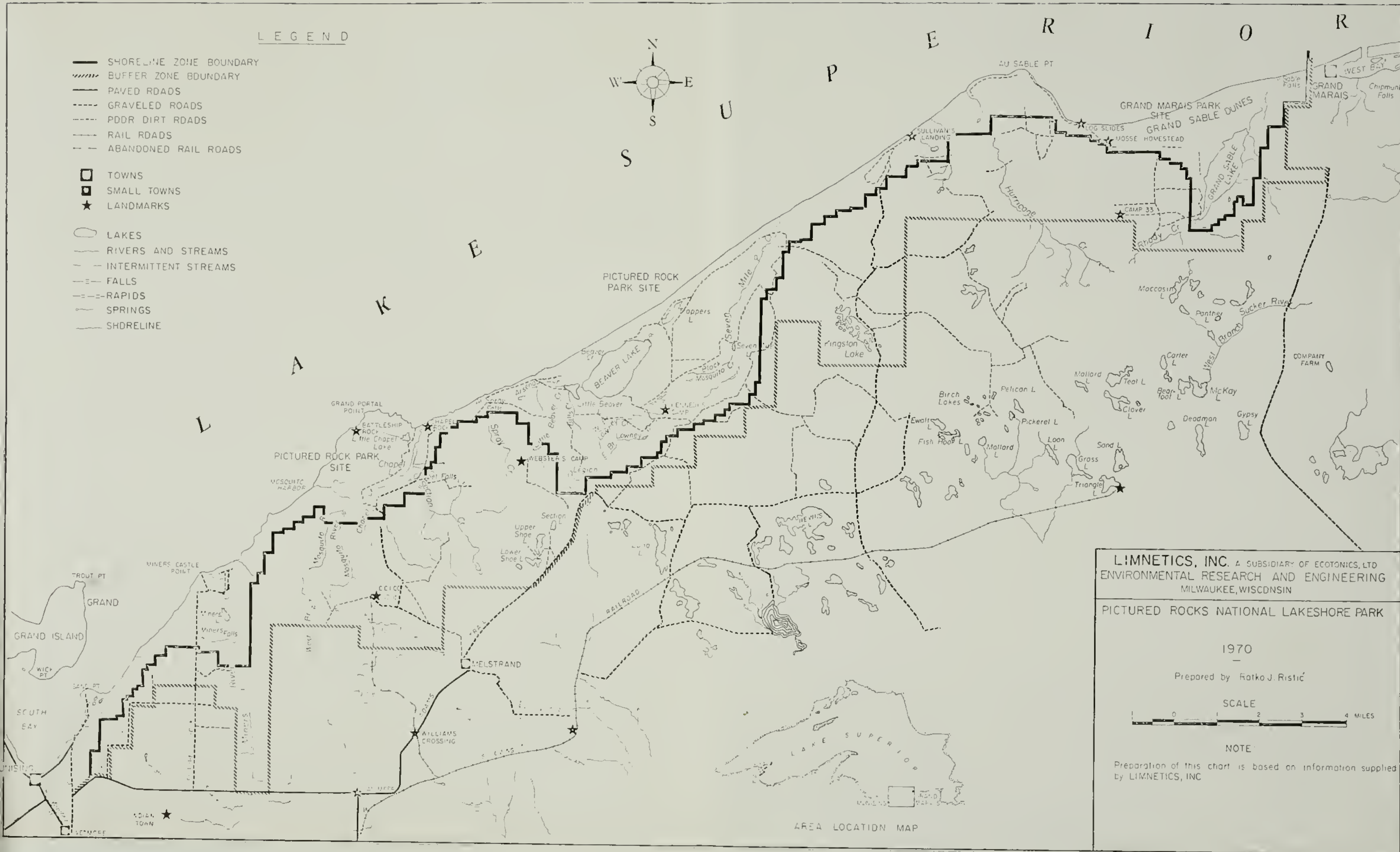
During the summer of 1970 a preliminary survey of the environmental quality of Pictured Rocks National Lakeshore and Recreational Area was undertaken. The purpose of the survey was to measure and record the present environmental quality of the park. The survey included measurements of the water, air, and noise quality of the enviornment and also the biological characteristics of the water resources within the park.

* Metric units are used in this report. See glossary for conversion factors.

The survey is synoptic in nature and is designed to lay the groundwork for the establishment of an Environmental Quality Benchmark System (EQBM). An EQBM is a reference point of environmental quality where environmental parameters are measured at given locations over a period of time. These measurements serve as baselevels to which changes can be referenced. In establishing an EQBM system, decisions must be made concerning which environmental parameters and locations are most representative of the total environment, and which techniques and intervals will monitor changes in the parameters. The present survey is not an EQBM but serves as the basis for designing such a system. This survey should be of value to the planners in providing a partial inventory of park resources, and of value to the park manager in identifying the fragile areas in need of careful husbandry.

This survey was undertaken in its entirety by the scientific and engineering staff of Limnetics, Inc. Certain measurements were made in the park during extensive field trips and all other analyses were undertaken at the Limnetics Inc. laboratories.

The following chapters are a compilation of the results and discussion as to the environmental quality of the Pictured Rocks National Lakeshore and Recreational Area.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TOWNS
SMALL TOWNS
LANDMARKS
LAKES
RIVERS AND STREAMS
INTERMITTENT STREAMS
FALLS
RAPIDS
SPRINGS
SHORELINE
LAKE SUPERIOR
PICTURED ROCK PARK SITE
GRAND MARAIS PARK SITE
GRAND SABLE DUNES
GRAND MARAIS
AU SABLE PT
GRAND ISLAND
MELSTRAND
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MILWAUKEE, WISCONSIN
PICTURED ROCKS NATIONAL LAKESHORE PARK
1970
Prepared by Ratko J. Ristić
SCALE
NOTE
Preparation of this chart is based on information supplied by LIMNETICS, INC
AREA LOCATION MAP

FIGURE 1. 1

CHAPTER II

THE AQUATIC ENVIRONMENT

1. General

The aquatic environment is a highly complex interaction of many forces involving geological, chemical, physical and biological phenomena affecting water. Water is continuously moving in a hydrologic cycle between the atmosphere, soil, ground water, streams and lakes changing in form from solid, liquid, and vapor under the pressure of natural forces. The constituents of water also change during the hydrologic cycle being relatively pure in its vapor phase and picking up dissolved gases during its condensation, then incorporating dissolved salts and organic matter as it flows across and into the soil.

The Great Lakes, and the lakes of Upper Michigan as we know them today, were formed as a result of glacial action over 10,000 years ago. The lakes are topographic lows which have filled with water and the streams are gullies cut by water as it flowed to the lakes. In the geological sense lakes are born and slowly evolve into senescence due to the deposition of sediments from the surrounding drainage basin area and biological growths in them.

In the ecological sense lakes are also said to evolve from young to old. However, the discussion and theories concerning lake evolution from the ecological standpoint are still in flux and no attempt will be made to detail the manner in which lakes may or may not undergo ecological evolution. The fact that lakes do evolve ecologically and have arrived today in a particular state or condition is not in dispute. The present condition of lakes has been the subject of much debate and several systems of lake classification have evolved. One system of classification involves biological productivity, a second system involves the chemical water quality and a third the geological formation of the lake. Many other classifications have also been proposed[1]. Four basic lake types may be recognized using the trophic (biological productivity) status of the lake: (1) the oligotrophic type, representing lakes with low biological productivity; (2) the mesotrophic with medium productivity, (3) the eutrophic lake representing the highly productive type, and (4) the dystrophic type which is characterized by, brown water, acidic conditions and low in nutrients with a low productivity. The oligotrophic type is generally large, deep, clear, well oxygenated in the deep waters, low in dissolved salts especially calcium and magnesium. The eutrophic lake is generally small, shallow, turbid, high in dissolved salts and has an oxygen deficit in the bottom waters during the summer. The mesotrophic type lies between the oligotrophic and eutrophic types. The salts and nutrients which help create the productivity of a lake are derived for the most part from the drainage area which also contributes silts and sediment. In oligotrophic lakes the bottom sediments are generally poor in organic matter while the eutrophic ones have a rich organic sediment. The dystrophic lake type sediments are very colloidal in nature and rich in organic matter which is derived primarily from terrestrial sources.

The biological life of lakes is composed of several distinct communities. The plankton is the community consisting of free-floating organisms and may be divided into phytoplankton and zooplankton. The phytoplankton is the plant portion of the plankton and the zooplankton is the animal portion. The planktonic organisms belonging to the phytoplankton and zooplankton which pass through fine plankton nets comprise the nannoplankton. The littoral community consists mainly of rooted plants with flexible stems and floating leaves but includes other organisms living near the shores. The benthos is the community living on and in the bottom sediments and consists of various insect larvae, snails, clams and worms. The fish and other organisms capable of strong swimming movements constitute a community referred to as the nekton.

Streams have a specialized fauna of their own and the organisms are specifically adapted to flowing water. The stream organisms almost without exception show special adaptations to remain attached to submerged rocks and stones. The major organisms of streams are the insect larvae and attached diatoms.

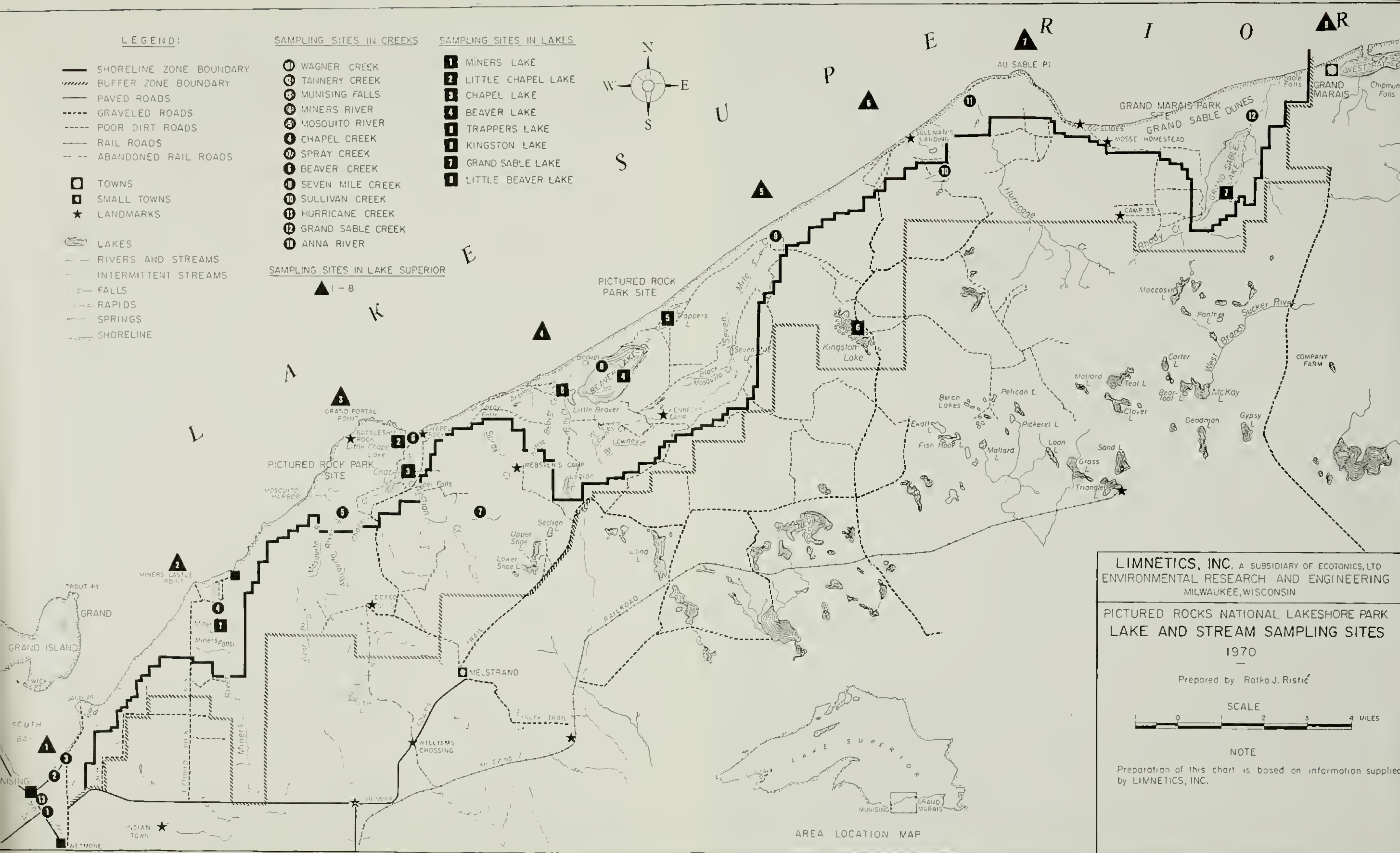
2. Methods

The sampling sites are shown in Figure 2. 1 including eight sites in Lake Superior, eight lakes and thirteen streams in the park. Each site was sampled on one occasion for water chemistry, plankton, benthos and sediment samples. The samples were then taken back to the Limnetics laboratories in ice chests to be analyzed. The water chemistry was performed using Standard Methods,[2] the metals by atomic absorption spectrophotometry, the pesticides and herbicides by gas chromatography and the biota by microscopic analysis. See Appendix A for a detailed description of the testing methodology.

3. Results

a. Water Chemistry Survey

The water quality survey consisted of sampling Lake Superior, the eight lakes, thirteen streams and the rainfall in the park. Lake Superior was sampled at eight points on the 15 meter contour line at eight kilometer intervals between Munising Bay and Grand Marais. The results of the chemical analyses are shown in Table 2. 2. The results show little difference between sampling stations with most parameters remaining fairly constant along the shoreline. The specific conductance and dissolved solids are low which is also reflected in the low calcium, magnesium and sodium concentrations. The trace metals, iron, aluminum and zinc were present in small quantities while manganese, copper, lead and arsenic were generally below the detectable limits of 0. 001, 0. 002, 0. 002 and 0. 125 mg/L, (milligrams per liter) respectively. The nutrients phosphorus and nitrogen were present in concentrations below what is regarded as sufficient to promote algal blooms.


LEGEND:
SHORELINE ZONE BOUNDARY
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WAGNER CREEK
TANNERY CREEK
MUNISING FALLS
MINERS RIVER
MOSQUITO RIVER
CHAPEL CREEK
SPRAY CREEK
BEAVER CREEK
SEVEN MILE CREEK
SULLIVAN CREEK
HURRICANE CREEK
GRAND SABLE CREEK
ANNA RIVER
SAMPLING SITES IN LAKES
MINERS LAKE
LITTLE CHAPEL LAKE
CHAPEL LAKE
BEAVER LAKE
TRAPPERS LAKE
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GRAND SABLE DUNES
LOG SLIDES
MOSSE HOMESTEAD
SULLIVAN'S LANDING
CAMP 33
Hurricane
Sucker River
PICTURED ROCK PARK SITE
Kingston Lake
Trappers L
Beaver Lake
Little Beaver
GRAND PORTAL POINT
BATTLESHIP ROCK
Little Chapel Lake
Chapel Falls
PICTURED ROCK PARK SITE
WEBSTER'S CAMP
MINERS CASTLE POINT
Miners Falls
GRAND ISLAND
MELSTRAND
WILLIAMS CROSSING
RAILROAD
SOUTH BAY
MUNISING
WETMORE
INDIAN TOWN
COMPANY FARM
Carter L
Mallard L
Teal L
McKay L
Clover L
Deadman L
Gypsy L
Pelican L
Pickerel L
Birch Lakes
Ewalt L
Fish Hook L
Loon L
Sand L
Grass L
Triangle L
Moccasin L
Panther L
Upper Shoe L
Lower Shoe L
Long L
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MILWAUKEE, WISCONSIN
PICTURED ROCKS NATIONAL LAKESHORE PARK
LAKE AND STREAM SAMPLING SITES
1970
Prepared by Ratko J. Ristić
SCALE
0 1 2 3 4 MILES
NOTE
Preparation of this chart is based on information supplied by LIMNETICS, INC.
AREA LOCATION MAP
LAKE SUPERIOR
MUNISING
GRAND MARAIS

FIGURE 2. 1

TABLE 2.1

LAKES AND STREAMS SURVEYED

No.	LAKES	AREA HECTARES	SHORELINE KILOMETERS	DEPTH METERS
L1	Miners Lake	4.05	0.48	2.4
L2	Little Chapel Lake	5.67	0.80	3.0
L3	Chapel Lake	27.54	4.02	18.3
L4	Beaver Lake	324.00	7.56	9.2
L5	Trappers Lake	20.25	2.41	6.0
L6	Kingston Lake	60.75	7.24	3.7
L7	Grand Sable Lake	243.00	9.49	12.8
L8	Little Beaver Lake	14.17	2.41	5.5
	STREAMS	LENGTH KILOMETERS		
C1	Wagner Creek	1.20		
C2	Tannery Creek	0.80		
C3	Munising River	3.21		
C4	Miners River	10.05		
C5	Mosquito River	8.05		
C6	Chapel Creek	3.22		
C7	Spray Creek	5.63		
C8	Beaver Creek	3.22		
C9	Seven Mile Creek	6.44		
C10	Sullivan Creek	3.22		
C11	Hurricane Creek	5.63		
C12	Grand Sable Creek	3.62		
C13	Anna River	11.26		

TABLE 2.2

WATER ANALYSIS DATA FOR LAKE SUPERIOR BY

PICTURED ROCKS NATIONAL LAKESHORE ON

7 JULY, 1970

Analysis/Sample	LS-1	LS-2	LS-3	LS-4	LS-5	LS-6	LS-7	LS-8
Ammonia-Nitrogen	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Organic-Nitrogen	0.14	0.14	0.20	0.03	0.14	0.17	0.25	0.20
Nitrite-Nitrogen	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Nitrate-Nitrogen	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Phosphorus-soluble	0.003	0.006	0.006	0.006	0.006	0.006	0.006	0.012
Phosphorus-Total	0.007	0.007	0.007	0.010	0.010	0.007	0.007	0.010
pH	7.3	7.2	7.4	7.3	7.2	7.4	7.5	7.4
Specific Conductance	82	83	82.5	82	82	82.5	80.5	81.
Temperature, °C	12	12	12	12	12	12	12	12
Dissolved Oxygen	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5
Total Alkalinity	48	46	48	50	49	49	50	40
Solids-suspended	0.52	1.24	1.16	0.76	1.12	2.08	0.84	1.16
Solids-dissolved	48.7	55.76	57.84	59.24	57.28	56.32	56.36	49.20
Hardness ($CaCO_3$)	26.5	26.5	26.5	26.5	26.5	26.5	26.5	26.5
Chloride	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Sulfate	4.1	3.5	3.2	3.2	3.2	2.8	2.8	3.2
Turbidity (J. T. U.)	10	12	10	10	10	5	12	5
Calcium	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Magnesium	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Iron	0.005	0.010	0.010	0.015	0.010	0.020	0.012	0.010
Aluminum	0.025	0.025	0.025	0.050	0.025	0.050	0.050	0.050
Manganese	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Lead	0.002	0.005	0.002	0.002	0.002	0.005	0.005	0.005
Zinc	0.015	0.020	0.016	0.021	0.016	0.009	0.013	0.016
Sodium	1.4	1.4	1.5	1.4	1.4	1.4	1.3	1.4
Arsenic	<0.125	<0.125	<0.125	<0.125	<0.125	<0.125	<0.125	<0.125

All values mg/L unless noted. Specific Conductance μ mhos/cm at 20°C.
J. T. U.-Jackson Turbidity Units.

The eight lakes surveyed show large differences in the physical and chemical parameters measured and are recorded in Table 2. 3.

In general, the lakes are characterized by brown alkaline water with a high specific conductance and dissolved solids. However, since the lakes vary as to the relative influence of inflowing streams, encroachment of vegetation and time of sampling, etc., it is not valid to make strict comparisons between the various lakes. Table 2. 1 shows the areas of the lakes surveyed and their shoreline length. Miners Lake is a shallow swampy area more deserving of the term pond than lake. The lake is an expansion of the Miners River and rapidly filling up with aquatic vegetation. The water is quite brown and flows straight through giving the lake a stream-like character. The water quality parameters closely parallel the Miners River even though the samples were taken at different times.

Little Chapel Lake is a small swampy depression rapidly filling in with aquatic vegetation. The water source is primarily from a small creek and surface drainage. The lake water is slightly acidic with a pH of 6. 8 which is a major difference from all other waters investigated. The calcium, magnesium, specific conductance and dissolved solids are all low while the nutrients phosphorus and nitrogen are high.

Chapel Lake is a large deep lake with steep sides. There is little aquatic vegetation by the shore and the bottom is primarily sandy. The main water

TABLE 2.3

WATER ANALYSIS DATA FOR THE LAKES FROM PICTURED ROCKS NATIONAL LAKESHORE

Analysis/Sample	Miners Lake 26 Sept.	Little Chapel Lake 15 Oct.	Chapel Lake 15 Oct.	Little Beaver Lake 27 Sept.	Beaver Lake 27 June	Trappers Lake 26 Sept.	Kingston Lake 28 June	Grand Sable Lake 8 June
Ammonia-Nitrogen	0.18	0.24	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Organic-Nitrogen	0.61	0.70	0.45	0.28	0.31	0.67	0.34	0.60
Nitrite-Nitrogen	<0.005	<0.005	<0.005	0.017	<0.005	<0.005	<0.005	<0.005
Nitrate-Nitrogen	0.01	0.02	0.01	0.01	0.02	0.01	0.02	0.02
Phosphorus-Soluble	0.04	0.04	0.04	0.006	0.003	0.04	0.003	0.006
Phosphorus-Total	0.06	0.06	0.06	0.010	0.016	0.05	0.010	0.010
pH	7.6	6.8	7.6	7.3	7.6	7.6	7.2	7.3
Specific Conductance	242	71	193	120	148	174	75	95
Temperature, ^{o}C	10.5	6.0	9.0	10.5	18.0	16.0	19.0	20.0
Dissolved Oxygen	11.2	12.0	11.5	14.0	9.0	10.2	8.9	10.2
Total Alkalinity	113.0	20.0	88.0	65.0	148	83.0	41	58
Solids-suspended	1.44	2.60	0.44	1.12	9.0	0.96		25
Solids-dissolved	174.9	73.0	130.8	98.9	110	97.8	80	45
Hardness, ($CaCO_3$)	102.4	29.3	77.6	89.5	50.9	50.4	24.5	46.7
Chloride	1.5	1.8	1.0	1.0	<1.0	1.0	<1.0	<1.0
Sulfate	20.3	13.9	14.7	9.8	6.5	5.4	10.5	6.5
Turbidity (J. T. U.)	20.0	20.0	20.0	12.0	15.0	15.0	15.0	20.0
Calcium	10.5	3.5	8.0	7.0	11.0	7.0	6.5	6.5
Magnesium	18.5	5.0	14.0	17.5	5.7	8.0	2.0	7.4
Iron	0.145	0.175	0.05	0.05	0.022	0.025	0.095	0.075
Aluminum	0.075	0.175	0.10	0.075	0.100	0.20	0.050	0.050
Manganese	0.012	0.012	0.009	0.022	0.012	0.005	0.002	0.002
Copper	<0.002	0.005	<0.002	<0.002	0.005	<0.002	<0.002	<0.002
Lead	<0.005	<0.005	0.002	<0.025	<0.025	<0.005	<0.005	<0.005
Zinc	0.012	0.015	0.018	0.031	0.022	0.014	0.015	0.010
Sodium	0.8	0.4	0.8	1.0	0.9	1.0	0.6	1.1
Arsenic	<0.125	<0.125	<0.125	<0.125	<0.125	<0.125	<0.125	<0.125

All values mg/L unless noted. Specific Conductance μ mhos/cm at 20^{o}C.
J. T. U. - Jackson Turbidity Units.

supply to the lake is from Chapel Creek and Section 34 Creek. The water quality of the lake very much reflects the quality of the inflowing Chapel Creek. The water has a high amount of nutrients, and other dissolved salts and was not thermally stratified at the sampling time, although it undoubtedly stratifies in the summer months.

Little Beaver Lake is a small lake with large amounts of aquatic vegetation and a rich loose organic bottom sediment. The main sources of water are surface drainage, some small springs and the Arsenault Creek which drains a large swampy area. The water has high amounts of dissolved salts and is rich in nutrients. The lake is joined by a small channel to Beaver Lake which is the largest of the park's lakes. Beaver Lake was once a bay of Lake Superior and was cut off by the sand dunes. Throughout most of its shoreline there are steep sloped dunes and consequently little aquatic vegetation. The lake is supplied with water from Lowney Creek and exits to Lake Superior via Beaver Creek. Thermal stratification occurs in the summer and the bottom waters become depleted of oxygen. Figure 2.2 shows the temperature and oxygen stratification on 27 June and 20 August. The water quality data for Beaver Lake shows high amounts of nutrients, dissolved solids and a high specific conductance. The bottom sediments were unconsolidated and richly organic.

Trappers Lake is a small (20 hectares) long and narrow lake with no inflowing or outflowing streams. The shoreline is thickly wooded with many dead trees that have fallen into the lake. The water chemistry data shows high amounts of dissolved salts and nutrients. The bottom sediments are unconsolidated and

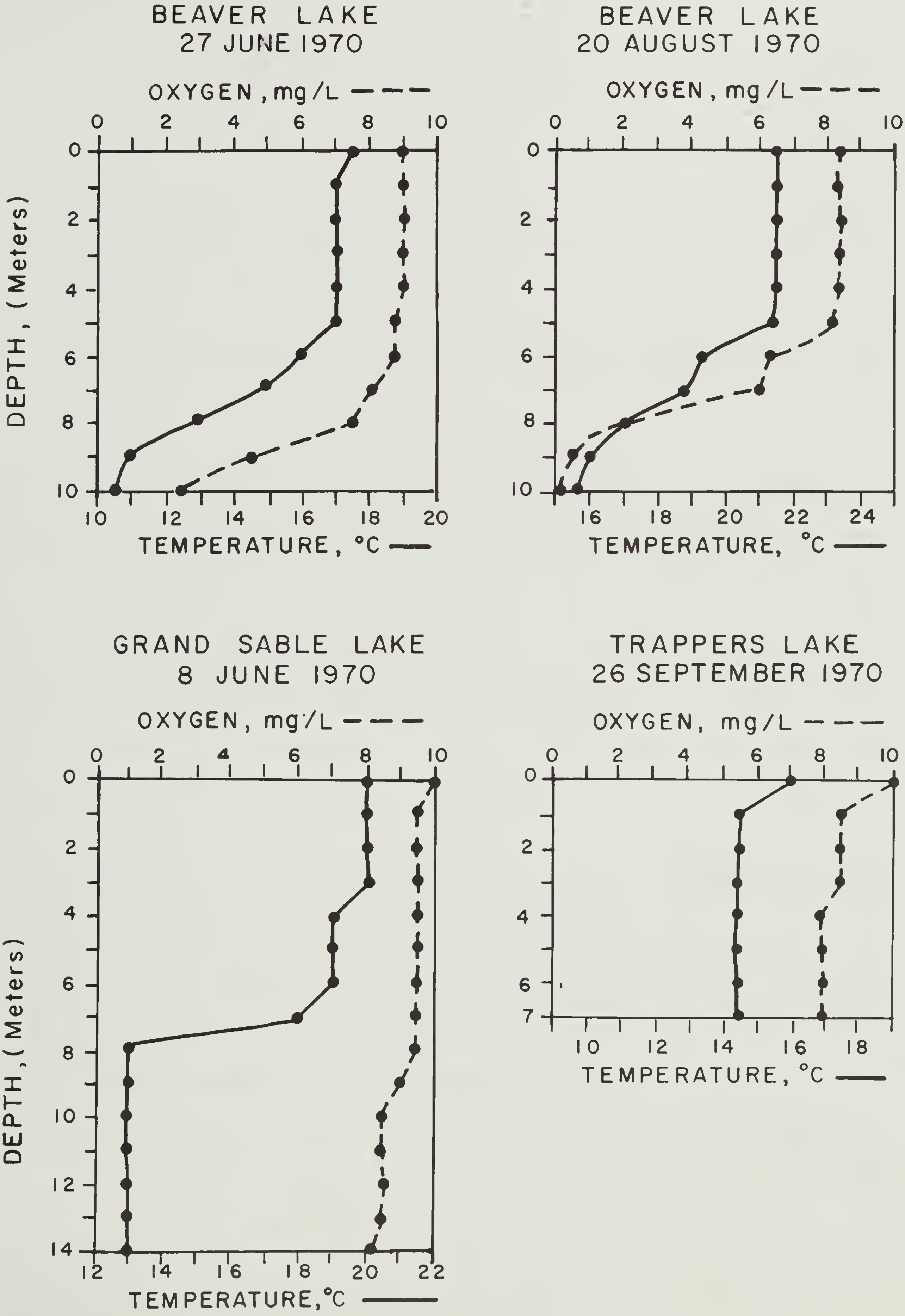

FIGURE 2.2 TEMPERATURE AND DISSOLVED OXYGEN PROFILES

highly organic. The lake does not stratify thermally during the summer owing to its shallowness.

Kingston Lake is a small lake and is characterized by a highly convoluted shoreline. The lake lies in a depression on the Kingston Plains and is shallow (5 meters) with a richly organic and unconsolidated bottom sediment. The lake does not stratify during the summer and is consequently oxygenated to the bottom.

Grand Sable Lake is the second largest lake (240 hectares) in the park and is surrounded by high sand dunes to the west and thick forest to the east. Several small creeks flow into the lake which discharge through Grand Sable Creek, into Lake Superior. The lake stratifies thermally but did not have an oxygen deficit in the hypolimnion during the survey which was in the early part of the summer. The bottom sediments are primarily sand with some organic material.

The thirteen streams in and near the park, which were sampled for water quality data were Wagner Creek, the Anna River both above and below the Munising Sewage Plant, Tannery Creek, Munising River, Miners River, Mosquito River, Chapel Creek, Spray Creek, Beaver Creek, Seven Mile Creek, Sullivan Creek, Hurricane Creek and Grand Sable Creek (Tables 2. 4 and 2. 5). Beaver Creek was also monitored on a continuous basis for 30 days using a water quality monitoring instrument.

Wagner Creek is situated west of the park and is tributary to the Anna River which flows into Lake Superior at Munising Bay. Tannery Creek is a small creek with less than 0. 015 cms (cubic meters per second) flow during the summer months and is situated just west of the park. The remaining creeks are all within the park and flow into Lake Superior. The creeks run through dense mixed deciduous and evergreen forest which for the most part are unspoiled. Many of the streams incorporate high waterfalls such as Wagner Falls, Miners Falls, Munising Falls, Chapel Falls, Spray Falls and the Grand Sable Falls. The streams start high in the Munising Moraine and run through densely wooded country picking up both ground and surface water. The surface waters are generally brown from humic acids which are leached from the bogs and swamps in the area. The streams are generally small with flow rates in the .5-1.5 cms range, although none of the streams were gauged. The Hurricane River, as would be expected from the name, is the largest stream in the park and has an approximate flow of 3 cms.

The streams are generally gravel bottomed with patches of sand bottom, especially toward the mouth of the streams. Some areas of the streams are quite sandy especially in the slower flowing reaches. The streams are generally blocked at various points by fallen trees, often a result of the banks being undercut by the current. In the streams which have small impoundments or which flow from lakes, the water quality reflects a lacustrine character. Such lacustrine character can be observed on Seven Mile Creek, Sullivan Creek and Miners Creek where there are small impoundments and the water is slowed down. Beaver Creek and Grand Sable Creek are noticeably influenced by the

TABLE 2.4

WATER ANALYSIS DATA FOR THE STREAMS FROM

PICTURED ROCKS NATIONAL LAKESHORE

Analysis/Sample	Wagner Creek 29 Sept.	Tannery Creek 27 Aug.	Munising River 26 Aug.	Miners River 26 Aug.	Mosquito River 27 Aug.	Chapel Creek 27 Aug.	Anna River Above Sewage Plant 28 Aug.
Ammonia-Nitrogen	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Organic-Nitrogen	0.34	0.28	0.22	0.28	0.17	0.34	0.03
Nitrite-Nitrogen	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Nitrate-Nitrogen	<0.01	<0.01	0.02	0.03	<0.01	0.02	<0.01
Phosphorus-soluble	0.010	0.02	0.01	0.01	0.01	0.01	0.01
Phosphorus-total	0.014	0.05	0.04	0.03	0.01	0.01	0.02
pH	7.4	7.8	7.9	8.0	7.9	7.8	7.7
Specific Conductance	173.0	250	220	290	230	220	180
Temperature, °C	8.0	20	15	16	13	13	11.5
Dissolved Oxygen	11.0	6.5	9.8	11.0	8.6	9.6	11.0
Total Alkalinity	59.6	98	115	144	118	116	84
Solids-suspended	0.8	2.36	1.52	0.88	0.52	0.16	2.44
Solids-dissolved	106.8	156.84	147.68	161.92	143.08	130.24	77.96
Hardness ($CaCO_3$)	45.9	55.4	58.3	106.9	89.1	87.1	39.3
Chloride	10.5	1.5	1.0	1.0	1.0	1.0	1.5
Sulfate	11.2	12.0	8.8	9.8	8.0	7.5	8.0
Turbidity (J.T.U.)	30.0	17	6	13	6	6	13
Calcium	8.5	9.0	8.5	9.0	8.5	8.5	7.5
Magnesium	6.0	8.0	9.0	20.5	16.5	16.0	5.0
Iron	0.112	0.110	0.220	0.108	0.035	0.095	0.048
Aluminum	0.15	0.175	0.300	0.225	0.150	0.175	0.125
Manganese	0.005	0.012	0.020	0.022	0.005	0.020	0.005
Copper	<0.002	0.005	<0.002	<0.002	0.005	<0.002	0.010
Lead	0.005	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc	0.012	0.010	0.006	0.008	0.008	0.034	0.015
Sodium	5.0	2.6	3.3	3.5	2.4	1.0	1.0
Arsenic	<0.125	<0.125	<0.125	<0.125	<0.125	<0.125	<0.125

All values mg/Lunless noted. Specific Conductance μ mhos/cm at 20°C.
J. T. U. - Jackson Turbidity Units.

TABLE 2.5

WATER ANALYSIS DATA FOR THE STREAMS FROM PICTURED ROCKS NATIONAL LAKESHORE

Analysis/Sample	Anna River Below sewage Plant 28 Aug.	Spray Creek 27 July	Beaver Creek 27 Aug.	Seven Mile Creek 9 July	Sullivan Creek 28 July	Hurricane River 28 July	Grand Sable Creek 28 July
Ammonia	<0.03	<0.03	<0.03	<0.34	<0.03	<0.03	0.40
Organic-Nitrogen	0.31	0.03	0.39	0.11	0.11	0.17	0.25
Nitrite-Nitrogen	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Nitrate-Nitrogen	<0.01	0.03	0.02	0.02	0.02	0.04	0.02
Phosphorus - soluble	0.15	0.003	0.003	0.006	0.003	0.016	0.010
Phosphorus- Total	0.21	0.007	0.013	0.007	0.010	0.013	0.012
pH	7.5	7.6	7.5	7.5	7.6	7.4	7.1
Specific Conductance	190	155	152	82	151	122	92
Temperature, ^{o}C	12.5	12.0	18.0	9.5	15.0	14.0	20.0
Dissolved Oxygen	9.0	9.3	9.0	11.1	8.8	9.9	10.5
Total Alkalinity	81	80	78	82	81	66	54
Solids- suspended	2.76	1	16.0	16.0	1	40	13
Solids-dissolved	114.04	120	120	76.8	120	80	63
Hardness, ($CaCO_3$)	43.4	61.6	51.3	52.1	52.2	42.6	46.7
Chloride	2.5	1.0	1.0	1.0	1.0	1.0	1.0
Sulfate	9.0	7.0	5.5	7.5	6.5	6.5	6.7
Turbidity (J. T. U.)	16	20	20	2	20	15	30
Calcium	7.5	11.0	11.0	9.5	11.0	8.5	6.5
Magnesium	6.0	8.3	5.8	6.9	6.0	5.2	7.4
Iron	0.068	0.062	0.075	0.022	0.145	0.108	0.075
Aluminum	0.175	0.125	0.100	0.025	0.050	0.100	0.050
Manganese	0.008	0.028	0.008	0.008	0.015	0.012	0.002
Copper	0.008	0.005	<0.002	<0.002	0.005	0.002	0.002
Lead	<0.005	<0.025	<0.005	<0.025	<0.025	<0.025	<0.005
Zinc	0.016	0.038	0.012	0.035	0.035	0.029	0.018
Sodium	1.0	1.0	0.9	1.1	0.8	0.9	1.0
Arsenic	<0.125	<0.125	<0.125	<0.125	<0.125	<0.125	<0.125

All values mg/L unless noted. Specific Conductance μ mhos/cm at 20^{o} C.
J. T. U. - Jackson Turbidity Units.

large lakes from which they flow. The creeks have a more stable flow since the lakes buffer any large flow changes. The creeks are more sandy than those without a lake system on the creek. The water quality of the creeks reflects the epilimnetic waters derived from the lakes.

The water quality varies considerably among the streams although there are some common characteristics. In general, they are all cold water streams saturated with oxygen and with a moderate specific conductance and dissolved solids content. The waters are all slightly alkaline, despite the brown appearance due to humic substances. The phosphorus and nitrogen concentrations are high in most cases and are above the amount thought to stimulate algal blooms in lakes. The streams to the west of Chapel Creek have higher sodium and sulfate contents than the eastern creeks, with the exception of the Anna River.

The very high sodium and chloride content of Wagner Creek appears to be a result of the storage of road salt in the vicinity of the creek. This is not the case with the other streams since sulfate is the dominant anion and not chloride which is similar in most of the streams. The Anna River is distinctive since the Munising Sewage Treatment Plant discharges into the river. A sample from above and below the plant shows increases of turbidity, sulfate, chloride, hardness, dissolved solids, specific conductance, temperature, phosphorus, and nitrogen, while the dissolved oxygen decreased slightly. Although the chemical data did not show dramatic changes the biological differences above and below the plant were significant.

Long term water quality monitoring was undertaken at Beaver Creek. The recorded data, is illustrated in figure 2.3, 2.4 and 2.5 and shows diurnal and long term variations in the water quality parameters measured. Five water quality parameters were measured, temperature, dissolved oxygen, pH, specific conductance and stream depth, during the period August 8 to September 27, 1970. The recording period was interrupted between August 22 and 28th to run performance tests on the system and to inspect the data. The temperature measurements show a diurnal variation of approximately 5^{o}C along with a seasonal 45 day mean value variation from 19^{o}C to 8^{o}C. The dissolved oxygen concentration shows approximate saturation levels with slight diurnal and other variations for the period August 8 to September 8. However, the dissolved oxygen values decreased beginning September 8 through September 27. This decrease is considered to be an instrumentation error and was verified by comparative tests taken at the end of the test period with an auxilliary laboratory dissolved oxygen meter. At that time, the correct dissolved oxygen readings should have been higher than 10 ppm due to the decreased water temperatures. Consequently, the dissolved oxygen record is unreliable during the last 20 days of recording, and is illustrated by the dashed lines in figures 2.4 and 2.5.

The pH record appears reasonably normal with slight diurnal and other variations superimposed on a relatively constant pH value of 7.9. The pH of the lake should not have changed appreciably over the recording period.

The specific conductance record shows a starting conductance value of 170 micromhos which was verified by laboratory analysis. However, the conduc-

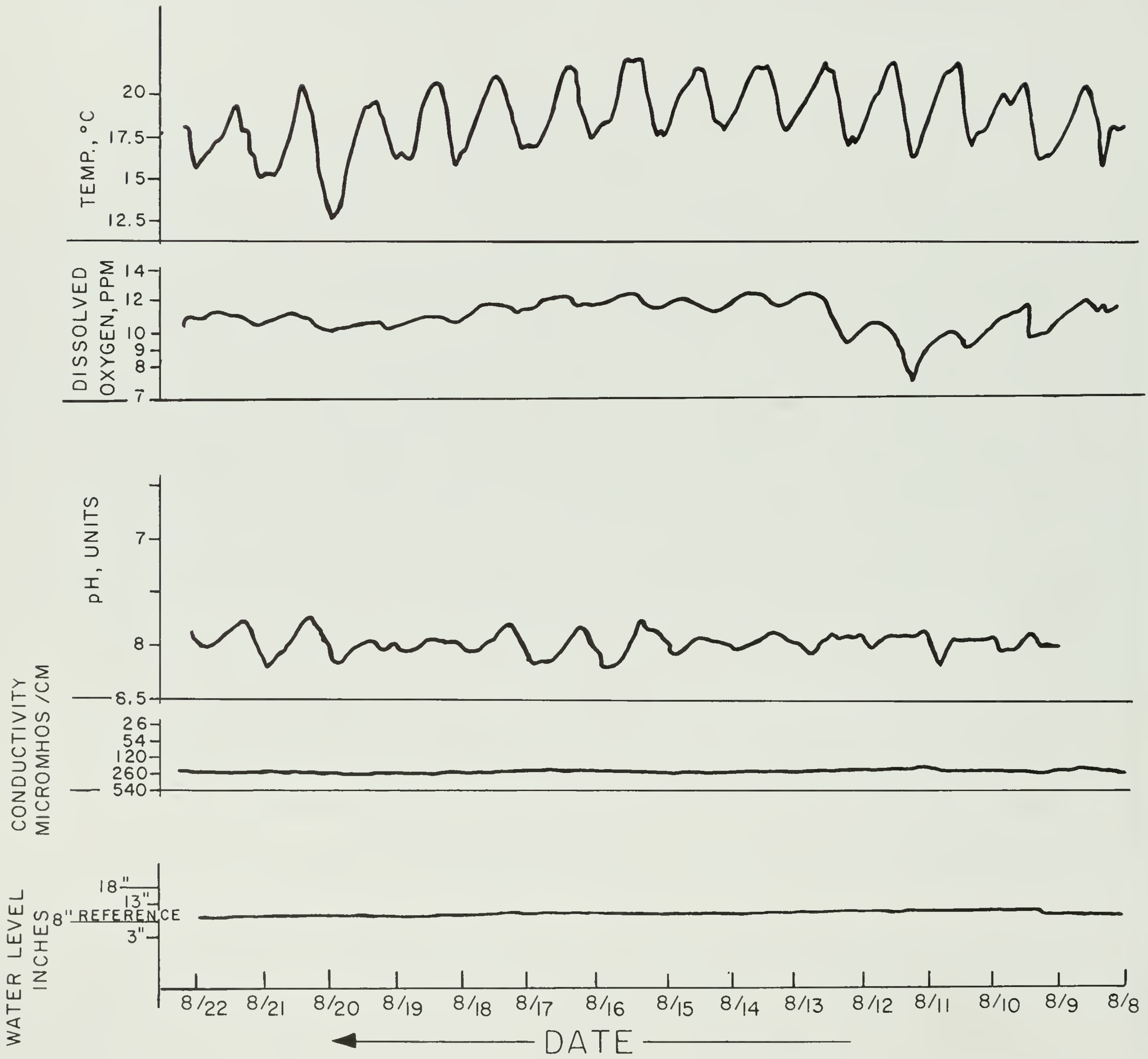

FIGURE 2. 3

BEAVER CREEK WATER QUALITY DATA
AUG. 8 — AUG. 22, 1970

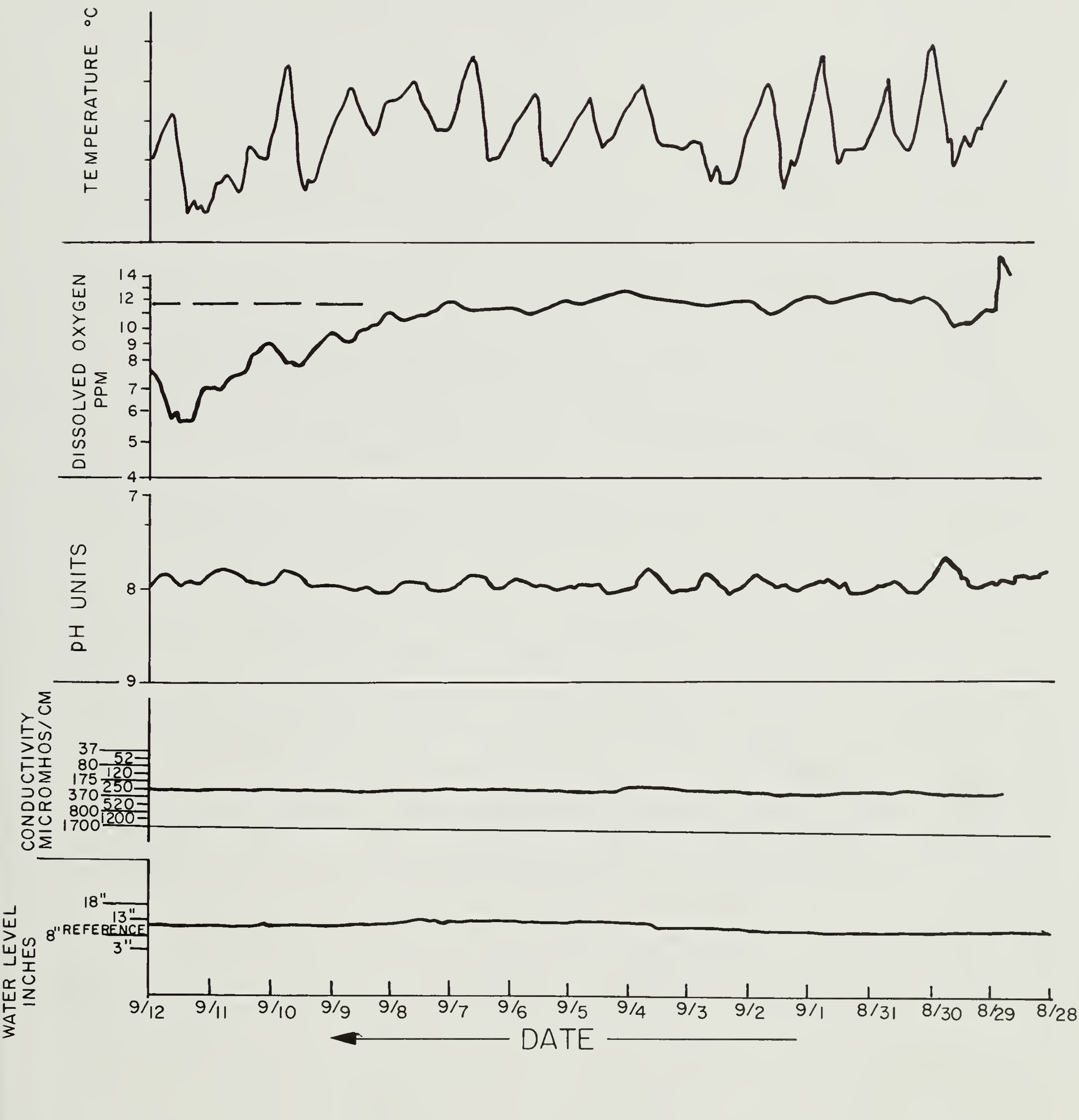

FIGURE 2. 4

BEAVER CREEK WATER QUALITY DATA
AUG. 28 — SEPT. 12, 1970

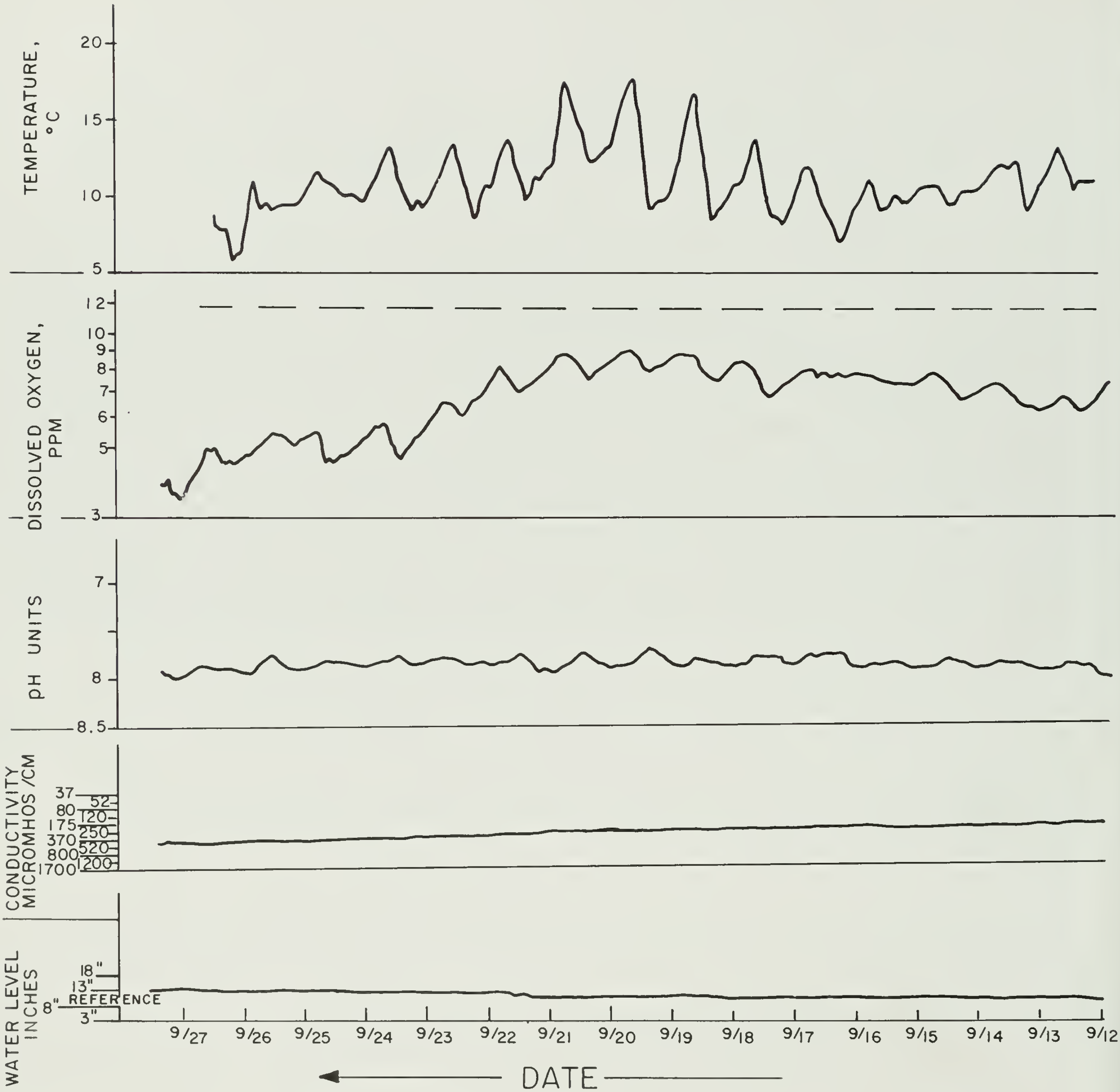

FIGURE 2. 5

BEAVER CREEK WATER QUALITY DATA
SEPT. 12 — SEPT. 27, 1970

tance values linearly increased over the 45 day period to above 500 micromhos. The equipment was cleaned and checked at the end of the recording period and found to be operating correctly.

An explanation to the linear increase of conductance may be provided by the large biological growth build-up around the probes. At the end of the 45 day period, a build-up of the tricopteran larva Cheumatopsyche was observed on the probes creating a complete cover around the sensor elements. This is a common problem in fresh water monitoring and difficult to prevent. It may be that due to the extensive biological mass and activity near the conductance sensing elements, increased dissolved solids were deposited in the water creating a lower resistivity and, apparently, high conductance. Again, this reflects an inherent limitation in this type of monitoring without periodic maintenance.

The stream depth record shows a gradual increase in depth from 8 to 13 inches over the recording period. Manual verification measurements over the same period indicated a slightly larger depth increase of 8 to 16 inches. The depth sensing mechanism was a simple float and weight assembly connected to a recording potentiometer. The problem here was one of sensitivity and could easily be corrected by equipment adjustments.

Rainfall was collected during a storm on 26 September 1970. Due to a lack of rain during the time of this survey only a small quantity of rain water was obtained. This water was subsequently analyzed for the more important parameters as the quantity collected would allow including nitrogen, phosphorus, pesticide residues, trace heavy metals, pH and specific conductance. The results of the rain analysis are shown in table 2.6.

b. Biological Survey

Both phytoplankton and zooplankton were collected from Lake Superior and the lakes within the park. Benthos was collected from Lake Superior and from the lakes and streams within the park. The term plankton refers to organisms which have a drifting mode of life and includes both microscopic and macroscopic forms. Phytoplankton refers to the plant or algal part of the plankton and zooplankton refers to the animal part of the plankton. Benthos refers to those organisms found on the bottom sediments of a lake or stream.

The eight samples from Lake Superior taken on the seventh of July, 1970, showed the presence of three classes of phytoplankters, the Chrysophyceae (yellow-brown algae) Bacillariophyceae (diatoms) and Chlorophyceae (green algae). Table 2.7 shows the distribution and relative abundance of the eighteen species found. The relative abundance is given as d, (dominant), f, (frequent) and r, (rare) and reflect a subjective estimate rather than a fixed percentage. The dominant algae in all eight of the samples was the diatom *Tabellaria fenestrata* with *Tabellaria flocculosa*, *Fragilaria capucina* and *Fragilaria crotonensis* occurring frequently, The other fourteen species occurred infrequently at the sampling time. The zooplankton was sampled simultaneously with the phytoplankton and a total of twelve species were identified. The dominant species occurring in all of the samples was *Diaptomus sicilis*

TABLE 2.6

RAINWATER ANALYSIS FROM PICTURED ROCKS NATIONAL LAKESHORE 26 SEPTEMBER, 1970

	mg/L
Ammonia Nitrogen	0.54
Total Organic Nitrogen	1.24
Nitrate Nitrogen	<0.01
Total Phosphorus	0.024
pH	6.0
Specific Conductance, μ mhos	24
Iron	0.060
Aluminum	0.050
Manganese	0.028
Copper	0.008
Lead	<0.005
Zinc	0.002
Sodium	0.5
Arsenic	<0.125

TABLE 2.7

FLORA AND FAUNA FROM LAKE SUPERIOR BY PICTURED ROCKS NATIONAL LAKESHORE I PHYTOPLANKTON

	Station Number							
	1	2	3	4	5	6	7	8
Chrysophyceae	yellow-brown algae							
Dinobryon bavaricum	r	-	r	r	f	f	f	f
Dinobryon claciformis	-	-	-	f	-	-	-	-
Dinobryon cylindricum	r	-	r	-	-	-	-	-
Dinobryon serlutaria	-	-	-	r	r	-	r	f
Dinobryon sp.	-	-	-	-	-	-	-	r
Bacillariophyceae	diatoms							
Asterionella formosa	-	-	-	r	-	-	-	-
Asterionella gracillima	r	r	r	r	r	r	r	f
Cyclotella sp.	r	-	r	r	r	r	r	r
Cymbella sp.	-	r	-	-	-	-	-	-
Fragilaria capucina	r	r	f	r	f	r	r	r
Fragilaria crotonensis	r	f	f	-	f	f	r	f
Melosira islandica	-	r	r	-	r	-	-	-
Synedra actinastroides	-	-	-	-	r	-	r	-
Synedra acus	r	-	r	r	r	r	r	r
Synedra ulna	-	-		-	r	r	r	-
Tabellaria fenestrata	d	d	d	d	d	d	d	d
Tabellaria flocculosa	f	-	f	f	-	r	f	r
Chlorophyceae	green algae							
Closterium sp.	-	-	-	r	-	-	-	-

d = dominant f = frequent r = rare - = not observed

TABLE 2.8

FLORA AND FAUNA FROM LAKE SUPERIOR BY PICTURED ROCKS NATIONAL LAKESHORE II ZOOPLANKTON

	Station Number							
	1	2	3	4	5	6	7	8
Copepoda								
Calanoidea								
Epischura lacustris	-	-	-	-	-	f	-	r
Diaptomus minutus	r	-	-	-	-	-	-	-
Diaptomus sicilis	d	d	d	d	d	d	d	d
Limnocalanus macrurus	-	-	-	f	-	-	-	-
Cyclopoidea								
Cyclops bicuspidatus thomasi	-	-	-	-	r	r	-	-
Cladocera								
Bosminidae								
Bosmina longirostris	f	r	-	-	r	r	r	r
Chydoridae								
Chydorus sphaericus	r	r	-	r	-	-	-	-
Daphniidae								
Ceriodaphnia lacustris	r	-	-	-	-	-	-	-
Daphnia galeata mendotae	r	f	-	r	r	r	r	r
Daphnia rosea (?)	-	-	-	-	-	r	-	-
Polyphemoidea								
Polyphemus pediculus	-	-	-	-	-	r	-	-
Sididae								
Sida crystallina	-	r	-	-	r	-	-	-

r = rare f = frequent d = dominant - = not observed and other Copepoda were rare, except for Epischura locustris which occurred frequently at station six and Limnocalanus macrurus which occurred frequently at station four (Table 2.8). The most common cladocerans were Bosmina longirostris and Daphnia galeata mendotae.

The bottom sediments of Lake Superior were analysed for organic matter at seven of the eight stations sampled. A bottom sediment sample was not collected at station three because of rock bottom.

TABLE 2.9

ANALYSIS OF BOTTOM SEDIMENTS

Lake Superior	% Solids	% Organic Matter
Station 1	32.18	4.06
2	75.30	0.09
4	81.57	0.08
5	76.55	0.08
6	73.56	0.10
7	74.77	0.14
8	66.28	0.12

The sediment samples were all clean sand except for station #1, which was a brown mud sand mixture. Station one from Munising Bay had four percent organic matter and the other samples contained negligible amounts. There was no benthos found in any of the samples except for Stations 1, 5, 6 and 8.

Station 1 contained two unidentified species of oligochaetes and the snail Valvata sincera. Previous work by Adams and Kregear[3] on the benthos of Munising Bay found the most abundant species to be Peloscolox ferox, then Limnodrilus sp., and Tubifex sp., Calopsectra sp., and Pentaneura sp., were also found. Other species found by Adams and Kregear include Asellus communis, Lirceus lineatus and the Molluscs Pisidium, Musculium and Sphaerium.

Station 5, 6 and 8 contained a few mosquite larva. No benthos was found at other stations.

The phytoplankton of the eight lakes in the park was more diverse than the phytoplankton of Lake Superior containing fifty-six species in five classes of algae (Table 2.10 and 2.11). The Chrysophyceae (yellow-brown algae), Bacillariophyceae (diatoms), Chlorophyceae (green algae) Myxophyceae (blue-green algae) and Dinophyceae (Dinophyceae (Dinoflagellates) were present in one or more of the lakes. Of the five groups of algae the blue-green algae were dominant in four of the lakes and the diatoms dominant in the other four. The yellow-brown algae, the dinoflagellates and the green algae played a

TABLE 2. 10

THE FLORA AND FAUNA OF THE LAKES OF PICTURED ROCKS NATIONAL LAKESHORE I PHYTOPLANKTON

	Miners Lake 26 Sept.	Little Chapel Lake 15 October	Chapel Lake 15 Oct.	Little Beaver Lake 27 Sept.	Beaver Lake 27 June	Trappers Lake 28 June	Kingston Lake 28 June	Grand Sable Lake 8 June
Bacillariophyceae	diatoms							
Asterionella formosa	-	-	d	f	-	-	-	f
Asterionella gracillima	-	-	-	-	r	-	r	-
Cymbella sp.	r	-	-	-	-	r	-	-
Fragilaria capucina	-	-	-	-	-	-	-	r
Fragilaria crotenensis	-	-	f	f	r	-	-	f
Fragilaria intermedia	d	-	-	-	-	-	-	-
Mastogloia sp.	-	-	-	-	-	r	-	-
Melosira iealica	-	-	-	r	-	-	-	-
Melosira islandica	-	-	-	-	f	-	d	f
Melosira varians	-	r	-	-	-	-	-	-
Navicula sp.	r	-	-	-	-	r	r	-
Pennularia sp.	-	-	-	-	-	r	-	-
Rhizosolenia eriensis	-	-	f	-	-	-	-	-
Stauroneis phoenicenteron	-	-	-	-	-	r	-	-
Synedra acus	-	-	r	-	-	-	-	-
Synedra ulna	f	r	-	-	-	r	f	-
Tabellaria fenestrata	f	d	f	-	f	-	r	f
Tabellaria floculosa	-	f	-	-	-	-	-	-
Chrysophyceae	yellow-brown algae							
Dinobryon bavaricum	-	r	r	-	-	f	-	-
Dinobryon divergens	-	f	f	-	-	-	-	-
Dinobryon sertularia	-	f	-	f	-	-	f	-
Dinobryon sociale	-	-	-	r	-	-	-	-
Dinophyceae	dinoflagellates							
Ceratium hirudinella	-	-	-	f	r	-	-	-

d = dominant f = frequent r = rare - = not observed

TABLE 2. 11

THE FLORA AND FAUNA OF THE LAKES OF PICTURED ROCKS NATIONAL LAKESHORE I PHYTOPLANKTON

	Miners Lake 26 Sept.	Little Chapel Lake 15 Oct.	Chapel Lake 15 Oct.	Little Beaver Lake 27 Sept.	Beaver Lake 27 June	Trappers Lake 28 June	Kingston Lake 28 June	Grand Sable Lake 8 June
Chlorophyceae	green algae							
Closterium sp.	-	r	-	-	-	-	-	-
Cosmarium sp.	r	-	-	-	-	-	-	-
Desmidium grevillii	-	f	-	-	-	-	-	-
Hormidium kleibsii	-	f	-	-	-	-	-	-
Micrasterias americana	-	f	-	-	-	-	-	-
Micrasterias apiculata	-	f	-	-	-	-	-	-
Micratinium pusillus velegans	-	f	-	-	-	-	-	-
Mougeotia sp.	r	-	-	-	-	-	-	-
Pediastrum boryanum	-	-	-	-	-	-	r	-
Pediastrum duplex	-	-	-	-	f	-	-	r
Spirogyra sp.	r	f	-	-	-	-	-	-
Staurastrum sp.	-	-	-	-	-	r	-	r
Zoochlorella conductrix	-	-	-	-	-	r	-	-
Zoochlorella parasitica	-	-	-	-	-	r	-	-
Myxophyceae	blue-green algae							
Anabaena spiroides v. crassa	-	-	-	-	-	-	-	r
Anabaena sp.	-	-	-	-	r	-	-	-
Aphanizomenon flos-aquae	-	-	-	-	-	-	-	d
Aphanocapsa pulchra	-	-	-	-	-	-	-	f
Aphanocapsa rivularia	-	-	-	-	-	d	r	-
Chroococcus dispersus	-	-	-	-	-	f	-	-
Chroococcus limneticus	-	-	-	-	d	-	-	-
Chroococcus turgidus	-	-	-	-	-	r	-	-
Chroococcus sp.	-	-	-	-	-	-	-	-
Gomphosphaeria aponina	-	-	-	-	-	r	-	-
Lyngbya birgei	-	-	-	d	-	-	-	-
Lyngbya nordgaaridii	-	f	-	-	-	-	-	-
Microcystis nicerta	-	-	-	-	-	r	-	-
Oscillatoria articulata	-	r	-	-	-	r	-	-

d = dominant f = frequent r = rare - = not observed

TABLE 2. 13

THE FLORA AND FAUNA OF THE LAKES OF PICTURED ROCKS NATIONAL LAKESHORE II ZOOPLANKTON

	Miners Lake 26 Sept.	Little Chapel Lake 15 Oct.	Chapel Lake 15 Oct.	Little Beaver Lake 20 Aug.	Beaver Lake 27 June	Trappers Lake 26 Sept.	Kingston Lake 28 June	Grand Sable Lake 8 June
Daphniidae								
Ceriodaphnia reticulata	-	r	-	-	-	-	-	-
Ceriodaphnia lacustris	-	-	-	f	-	f	r	-
Daphnia catawba	-	-	-	-	-	-	r	-
Daphnia galeata mendotae	-	-	-	f	f	-	f	f
Daphnia retrocurva	-	-	-	r	-	-	-	-
Scapholeberis kingi	-	-	-	-	-	-	f	f
Holopedidae								
Holopedium gibberum	-	-	-	-	f	-	f	f
Leptodoridae								
Leptodora kindtii	-	-	-	-	r	-	-	f
Macrothricidae								
Drepenothrix dentata	-	-	-	-	-	f	-	-
Macrothrix laticornis	-	-	-	r	-	-	-	-
Ophryoxus gracilis	-	-	-	r	-	-	-	-
Polyphemidae								
Polyphemus pediculus	-	-	-	f	f	-	-	f
Sididae								
Sida crystallina	-	r	-	f	f	f	-	f
Rotifera								
Asplanchna priodonta	-	-	-	f	r	-	f	-
Cladocera (sub-fossil)								
Acroperus harpae	f	f	-	r	r	r	r	f
Alona affinis	-	f	-	f	f	d		
Alona barbulata (?)	-	-	-	-	-	-	r	-
Alona quadrangularis	-	-	-	f	f	-	f	-
Alona setulosa	-	-	-	-	-	-	r	-
Alonella excisa	-	d	-	-	-	r	-	-
Alonella exigua	-	-	-	-	-	-	r	-
Alonella nana	-	f	-	r	-	-	r	r
Bosmina longirostris	-	-	d	d	d	f	d	d
Chydorus sphaericus	-	-	-	-	f	-	f	f
Chydorus faviformis	-	-	-	-	-	r	r	-
Chydorus piger	-	f	-	-	-	-	-	r
Eurycercus lamellatus	d	-	-	-	-	f	-	-
Graptoleberis testudinaria	-	r	-	-	-	-	-	-
Pleuroxus denticulatus	-	-	-	-	r	-	-	-

d = dominant f = frequent r = rare - = not observed

TABLE 2. 12

THE FLORA AND FAUNA OF THE LAKES OF PICTURED ROCKS NATIONAL SHORELINE, II ZOOPLANKTON

	Miners Lake 26 Sept.	Little Chapel Lake 15 Oct.	Chapel Lake 15 Oct.	Little Beaver Lake 20 Aug.	Beaver Lake 27 June	Trappers Lake 26 Sept.	Kingston Lake 28 June	Grand Sable Lake 8 June
Copepoda								
Calanoidea								
Diaptomus minutus	-	-	-	-	-	-	f	-
Diaptomus oregonensis	-	d	d	d	d	-	-	d
Epischura lacustris	-	-	-	-	f	-	d	f
Cyclopoidea								
Cyclops vernalis	-	-	-	-	-	d	f	-
Mesocyclops dybowskii	-	-	f	f	-	-	-	f
Mesocyclops edax	-	-	-	-	f	-	-	-
Cladocera								
Bosminidae								
Bosmina longirostris	-	-	f	f	f	f	f	f
Chydoridae								
Acroperus harpae	f	f	-	-	-	-	r	f
Alona affinis	-	r	-	r	r	r	-	-
Alona barbulata (?)	-	-	-	-	-	-	-	r
Alona pulchella (?)	-	-	-	-	-	-	-	r
Alona quadrangularis	-	-	-	r	r	-	r	-
Alona rustica	-	-	-	-	-	-	-	r
Alonella exigua	-	-	-	-	-	-	r	-
Chydorus sphaericus	-	f	-	f	r	-	-	f
Chydorus piger	-	-	-	r	-	-	-	-
Eurycercus lamellatus	d	r	-	-	-	f	-	-
Leydigia leydigi	-	-	-	r	-	-	-	-
Monospilus dispar	-	-	-	r	-	-	-	r
Pleuroxus hastatus	-	-	-	f	-	-	-	-
Pleuroxus denticulatus	-	r	-	-	-	-	-	-

d = dominant f = frequent r = rare - = not observed

relatively small part in the phytoplankton except for Little Chapel Lake where the green algae were frequent.

Miners Lake which contained only five species of Bacillariophyceae and three species of Chlorophyceae was dominated by the diatom Fragilaria intermedia. Little Chapel Lake contained sixteen species including two species of blue-green algae seven green algae, four diatoms and three yellow-brown algae. Chapel Lake contained only seven algal species, two of which were yellow-brown algae and the remainder being diatoms, including the dominant Asterionella formosa.

Little Beaver Lake contained seven species of algae with the blue-green alga Lyngbya birgei dominant and the dinoflagellate Ceratium hirudinella frequent. Beaver Lake has eight species of algae with the blue-green alga Chrococcus limneticus the dominant form. Trappers Lake has sixteen species of algae six of which are blue-green including the dominant Aphanocapsa rivularia. The six species of diatoms and three species of green algae were all rare but the yellow-brown alga Dinobryon bavaricum was frequent.

Kingston Lake was the only large lake other than Chapel Lake which was not dominated by a blue-green alga. The only blue-green alga present was Aphanocapsa rivularia which occurred infrequently. The dominant alga was the diatom Melosira islandica. Grand Sable Lake which is the largest of the lakes in the park, was dominated by the blue-green alga Aphanizomenon flos-aquae while Aphanocapsa pulchra was frequent.

The zooplankton distribution and abundance are shown in Tables 2. 12 and 2. 13. The zooplankton was composed of six species of Copepoda, twenty-eight species of Cladocera and one species of Rotifera. Of the thirty-five species, only fifteen were truly planktonic and the rest were primarily littoral organisms. The majority of the littoral plankters were found in Little Chapel Lake, Little Beaver Lake and Grand Sable Lake where there were extensive weed beds. The dominant littoral group was the chydorid Cladocera of which there were fourteen species. The other lakes had a very small amount of littoral vegetation and consequently, few chydorid cladocera. In Miners Lake only two species of chydorid cladoceran were found. The dominant zooplankters were calanoid Copepoda with the exception of Trappers Lake which was dominated by the cyclopoid copepod, Cyclops vernalis. The dominant calanoid was Diaptomus oregonesis in each case except Kingston Lake where it was absent. The dominant plankter in Kingston Lake was Epischura lacustris and Diaptomus minutus was frequent.

The bottom sediments were analysed for organic matter, benthos and sub-fossil cladocera. The sub-fossil cladocera found are reported in Table 2. 13. The sub-fossil forms are those plankters which have died and have fallen to the bottom sediments. The sub-fossil forms decay but the shells become incorporated into the sediment. On occasion the sub-fossils can be very numerous and give a good representation of the species present in the lake. However, the lakes were sparsely populated with sub-fossil cladocera in both species and numbers compared with many other mid-western lakes.

The bottom sediments were analysed for organic matter and percent of solid material. The percent solid material was found by taking the dry weight of the sediment at 100°C and the organic matter by ashing at 525°C.

TABLE 2.14

ANALYSIS OF BOTTOM SEDIMENTS

Lake	% Solids	% Organic Matter
Miners Lake	76.90	0.56
Little Chapel Lake	40.38	10.23
Chapel Lake	81.97	0.22
Little Beaver Lake	8.27	50.20
Beaver Lake	6.87	44.60
Trappers Lake	6.71	44.59
Kingston Lake	5.54	52.41
Grand Sable Lake	33.54	4.85

The sediments were either very high in organic matter or were very low. The sediments from Miners Lake, Chapel Lake and Grand Sable Lake was primarily sand and contained very little organic matter. In the other lakes the amount of organic matter was very high and the percent solids generally low. The bottom sediments from the lakes with a high organic content did not have a clear sediment water interface but the sediments were unconsolidated resembling a colloidal suspension. In the deep water areas of the lakes the benthic fauna was scarce. In Miners Lake there were a few oligochaetes (worms) and the snail Lymnea palustris. In Little Chapel Lake there was no deep water benthos at the time of sampling. Chapel Lake contained large numbers of Chironomus sp. in the deep water and two snails Amnicola limnosa and Hyraulus (Torquis) parvus and a fingernail clam (Sphaerium sp.) in the littoral. No benthos was found in Little Beaver Lake at the time of sampling. Beaver Lake had no benthos in the deep-waters but the clam Anodonta grandis was abundant in the shallow littoral shelf. The Ostracod Candona sharpei was also found.

Trappers Lake had no benthos but the Molluscs Helisoma anceps and Amnicola limnosa were found in the littoral zone. Kingston Lake was devoid of benthos. Grand Sable Lake had very little benthos except for a few unidentified Oligochaetes, a tardigrade, the clam Anodonta grandis and a few Chironomus sp.

The fish populations from the lakes and streams of the park were not studied in this survey. However, data was available from the records of Mr. Leland R. Anderson, Michigan Department of Natural Resources. Table 2. 15 is a compilation of the data from the five large lakes in the park. Twenty-six species of fish representing nine families were recorded. The absence of fish in Table 2. 15 may not mean that the fish is not present in the lake but that it was not found during the sampling period.

Nine streams were surveyed for macrobenthos within the park and three outside the park. The streams were sampled on one occasion at a single 1/2 kilometer section of the stream, generally close to the mouth of the stream.

TABLE 2.15

FISH FROM THE LAKES OF PICTURED ROCKS NATIONAL LAKESHORE

	Chapel Lake	Beaver Lake	Little Beaver Lake	Kingston Lake	Grand Sable Lake
Salmonidae (Trout)					
Salvelinus namaycush (Lake Trout)	-	-	-	-	x
Salvelinus fontinalis (Brook Trout)	x	x	-	-	-
Salmo gairdneri (Rainbow Trout)	-	x	-	-	-
Splake	-	x	-	-	x
Osmeridae (Smelt)					
Osmerus mordax (Smelt)	-	-	-	-	x
Esocidae (Pike)					
Esox lucius (Northern Pike)	-	x	x	-	x
Cyprinidae (Minnow)					
Chrosomus eso (N. Redbelly Dace)	-	x	-	-	-
Notemigonus crysoleucas (Golden Shiner)	x	-	-	-	-
Notropis cornutus (Common Shiner)	x	-	-	-	-
Notropis hudsonius (Spottail Shiner)	-	x	-	-	-
Notropis stramineus (Sand Shiner)	-	x	-	-	-
Pimephales notatus (Bluntnose Minnow)	-	x	-	x	-
Semotilus atromaculatus (Creek Chub)	-	-	-	x	-
Catastomidae (Sucker)					
Catostomus commersoni (White Sucker)	x	x	x	x	x
Gasterosteidae (Stikleback)					
Eucalia inconstans (Brook Stickleback)	x	x	-	-	-
Centrachidae (Sunfish)					
Ambloplites rupestris (Rock Bass)	x	x	-	-	x
Lepomis cyanellus (Green Sunfish)	-	-	-	x	-
Lepomis gibbosus (Pumkinseed)	x	-	-	x	-
Lepomis macrochirus (Bluegill)	-	-	-	x	-
Micropterus dolomieui (Smallmouth Bass)	-	x	x	x	x
Perchidae (Perch)					
Etheostoma nigrum (Johnny Darter)	-	x	-	-	-
Etheostoma sp. (Darters)	x	-	-	-	-
Perca flavescens (Yellow Perch)	x	-	x	x	x
Percina caprodes (Log Perch)	-	x	-	-	-
Stizostedion vitreum vitreum (Walleye)	-	-	-	x	-
Cottidae (Sculpin)					
Cottus sp. (Sculpins)	x	-	-	-	-

x = present - = not found during survey

Data from Mr. Leland R. Anderson, Michigan Department of Natural Resources.

The Anna River was sampled at two sites and Beaver Creek was sampled at one site on two separate occasions. The results of the survey are shown in Table 2. 16.

Twenty-seven species of organisms were found including insects, Crustacea, Molluscs and sponges. The insect larvae were most frequent with twenty-one of the twenty-seven species. Six orders of insecta including the Coleoptera (bettles), Ephemeroptera (Mayflies), Hemiptera (Bugs), Odonata (Dragonflies and Damselflies), Plecoptera (Stoneflies) and the Trichoptera (Caddis Flies).

The streams are all fast flowing with large numbers of a few species. Generally, not more than four species were found in any one stream after an intensive search under the stones in the creeks. More intensive searches over a longer period of time would no doubt have revealed more species than were found in this preliminary survey. The dominant species found in most of the streams was Glossosoma sp., the "saddle-case" caddis, which makes its retreat (house) from small sand grains and the second most abundant species was _Cheumatopsyche sp._ Beaver Creek was sampled on two occasions, once on the 27th of August and once on the 20th of September. On the 27th of August, the dominant species was the fingernail clam _Sphaerium_ and on the 20th of September the caddisfly larva _Cheumatopsyche_ became dominant. The bug _Metrobates sp._ and the stonefly _Paragnetia media_ were absent during the first sampling period but were present on the second. The dragonfly _Progomphus sp._

TABLE 2. 16

THE FAUNA FROM THE STREAMS IN PICTURED ROCKS NATIONAL LAKESHORE

	Wagner Creek 29 Sept.	Anna River Above Sewage Plant 28 Aug.	Anna River Below Sewage Plant 28 Aug.	Tannery Creek 27 Aug.	Munising River 26 Aug.	Miners River 26 Aug.	Mosquito Creek 27 Aug.	Chapel Creel 27 Aug.	Spray Creek 27 July	Beaver Creek 27 Aug.	Beaver Creek 20 Sept.	Sullivan Creek 28 July	Hurricane Creek 28 July	Grand Sable Creek 28July
Coleoptera (Beetles)														
Donacia sp. (Donaciidae)	-	-	-	-	-	r	-	-	-	-	-	-	-	-
Ephemeroptera (Mayflies)														
Heptagenia sp. (Heptageniidae)	-	-	-	-	-	f	-	-	-	-	-	-	f	-
Isonychia sp. (Siphlonuridae)	-	-	-	-	-	-	f	f	-	-	-	-	-	-
Stenonema sp. (Heptageniidae)	-	-	-	-	-	-	-	-	-	-	-	-	-	f
Hemiptera (Bugs)														
Metrobates sp. (Gerridae)	-	-	-	-	r	-	-	-	-	-	-	-	-	-
Hydrometra sp. (Hydrometridae)	-	-	-	-	-	-	-	-	-	-	r	-	-	-
Odonata (Dragonflies and Damselflies)														
Progomphus sp. (Gomphidae)	-	-	-	-	-	-	-	-	-	f	-	-	-	-
Plecoptera (Stoneflies)														
Isogenus (Yugus) arinus (Perlidae)	f	-	-	-	-	-	-	-	-	-	-	-	-	-
Paragnetina media (Perlidae)	-	-	-	-	-	-	f	-	-	-	f	-	-	-
Petronarcys sp. (Petronarcidae)	-	-	-	-	-	r	-	-	f	-	-	-	-	-
Pteronarcys princeps (Pteronarcidae)	-	-	-	-	-	-	-	-	-	-	-	r	r	-
Trichoptera (Caddisflies)														
Brachycentrus sp. (Brachycentridae)	-	d	-	-	-	-	-	-	-	-	-	-	-	-
Cheumatopsyche sp. (Hydrophsychidae)		-	-	-	-	-	-	-	-	-	d	-	-	d
Drusinus sp. (Limnephilidae)	-	r	-	-	r	-	-	r	d	-	-	-	-	f
Glossosoma sp. (Glossosomatidae)	d	-	-	-	d	d	d	d	-	-	-	d	d	-
Helicopsyche sp. (Helicopsychidae)	-	-	-	-	-	-	-	-	-	-	-	-	-	r
Limnephilus sp. (Limnephilidae)	-	-	-	-	-	-	-	-	-	-	-	-	r	-
Neophylax sp. (Limnephilidae)	-	-	-	-	-	-	-	-	-	-	-	-	-	f
Phylocentropus sp. (Psychomyiidae)	-	-	-	-	-	-	-	-	-	-	-	r	r	-
Polycentropus sp. (Psychomyiidae)	-	-	-	-	-	-	-	f	r	-	-	-	-	-
Psychomyia sp. (Psychomyiidae)	-	-	-	-	-	-	-	r	-	-	-	-	-	-
Crustacea														
Gammarus pseudolimnaeus (Gammaridae)	-	f	-	-	f	-	-	-	-	-	-	-	-	-
Mollusca														
Aplexa hypnorum (Physidae)	-	-	d	-	r	-	-	r	-	-	-	-	-	-
Campeloma decisum (Viviparidae)	-	-	-	-	-	-	-	-	-	f	f	-	-	-
Promentus exacuous (Planorbidae)	-	-	-	-	-	-	-	-	-	-	-	r	-	-
Sphaerium sp. (Sphaeriidae)	-	-	-	-	-	-	-	-	-	d	f	-	-	-
Porifera														
Spongilla lacustris (Spongillidae)	-	-	-	-	-	-	-	-	-	f	-	-	-	f

r = rare f = frequent d = dominant - = not observed and the sponge Spongilla lacustris were present on the first sampling of Beaver Creek but absent on the second. The snail Campeloma decisum and the clam Sphaerium sp. were present on both occasions. The Anna River receives the effluent from the City of Munising sewage treatment plant and samples were taken above and below the outfall. Above the outfall the dominant species were the caddisfly Brachycentrus sp. and the crustacean Gammarus pseudolimnaeus was frequent. Below the outfall the only organism found was the snail Aplexa hypnorum. The bacteriological quality of the water was tested above and below the outfall on the 28th of August at 11:30 a.m. The total coliform/100 ml. count was 1400 above and 8,400 below, the fecal coliform count was 250/100 mls. above and 4400 below the outfall.

c. Pesticide, Herbicide and Toxic Metal Analysis

Pesticide and herbicide residue analysis was carried out on all of the water samples. In addition, pesticide and herbicide residue analysis was carried out on five representative species of fish from Lake Superior. Also, the fish were analysed for toxic metals, mercury and arsenic.

TABLE 2. 17

PESTICIDES AND HERBICIDES INVESTIGATED

Common Name	Chemical Name	Detection Limit * ng/Liter
1. Aldrin	1, 2, 3, 4, 10, 10-hexachloro-1, 4, 4, 5, 8, 8a-hexahydro-1, 4-endoexo-5, 8-dimethanonaphthalene	50
2. DDT	1, 1, 1-trichloro-2, 2-bis (p-chlorophenyl) ethane	100
3. DDD	2, 2-bis-(p-chlorophenyl)-1-chloroethylene	75
4. DDE	2, 2-bis-(p-chlorophenyl)-1, 1-dichloroethylene	75
5. Dieldrin	1, 2, 3, 4, 10, 10-hexachloro-6, 7-epoxy-1, 4, 4, 5, 6, 7, 8, 8a-octahydro-1, 4-endoexo-5, 8-dimethanonaphthalene	50
6. Endrin	1, 2, 3, 4, 10, 10-hexachloro-6, 7-epoxy-1, 4, 4a, 5, 6, 7, 8, 8a-octahydro-1, 4-endo, endo-5, 6-dimethanonaphthalene	75
7. Heptachlor	1, 4, 5, 6, 7, 8, 8-heptachloro-3a, 4, 7, 7a-tetrahydro-4, 7-methanoindene	50
8. Heptachlor Epoxide	1, 4, 5, 6, 7, 8, 8a-heptachloro-2, 3-epoxy-2, 3, 3a, 4, 7, 7a-hexahydro-4, 7-methanoindene	50
9. Lindane	gamma-1, 2, 3, 4, 5, 6-hexachlorocyclohexane	100
10. 2, 4-D	2, 4-dichlorophenoxyacetic acid	300
11. 2, 4, 5-T	2, 4, 5-trichlorophenoxyacetic acid	100
12. Silvex	2-(2, 4, 5-trichlorophenoxy)propionic acid	100
13. Toxaphene	chlorinated camphene	3000

(ng/Liter, nanograms/Liter is equivalent to parts per trillion)

* in the water samples

Table 2.17 shows the lowest significant detection limit for the pesticide and herbicide residues investigated using the methods previously described. Water samples from the eight Lake Superior sites, eight inland lakes and thirteen streams show no detectable traces of pesticide or herbicide residues. Five species of Lake Superior fish were tested for the pesticides and herbicides shown in Table 2.17, and also for mercury and arsenic. Traces of DDE were found in all five species of fish and DDD in three species of fish as shown in Table 2.18. No traces of mercury or arsenic were found in any of the fish tested.

TABLE 2.18

PESTICIDE RESIDUES IN FISH FROM LAKE SUPERIOR

	DDT ng/gm	DDE ng/gm	DDD ng/gm
Coho Salmon (Oncorhynchus kisutch)	nd	2,800	500
Lake Trout (Salvelinus namaycush)	nd	2,400	500
Whitefish (Coregonus clupeaformis)	nd	500	nd
White Sucker (Catostomus commersoni)	nd	1,400	nd
Dogfish (Amia calva)	nd	1,700	300

Results in ng/gm (parts per billion)

nd (not detectable) less than 250 mg/gm

all other pesticides and herbicides not detectable

The pesticide residue analysis performed on the rain water sample showed no detectable traces of any of the compounds listed in Table 2. 17. There were several compounds with strong electron capture affinity present but these did not appear to be of the chlorinated hydrocarbon or herbicide compound group.

Examples of the gas-liquid chromatographic analyses are presented in appendix A. There were traces of other organic materials, possibly other chlorinated compounds such as the poly chlorinated biphenyls in some of the samples.

4. Discussion

Lake Superior was sampled along the shoreline of the park at the 15 meter contour for various environmental quality parameters. The first sample was taken from Munising Bay which receives effluent from the City of Munising sewage treatment plant and a paper mill. The water quality is very similar to that of the other sampling stations and reflects the flow of water through the bay. Although the water in the bay is clear and of high quality the bottom sediments show the future trend of the bay. The bottom sediments contained over four percent organic matter and two species of oligochaetes (worms). Previous work (Adams and Kregear)[3] indicates that these benthic organisms are of the type usually found in eutrophic conditions.

The other seven sites showed sediments which are primarily sand except in station three which was rock. The sand is clean and contains very little organic matter which may indicate low productivity.

One of the criteria for water quality is the amount of nutrients present. It is thought that excessive algal growth will not be supported unless the nutrients nitrogen and phosphorus are above certain critical limits. The so-called critical limit for phosphorus has been reported to be 0.01 mg/L of soluble ortho-phosphate and 0.3 mg/L for inorganic nitrogen. Although other factors also influence excessive algal growth, this simplified picture works from the practical and operational viewpoint. The soluble ortho-phosphorus is less than the critical limit in all cases except sample eight by Grand Marais, which contained 0. 012 mg/ L soluble ortho-phosphate. All eight samples contained 0. 05 mg/ L of inorganic nitrogen which is considerably less than the amount which would be required to cause algal blooms. On a nutrient basis therefore, the water quality of Lake Superior along the park shoreline is very good. The algal populations reflect an essentially oligotrophic situation with the dominance of the diatom flora and absence of blue-green forms. The diatom Tabellaria fenestrata an oligotrophic form, is the dominant alga. Another common form is Dinobryon bavaricum which is usually present in oligotrophic waters. However, the presence of large amounts of Fragilaria capucina is of interest since Lake Erie showed a change from a flora dominated by Asterionella formosa, Melosira ambigua and Tabellaria fenestrata before 1950 to a flora dominated by Fragilaria capucina, Coscinocliscus radiatus and Melosira binderana after 1960. Also the frequent presence of Fragilaria crotonensis which is generally thought to be a more eutrophic species may indicate a more eutrophic condition for the lake than might formally be supposed, although a single sampling of the phytoplankton populations is insufficient basis for firm conclusions.

The zooplankton population consisted of twelve species and was dominated by the copepod Diaptomus sicilis at all eight sites. The second most common zooplankter was Daphnia galeata mendotae which is common in the other Great Lakes. Bosmina longirostris occurred at most stations in small numbers. The taxonomy of the North American Bosminas is in flux and the identification was made on the basis of the head pores and the pecten of the claw. Chydorus sphaericus is rarely present in the plankton except under highly eutrophic conditions but the variety C. s. minor is occassionally found in the open water. Sida crystallina is a littoral form and its occurrence in the plankton is probably accidental. Whitefish (Coregonus clupeaformis), Lake Trout (Salvelinus namaycush), Coho Salmon (Oncorhynchus kisutch), and White Sucker (Catostomus commersoni) fishes were examined for traces of mercury and arsenic. There were no detectable traces of either metal in cross-section portions of the caudal peduncle area of the fish (included flesh, bone and skin). The detectable limits of the methods used were 0.02 mg/kg. for the mercury and 0.4 mg/kg. for arsenic and the results are based upon the wet weight of the fish. The World Health Organization recommended safety limit for mercury is 0.05 mg/kg. (C & EN October 5, 1970), and the allowable maximum limit for mercury in food material recognized by the Food & Drug Administration is 0.5 mg/kg. (C & EN June 22, 1970). The U. S. Public Health Service has set a tentative recommended maximum mercury content for drinking water at 0.005 mg/L (Willing Water (AWWA), Vol. 14 No. 7 - April 15, 1970). A report (C & EN June 22, 1970) of mercury content of various fishes from Lake Erie and the St. Clair River showed from 0.24 to 3.57 mg/kg. mercury in the edible portions of the fish. Mercury is accumulative, from diet or water sources, and can have a concentration factor of as much as 3000 to 1 (Science, 17 July, 1970, Vol. 169 No. 3942). This indicates that water containing as little as 0.005 mg/kg. of mercury could produce fish containing up to 15 mg/kg. of this metal.

Information concerning arsenic in the environment is not as extensive and comprehensive as in the case of mercury. In general, it would appear that from 1 to 3 ppm as in water may be toxic to some fish (Water Quality Criteria, 2nd Ed. State Water Quality Control Board of California). The reported human toxic level was 130 mg and the accumulative action of arsenic is not as high as that of mercury, so apparently much more arsenic can be tolerated in the food chain.

The fish were also analyzed for the pesticide and herbicides shown in Table 2. 17. The pesticides most frequently found in fish have been DDT and its metabolic derivatives DDD and DDE. While DDD and DDE are used,

as pesticides themselves, their presence in animal tissue may indicate that DDT had been ingested and metabolized. Controlled studies indicate conversion of DDT to DDE in animals, fish and insects but also DDD has been found in animal liver tissue. It would appear then that if the fish contained DDT, it would have been ingested fairly recently before sampling, whereas if only DDE was evident, the ingestion would have occurred at some earlier time or in very small amounts and accumulated as a metabolic product. The five species of fish investigated for this study showed only DDE in significant quantity, with some instances of traces of DDD and DDT, as shown in Table 2. 18.

The larger lakes of the park, Chapel Lake, Little Beaver Lake, Beaver Lake, Trappers Lake and Grand Sable Lake are all of an unusual type and do not fit into the classification of lakes presented at the beginning of this chapter. The lakes have some of the characteristics of both dystrophic lakes and eutrophic lake types, certainly they are of a unique type. The waters are slightly alkaline in reaction and therefore differ from the so-called dystrophic lake type. Also, the dissolved salts and specific conductance is higher than one would normally expect in the dystrophic lake type. A further important departure from dystrophy is the high concentration of nutrients with phosphorus generally over the amount necessary to produce algal blooms. The inorganic nitrogen is below that amount thought necessary to produce nuisance algal blooms although the organic nitrogen content is high indicating that the nitrogen is present in the form of organic production.

The bottom sediments in Little Beaver Lake, Beaver Lake, Trappers Lake and Kingston Lake, are highly organic and unconsolidated existing in a suspension without any well defined sediment water interface. These type of sediments are generally characteristic of the dystrophic lake type as is the brown water of these lakes. The unconsolidated nature of the sediments in Little Beaver Lake, Beaver Lake, and Trappers Lake accounts for the lack of benthos in these lakes since the organisms have no solid medium on which to live. Also, all of the lakes are probably subject to complete oxygen deficits in the bottom waters during the summer which would effectively exclude most benthic forms.

From the production viewpoint the lakes of the park are eutrophic with heavy crops of algae and zooplankton during the summer months. The species of algae in the lakes are those which are found in eutrophic environments. The blue-green algae which are generally responsible for nuisance conditions in lakes are dominant in most of the lakes with the exception of Chapel Lake and Kingston Lake. In the case of Chapel Lake the sampling of the lake did not take place until 15 October which is late in the season, and the blue-green algae may have been present earlier in the year. The dominant phytoplankton in Chapel Lake was the diatom Asterionella formosa and Tabellaria fenestrata was frequent; both algae are generally associated with oligotrophic lakes. However, Fragilaria crotenensis is frequent and this diatom is generally associated with eutrophic environments.

Kingston Lake was dominated by the diatom Melosira islandica which is generally considered to be an oligotrophic species and the blue-green algae Aphanocapsa rivularia occurred rarely. Kingston Lake is one of the better lakes in terms of low nutrients and dissolved salts which may account for the dominance of oligotrophic species. However, the lake certainly appears to be eutrophic judging from the heavy crop of both phyto and zooplankton. The other lakes were dominated by the blue-green algae and would be typically classified as eutrophic. The zooplankton of the lakes was quite diverse with thirty-five species present and the dominant species was the calanoid copepod Diaptomus oregonesis.

The rotifera were poorly represented in the plankton with only a single species Asplanchna priodonta present in three of the lakes.

Many of the most popular game fish of the Great Lakes region are found in these lakes. These game fish include the Lake Trout, Brook Trout, Rainbow Trout, Splake, Northern Pike, Smallmouth Bass and Walleye. There is also a wide variety of minows and other small fish which can be used as food by the larger fish. These include the Smelt, Redbelly Dase, Shives, Bluntnose Minnow and Creek Chub and Log Perch.

The Sunfish or "pan fish" are also found in the park. These fish are very popular especially with children because they can be caught with the simplest of equipment. The sun fish include the Rock Bass, Green Sunfish, Pumpkinseed, and Blue Gill.

In order to understand the odd character of the lakes the history of the area has to be considered. In the late 1750's the first indications of development of the forest resources occurred. With the advent of the Detroit, Mackinac, and Marquette railroad in 1880 the logging industry boomed until the turn of the century when the majority of the logging in the virgin areas took place. Some areas such as Kingston Plains were stripped of timber and swept by recurrent fires. The intensive logging and recurrent fires must have caused considerable erosion and nutrient deposition in the lakes of the park thereby aiding in the eutrophication of the lakes. The most oligotrophic lakes appear to be Grand Sable Lake and Chapel Lake followed by Beaver Lake, Kingston Lake, Little Beaver Lake and Trappers Lake. Miners Lake and Little Chapel Lake hardly are worthy of the title Lake since the former is little more than an expansion of the Miners River and the latter is a pond.

The streams of the park are all characteristically brown water streams draining the swampy areas in the Munising Moraine. The streams generally had gravel and sand bottoms and were shallow, cold and well aerated. The water chemistry of the streams varied considerably especially with respect to the concentration of calcium and magnesium and the ratio between the two salts. The streams are all alkaline which may reflect the ground water coming through the underlying dolomite and limestones. The streams have high nutrient contents and those which flow into lakes may be the cause of further eutrophication in the lakes. The majority of the fauna found in the streams were insect larva of which there was a considerable diversity. Each stream had a maximum of six species, but generally less, out of a possible twenty-seven which were observed. The most common organism was the caddis larva Glossosoma sp. which was dominant when it occurred. In the streams where Glossosoma sp. was not dominant the caddis larvae Cheumatopsyche sp. or Brachycentrus sp. were the most abundant. Beaver Creek was sampled on two occassions and the dominant organism changed from the fingernail clam Sphaerium sp. on the 27th of August to Brachycentrus sp. on the 20th of September, which illustrates the seasonal influence. It is usual in streams for the dominant forms to change throughout the season as different insects hatch out and leave the stream.

Wagner Creek, the Anna River, and Tannery Creek were all special cases and lie outside of the park. Wagner Creek had a chloride content of 10.5 mg/L and a sodium content of 5 mg/L. This relatively high chloride content probably comes from the ground water since it is known[4] that high chloride water occurs in some parts of Alger County. The Anna River receives the sewage effluent from the city of Munising and samples from above and below the outfall show dramatic differences in terms of the fauna. However the water quality differences were not great enough to be sure that the reason for the difference in the fauna was not due to some other environmental difference such as bottom sediment, flow rates, shade, etc. The Tannery Creek in the section investigated was completely destroyed from the faunistic viewpoint by construction work being undertaken. Erosion had caused much deposition in the stream and the sand was shifting thus causing an unstable bottom environment which was not conducive to stream fauna.

In conclusion, the Pictured Rocks National Lakeshore and Recreational Area has a number of diverse aquatic environments ranging from the oligotrophic waters of Lake Superior to dystrophic and eutrophic inland lakes, and many streams of varying character. The lakes are generally highly productive and present an interesting biological problem as to how they evolved into their present condition. The fish and other aquatic organisms of the park combine a richness and diversity of life which will present a great challenge to the park planners and managers responsible for these resources.

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[3] Proc 12th Conf. Int. Assoc. Great Lakes Res. 1-20 (1969).

[4] Vanlier, K. E. (1963). Reconnaissance of the Ground-Water Resources of Alger County, Michigan. Dept. of Conservation, Geological Survey Division, Michigan.

CHAPTER III

THE TERRESTRIAL ENVIRONMENT

1. General

A survey of the terrestrial environment was not a part of the contracted study with the exception of pesticide and herbicide analysis of soil, grass and leaves from three campgrounds. A total environmental survey, however, should include a study of the terrestrial environment.

An analysis of the terrestrial environment should contain information on the geology, the soils, the vegetation and the wildlife present in the area, therefore a brief description of these important aspects is given for the sake of completeness.

The geologic history of Alger County and the Pictured Rocks National Shoreline begins early in the geologic time with the formation of masses of granite, schist and other precambrian rocks which are mantled by Paleozoic and glacial sediments. The early and middle cambrian sediments were deposited in an area similar to but larger than Lake Superior and is represented by the Jacobsville sandstone. The Late Cambrian sediments also deposited in the Lake Superior basin consist of the Munising Sandstone. The Munising Sandstone is overlain by a thick sequence of sandstone, sandy dolomite and domomite. Although the rocks are exposed only at widely separated localities the sequence can be differentiated as a single unit. During the Middle Ordovician the Michigan Basin received large amounts of soluble minerals from adjacent oceans and land areas. The compaction and lithification of the sediments formed the Black River and Trenton Limestones. The shale, domomite and limestone of the Late Ordovician and Silurian, which once extended into Alger County, are no longer present as a result of the Post Paleozoic erosion.

The most recent history of the area is recorded in its physiographic features and the deposits of unconsolidated sand gravel silt and clay. During the glacial period the area was covered by thick sheets of glacial ice and inundated by glacial lakes. The topographic features of the area are largely related to the erosional and depositional processes associated with glacial lakes. The most spectacular features are the rock escapements known as Pictured Rocks along the Lake Superior shoreline.

The hills in the park are part of the Munising moraine formed from the materials deposited as the ice retreated toward Canada. Other prominant features in the park include the Kingston outwash plain formed from the outwash of the melting glacial ice. Kingston Lake was formed as a depression in the outwash plain in contrast to Beaver Lake which was originally a bay of Lake Superior and separated by the build-up of bars, beaches and dunes across the mouth of the bay. Dunes and small deposits of windblown sand are scattered throughout the area although the Grand Sable Dunes covering above ten (10) square kilometers and up to 120 meters high is the largest active area where the dunes are still shifting due to the wind. The more inland dunes are forested and inactive.

In general the soils of the park are light colored, well drained sandy soils with inclusions of some locally poorly drained organic soils to the east of Beaver Basin. To the west of Beaver Basin the soils are generally light colored well drained sandy loams with extremely stony areas and some local poorly drained mineral and organic soils.

The climate because of the mid-continental position is subject to great extremes of weather conditions although winter temperatures are somewhat modified by the influence of Lake Superior. The normal monthly July temperature recorded at nearby Marquette is 16^{o}C and the normal January temperature is -8^{o}C. The mean annual temperature is about 6^{o}C. The frequent passage of cyclonic (low) storms produce winds of hurricane force which generally occur between October and May. Wind velocities of up to 150 kmph. were recorded in one storm during 1950. The average annual precipitation is about 86 centimeters and during normal winters snowfall is generally over 250 centimeters.

The forests of the area are under intensive management and are logged on a sustained yield basis. The forests of the park are particularly attractive since there is a considerable mixture of evergreen and deciduous trees. The main softwoods present are the Pine, Cedar, Hemlock, Balsam Fir, Tamarack, and Spruce. The hardwoods present are the Sugar Maple, Yellow Birch, Beech, Basswood, Red Oak, White Oak, Ash, Elm, Red Maple, Balsam, Poplar, Aspen, and the Paper Birch. There is a great variety of wildlife within the park including Deer, Black Bear, Ruffed Grouse, Woodcock, Sharptails, and the Snowshoe Hare.

2. <u>The Pesticide and Herbicide Survey</u>

A brief survey of the pesticide residues from three of the campsites was undertaken. The survey consisted of single samples of soil, grass and leaves from Little Beaver Lake, Kingston Lake and Au Sable Point campgrounds. The samples were taken near the well at each site.

The soil sample from Little Beaver Lake campsite was taken on 27 June, 1970. The analysis showed the presence of 5.1 ppb DDE and 19.4 ppb DDT. The DDE concentration could also be interpreted as o, p'-DDD or Dieldrin but it is more likely to be DDE. A soil sample from the Kingston Lake campsite was obtained on 6 August, 1970. No pesticides or herbicides were detected in the sample. The Au Sable Point campsite soil sample was obtained on 5 August, 1970. The analysis indicated the presence of 3.1 ppb DDE, 3.0 ppb p, p'-DDD and 15.6 ppb DDT.

Samples of various tree leaves including Maple, Birch, Aspen and Poplar were composited to represent the foliage from three of the park campsites. The chromatographed extracts of the leaf samples from Little Beaver Lake and Au Sable Point campsites indicated that none of the pesticides listed were present at the levels measured. The tree leaf samples from the Kingston Lake campsite were quite different from the other two samples because the extract contained more unknown constituents with electron capturing characteristics. A major constituent of the extract corresponded to Lindane, which would indicate the presence of 5,300 ppb. This same compound appears in the grass sample extract but not in the soil.

Three samples of grass, from Little Beaver Lake, Au Sable Point and Kingston Lake campsites were analyzed for pesticides and herbicides similar to the soil and leaf samples. Little Beaver Lake campsite sample showed no evidence of the listed pesticides and herbicides which represents a minimum detection limit of 50 ppb. The Au Sable Point campsite did not have grasses growing in it, so a sample of young ferns, (Dryopterus felix-mas) growing profusely in the area, was taken. The extract from this showed evidence of 90 ppb lindane. The grass sample from the Kingston Lake campsite showed evidence of 130 ppb lindane.

The results indicate that pesticides are present at the campsites but more samples and further intensive study should be undertaken to define the extent of potential pesticide contamination in the campgrounds.

CHAPTER IV

THE AIR ENVIRONMENT

1. General

A program of both short term and long term air monitoring was performed to assess the quality of the air in the park and to demonstrate monitoring techniques. The short term monitoring included both particulate matter and sulfur dioxide while the long term monitoring was limited to particulate matter only.

The short term air monitoring was performed over a large area (see figure 4.1) at 14 sampling sites while the long term monitoring was conducted at the park Ranger Station at Sand Point for a continuous period of 28 days.

2. Methods

The short term air monitoring was performed with a portable air monitor to collect particulate matter and sulfur compounds. The analyses were then performed by weight and iodometric titration respectively at the Limnetics laboratories. The long term monitoring was performed in accordance with the Standard Method of Test for Particulate Matter in the Atmosphere (American Society for Testing and Materials Specification D-1704-61). In the above procedure, the particulate matter of the atmosphere is collected with an Automatic Tape Sampler which filters air through a paper tape for a programmed period of time. The tape was then returned to the Limnetics laboratory where an

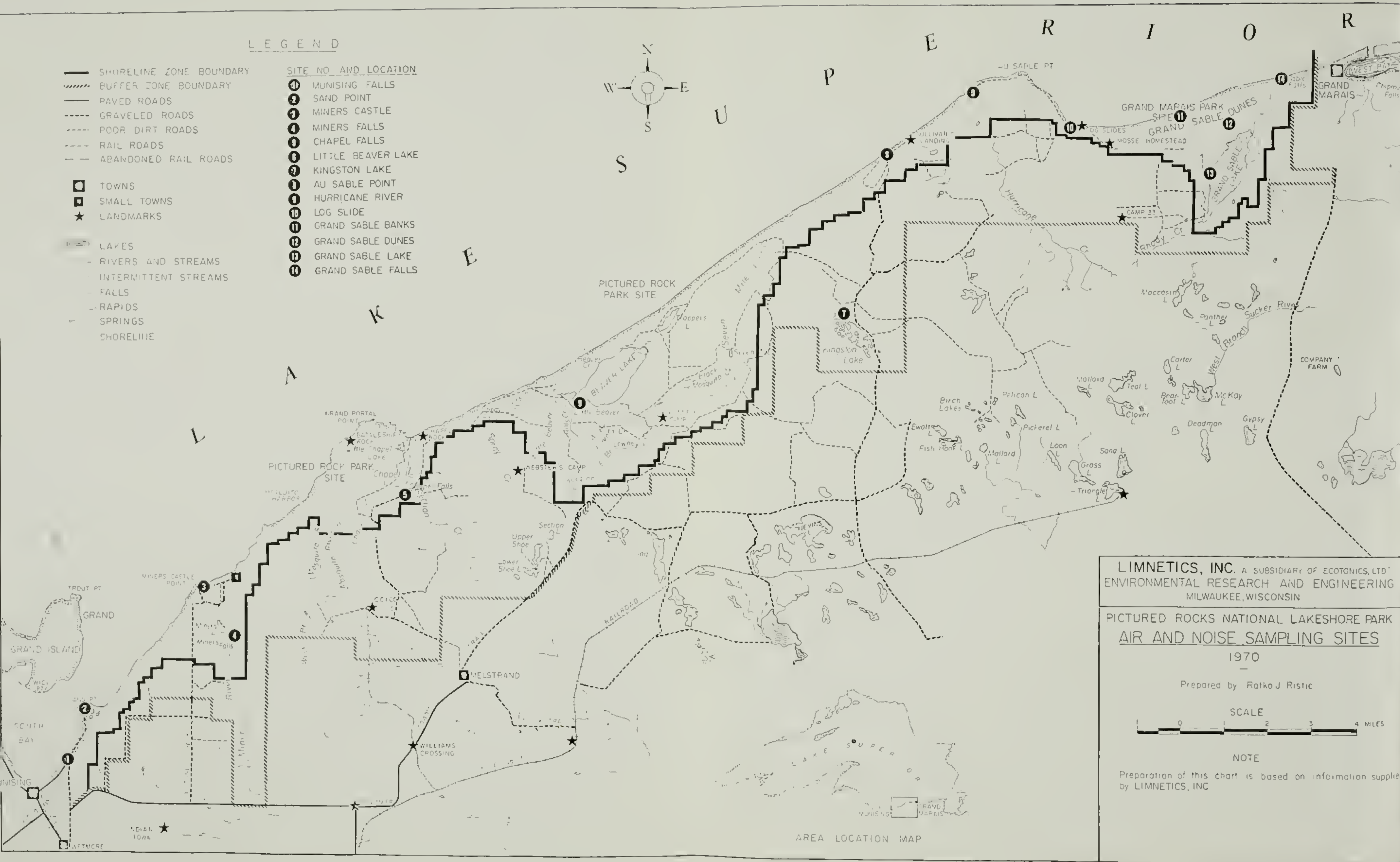

LAKE SUPERIOR
LEGEND
SHORELINE ZONE BOUNDARY
BUFFER ZONE BOUNDARY
PAVED ROADS
GRAVELED ROADS
POOR DIRT ROADS
RAIL ROADS
ABANDONED RAIL ROADS
TOWNS
SMALL TOWNS
LANDMARKS
LAKES
RIVERS AND STREAMS
INTERMITTENT STREAMS
FALLS
RAPIDS
SPRINGS
SHORELINE
SITE NO. AND LOCATION
1 MUNISING FALLS
2 SAND POINT
3 MINERS CASTLE
4 MINERS FALLS
5 CHAPEL FALLS
6 LITTLE BEAVER LAKE
7 KINGSTON LAKE
8 AU SABLE POINT
9 HURRICANE RIVER
10 LOG SLIDE
11 GRAND SABLE BANKS
12 GRAND SABLE DUNES
13 GRAND SABLE LAKE
14 GRAND SABLE FALLS
N
S
E
W
AU SABLE PT
GRAND MARAIS
GRAND MARAIS PARK SITE
GRAND SABLE DUNES
GRAND SABLE LAKE
PICTURED ROCK PARK SITE
PICTURED ROCK PARK SITE
Kingston Lake
MELSTRAND
GRAND
GRAND ISLAND
COMPANY FARM
AREA LOCATION MAP
LIMNETICS, INC. A SUBSIDIARY OF ECOTONICS, LTD.
ENVIRONMENTAL RESEARCH AND ENGINEERING
MILWAUKEE, WISCONSIN
PICTURED ROCKS NATIONAL LAKESHORE PARK
AIR AND NOISE SAMPLING SITES
1970
Prepared by Ratko J. Ristic
SCALE
0 1 2 3 4 MILES
NOTE
Preparation of this chart is based on information supplied by LIMNETICS, INC.

FIGURE 4.1

optical procedure was employed to measure the opaqueness of the tape to predict the relative amounts of collected matter.

Appendix B presents a detailed explanation of the air monitoring and analysis methods used during this survey.

3. Results

Table 4. 1 lists the results of the short term air monitoring. Two of the samplings were purposely performed in adverse conditions in order to obtain some idea of significant air pollution levels. The Little Beaver Lake campsite air sample was taken in the evening, with the sampler located about 100 feet down wind from the several campfires buring in the campgrounds. Also the Miner's Castle sampling was performed at the edge and down wind from the gravel-surfaced auto parking lot which was quite busy at the time. These examples show the adverse effects of smoke and gravel dust on the air quality.

The long term air monitoring data is illustrated in Figures 4. 2 through 4. 4. The Automatic Tape Sampler adjusted for a four hour sampling period, has an unattended monitoring capacity of 40 days. However, the Automatic Tape Sampler operation was disrupted on September 17, 1970 due to an electrical power failure. Consequently, only 28 days of continuous data was collected during the 40 day testing period.

TABLE 4.1

AIR QUALITY ANALYSIS

2 Hour Monitor

SITE	Date	Air Volume Liters	Particulates µg/L	Sulfur Dioxide ppm
1. Munising Falls	9/28/70	240	< 1	< 0.03
2. Sand Point	8/4/70	240	< 1	< 0.03
3. Miners Castle	8/7/70	240	1.3	< 0.03
4. Miners Falls	8/7/70	240	< 1	< 0.03
5. Chapel Falls	9/27/70	240	< 1	< 0.03
6. Little Beaver Lake	8/7/70	120	8.9	0.13
7. Kingston Lake	6/28/70	120	1.0	< 0.03
8. Au Sable Point	8/5/70	240	< 1	< 0.03
9. Hurricane River	8/5/70	240	< 1	< 0.03
10. Log Slide	8/5/70	240	< 1	< 0.03
11. Grand Sable Banks	10/15/70	240	< 1	< 0.03
12. Grand Sable Dunes	10/16/70	240	< 1	< 0.03
13. Grand Sable Lake	8/6/70	240	< 1	< 0.03
14. Grand Sable Falls	8/6/70	240	< 1	0.10

Figure 4. 2 in the results section presents the air data as percent of light transmittance. Figure 4. 3 presents the same data in terms of Coh (Coefficient of Haze) units per 1000 ft. of air sample. A statistical summary of the air data is given in Figure 4. 4.

4. Discussion

The environmental quality of the atmosphere depends on several factors including the physical and chemical composition of the air, which is normally composed of the gases nitrogen (approx. 78%) and oxygen (approx. 21%) and many other trace gases (approx. 1%) along with suspended and settling matter. According to the First Annual Report of the Council on Environmental Quality,[1] five main classes of pollutants are deposited into the air over the United States. These classes are carbon monoxide, particulates, sulfur oxides, hydrocarbons and nitrogen oxides. The sources of these pollutants include transportation, fuel combustion in stationary sources, industrial processes, forest fires, agricultural burning, coal waste fires, solid waste disposal, and natural sources such as the flowering and non-flowering plants which deposit pollen and spores into the air.

The automobile is considered the largest single source of air pollutants, especially in urban areas, where most of the air pollution studies have been made.

Following carbon monoxide, which is primarily emanated from internal combustion engines, particulates and sulfur oxides together are the largest group of pollutants with over 60 million tons being released per year. This study

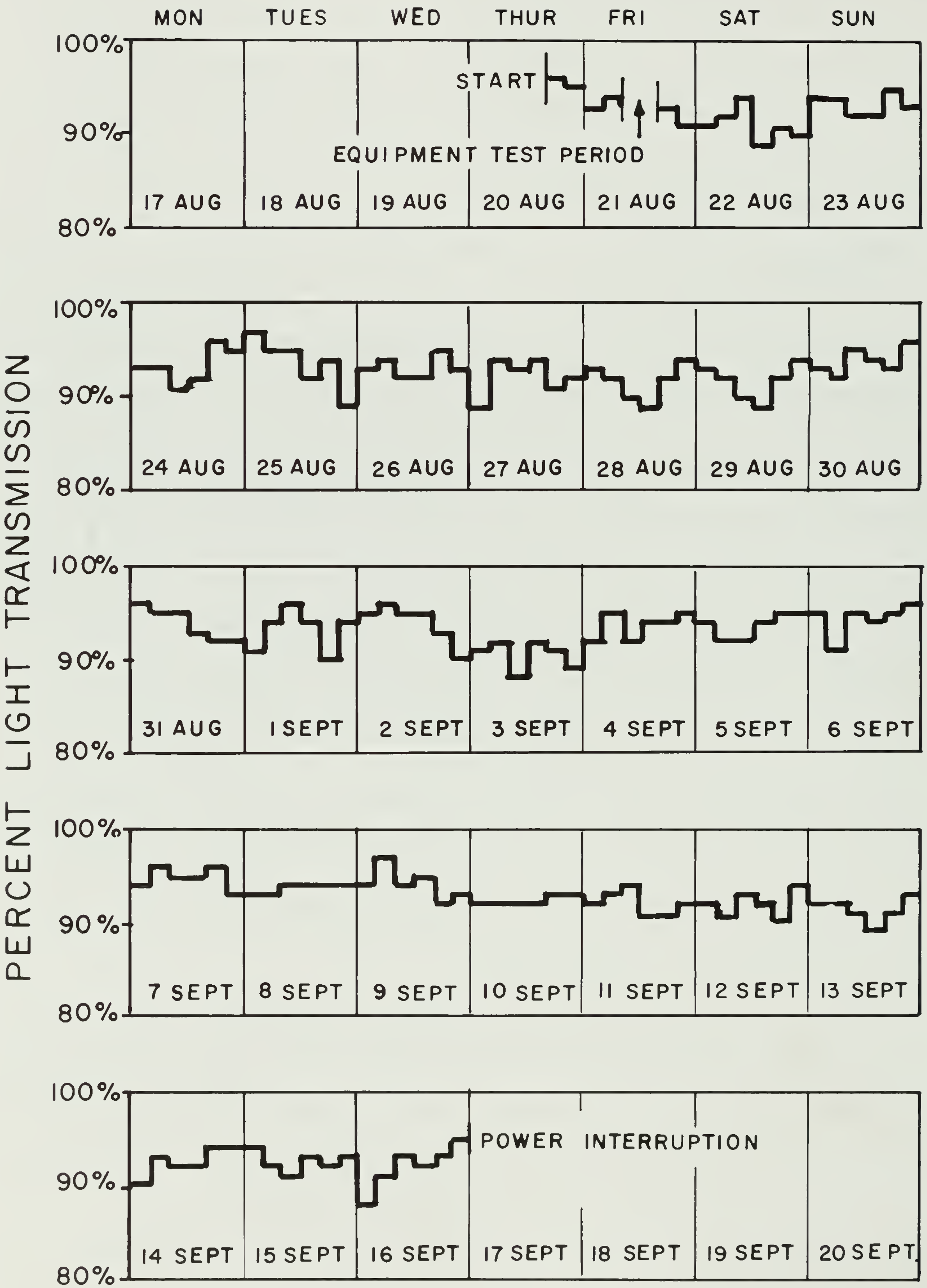


FIGURE 4.2

AIR DATA AS PERCENT OF LIGHT TRANSMISSION

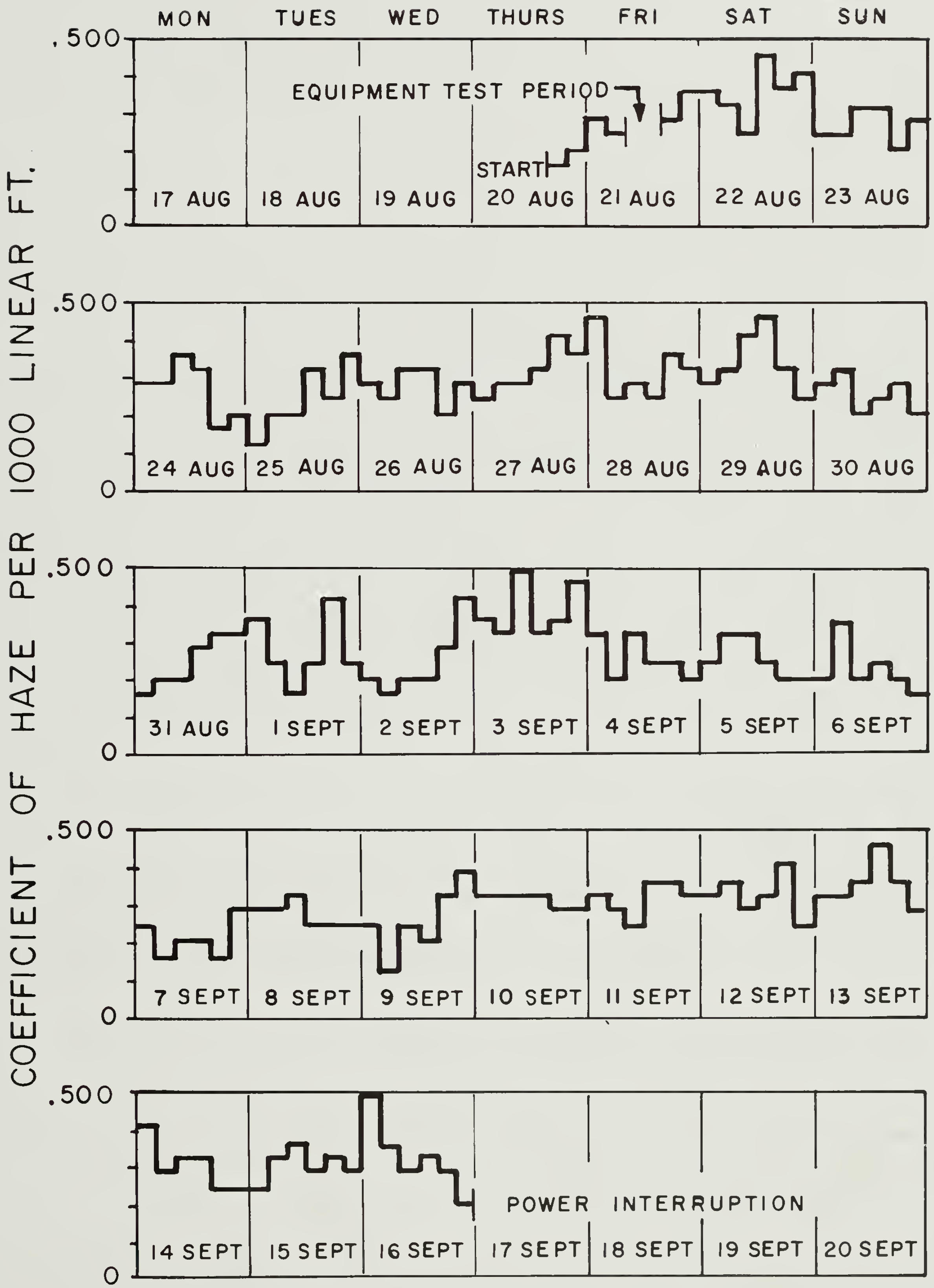
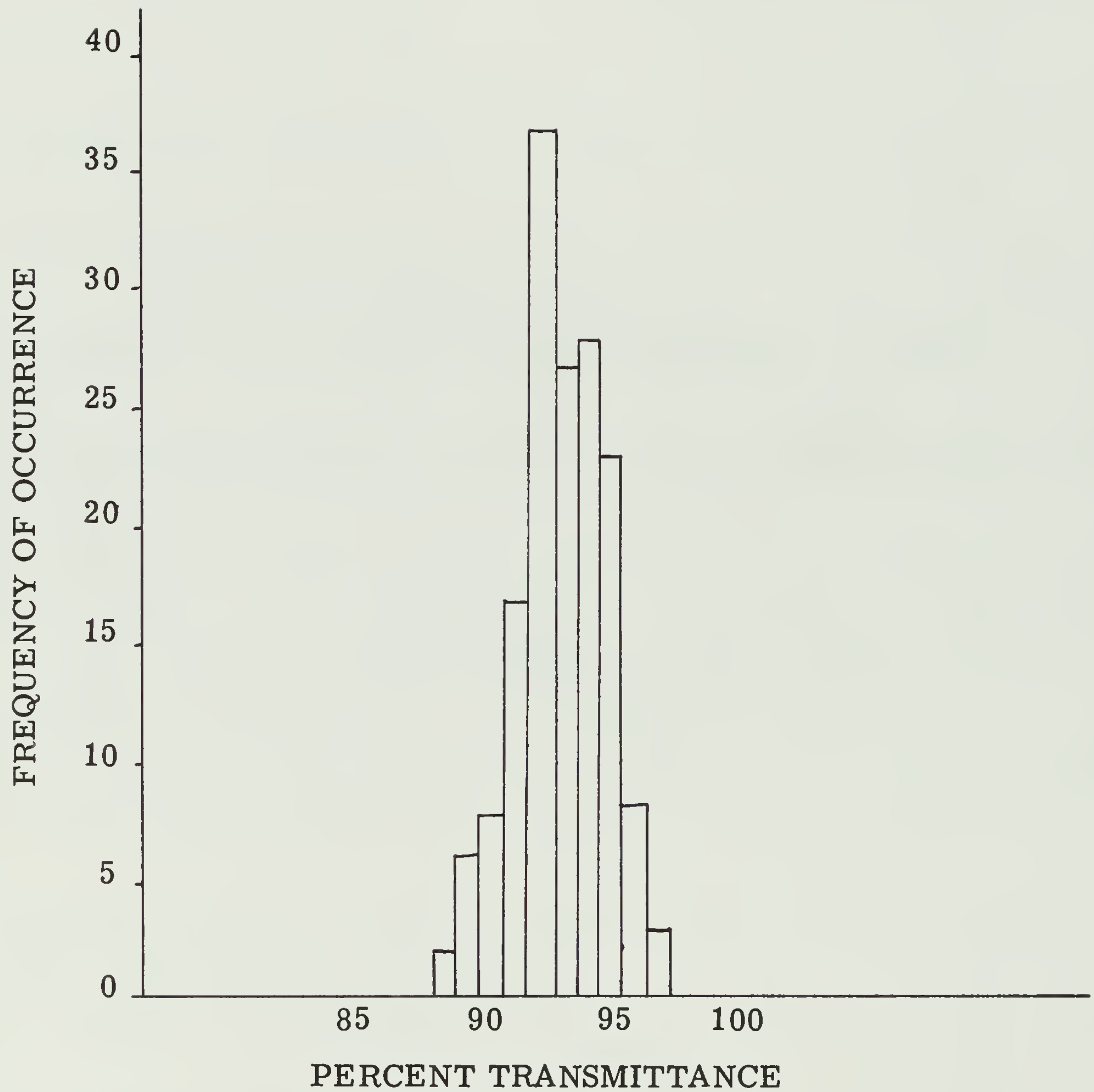


FIGURE 4.3

AIR DATA AS COEFFICIENT OF HAZE



Sample Mean = 93% Transmittance
Sample Median = 0. 289 Coh units/1000 ft. air

Sample Range: 88 to 97% Transmittance
0. 528 to 0. 127 Coh units/1000 ft. air

Sample Std. Deviation = 1. 887%

FIGURE 4. 4 STATISTICAL SUMMARY OF LONG TERM AIR DATA

chose the particulates and sulfur oxides to be measured based upon their importance and relative ease of monitoring. However, a complete study of air quality must take into consideration all possible pollutants in a particular area.

Extensive air quality criteria have been developed for particulates and sulfur oxides by the U. S. Department of Health, Education, and Welfare.[2,3]

Particulate matter consists of very fine particles, from many sources, floating in and falling through the air. Most particulates in the air range between 0.1 μ (microns) to 10 μ in size. Very small particles (0.1 to 1 μ) originate from condensation and combustion products, while larger particles are produced by comminution ("grinding up") of matter. Particles between 1 and 10 μ include local soil and fine dusts emitted by industrial processes. Particles larger than 10 μ may result from such things as road construction and wind erosion, but these particles tend to settle rapidly. Several methods are available for monitoring particulates including the high volume sampler and the paper tape spot sampler which employs an optical procedure for analysis, such as used during this program.

According to several standards, particle concentrations expressed in annual mean values should be well below .2 μg/L (micrograms per liter), however, 24 hour mean values normally can be three to seven times higher than annual values. The highest concentration times are during the winter when additional heating fuel is being used and peak values correspond to hours of greatest human and transportation activity such as the morning and late afternoon rush hours. The lowest concentration times are usually during the summer. These statements reflect conditions near urban areas and are not necessarily truefor rural areas such as the park.

During this monitoring program carried out in the late summer, it appears that the long term particulate matter monitoring as expressed in Coh units accurately reflects the very good quality of air in the park area. The day to day fluctuations of the Coh readings are probably only caused by varying meteorological conditions. (Appendix D presents the meterological data recorded during the survey period.) There are no acceptable universal standards for Coh units but many states such as New Jersey consider the Coh range of 0 to 0.9 per 1000 lineal feet of air as the lightest range of concentration. Colorado has adopted a standard of 0.5 Coh units per 1000 feet of air as acceptable when averaged over a 3 month period.

The particulate matter measurements made with the short term monitor are not considered significant. Due to the very low amounts of air sampled, the possible detection limits are far too high when compared to the expected very low concentrations to be found. The high volume air sampler must be used to detect low particulate concentrations and the tests should be run continuously for at least 24 hours (and repeated daily). This requirement will impose a difficulty since line power is generally not available in the park. Much more work is needed to develop portable high volume air samplers for the above function. In addition, research into the non collection methods for monitoring particulates, such as condensation nuclei counters, should be carried out for park monitoring.

Sulfur oxides are common atmospheric pollutants which originate mainly from combustion processes of fossil fuels, such as coal and oil, which contain sulfur. Sulfur dioxide is a colorless gas which can be detected by taste in concentrations above .3 ppm and has a pungent, irritating odor above 3 ppm. The importance of this gas with respect to air pollution is multiplied by its ability to react with other materials in the atmosphere forming sulfur trioxide, sulfuric acid and salts of sulfuric acid. Some effects of high levels of sulfur dioxide are very important.

Sulfur dioxide is the major sulfux oxide air pollutant and was measured during this survey. The possible damaging effects of significant levels of sulfur dioxide in the air is an extremely serious and complex matter which is beyond the scope of this report. The following brief discussion of the results is limited to only the essential points and the reader is referred to reference[3] for a detailed analysis of the subject.

Sulfur dioxide levels in urban areas are considerably higher than in rural areas and the SO_2 levels measured within the park are considered very low. Some urban areas of high congestion experience SO_2 levels in the .1 to 1 or more ppm range while the park levels were generally below .03 ppm. Furthermore, 2 hour sample levels normally range many times higher than annual mean values, which are used for air criteria. Certain criteria have been proposed for many different considerations such as effects on materials and toxicological effects on man and animals. However, one of the lowest acceptable criteria levels is that recommended to avoid long term effects on vegetation; which is .03 ppm as an annual mean value. Above this level, chronic plant injury and excessive leaf drop may occur. One example of this effect is the brownish-redish discoloration of pine needles due to the slow build-up of sulfate in the plant tissue. This type of discoloration is occasionally apparent in localized parts of the park and probably due to a combination of many factors including frequent local campfires.

Long term single station monitoring of the park's air quality should be conducted over a period of at least one year to establish annual mean values of air pollutants. Many continuous air monitors are now becoming available that could perform such a function, provided 110 vac line power is available. Automated recording of SO_2 levels is possible using conductometric methods which draw air through prepared solutions and the SO_2 concentration is estimated from the conductivity of the final solution. This is a general method, rather than specific, and certain precautions are necessary to elimate other pollutants which could also effect conductivity. Continuous monitoring over a very long period is especially required in areas of very low air pollutants, such as the park, to accurately determine the low level readings. In addition, remote sensing surveys using infrared and other optical techniques should be considered to assess the year to year condition of the park's plants and forests.

In summary, the air quality of the park is presently considered very good. Long term, continuous monitoring of the air over an extended period should be considered to accurately assess the total picture.

REFERENCES

[1] First Annual Report of the Council on Environmental Quality (1970).

[2] Air Quality Criteria For Particulate Matter, U. S. Department of Health, Education, and Welfare (1969).

[3] Air Quality Criteria For Sulfur Oxides, U. S. Department of Health, Education, and Welfare (1969).

CHAPTER V

THE NOISE ENVIRONMENT

1. General

Three different methods of monitoring the park's noise environment were used during this survey at the request of the National Park Service. These methods were used to attempt to charcterize the park's present noise environment and to demonstrate possible methods for future surveys. These methods are:

a. Sample noise recordings taken at 14 noise sampling stations(see figure 4. 1)

b. 24 hour continuous tape recordings taken at the three park campgrounds. Little Beaver Lake, Kingston Lake and Au Sable Point.

c. 30 day continuous integrated noise recordings taken in the Beaver Lakes Basin area.

The data for the first two methods is on magnetic tape records and has been supplied to the National Park Service separately. Only a brief summary of the tape records is presented herein. The third method of noise recording presents graphical "noise" records which are presented and analyzed in the following report. This method, referred to as Integrated Noise

Recording was developed by Limnetics engineers to produce visible long term noise records in an economical manner.

2. Methods

The sample noise recordings were made with a portable AIWA-TP-728 Tape Recorder. The 24 hour noise recordings were made with the Soundscriber Model S-124, 24 hour Magnetic Tape Recorder-Reproducer. The 30 day integrated noise recordings were made with the Limnetics Integrated Noise Recorder. All noise level recordings were made with the General Radio Sound Level Meter type 1565-A, using the weighted A scale. A detailed description of the equipment used is given in Appendix C.

3. Results

a. Sample Noise Recordings

15 to 30 minute tape records were taken at the 14 air and noise sampling stations within the park in a random manner. The noise level records are presented in Figures 5.2 through 5.16. Some locations were recorded more than once for comparative purposes. Following is a brief summary of the results:

FIGURE 5.2
LITTLE BEAVER CAMPGROUND
June 27, 1970
8:00 P.M.

The campground area had a moderate level of wildlife noises, comprised of bird calls and an occasional chipmunk or squirrel. The bird calls were very

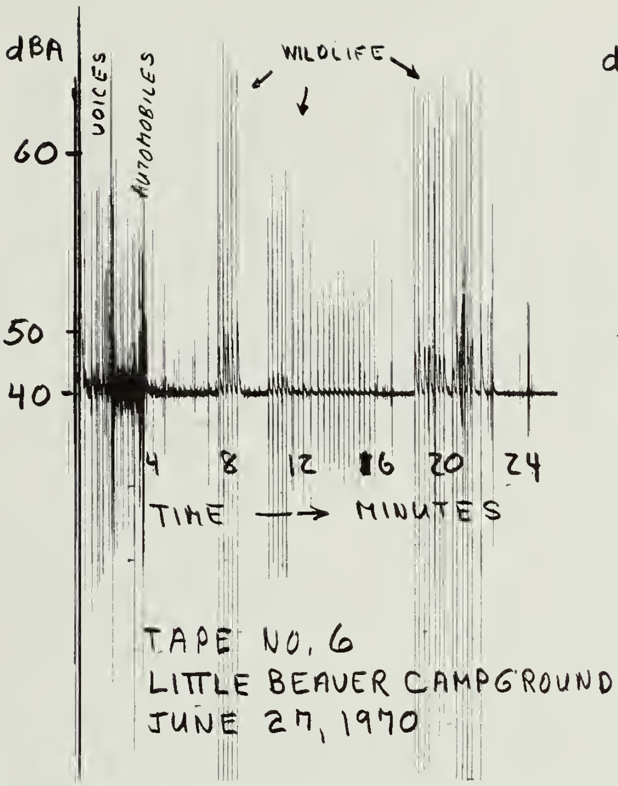


FIGURE 5.2

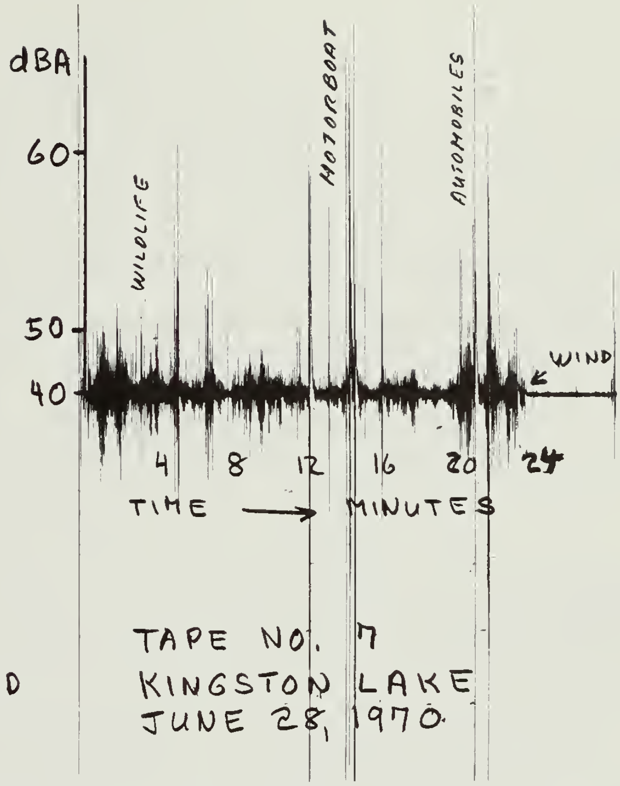


FIGURE 5.3

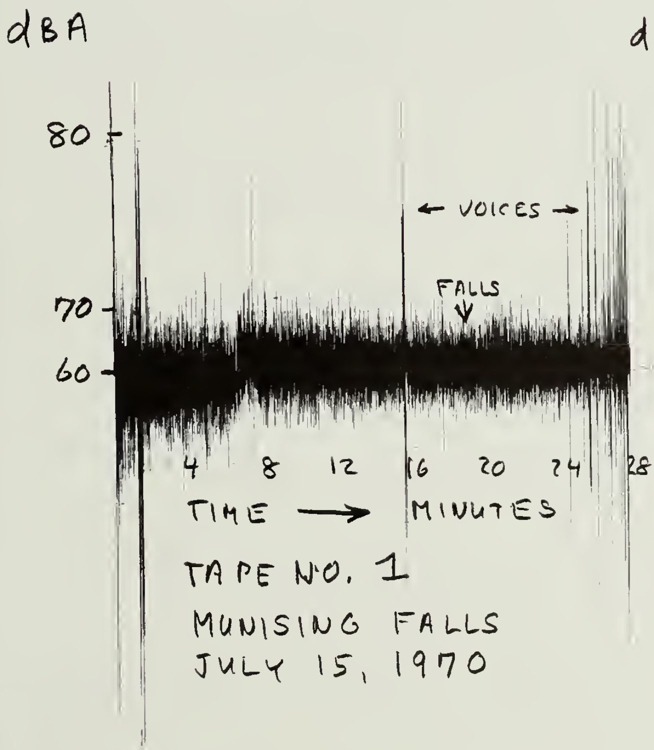


FIGURE 5.4

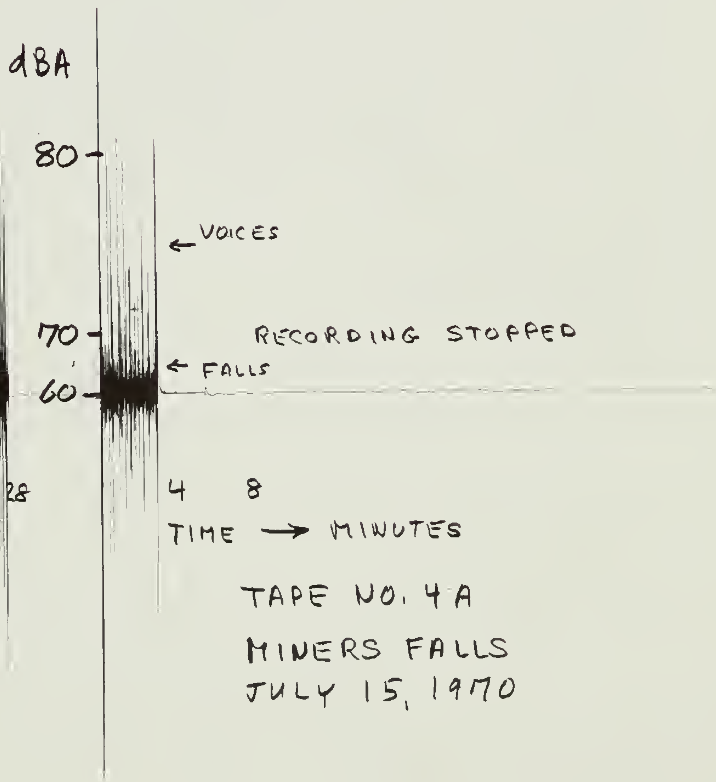


FIGURE 5.5

distinct and occurred at periodic intervals. Children's voices were easily discerned in the distance and noises from automobiles were scattered throughout the recording. The background noise levels ranged between 40 and 50 dBA, while the wildlife and human activity noise levels were in the 50 to 60 dBA range. During one of the relatively quiet periods, movement of a small animal could be faintly heard.

FIGURE 5.3
KINGSTON LAKE
June 28, 1970
12:30 P.M.

A constant background noise of 45 to 50 dBA is provided by wind blowing through the trees, occasionally interspersed with bird calls. For a brief moment, what seemed to be a motor boat was heard on the lake (65 dBA level). Human voices were detected at the half-way point. Late in the tape, one can establish the existence of a highway adjacent to the recording site by the loud road noises, which were in excess of 60 dBA.

FIGURE 5.4
MUNISING FALLS
July 15, 1970
12:30 P.M.

The Munising Falls area is apparently well frequented by tourists. Approximately one dozen people were present at the beginning of the tape and from the continued frequency of human conversations, one might assume this number remains constant. At the half-way point, the recorder was discovered by a child; other than this occurance, nothing deviates from the standard background level of the falls, which was approximately 70 dBA.

FIGURE 5.5
MINERS FALLS
July 15, 1970
1:45 P.M.

This recording was stopped after a few minutes due to rain. However, the record shows an average noise level of the falls to be approximately 65 dBA with voices heard over the falls roar ranging between 70 and 80 dBA.

FIGURE 5.6
MINERS CASTLE
July 15, 1970
2:30 P. M.

The Miners Castle area is apparently well frequented, as indicated by the reported number of automobiles in the parking lot. The average noise level was approximately 50 dBA. At both the beginning and end of the tape, automobile and human noises could be easily distinguished. The remainder of the tape, outside of a few exceptions, was relatively free of noise. Frequently, the voices of children could be heard in the distance, along with occasional bird calls. There were also a few incidences of wind whistling over the microphone. A rather distinctive noise was recorded at approximately the one-half mark, when a plane passed over the shoreline.

FIGURE 5.7
SAND POINT
August 4, 1970
3:55 P.M.

This was a very quiet recording. The average noise level was less than 45 dBA. Throughout the tape the only background noise heard was an occasional birdcall. There were, however, two seperate instances where low

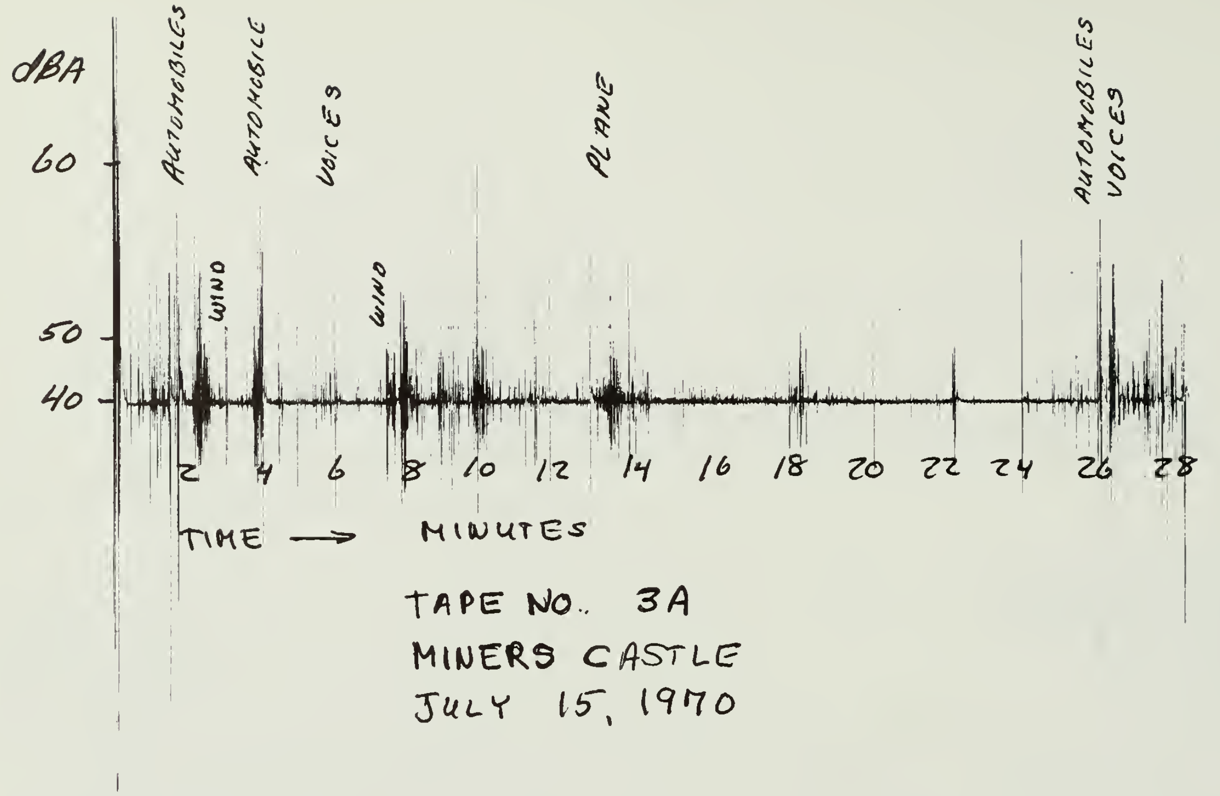


FIGURE 5.6

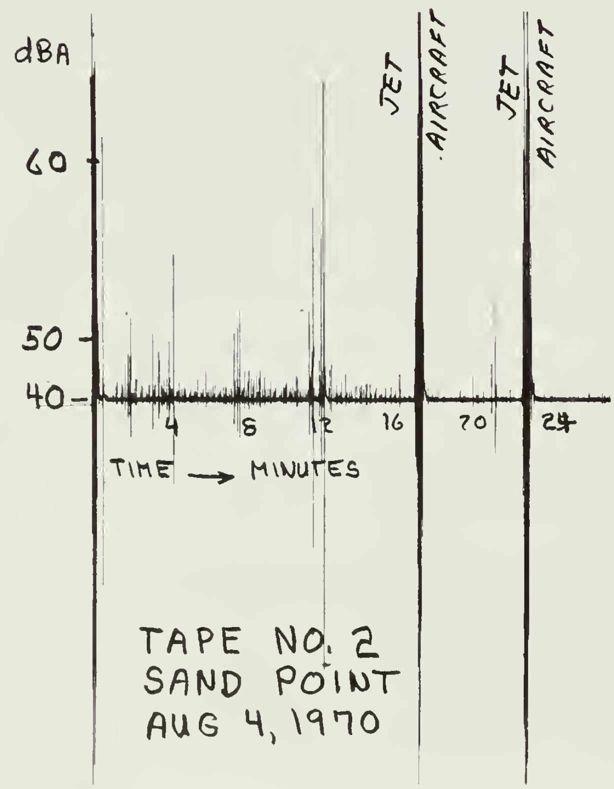


FIGURE 5.7

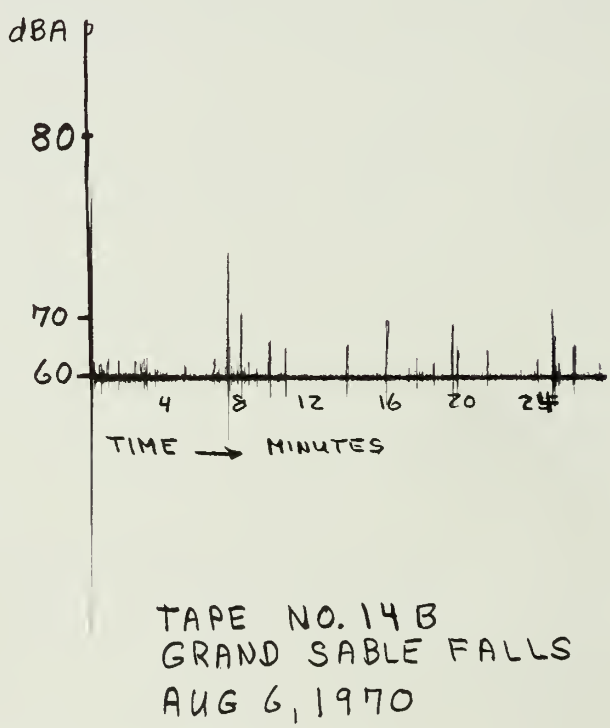


FIGURE 5.8

flying jets passed over the recording site. The jet noise levels were above 65 dBA. These occurances give excellent references from which the relative quiet of the area could be determined. After the jets passed, the background noise activity decreased.

FIGURE 5.8
GRAND SABLE FALLS
August 6, 1970
11:00 A.M.

A moderate to loud level of background noise is produced by the Grand Sable Falls, with the average noise level 60 to 65 dBA. Other than the occasional emergence of the high pitched voices of children, no additional noises were heard.

FIGURE 5.9
HURRICANE RIVER
August 5, 1970
10:25 A.M.

The Hurricane River streamflow produces a steady yet subdued roar of approximately 50 dBA which fills the background. Throughout the recording, human voices and conversation were discerned in the 50 to 60 dBA range, but birds and other wildlife were infrequently recognized, possibly a result of man's presence.

FIGURE 5.10
LOG SLIDE
August 5, 1970
12:45 P.M.

This area was extremely quiet, with average noise levels below 45 dBA. Initially, children's voices were heard in the distance, but the majority of the recording contained no identifiable noise.

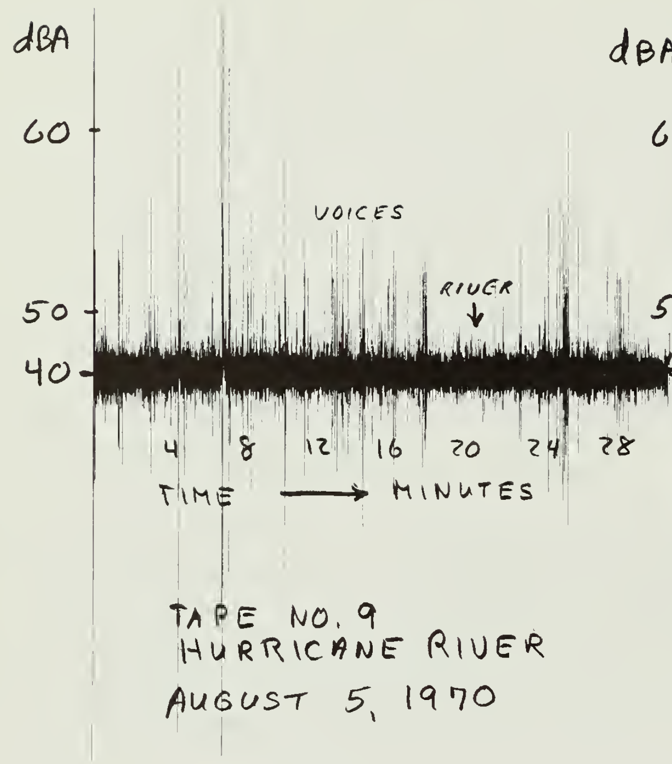


FIGURE 5.9

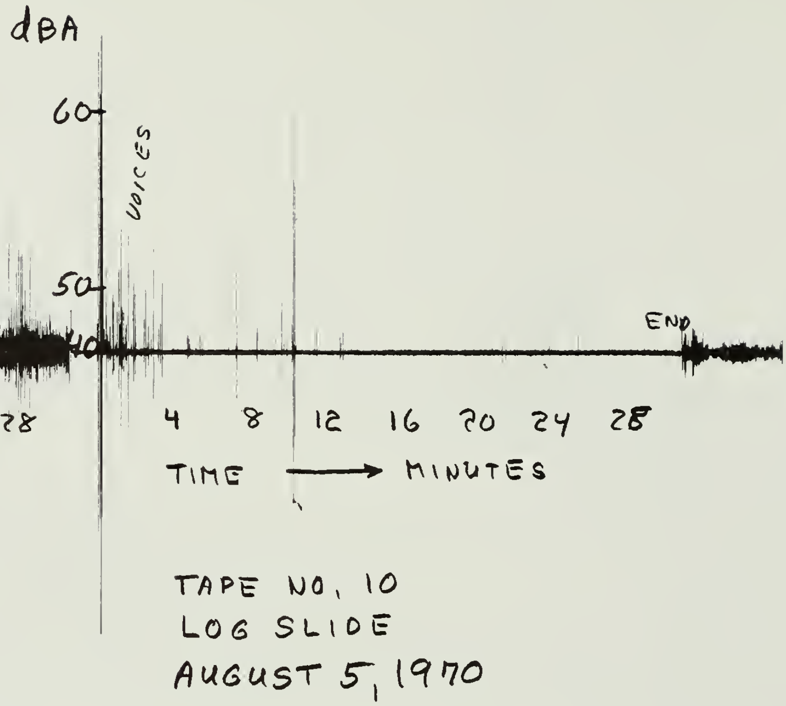


FIGURE 5.10

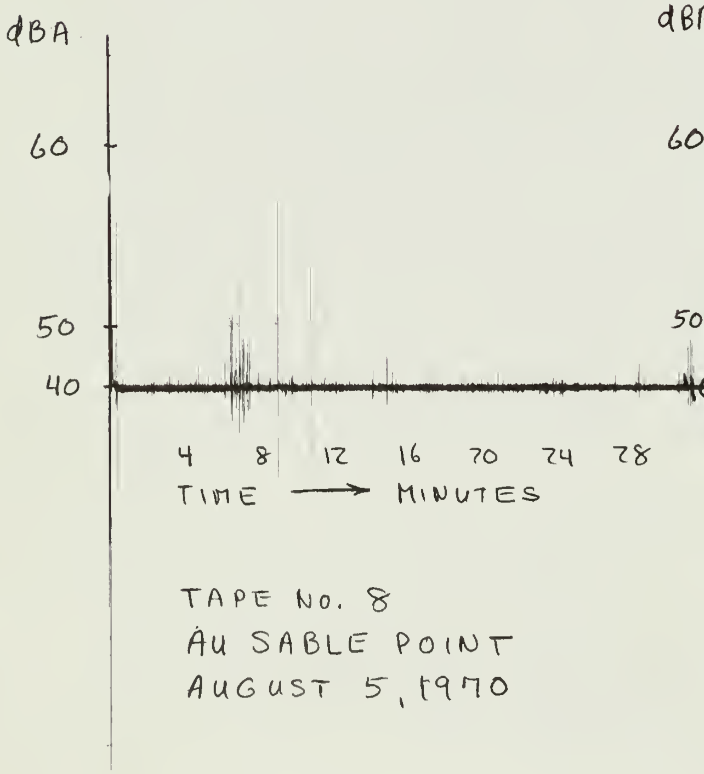


FIGURE 5.11

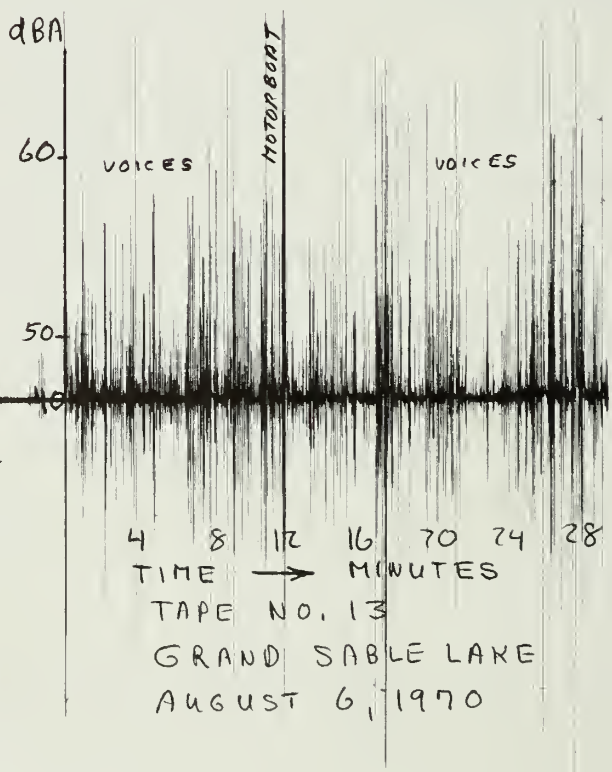


FIGURE 5.12

FIGURE 5.11
AU SABLE POINT
August 5, 1970
3:50 P.M.

The Au Sable Point recording was extremely quiet (40 dBA) and was marked by only one occurance of human presence - a man walking his dog. The background noise was produced by a solitary bird and wind rustling the leaves. This quiet period is considered unusual for the location, since it is near Lake Superior and is a popular spot.

FIGURE 5.12
GRAND SABLE LAKE
August 6, 1970
2:30 P.M.

The Sable Lake recording has much noise activity, mostly human voices in the 60 dBA range. This area is apparently used for swimming, picnicing and other recreational activities. The sound of adults, children, motorcycles and cars were easily distinguished. In spite of the high level of human noise and conversation, the sounds of wildlife, birds and squirrels could also be heard.

FIGURE 5.13
MINERS FALLS TRAIL
August 7, 1970
11:38 A.M.

Miners Falls Trail is characterized by a low background noise level, comprised of bird and chipmunk calls. This noise level, which is approximately 45 dBA, is maintained throughout the recording. Initially, the area appears to be heavily populated but the human voices rapidly disappear, returning only

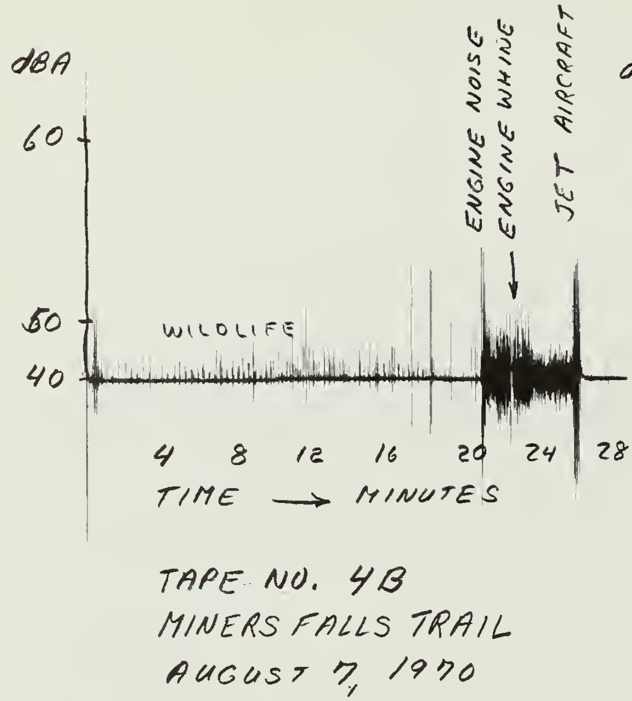


FIGURE 5.13

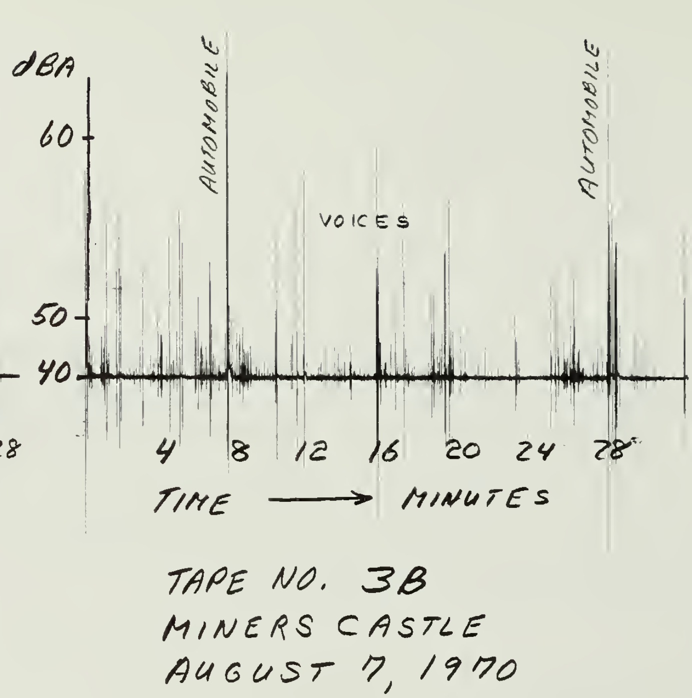


FIGURE 5.14

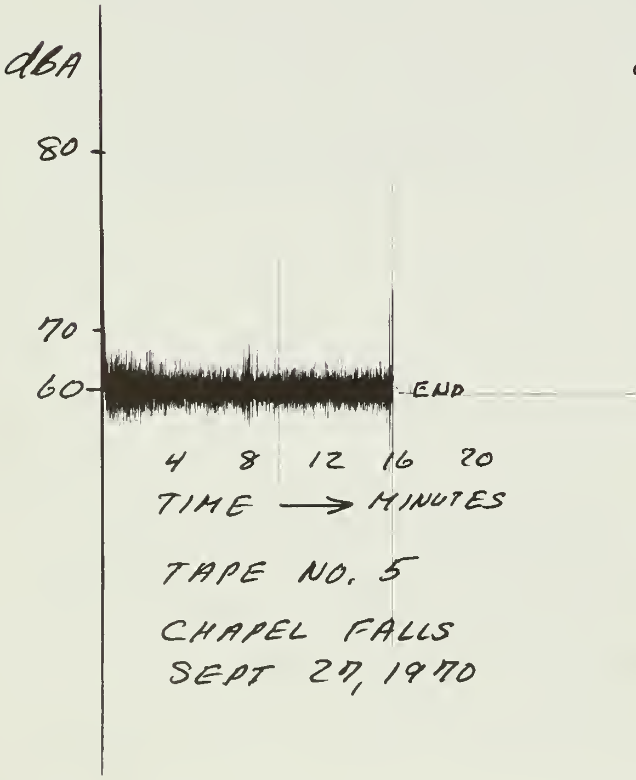


FIGURE 5.15

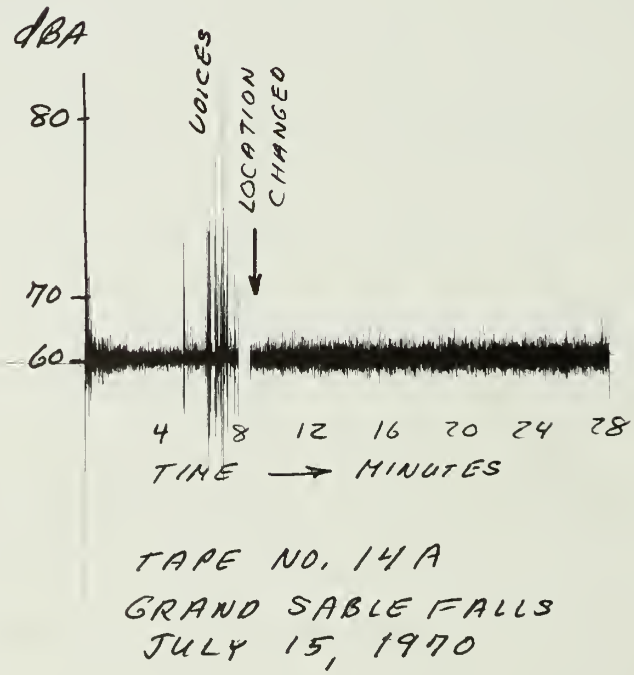


FIGURE 5.16

briefly, halfway through the recording. At one point, the sound of water fowl was distinguished but remained for less than a minute.

Some unusual noises were recorded in the last quarter of the recording. Initially, a moderately loud whine of 55 dBA is suddenly produced by what sounds like heavy machinery. This noise level either masks or scares off the surrounding wildlife. The seven-eights mark records what was reported by the technician as a low flying jet aircraft with a noise level of 55 dBA also. The passing of the jet coincides with the disappearance of the previously mentioned whine. The background noise level is reduced after the jet passes.

FIGURE 5.14
MINERS CASTLE
August 7, 1970
11:55 A.M.

Human conversation was audible throughout the entire recording. Obviously, the spot is popular with tourists and campers, because there appeared to be a continuous influx of people. Significantly, there was no noticiable wildlife noises throughout the entire recording period. The average noise level reading was 50 to 55 dBA.

FIGURE 5.15
CHAPEL FALLS
September 27, 1970
4:30 P.M.

At the Chapel Falls recording site, the roar of the falls predominantly masked other background noises. On two occasions, voices were momentarily distinguished and a bird's song frequently pierced the roar. But the roaring falls still predominates as the major background noise. The background noise level was 65 dBA.

FIGURE 5.16
GRAND SABLE FALLS
July 15, 1970
5:30 P.M.

Grand Sable Falls obscures most normal background noises with an average noise level of 65 dBA. However, human conversation can be heard at the one-fourth mark. Apparently, the recording technician felt this particular group of tourists to be unusual in their group size and loudness (approximately 75 dBA). As a result, at the one-third mark, the recording site was relocated closer to the falls. At this new location no human conversation was audible, but bird calls were occasionally distinguished over the roaring falls.

b. 24 Hour Noise Recordings

Continuous tape recordings of 24 hours each were made at the 3 campgrounds within the park. An abbreviated summary of the identification and intensity levels of the recorded sounds at each site is presented in Tables 5.1, 5.2 and 5.3. This summary includes the more significant or louder sounds identified and it can be assumed that at other times the noise activity was not important. The noise levels ranged from below 50 db (the lower threshold of the recorder due to background noise) to above 80 db.

TABLE 5.1

TAPE NO. 1 - SEPTEMBER 25, 1970
LITTLE BEAVER LAKE CAMPGROUND

Ref. No.	Time	Remarks	Level (dBA)
0001	9:43 PM	Start reference by Limnetics personnel	75
0008-0132	9:51 PM	General campground noise and conversation. Activity in other campsites	65
0134-0160	11:56 PM	General campground noise, mostly distant conversation	50
0240	1:32 AM	Background noise level	50
0265	1:57 AM	Animal noise	55
0333	3:05 AM	Rain begins	50
0338-0340	3:10 AM	Unknown sounds	60
0370	3:42 AM	Rain ends	50
0500	5:52 AM	Background noise level	50
0622-0742	7:54 AM	Conversation and activity by campers. Birds can be faintly heard in background	60
0745	9:57 AM	Truck started up and idling	70
0746	9:58 AM	Truck leaving camp area	65
0775	10:27 AM	Background noise level	55
0778-1035	10:30 AM	Frequent birdcalls	55-68
1050	3:02 PM	Background noise level	55
1082	3:34 PM	Truck entering campground area	65

Little Beaver Lake Campground (Cont.)

1140	4:32 PM	Birds	55
1210-1211	5:42 PM	Camper pumping water	58
1244-1252	7:16 PM	Activity in campground campers conversation	55
1351-1359	9:03 PM	Campers conversing at pump while pumping water	55

TABLE 5.2

TAPE NO. 2 - OCTOBER 14, 1970
KINGSTON LAKE CAMPGROUND

Ref. No.	Time	Remarks	Level (dBA)
0000	6:20 PM	Start reference by Limnetics personnel	75
0001	6:21 PM	Very quiet background	50
0004	6:25 PM	Limnetics truck leaving	60
0014-0015	6:35 PM	Unrecognizable sound	58
0020	6:41 PM	same	60
0091	7:52 PM	same	58
0131-0039	8:32 PM	same	54
0172	9:13 PM	same	54
0180	9:21 PM	same	58
0192	9:33 PM	same	55
0199	9:40 PM	same	56
0200	9:41 PM	some wind or wave noise developing	53
0319	11:40 PM	Bird or duck call	55
0320	11:41 PM	Bird or duck call	55
0575	3:56 AM	Background noise level	55
0580-0582	4:01 AM	Rain or clicking sound	60
0584	4:05 AM	propeller aircraft	60
0615	4:36 AM	Unrecognizable sound	58
0622-0630	4:43 AM	Rain	58-70

Kingston Lake Campground (Cont.)

0653-0715	5:14 AM	Intermittent rain	60-70
0716-0729	6:17 AM	Birds or animals eating or drinking	55
0730-0800	6:33 AM	Rain	60-70
0808	7:41 AM	Loud fall of water from nearby tent	75
0810-0815	7:43 AM	Rain	60
0820-0860	7:53 AM	Intermittent rain	60
0869-0870	8:42 AM	Bird calls	58
0881	8:54 AM	Geese	62
0883-0885	8:56 AM	Bird calls (Rain diminishing)	58
0891	9:04 AM	Unrecognizable sounds	55
0895-0897	9:08 AM	Distant bird calls	57
0898-0899	9:11 AM	Geese	60
0902	9:15 AM	Bird call	64
0905	9:18 AM	Rifle shot	68
0913-0914	9:26 AM	Distant jet	58
0915	9:28 AM	Quiet background level	50
0924-0926	9:37 AM	Geese	52
0986-0987	10:39 AM	2 loud rifle shots	84
1002	10:55 AM	3 distant rifle shots	62
1003-1008	10:56 AM	Voices and engine noise	60-66
1008	11:01 AM	Car door shutting	62

Kingston Lake Campground (Cont.)

1009	11:02 AM	Engine noise	62
1015	11:08 AM	Car or truck	65
1031	11:24 AM	Loud cracking noise	68
1048	11:41 AM	Rain or wind noise	65
1072-1073	12:05 PM	Loud cracking noise	68
1075	12:08 PM	Distant voice	60
1102	12:35 PM	Jet aircraft	62
1111-1112	12:44 PM	Voices and shots	70
1113	12:46 PM	Voices and birdcalls	60
1120-1126	12:53 PM	Chain saw or motorcycle	66-79
1129-1133	1:02 PM	Voices	62
1140	1:13 PM	Voices and chopping wood	60
1167-1169	1:40 PM	Jet in distance	58
1184	2:02 PM	Voices	55
1211	2:24 PM	Truck enters area	60
1212	2:25 PM	Limnetics personnel making equipment check	60
1222 1/2	2:35 PM	Check by Limnetics	75
1230	2:43 PM	Truck leaves area	60
1236	2:49 PM	Animal noise	65
1238	2:51 PM	Background noise level	58
1240-1275	2:53 PM	Wind interspaced with some bird calls	68
1275-1295	3:28 PM	Mostly wind	55-60

1304	3:57 PM	Animal noise (Wind diminishing)	55
1325	4:18 PM	Animal noise	55
1333	4:26 PM	Wind, leaves fall on microphone	63
1339	4:32 PM	Wind and rain	66
1340-1372	4:33 PM	Slight wind	63
1391	5:24 PM	Hunter discharges rifle in immediate area	75
1404-1409	5:37 PM	Gulls and shore birds, night hawks	65

TABLE 5.3

TAPE NO. 3 - OCTOBER 15, 1970
AU SABLE POINT CAMPGROUND

Ref No.	Time	Remarks	Level (dBA)
0000	8:50 PM	Wind and wave noise of Lake Superior in background	80
0400	3:30 AM	Waves diminishing in loudness	70
0403	3:33 AM	Canadian Geese flight	75
0431	4:01 AM	Canadian Geese flight	75
0530	5:40 AM	Wave noise greatly diminished	58
0608-0609	7:48 AM	Wildlife, probably ducks	60
0643	8:33 AM	Birdcalls	63
0700	9:30 AM	Background noise level	60
0713	9:43 AM	Wildlife, ducks or geese noticeably excited	75
0716-0723	9:45 AM	Continuous crowcalls	65
0735-0739	10:04 AM	Diminishing crowcalls	60
0748-0749	10:17 AM	Birdcalls (unknown)	75
0808-0809	11:17 AM	Crowcalls	60
0891-0892	12:40 PM	Birdcalls (unknown)	65
0936	1:25 PM	Animal sounds	60
0960	1:39 PM	Very weak wave noise	60
0974	1:53 PM	Jet aircraft	65
0981	2:00 PM	Continuing aircraft noise in background	60

0998	2:17 PM	Jet aircraft	65
1000	2:19 PM	Background noise level	60
1006	2:25 PM	Geese, ducks, birdcalls	60
1007	2:26 PM	Low jet (geese, etc. in background)	65
1008	2:27 PM	High pitched birdcall	60
1009	2:28 PM	Continuing jet aircraft noise in background	60
1100	3:59 PM	Very faint but distinct wave sounds above quiet background	55
1130	4:29 PM	Sound of hitting wood	60
1132	4:31 PM	Shrill whistle (human)	65
1150	4:49 PM	Background noise level	60
1155-1157	4:54 PM	Unrecognizable wildlife sounds	62
1160	4:59 PM	Unrecognizable sounds, similar to truck being loaded with material	60
1161	5:00 PM	Vehicle horn sound over people talking in background	73
1162	5:01 PM	Automobile or truck horn above people talking and human or animal walking sound	73
1163	5:02 PM	Automobile horn	73
1164	5:03 PM	Children calling out	65
1165	5:04 PM	Automobile door closing	63
1172	5:11 PM	Truck or automobile engine noise	60

1200		5:39 PM	Background noise level	60
1248		6:27 PM	Wave noise with period of approximately 15 seconds	62
1249		6:28 PM	Animal sounds	61
1300		7:19 PM	Background noise level	60
1308		7:27 PM	Truck engine noise	65
1309		7:28 PM	Truck door closing	64
1317	End	7:36 PM	Limnetics Personnel	70

c. Integrated Noise Records

Integrated Noise Records were obtained from Beaver Lake (BL) and Little Beaver Lake Campground (LBLC). The former was chosen to show the natural background noise while the latter was chosen to show campground noise.

The recorded noise data is illustrated in figures 5.17 through 5.47 on a 0 to 10 unit relative scale. The integrated noise data diagrams clearly show a great variety of audible noise activity with both random and patterned variations. Figure 5.48 illustrates the average total noise vs. the day of the week while Figure 5.49 summarizes the total amplitude of noise over a 24 hour period for each day of recording.

The noise data is expressed on an amplitude scale rather than a db scale since the recordings represent "integrated" noise and not real time noise. At present, there are no acceptable units of measurement or scales for integrated noise and therefore the data must be interpreted on a relative rather than absolute basis. However, if a particular integrated noise record resulted from a constant level of noise generated (rather than time varying) then the amplitude scale would correspond to a db scale as follows:

AMPLITUDE	dB
0.0	40
0.316	50
1.0	60
3.16	70
10.0	80

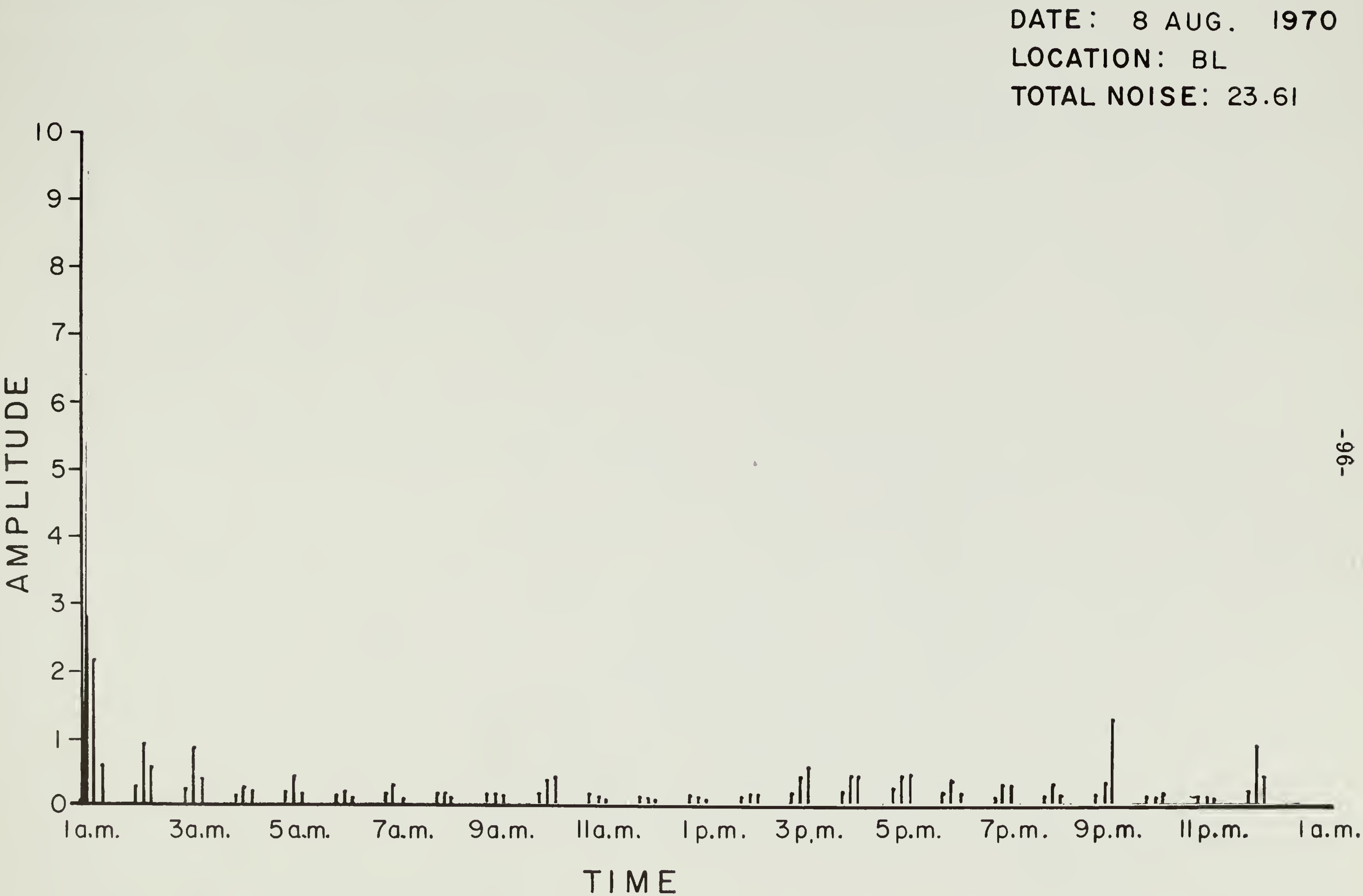

DATE: 8 AUG. 1970
LOCATION: BL
TOTAL NOISE: 23.61
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.17

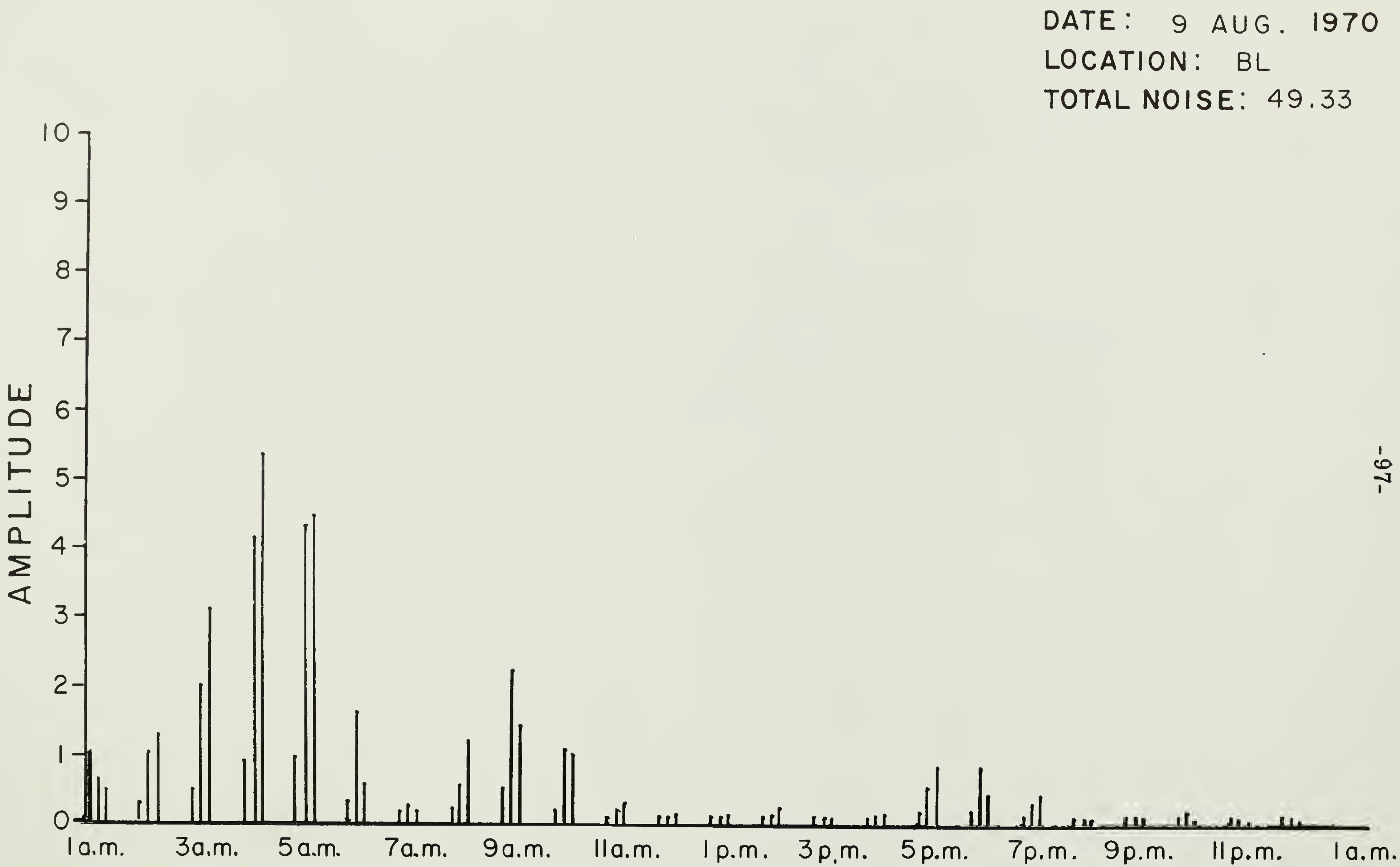

DATE: 9 AUG. 1970
LOCATION: BL
TOTAL NOISE: 49.33
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.18

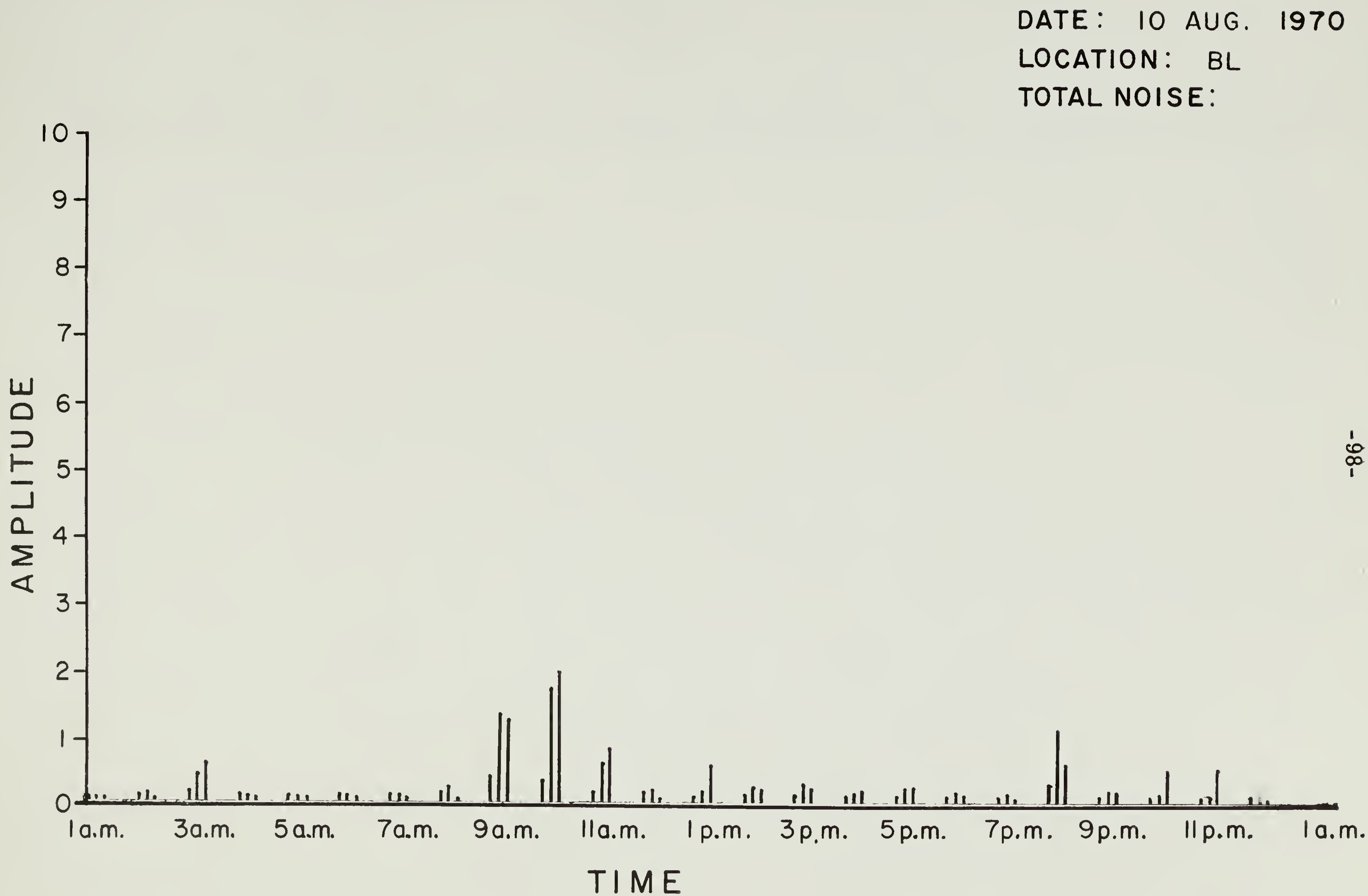

DATE: 10 AUG. 1970
LOCATION: BL
TOTAL NOISE:
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.19

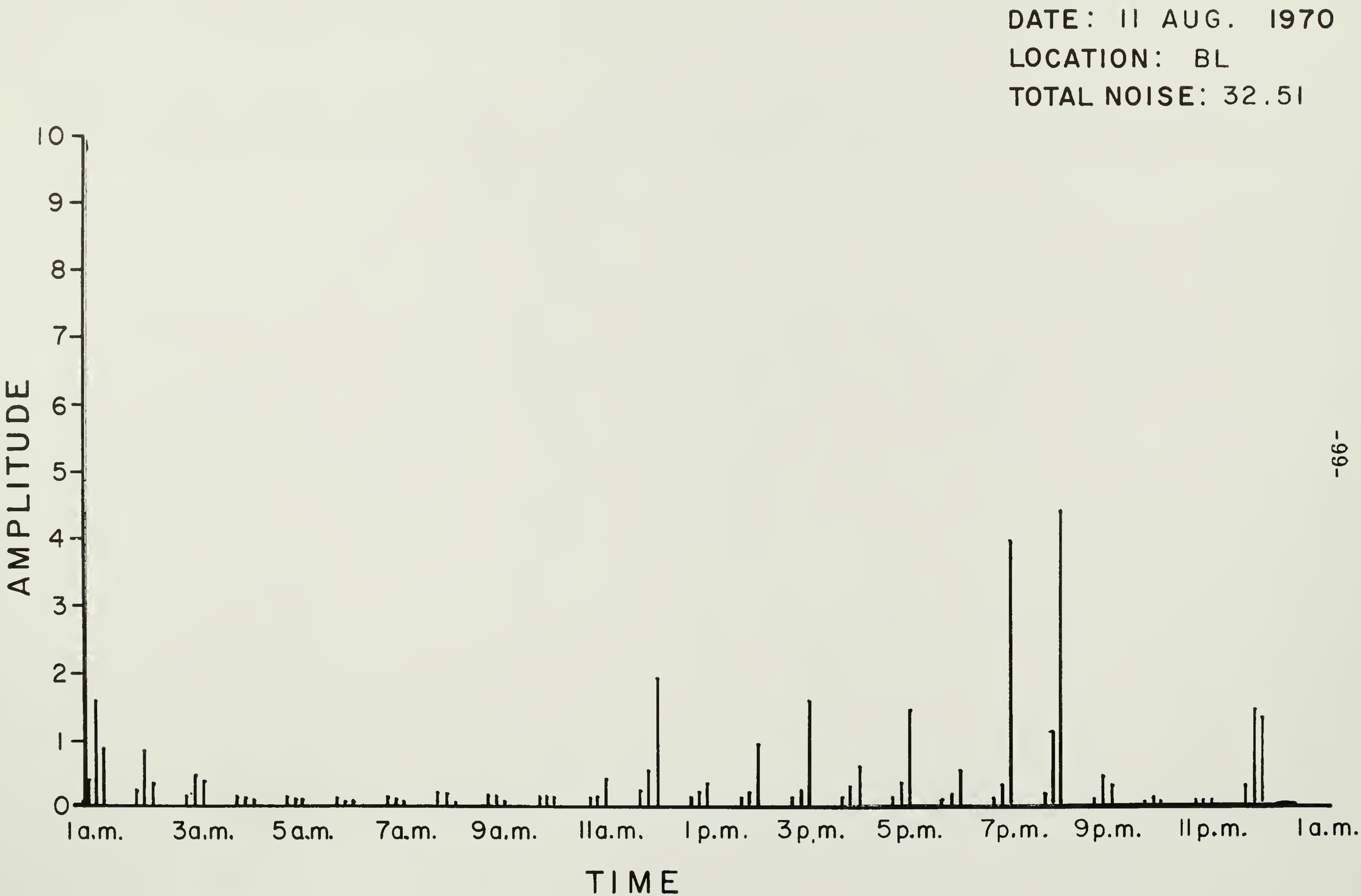

DATE: 11 AUG. 1970
LOCATION: BL
TOTAL NOISE: 32.51
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.20

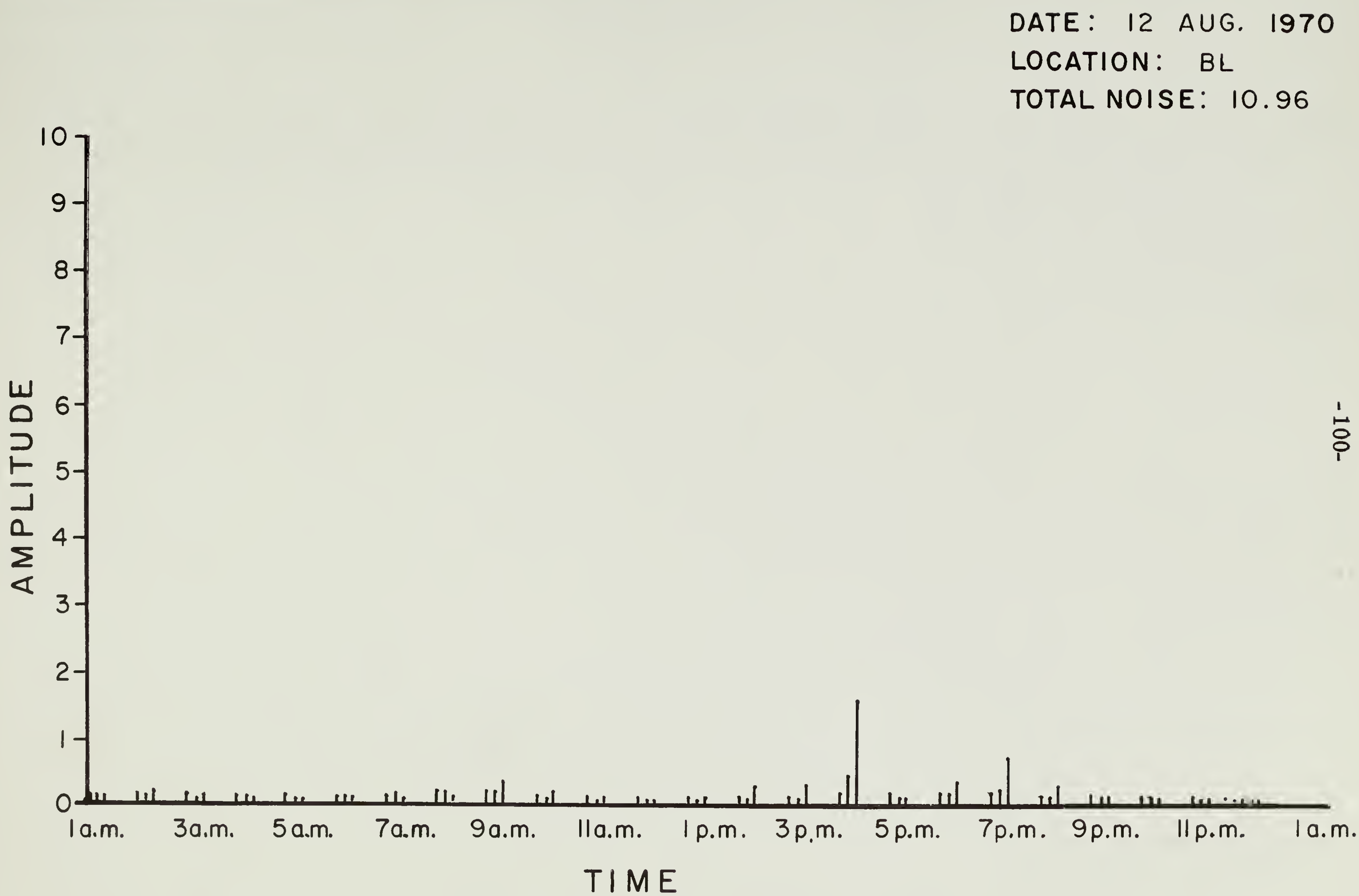

DATE: 12 AUG. 1970
LOCATION: BL
TOTAL NOISE: 10.96
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.21

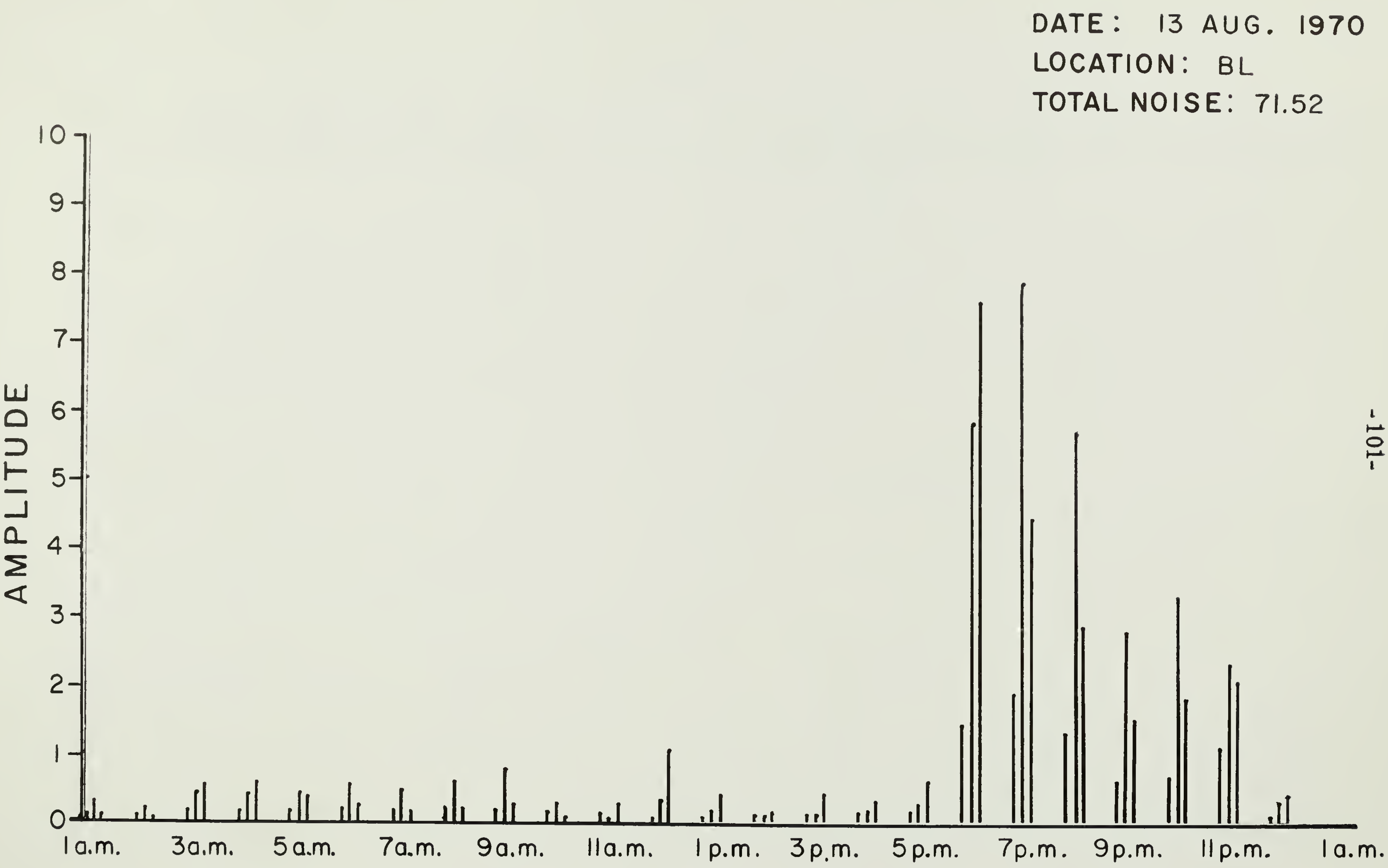

DATE: 13 AUG. 1970
LOCATION: BL
TOTAL NOISE: 71.52
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.22

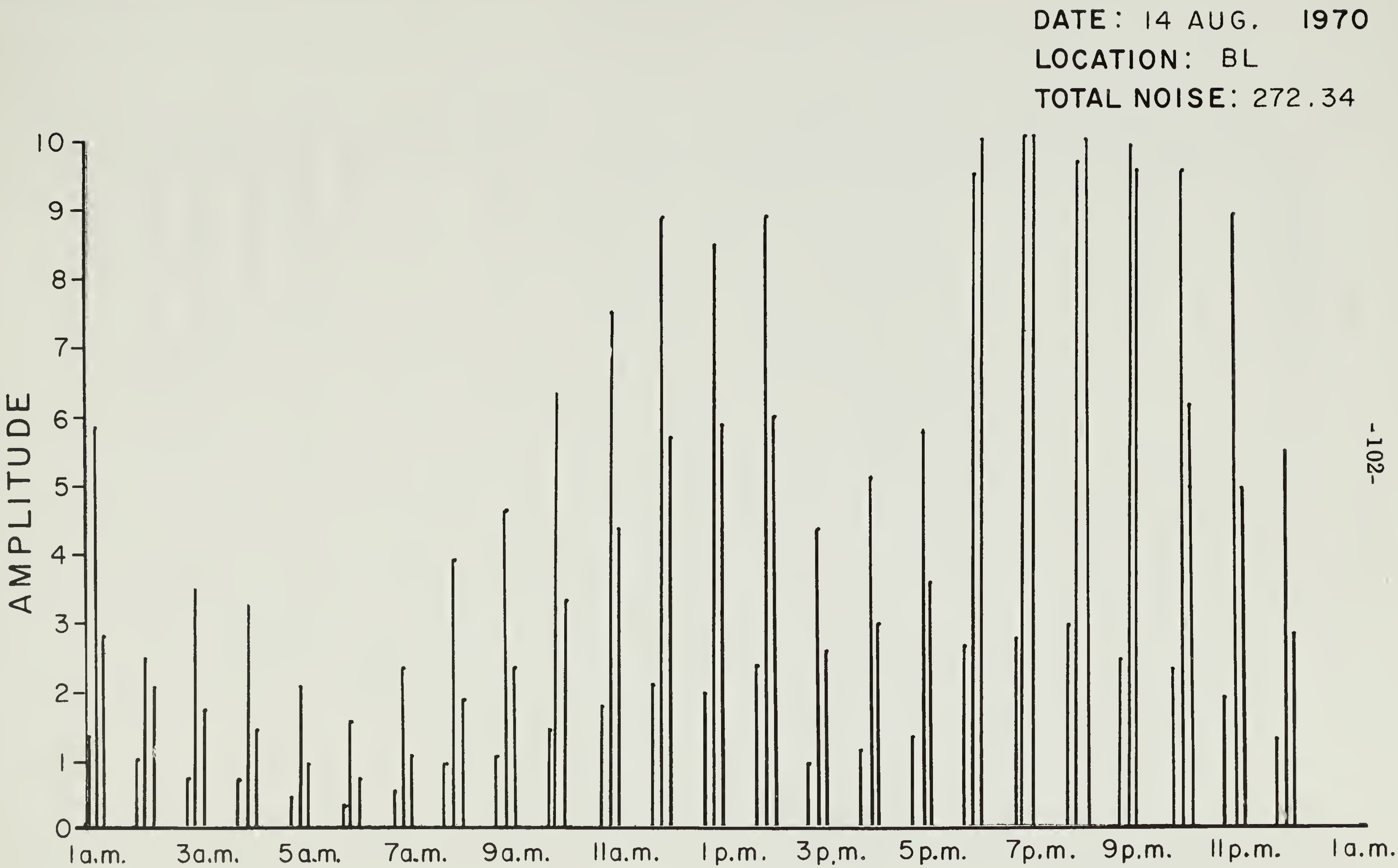

DATE: 14 AUG. 1970
LOCATION: BL
TOTAL NOISE: 272.34
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.23

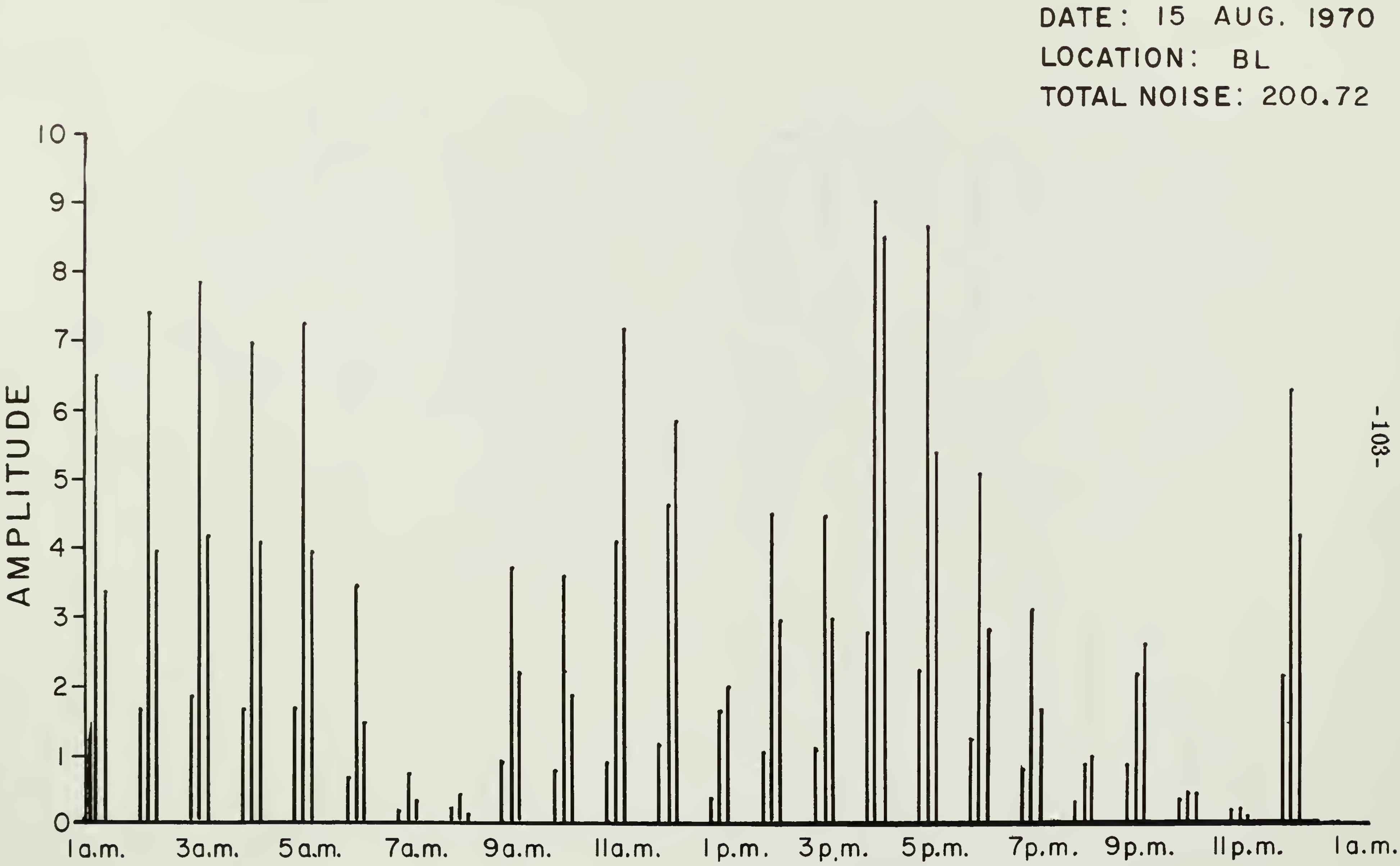

DATE: 15 AUG. 1970
LOCATION: BL
TOTAL NOISE: 200.72
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.24

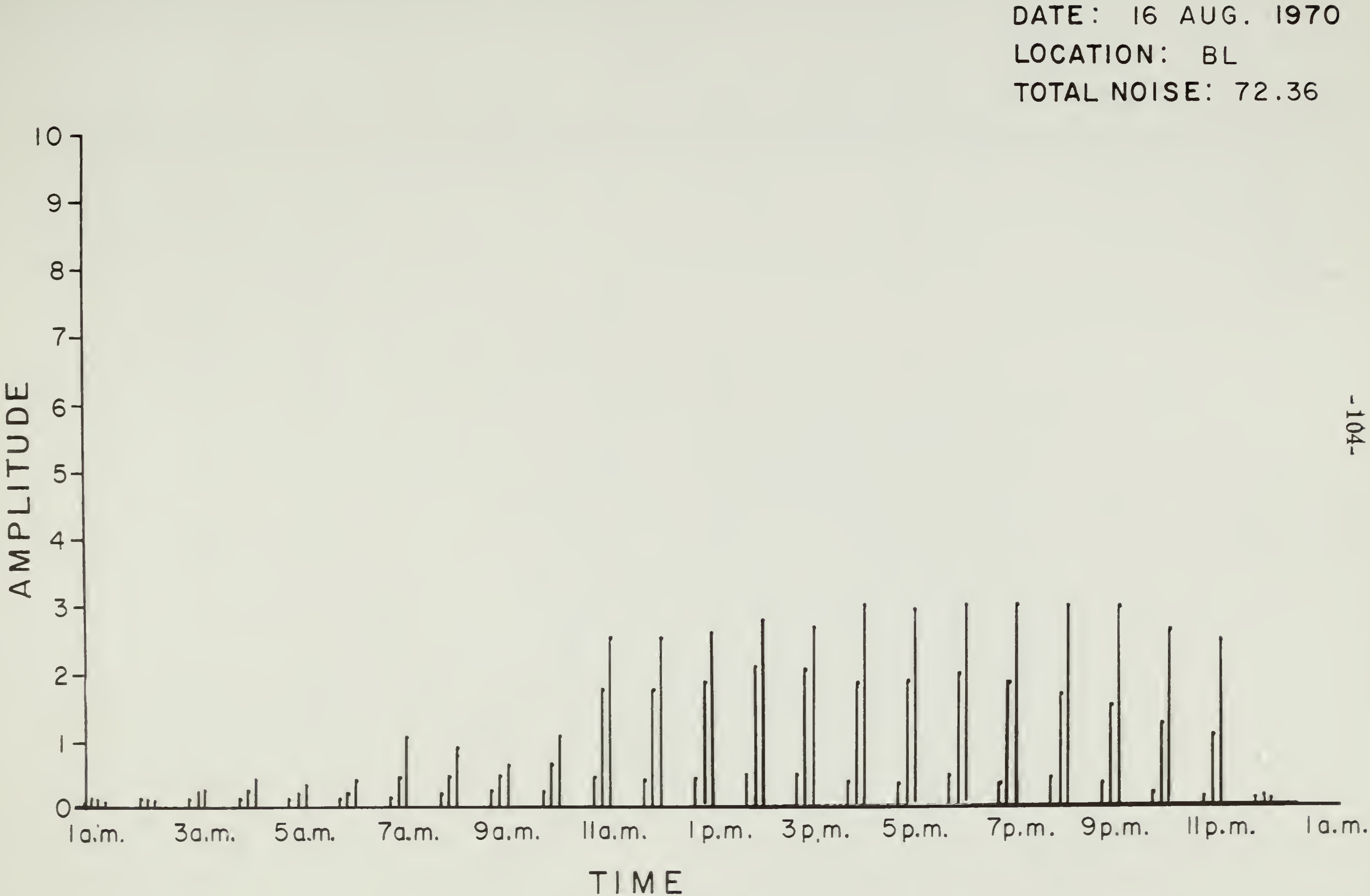
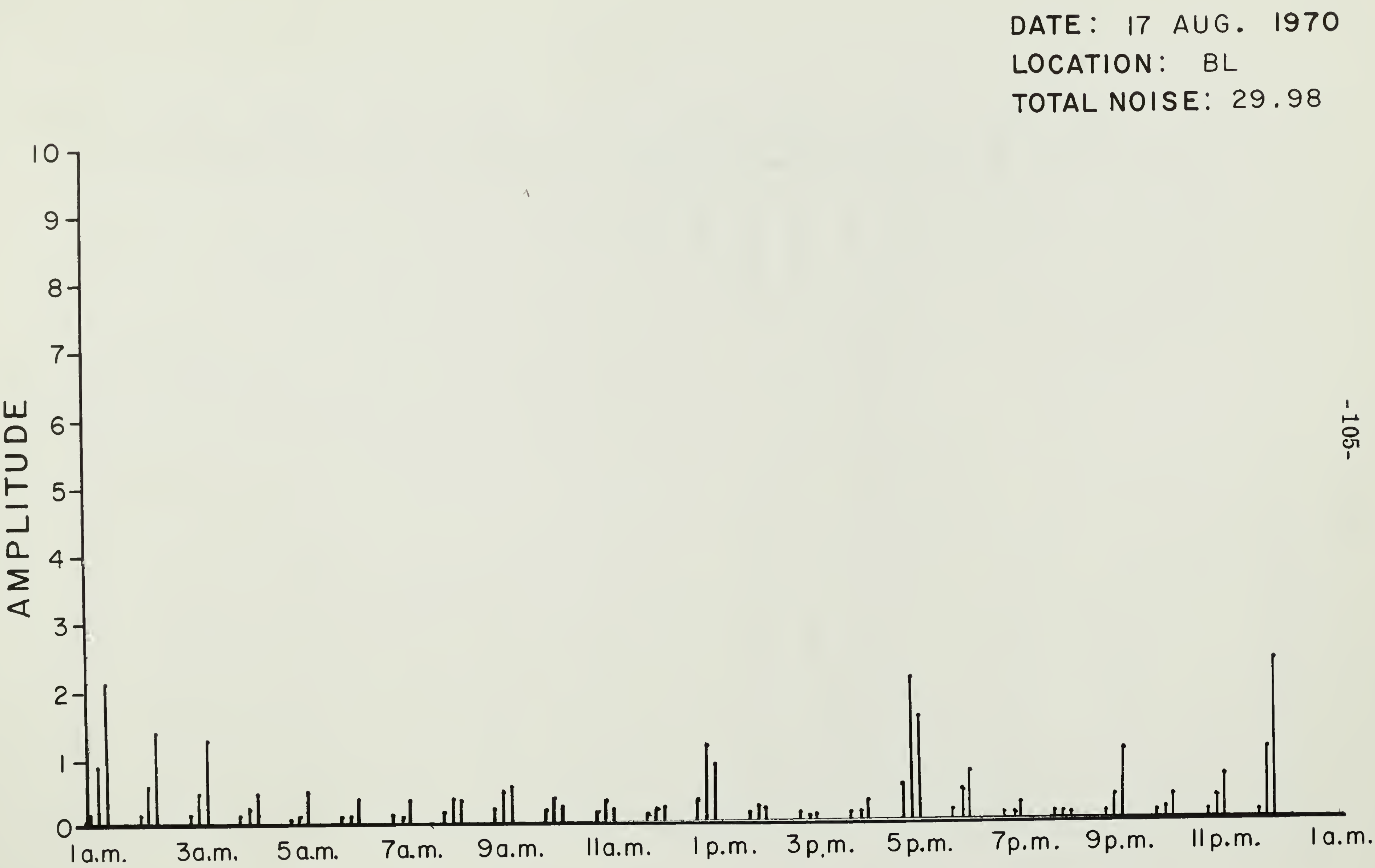

DATE: 16 AUG. 1970
LOCATION: BL
TOTAL NOISE: 72.36
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.25



DATE: 17 AUG. 1970
LOCATION: BL
TOTAL NOISE: 29.98
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.26

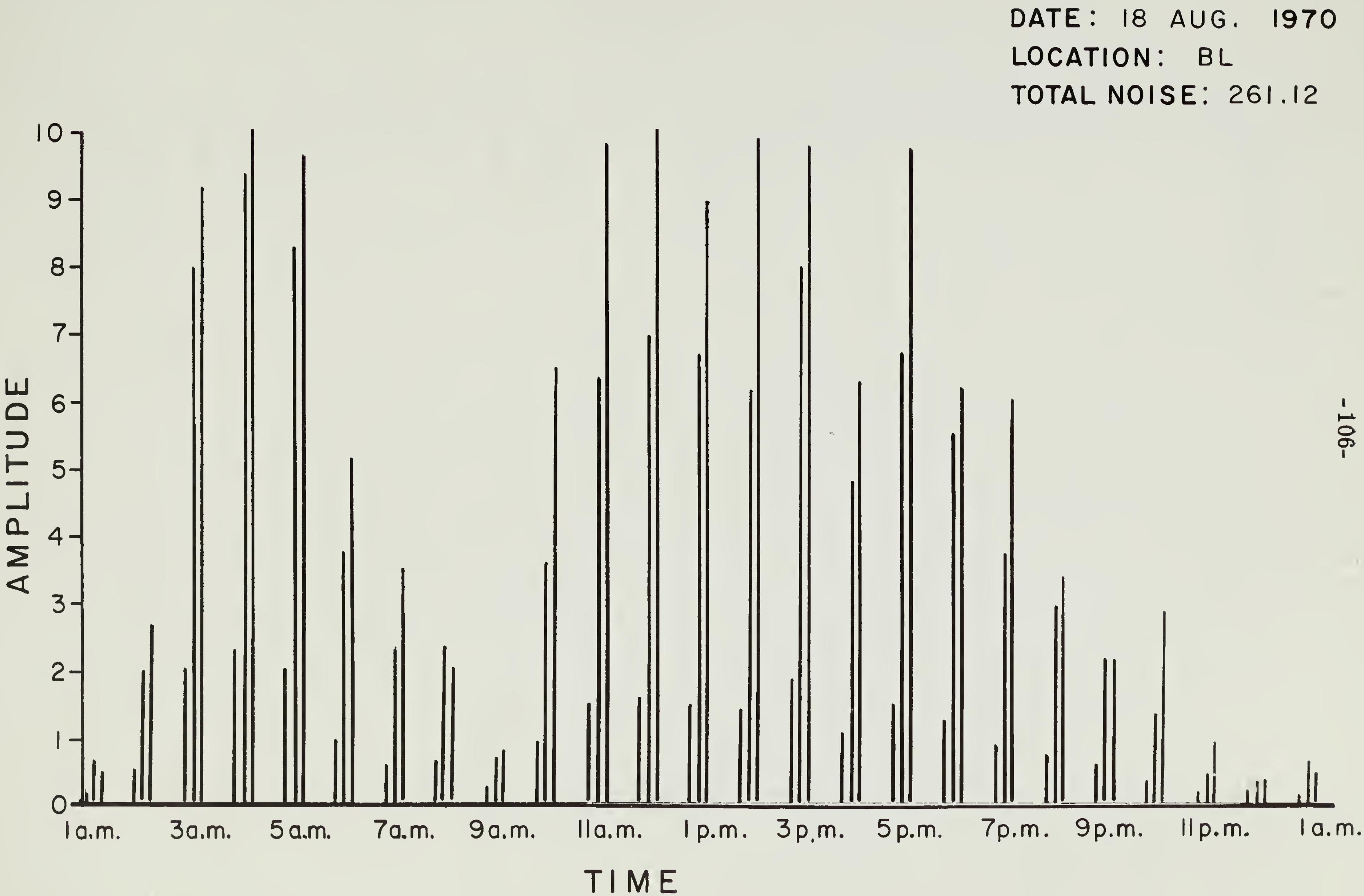

DATE: 18 AUG. 1970
LOCATION: BL
TOTAL NOISE: 261.12
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.27

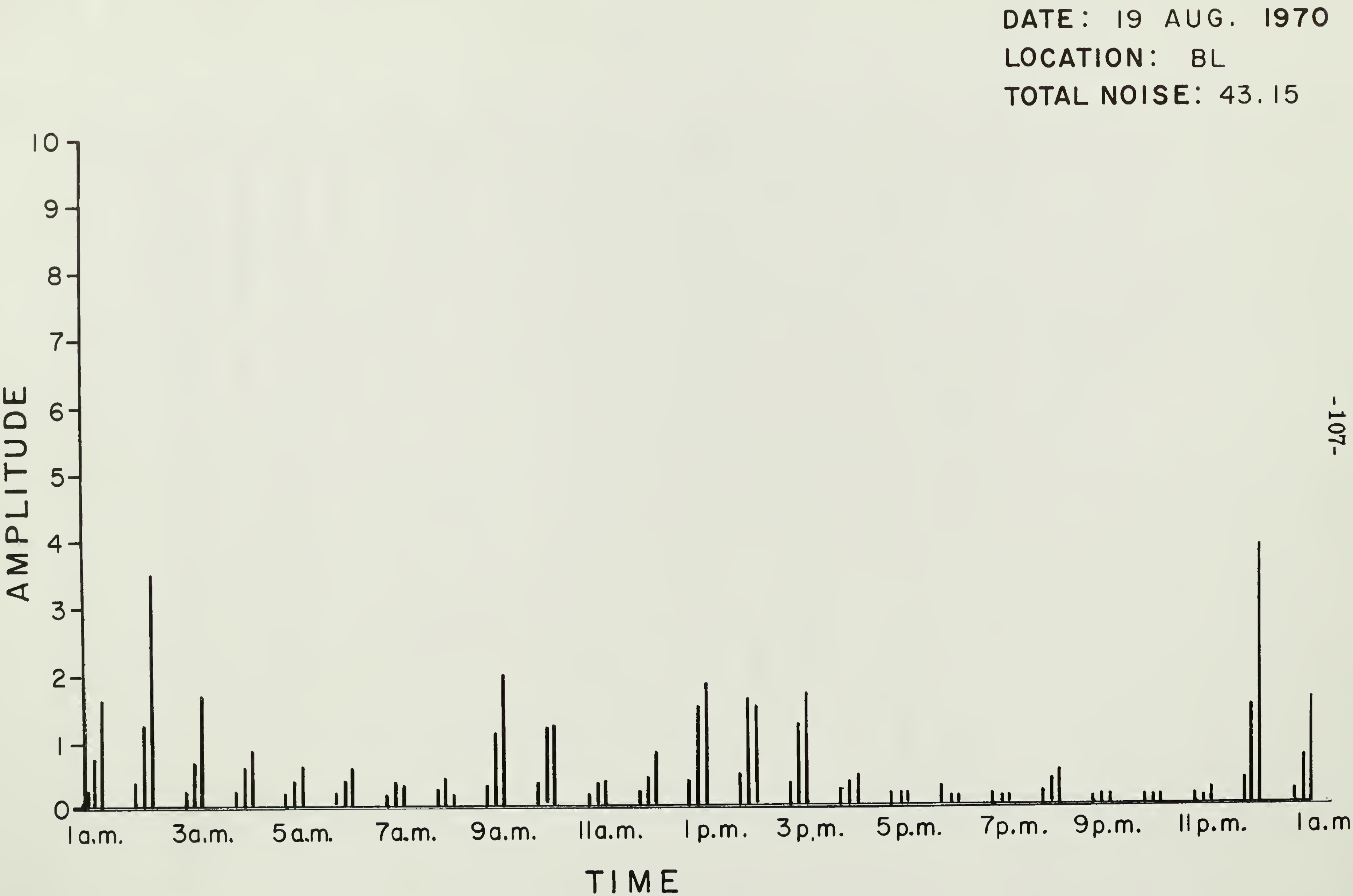

DATE: 19 AUG. 1970
LOCATION: BL
TOTAL NOISE: 43.15
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.28

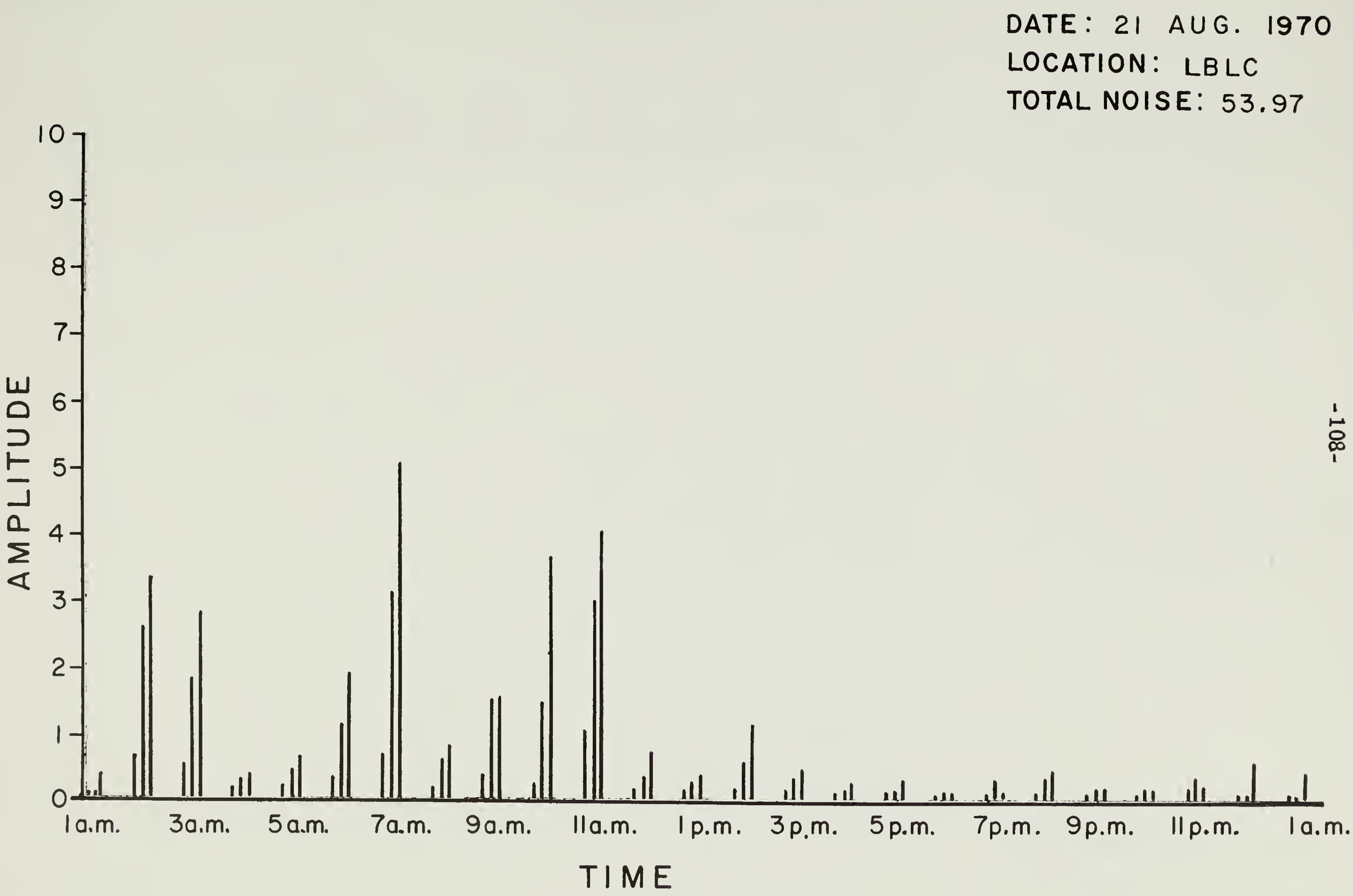
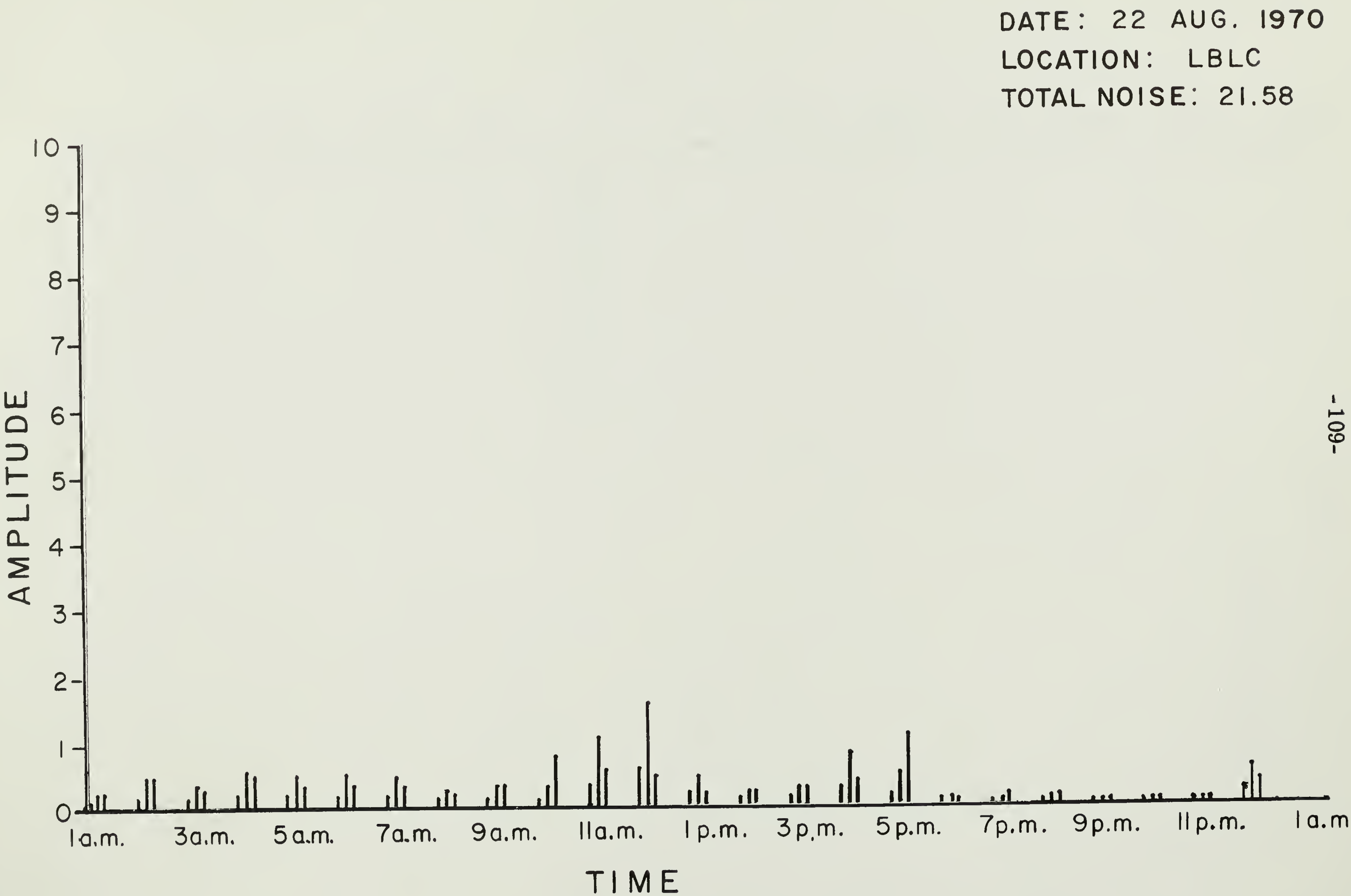

DATE: 21 AUG. 1970
LOCATION: LBLC
TOTAL NOISE: 53.97
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.29



DATE: 22 AUG. 1970
LOCATION: LBLC
TOTAL NOISE: 21.58
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.30


DATE: 23 AUG. 1970
LOCATION: LBLC
TOTAL NOISE: 10.55
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.31

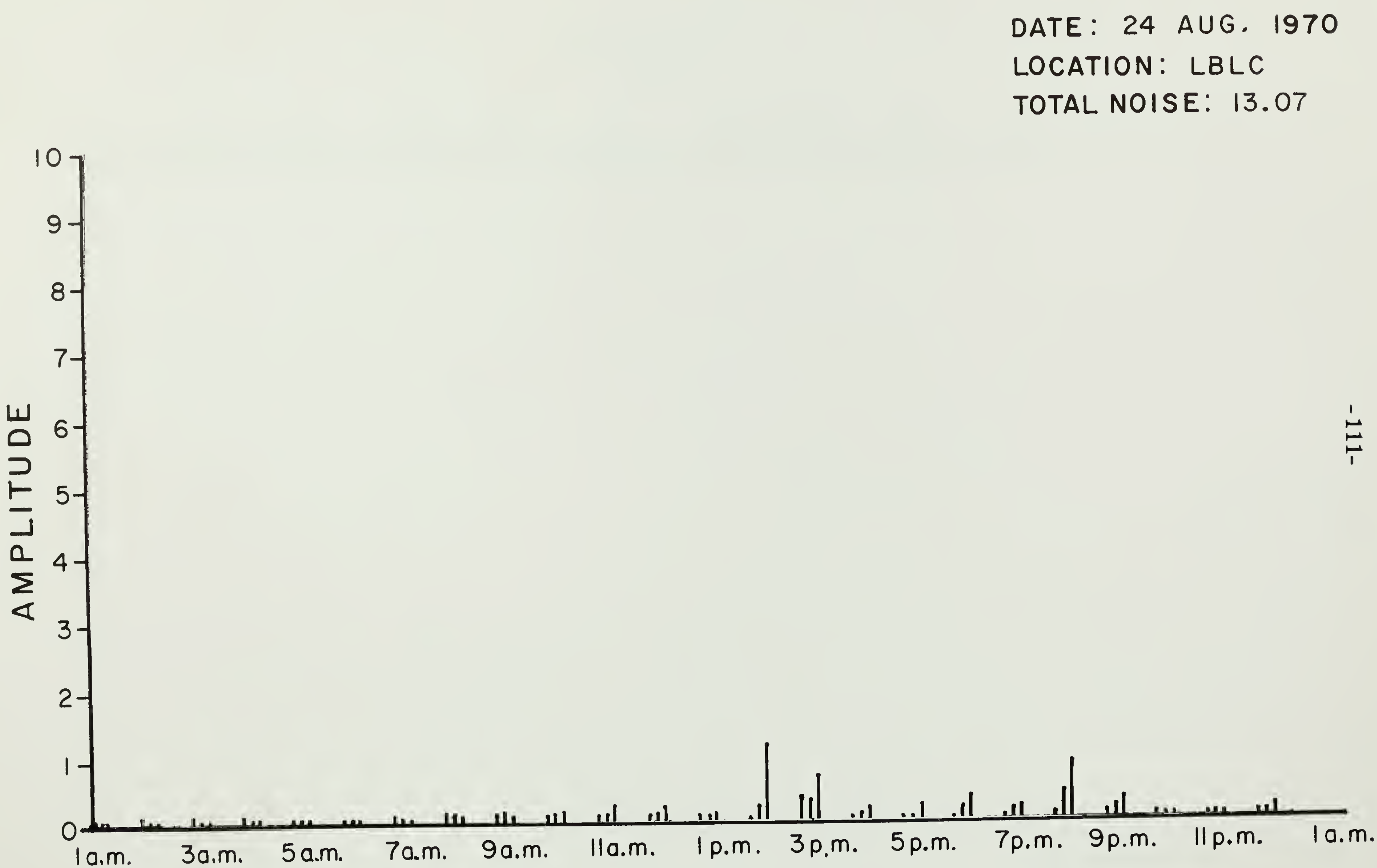

DATE: 24 AUG. 1970
LOCATION: LBLC
TOTAL NOISE: 13.07
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.32

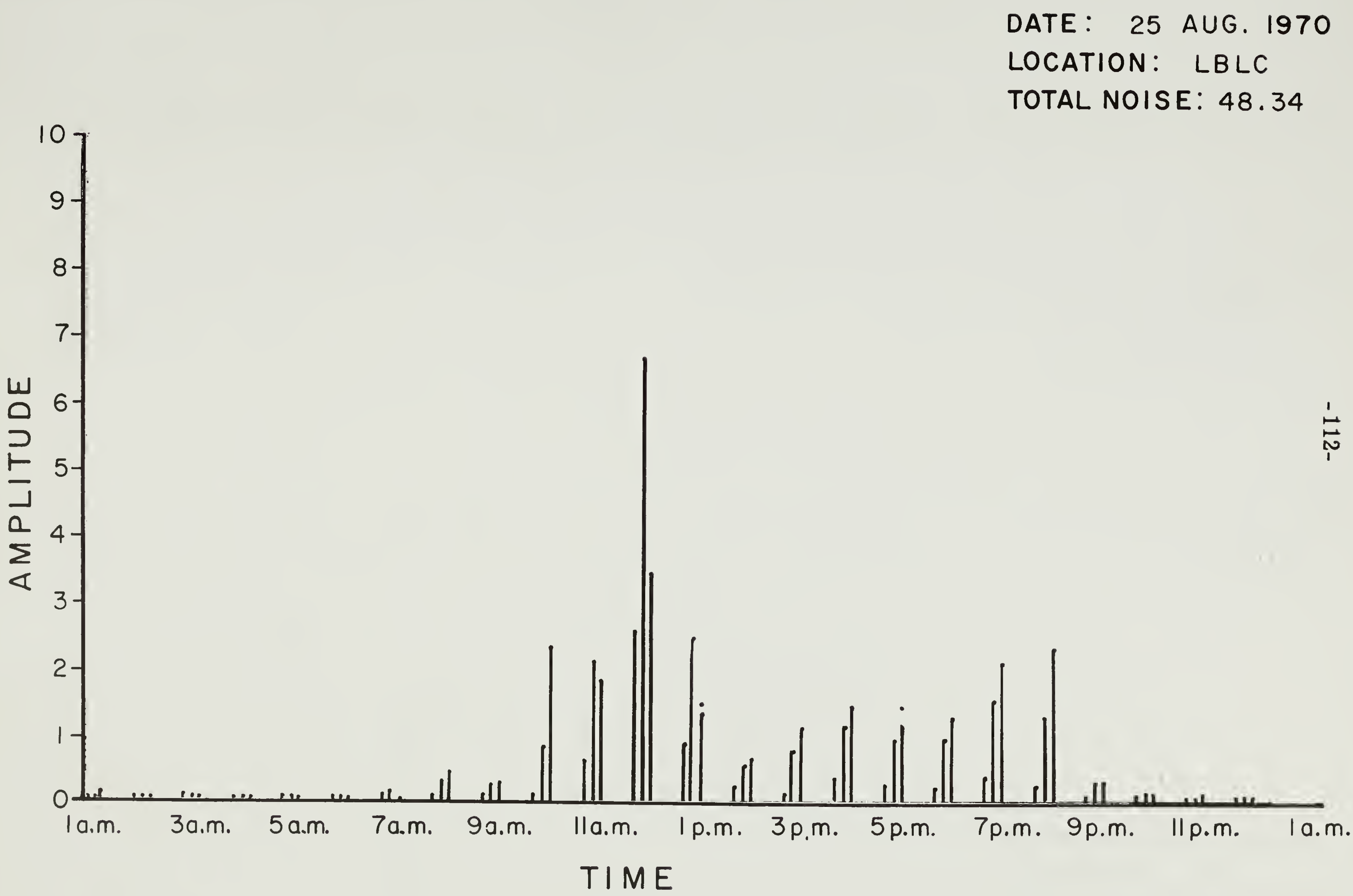

DATE: 25 AUG. 1970
LOCATION: LBLC
TOTAL NOISE: 48.34
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.33

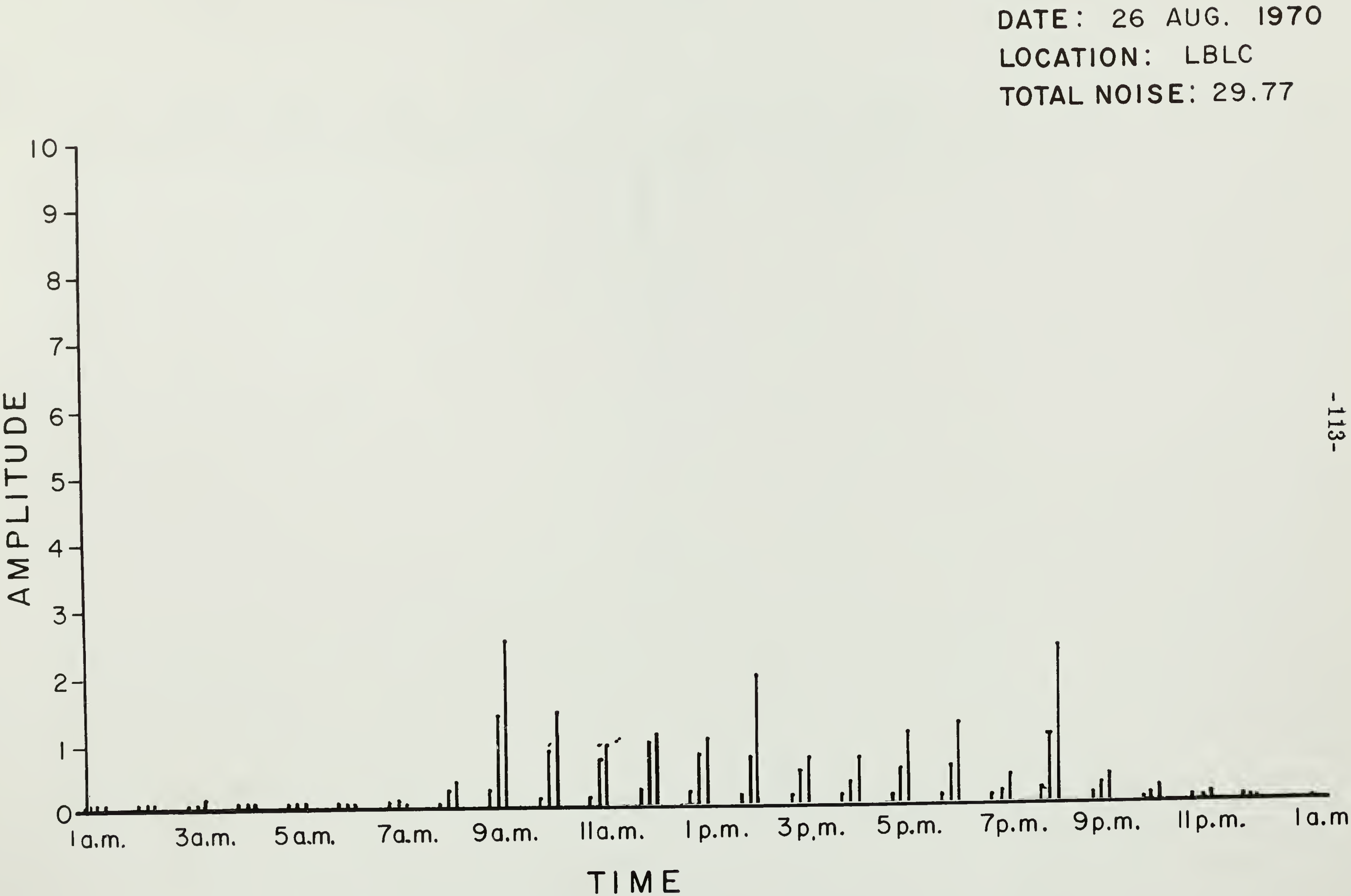

DATE: 26 AUG. 1970
LOCATION: LBLC
TOTAL NOISE: 29.77
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.34

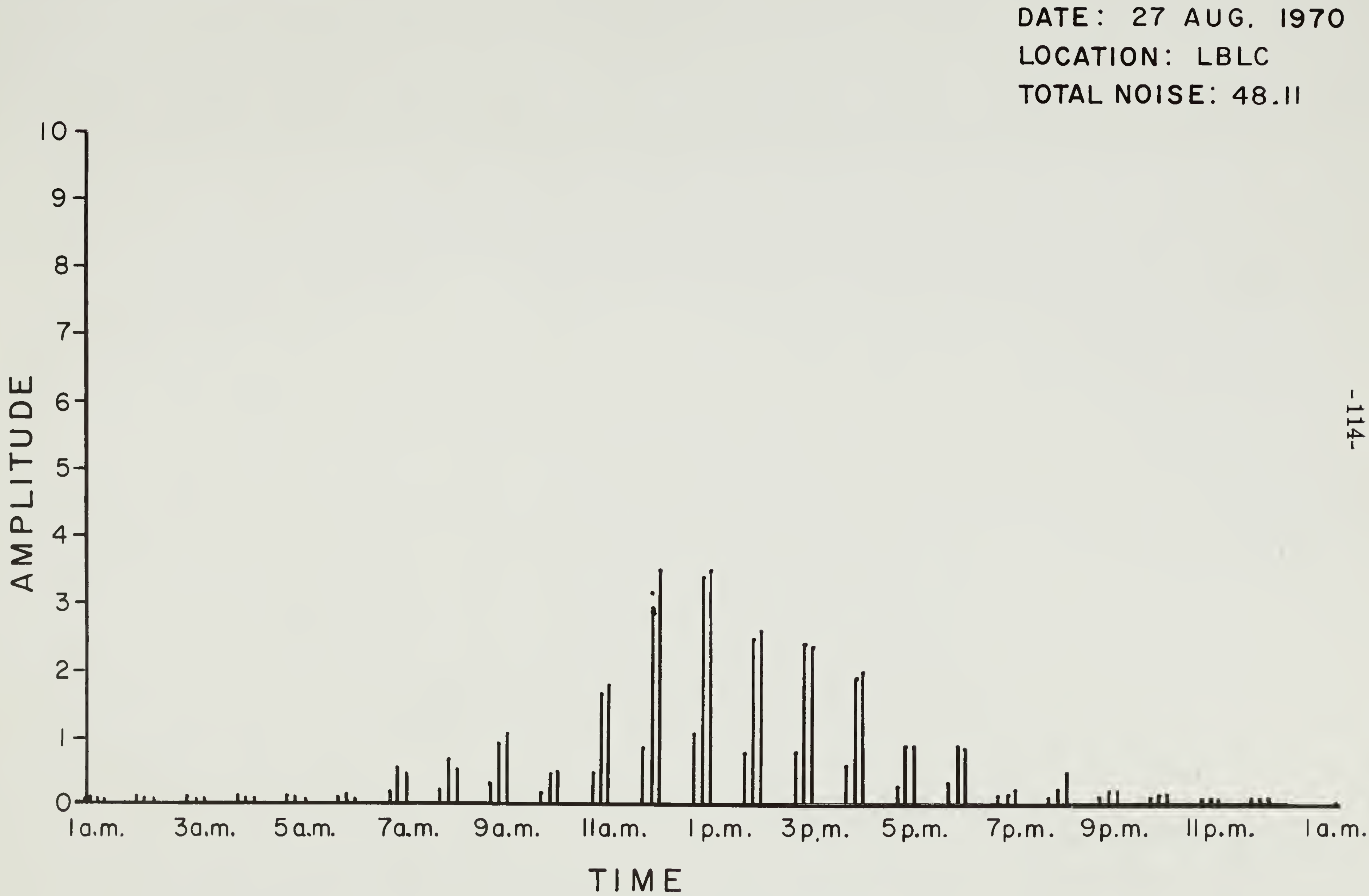

DATE: 27 AUG. 1970
LOCATION: LBLC
TOTAL NOISE: 48.11
AMPLITUDE
10
9
8
7
6
5
4
3
2
1
0
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.35

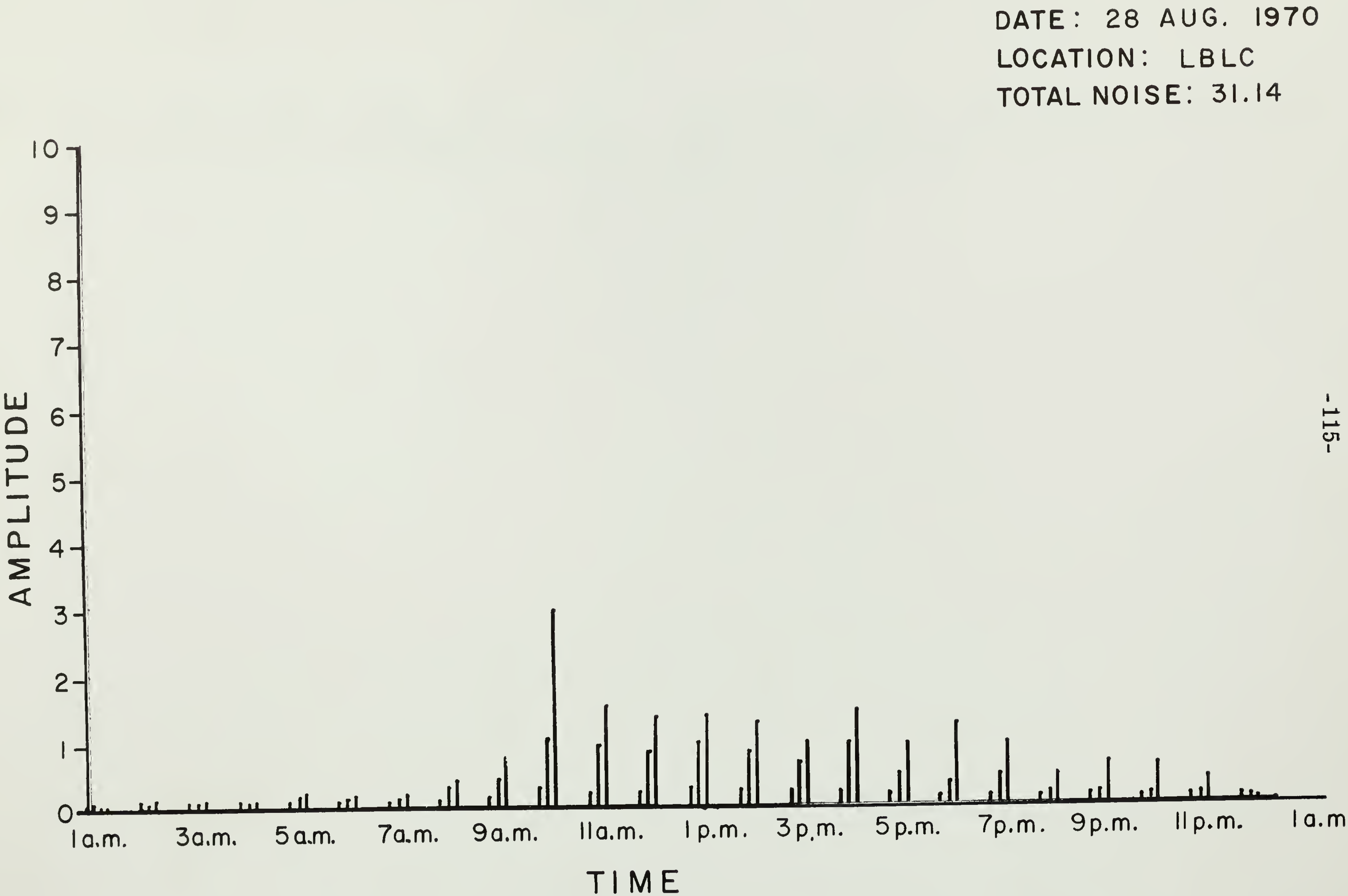

DATE: 28 AUG. 1970
LOCATION: LBLC
TOTAL NOISE: 31.14
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.36


DATE: 29 AUG. 1970
LOCATION: LBLC
TOTAL NOISE: 13.40
AMPLITUDE
10
9
8
7
6
5
4
3
2
1
0
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.37

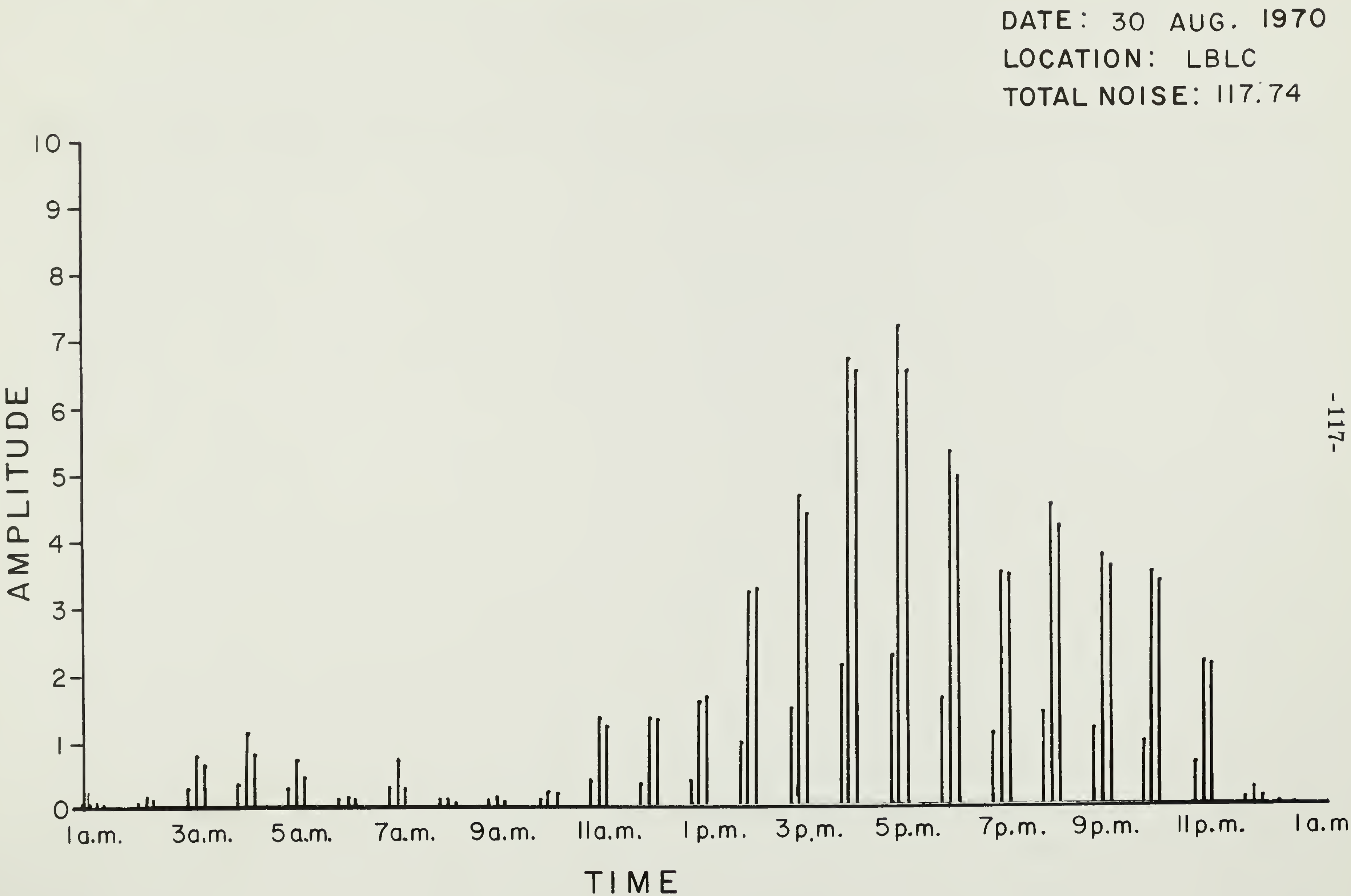

DATE: 30 AUG. 1970
LOCATION: LBLC
TOTAL NOISE: 117.74
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.38

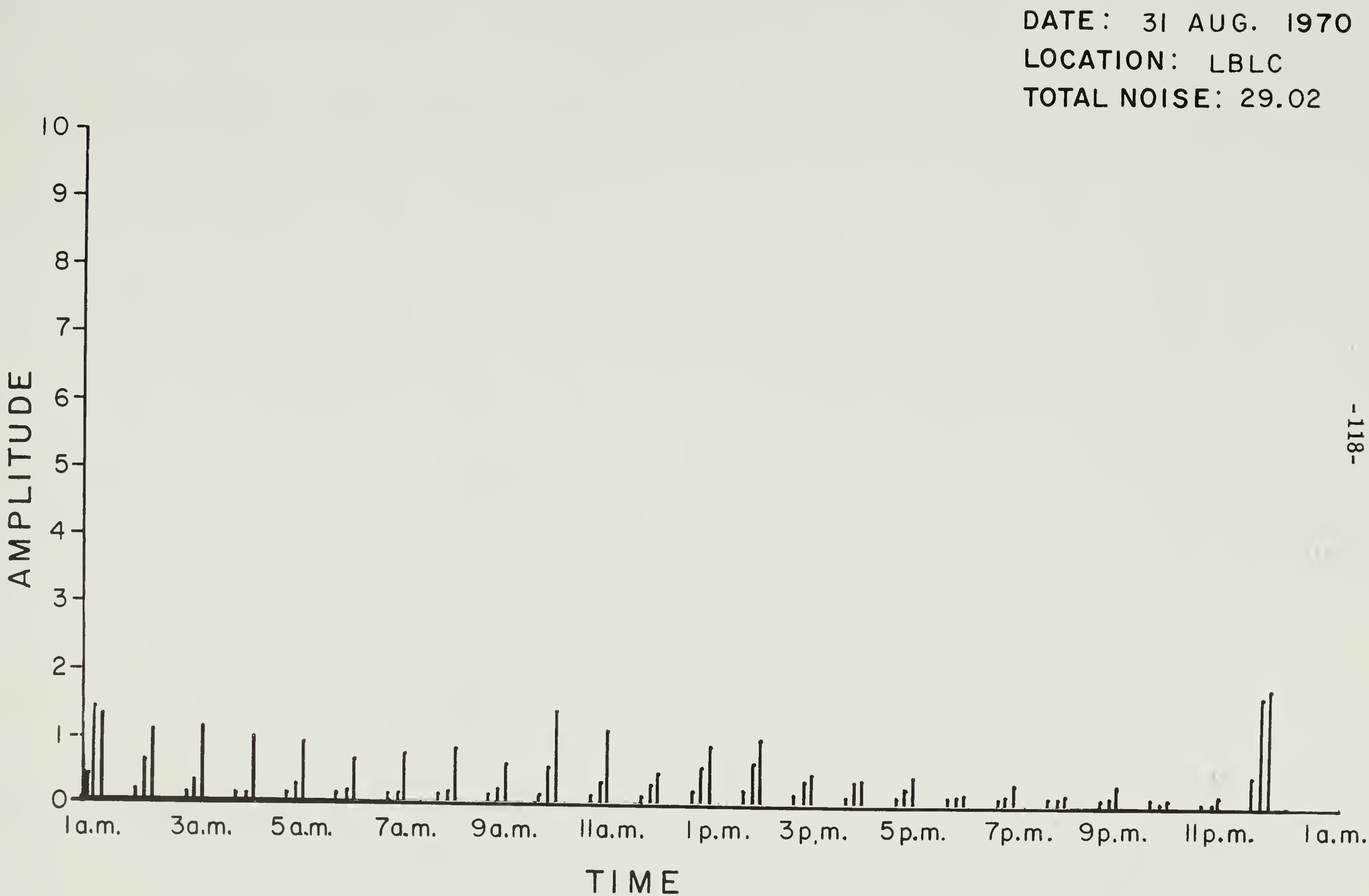

DATE: 31 AUG. 1970
LOCATION: LBLC
TOTAL NOISE: 29.02
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.39

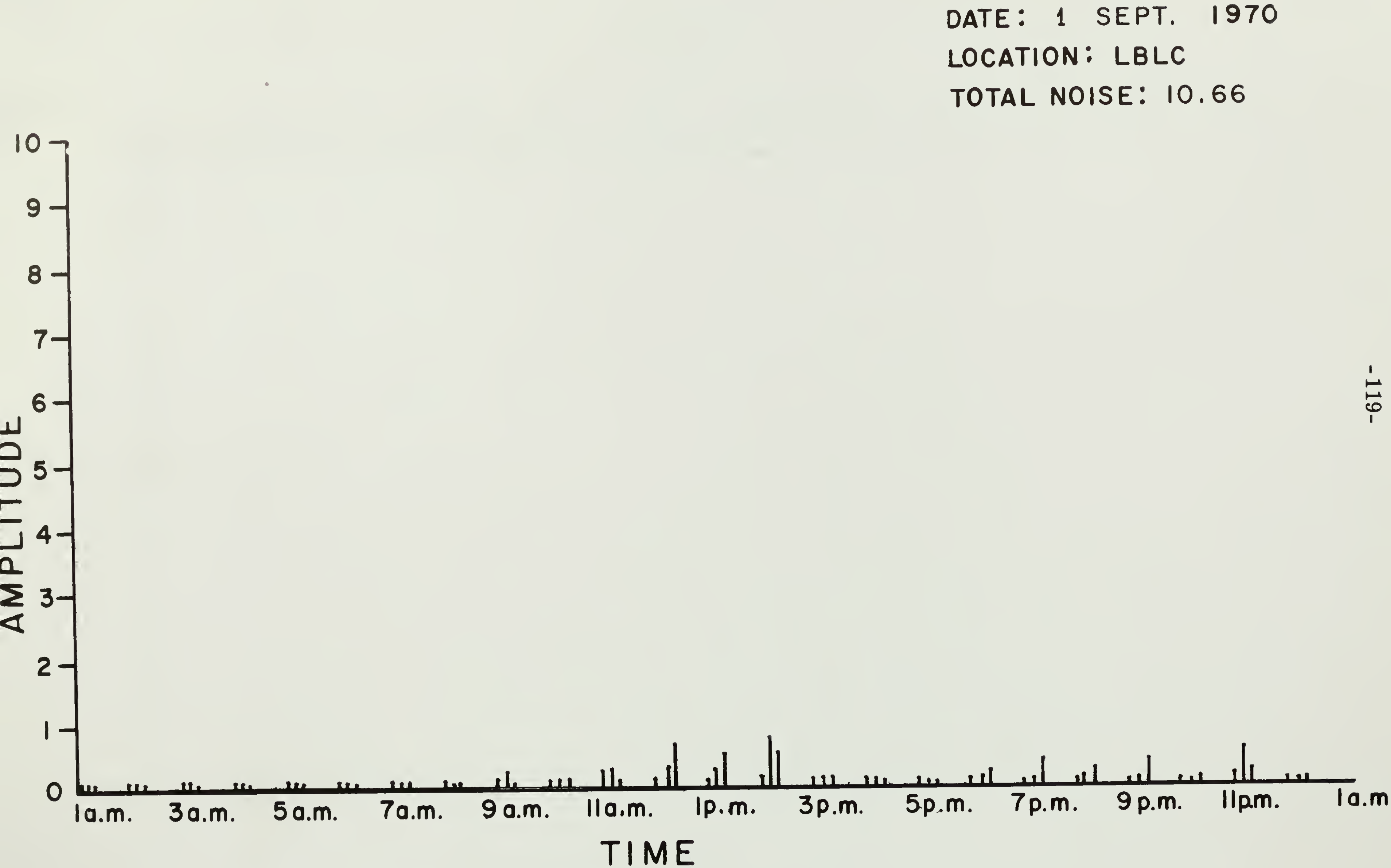

DATE: 1 SEPT. 1970
LOCATION: LBLC
TOTAL NOISE: 10.66
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.40

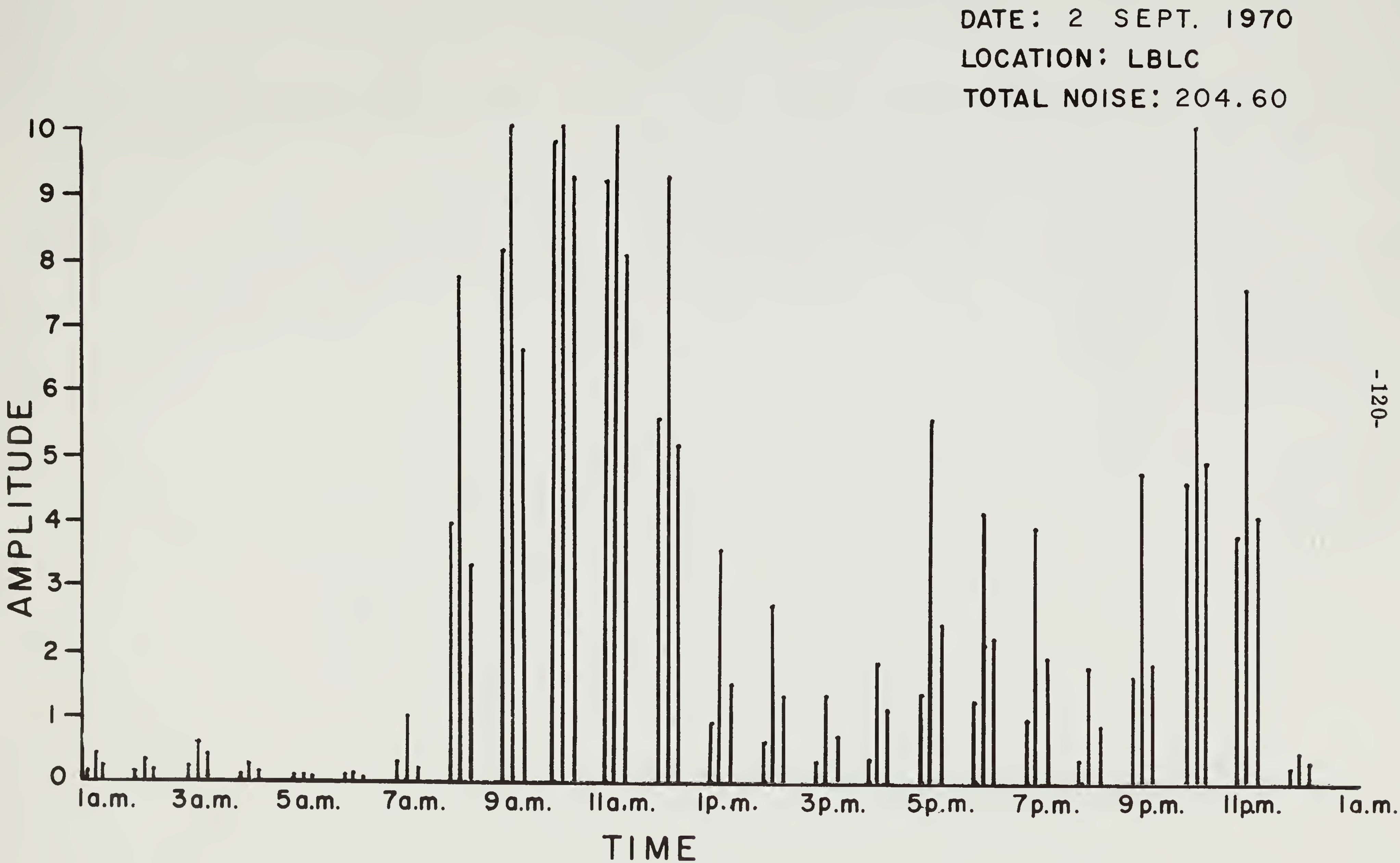

DATE: 2 SEPT. 1970
LOCATION: LBLC
TOTAL NOISE: 204.60
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.41

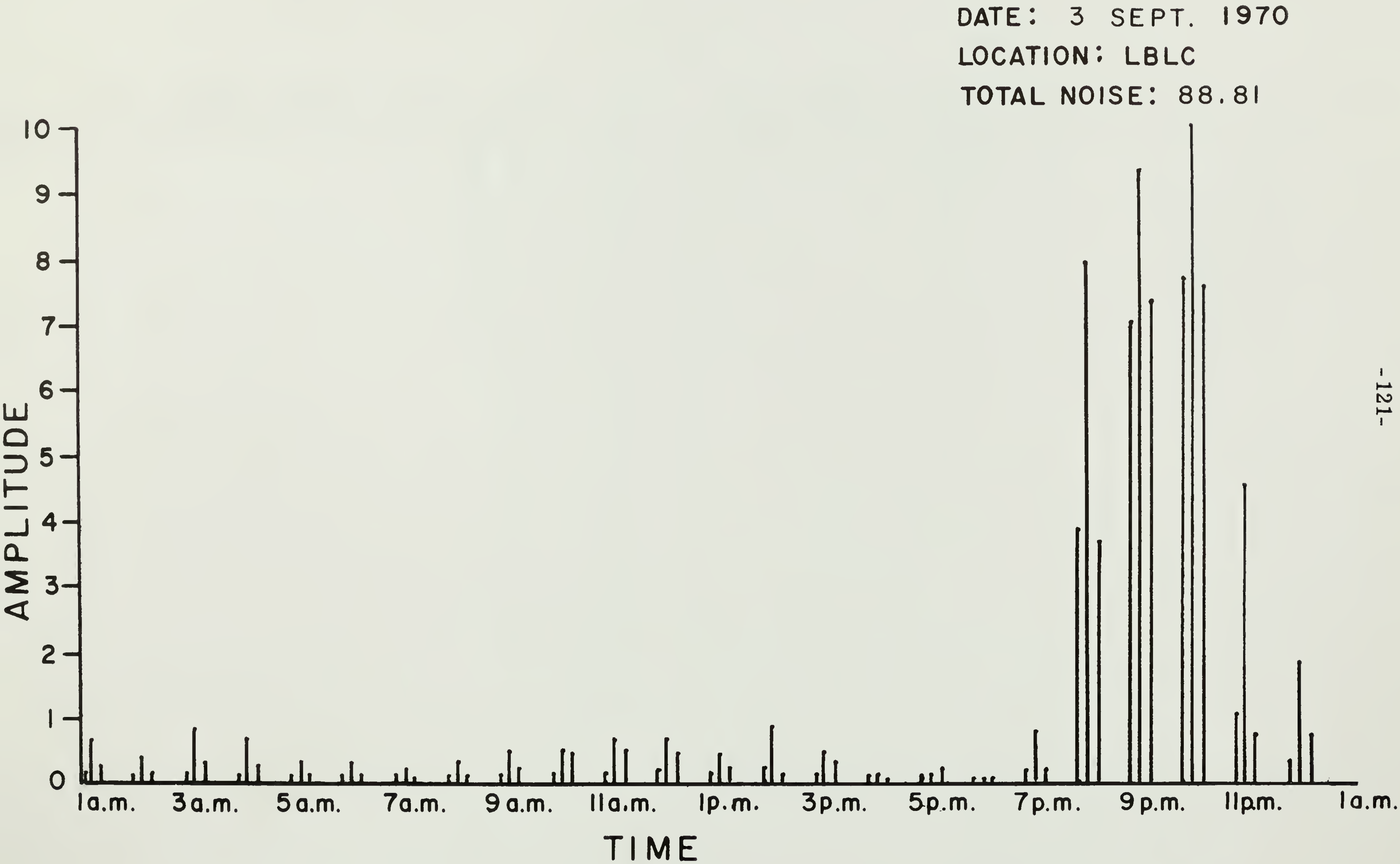

DATE: 3 SEPT. 1970
LOCATION: LBLC
TOTAL NOISE: 88.81
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.42

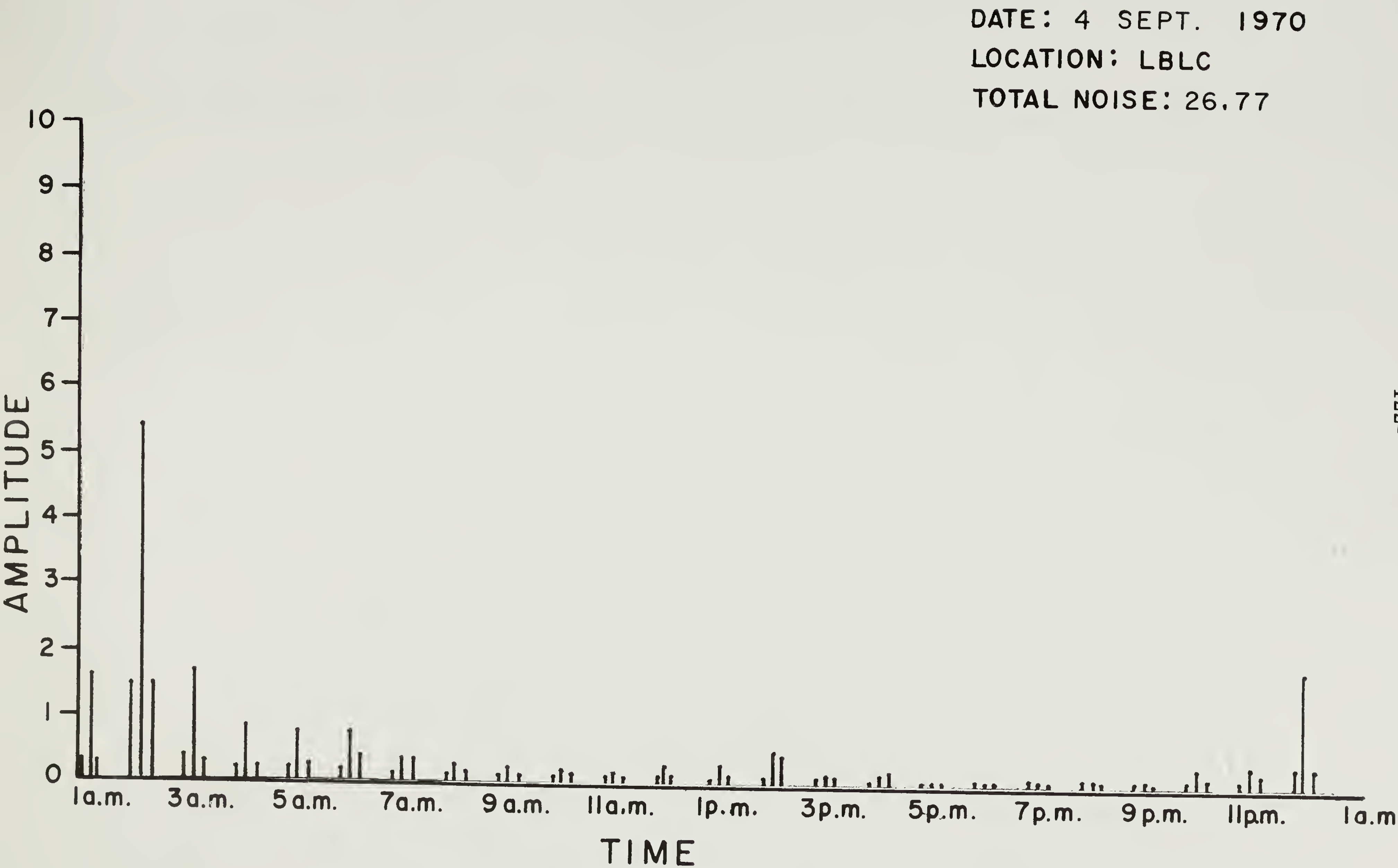

DATE: 4 SEPT. 1970
LOCATION: LBLC
TOTAL NOISE: 26.77
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.43

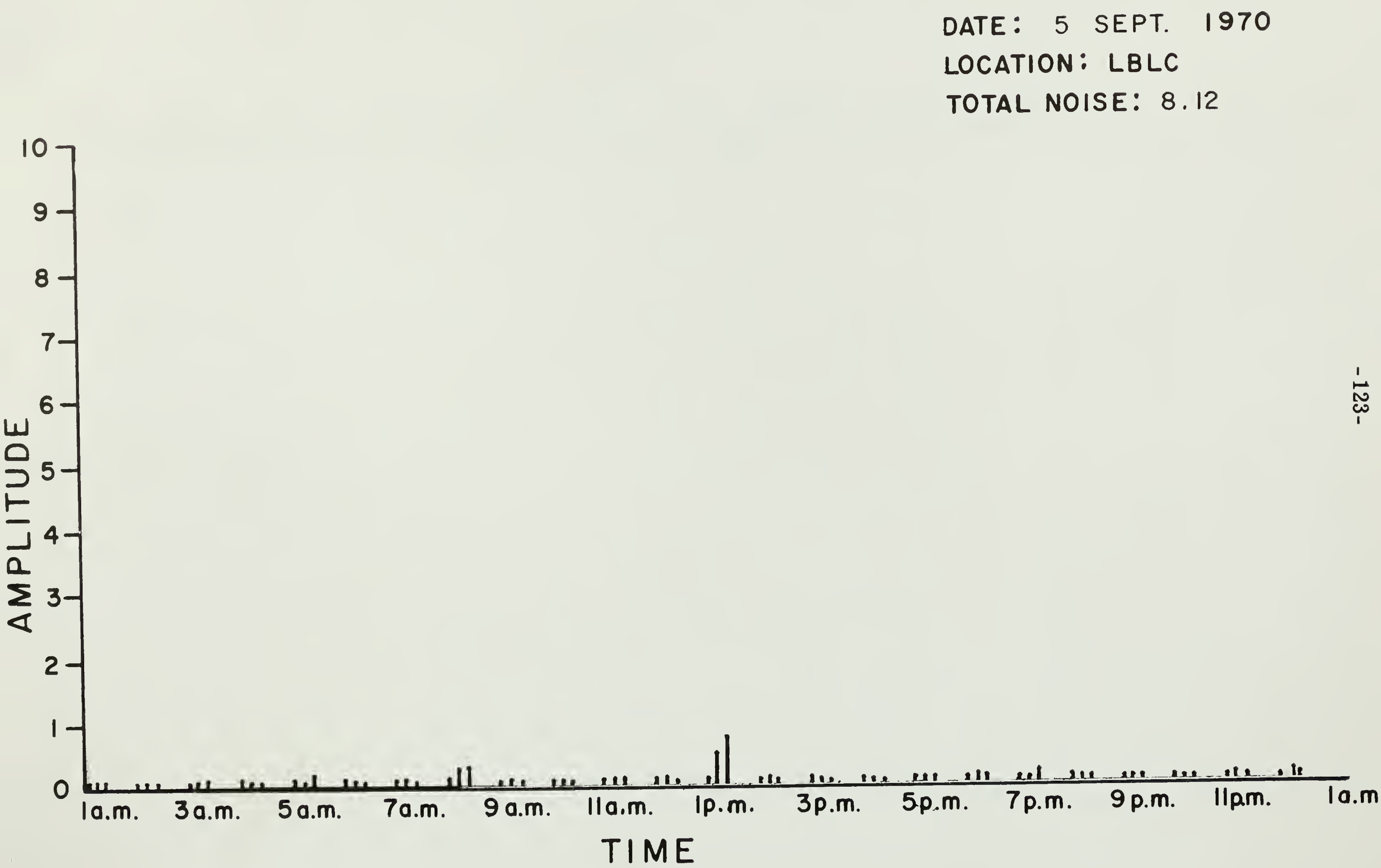

DATE: 5 SEPT. 1970
LOCATION: LBLC
TOTAL NOISE: 8.12
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m
TIME

FIGURE 5.44

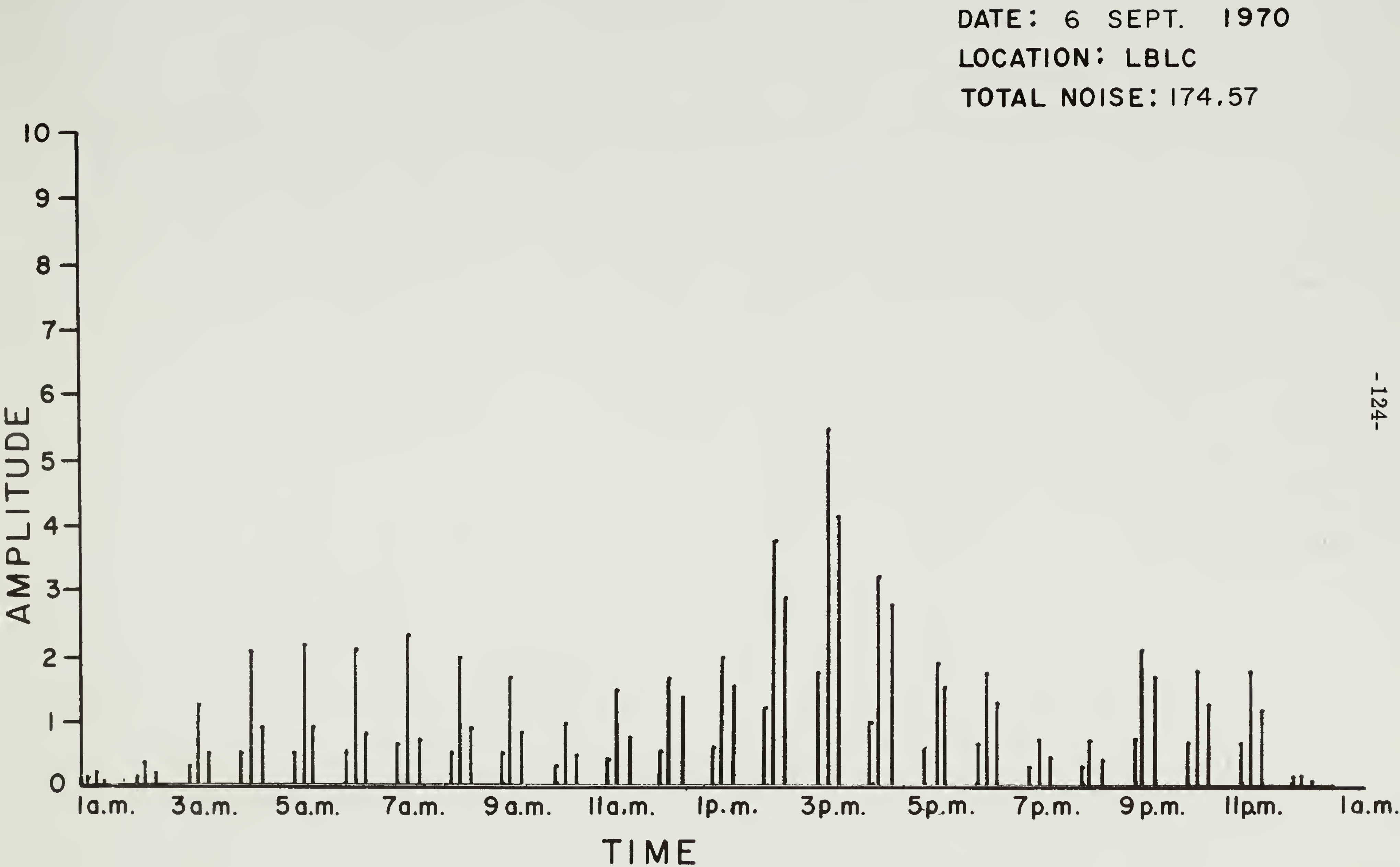

DATE: 6 SEPT. 1970
LOCATION: LBLC
TOTAL NOISE: 174.57
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.45

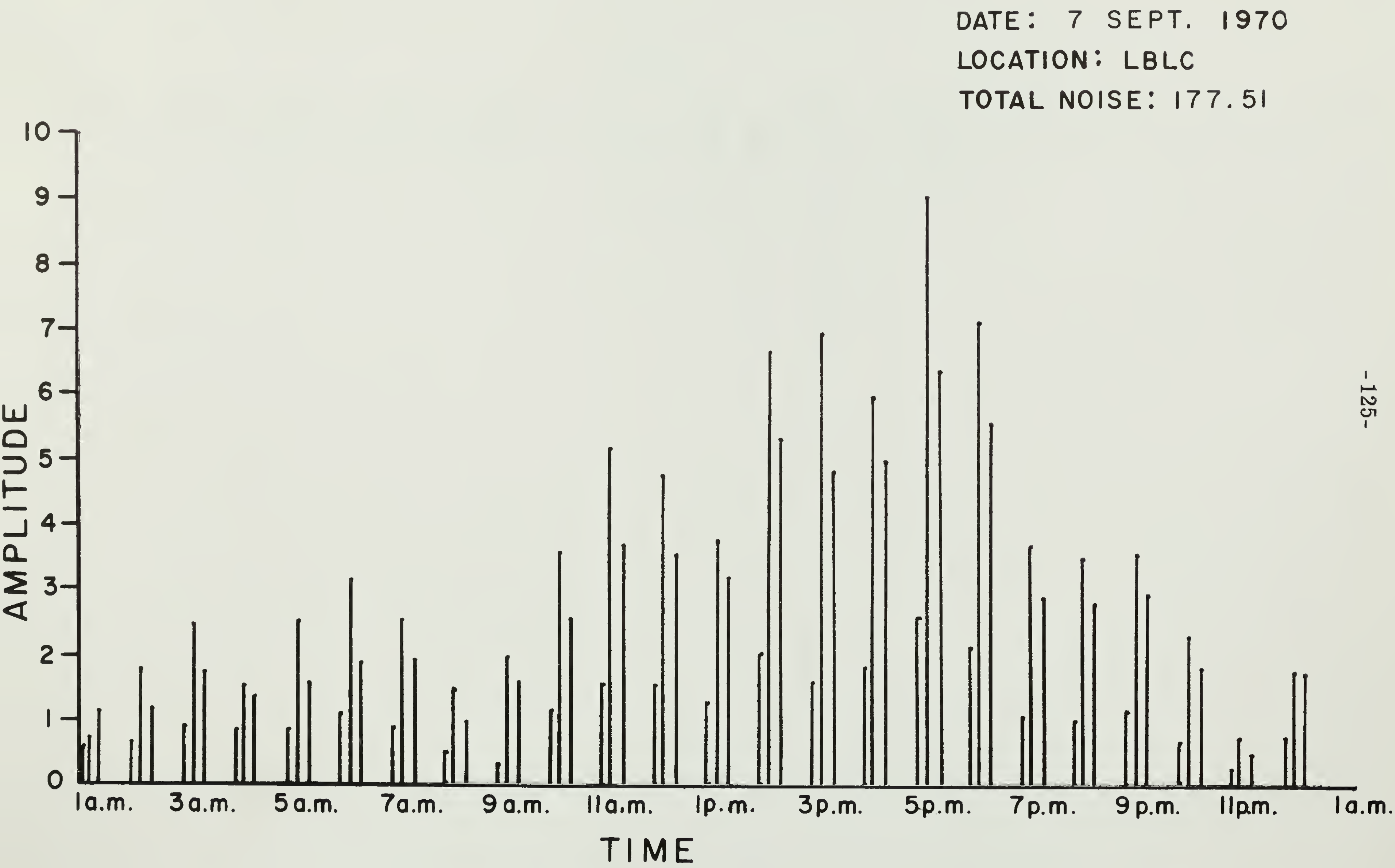

DATE: 7 SEPT. 1970
LOCATION: LBLC
TOTAL NOISE: 177.51
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.46

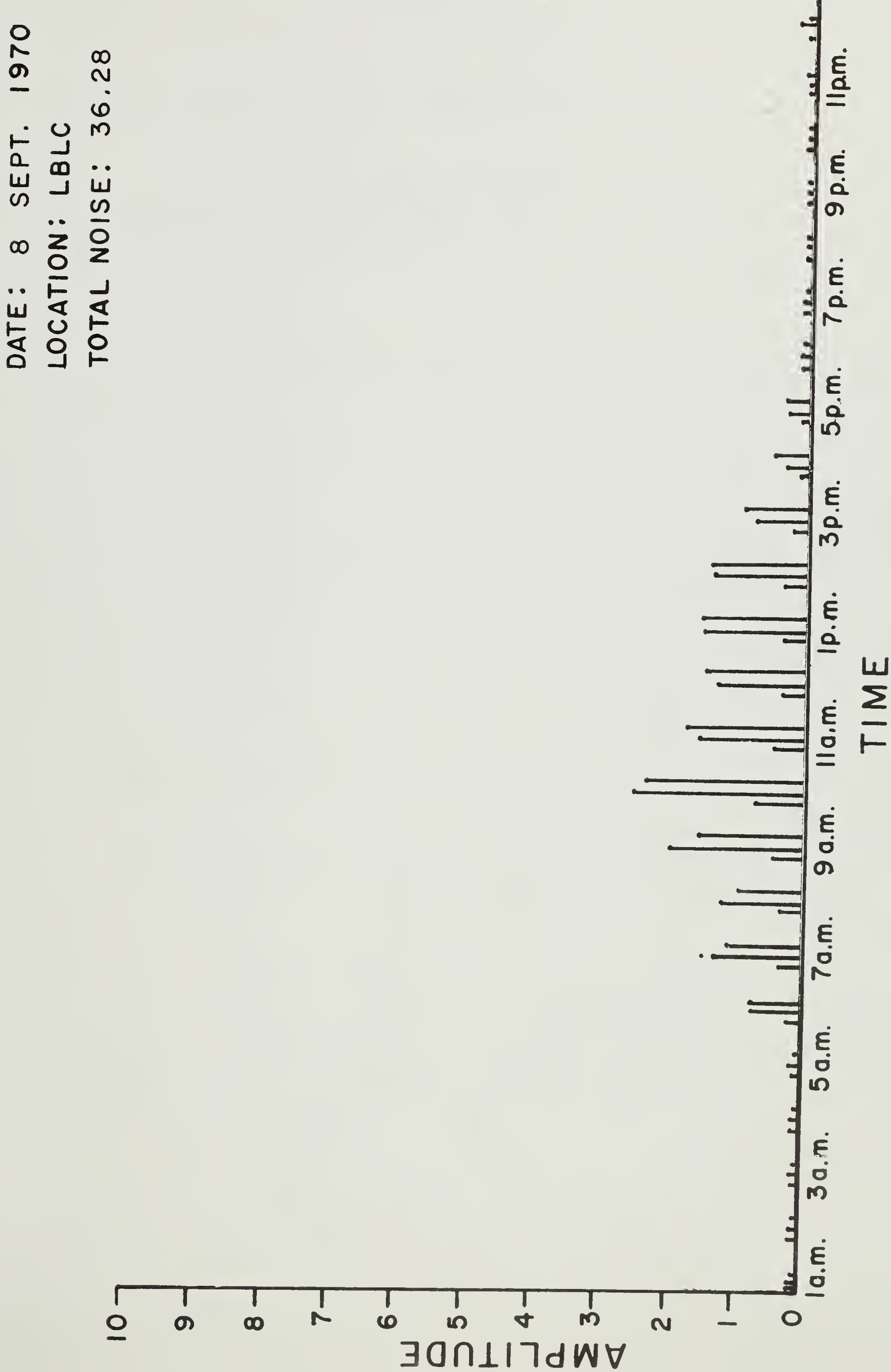

DATE: 8 SEPT. 1970
LOCATION: LBLC
TOTAL NOISE: 36.28
AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
1a.m.
3a.m.
5a.m.
7a.m.
9a.m.
11a.m.
1p.m.
3p.m.
5p.m.
7p.m.
9p.m.
11p.m.
1a.m.
TIME

FIGURE 5.47

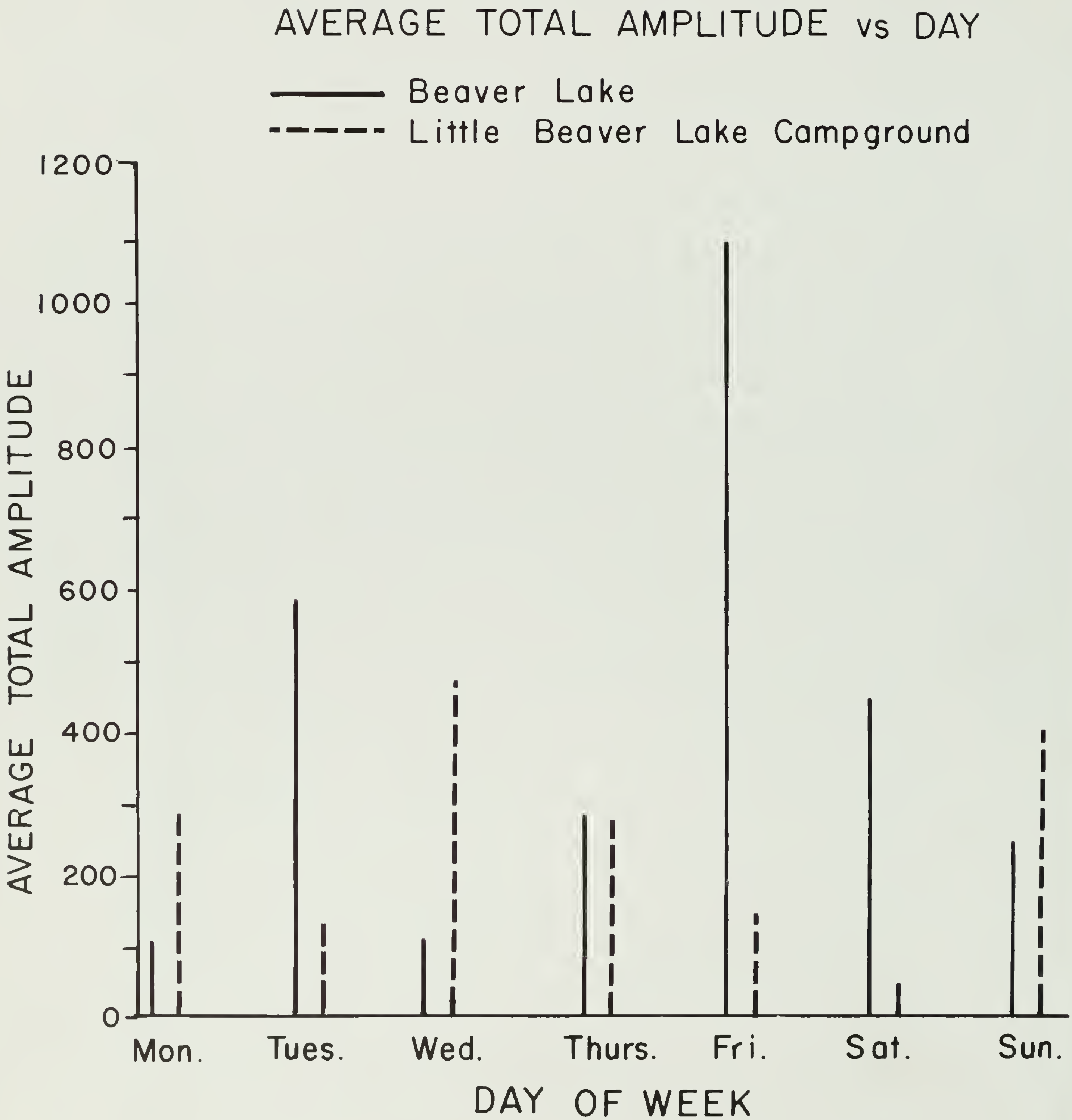

AVERAGE TOTAL AMPLITUDE vs DAY
Beaver Lake
Little Beaver Lake Campground
1200
1000
800
600
400
200
0
AVERAGE TOTAL AMPLITUDE
Mon.
Tues.
Wed.
Thurs.
Fri.
Sat.
Sun.
DAY OF WEEK

FIGURE 5. 48

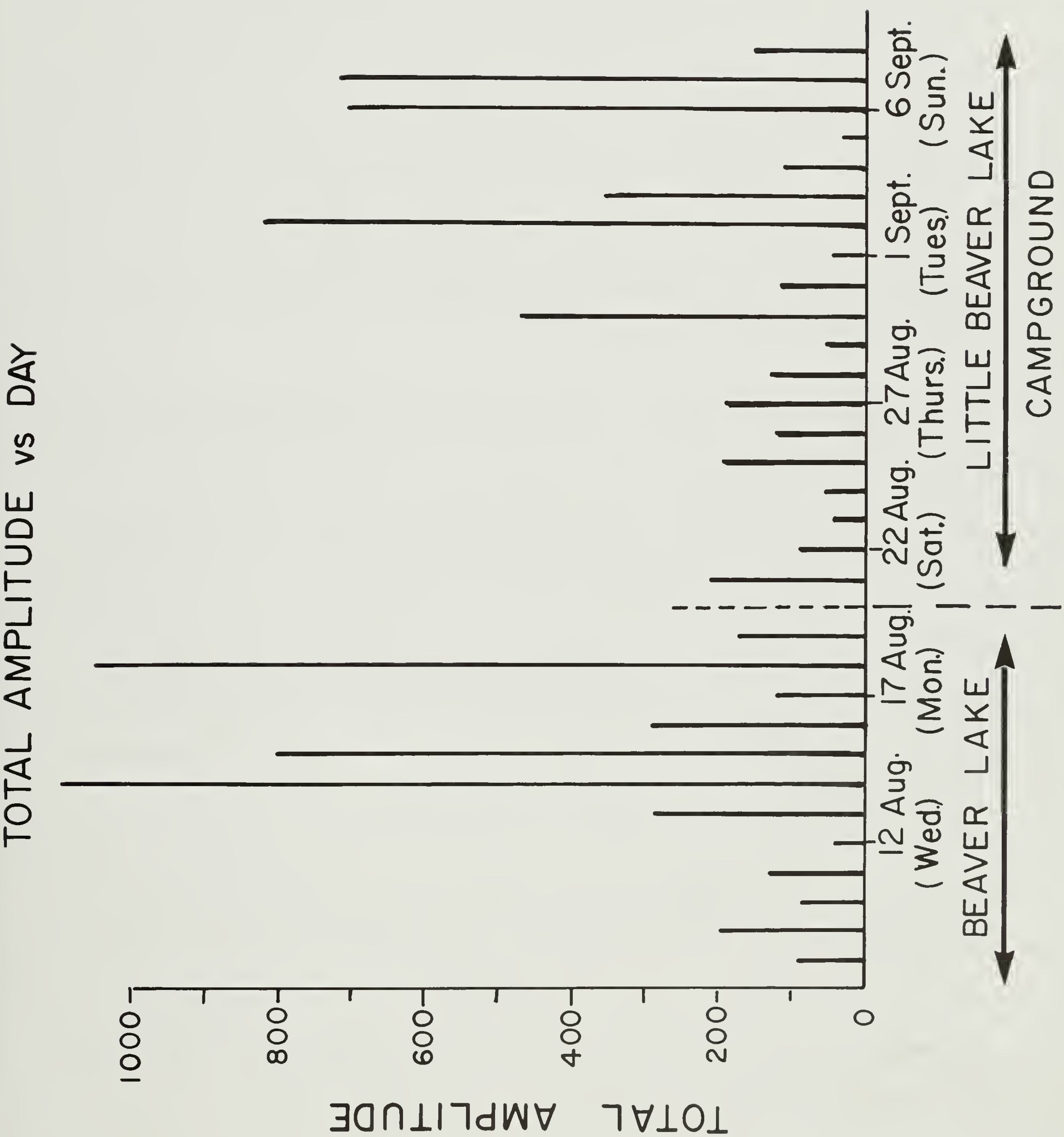

TOTAL AMPLITUDE vs DAY
TOTAL AMPLITUDE
0
200
400
600
800
1000
12 Aug. (Wed.)
17 Aug. (Mon.)
22 Aug. (Sat.)
27 Aug. (Thurs.)
1 Sept. (Tues.)
6 Sept. (Sun.)
BEAVER LAKE
LITTLE BEAVER LAKE CAMPGROUND

FIGURE 5. 49

4. Discussion

The short term tape recordings (both sample noise and 24 hours) present very qualitative data from which it is difficult to draw conclusions. In general, a low amount of sound activity was observed. Some areas of the park are very quiet and should be preserved as such. In other cases, the existing natural noise such as wind and wave motions or waterfalls inundate all other sounds. In the latter cases, human activity sounds such as automobiles, aircraft and campers do not disturb the noise environment and should not be of great concern.

The important noise areas of the park are those that are normally quiet (without either loud human or natural activity sounds) but still exhibit low level wildlife and other natural sounds. It is not possible to exactly identify those areas from the limited noise monitoring performed. It is strongly felt that extensive sound recordings for this purpose are generally impractical and this method of monitoring should not be expanded. As an alternative, periodic noise level measurements (in dbs) could be made with noise meters presently used for recording industrial noise levels.

The most important result of the noise tests was the extensive visible records produced by the integrated noise recording technique. This method was considered very successful and should be expanded. The long term, quantitative records produced could be repeated frequently over a large area and used for both absolute and relative comparison purposes.

One of the interesting results observed from the integrated noise records is that the remote wilderness site of Beaver Lake actually produced more noise than that of the camping site of Little Beaver Lake (see figure 5.49). However, this result is almost certainly due to different meteorological conditions during the respective recording periods. In fact, the total noise amplitudes recorded correlate very well with the average wind velocity recorded by the U. S. Coast Guard and documented in Appendix D. The important point is that remote wilderness sites are <u>not</u> necessarily "quiet" in the sense of amplitude, but the natural wind, wave and tree rustling sounds produced represent a type of sound referred to as incoherent noise (many random frequencies with no specific patterns). On the other hand, human activity noise such as automobiles, motorcycles, snowmobiles, aircraft, or just loud conversation can be and is annoying both to humans and wildlife, although this type of noise may be below the amplitudes of the natural background sounds. It would appear that the annoyance results from the human activity noise being coherent and recognizable and usually appearing in sharp distinct tones.

Much more research needs to be done in monitoring and analyzing environmental noise, particularly from the psychophysical side of sounds. Psychologists refer to the "aversiveness" qualities of a noise.[1] Aversiveness can be regarded as the behavioral response reaction of avoiding or escaping a particular stimulus; in this case, a particular sound. This phenomenon illustrates the very complicated physchological (and animal) considerations of assessing the quality of the noise environment.

The noise levels recorded over a 24 hour period varied widely depending on the location, time of day and the meteorological conditions. In general, more noise activity is apparent during the day than at night, which should be obvious. The loudest and most annoying sounds were those caused by human activity and in particular, the motorcycle or chain saw noise; the rifle shots and the jet aircraft. It can only be assumed that the noise created by snowmobile engines would be equally annoying with high sustained levels of intensity. This type of noise should be carefully monitored and researched to establish what effects, if any, it is having on the park wildlife.

The reader is referred to the below listed references for an in depth treatment of noise and its measurement.

REFERENCES

[1] Kryter, K., Concepts of Perceived Noiseness, Their Implementation and Application, J. Accoust. Soc. Am. 43, 344-361 (Feb. 1968).

[2] Bruce, R. D. Measurement of Noise, IEEE Transactions on Geoscience Electronics, Vol. GE-8, No. 3, (July, 1970).

[3] Gross, E. E. and Peterson, A. P., Handbook of Noise Measurement, published by the General Radio Company (1967).

APPENDIX A

WATER QUALITY MONITORING METHODS

1. Field Sampling

Because of the inaccessability of some of the lakes and streams in the park, collection of biological and chemical samples was difficult and time consuming. However, all lake and stream sites were visited at least once and the samples were obtained during this visit. Streams were sampled close to the center of the stream. Lake Superior was sampled at the 15 meter contour with the assistance of the United States Coast Guard, Munising Station. At each site *in situ* measurements were made of dissolved oxygen and temperature, using a YSI model 54 oxygen meter with membrane probe and 15 meter cable. Grand Sable, Beaver, Trappers, Kingston, and Little Beaver Lakes were sampled at one meter intervals to the bottom for temperature and oxygen profiles. All other sites were measured for surface conditions only since the lakes were isothermal and no differences between the surface and bottom waters were apparent.

Water samples were collected for chemical analysis at each site. Water for chemical analysis was collected in 1000 ml. bottles and kept cold in ice chests. A separate sample was collected at each site, in a 2 liter glass container for pesticide analysis. These samples were also stored in ice chests prior to and during transportation to the laboratory. Prior to use all containers were acid washed and rinsed with distilled water. The 2 liter glass containers were also rinsed with acetone and all containers were rinsed with the sample water prior to sampling.

The lake bottom sediments were sampled for benthic organisms using an Eckman dredge. The sediment samples were then stored in large glass containers and transported to the laboratory for identification. The stream benthos was sampled by physically removing the organisms from the substrate. Three man hours were spent at each site to collect the maximum number of species from each stream. These organisms were fixed in 5% formalin solution before transportation to the laboratory for identification.

Water for bacteriological examination was collected in sterile containers transported to the laboratory and the analysis initiated within 12 hours. Plate A1 shows some of the equipment used in field sampling.

PLATE A1. FIELD SAMPLING EQUIPMENT

2. Long Term Water Quality Monitoring

The water quality of Beaver Lake at the inflow of Beaver Creek was continuously monitored between August 8th, and September 27th, 1970. This site was chosen primarily on the basis of its remoteness and inaccessibility, in order to avoid equipment damage due to vandalism. The purpose of this long term monitoring was to demonstrate the techniques used and the difficulties encountered in the collection of long term water quality data of a stream in the park and also to collect preliminary data.

The equipment used was an *in situ* water quality monitoring system developed by American Limnetics Instruments, Inc. This system employs solid state sensor probes and a battery operated digital recorder to continuously monitor and record water quality parameters over a long term period. The parameters monitored were:

1) temperature
2) dissolved oxygen
3) specific conductance
4) pH
5) stream depth

This equipment was installed at the inflow of Beaver Creek by suspending the sensor probes from the equipment housing unit. The recorder and battery pack were also contained within the housing unit. This system employs a roll of 35 mm film as the recording medium on which digital data is impressed as a series of dots. The film was then developed and the digital data is converted back to an analog strip chart by a tape reader and printer. Plate A2 illustrates the in situ water quality monitoring system.

PLATE A2. WATER QUALITY MONITORING SYSTEM INSTALLED AT BEAVER CREEK

3. Laboratory Analyses

a. General Chemistry

The analyses for general chemical parameters were performed according to "Standard Methods",[1] except where modifications were necessary or acceptable. All modifications were verified prior to use in actual tests.

Ammonia and organic nitrogen were determined by the Kjeldahl method using standard acid titration. Soluble ortho-phosphate and total phosphorus analyses were achieved by the stannous chloride method, using Whatman GF/A fiber glass filters to provide filtrate for the soluble phosphate. Nitrate nitrogen (brucine method), nitrite nitrogen (diazotization method), chloride (diphenyl carbazone), sulfate (barium chloride-turbidimetry), and alkalinity were standard methods. Conductivity measurements were made with a Lectro Mho-Meter (Lab-Line Instruments, Inc.). Hydrogen ion concentration (pH) was measured using an Orion Model 404 Ionanalyzer.

Calcium, magnesium and sodium determinations were made directly on the samples using atomic absorption spectrometry. Water hardness values were calculated from the metal analysis and were reported as mg/L calcium carbonate.

The trace metal analysis included iron, manganese, aluminum, lead, copper, zinc and arsenic. The analyses were made by atomic absorption spectrometry using a Bausch & Laumb AC 2-20 Atomic Absorption Spectrophotometer (Plate A3). The detectable concentration limits of these metals by atomic absorption analysis range from 0.05 to 1.0 mg/L, therefore sample concentration was employed to extend these limits by evaporation of the sample to 1/40 of the original volume, allowing detection of from 0.001 to 0.025 mg/L.

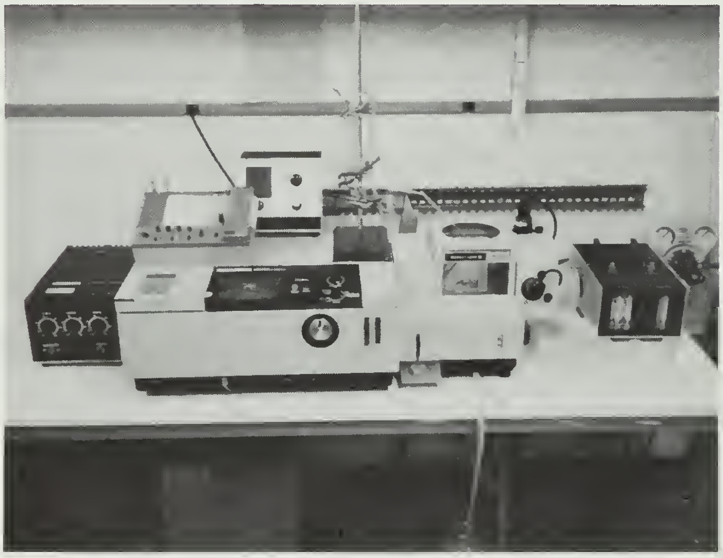


PLATE A3. THE ATOMIC ABSORPTION SPECTROPHOTOMETER

The fish obtained from Lake Superior were analyzed for mercury and arsenic. The mercury assay was performed using the flameless atomic absorption technique and the arsenic determined by the silver diethyldithiocarbonate method (Standard Methods, 12th Edition). The fish samples were dissected and the portion of skin, flesh and bone of the caudal peduncle area was used for these analyses. A 50 gram portion of the sample was homogenized in a high-speed blender with water, transfered to a volumetric flask and made up to 500 mL. Aliquots of this were taken for the analysis.

Mercury was analyzed by taking 0.5, 1.0, and 2.5 gram aliquots of the homogenized fish. The aliquots were then digested with nitric acid, oxidized with potassium permanganate, reduced with stannous chloride and the mercury vapor aspirated through a 9 cm glass cell positioned in the atomic absorption spectrophotometer to measure absorbed mercury emission radiation. Standard mercury solutions and "spiked" fish samples were also determined and the method detection limit determined at 0.02 ppm (parts per million) (0.05ug).

The arsenic determination was performed using 2.5 and 3.5 grams samples of the fish by arsine generation and spectrophotometric measurement of the resulting arsenic-silver salt complex color. The method is sensitive to 1 ug arsenic, therefore the detection limit in these analyses was 0.4 ppm.

b. Pesticide and Herbicide Analysis

A Packard 7400 Series Gas Chromatography System, with a Model 884 dual electron capture/argon ionization and hydrogen flame ionization detector was used for this study (Plate A4). The electron capture detector employed a tritium foil radioactive source.

Coiled borosilicate glass columns, 2.6 meters in length and 4 mm internal diameter were packed with a 2% gas chromatographic grade SE-30 silicone polymer plus 0.2% Carbowax 20M Terephthalic Acid coated on 60/80 mesh

Chromosorb G (DMCS treated and acid washed). Two columns were prepared; one used with the hydrogen flame ionization detector and the other with the electron capture detector.

The majority of the GLC (gas-liquid chromatography) determinations were made with isothermal column conditions but in several instances the column temperature programming capabilities of the instrument were utilized, permitting wider separations of sample components for better identification.

The majority of the pesticide determinations were made isothermally using the following instrument parameters:

Temperature:	Inlet	220°C
	Column	195°C
	Detector	200°C
Carrier Gas:	Nitrogen @ 67 cc/min.	
	28 psig inlet pressure	
Electron Capture Detector:	30 volts	
	2-3x10^{-8} amps suppression	
Recorder:	1 mv range and 5 min./inch	

When the hydrogen flame ionization detector was used, its conditions were:

150 volts

$1x10^{-9}$ amps suppression

40 cc/min. hydrogen rate

400 cc/min. air rate

The temperature program for the column oven was set at $100^{O}C$ for one minute; 5^{O}/minute rate to $225^{O}C$; and hold for 15 minutes.

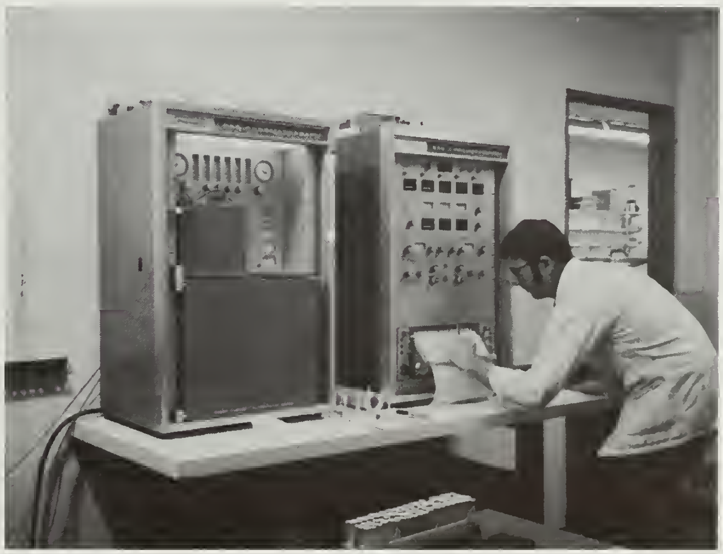


PLATE A4. THE GAS CHROMATOGRAPH

Apparatus and Reagents:

Sampling of extracts for injection and preparing dilutions was performed using Hamilton 0.01, 0.10 and 1.0 mL syringes.

Solvents used for this study were n-hexane, diethyl ether and acetone (for cleaning equipment). They were either purchases as "nanograde" or certified as pesticide-free by GLC assay prior to use.

Other chemical reagents used in this study were:

Boron Trifluoride (BF_3)
14% in methanol
(Applied Science Laboratories)

Magnesium Sulfate, anhydrous

Sodium Sulfate, anhydrous

Sulfuric Acid

Standard pesticides and herbicides were obtained as kits from PolyScience Corporation (Evanston, Illinois). Other standards were received from the Food and Drug Administration, Perrine Primate Research Branch, Perrine, Florida. Standard laboratory equipment filled the remaining requirements.

Standard solutions of each of the pesticides were prepared in hexane, ranging from 2.5 - 250 parts per billion. These were used to determine the retention time and quantitative detector response of each compound. The retention times for this system were quite close to other reported data using similar columns. Standardization of the instrument was performed every day to insure accuracy.

Sample extracts were obtained as either 10 mL or 25 mL solutions in n-hexane. All of the samples were analyzed by direct injection of the extract, without prior clean-up to remove other organic matter. In none of the cases did the interference from extraneous matter excessively hinder the analysis. In most cases a 10 uL injection of sample extract was used. Each determination was allowed to run at least 30 minutes and if necessary the column oven was heated to 240^{o}C for from 1/2 - several hours between samples to remove less volatile sample components. The herbicides: 2, 4-D; 2, 4, 5-T; and Silvex are polychlorinated organic acids and are non-volatile and not amenable to GLC. Therefore, an aliquot of the sample extract was treated to obtain the methyl esters of these compounds, which are more readily volatilized. The sample aliquot was evaporated to dry in a hot water bath in a 25 mL volumetric flask. To the flask was added 2 mL of 14% BF_3 in methanol and this was heated for 2 minutes in hot water. The flask was cooled and filled with n-hexane. The mixture was shaken vigorously to effect the extraction of the esters and other chlorinated hydrocarbons from the BF_3-methanol, which separated and formed a layer at the bottom of the flask. The hexane extract was subsequently injected for GLC assay.

Using this procedure with standards and actual samples spiked with standards showed a good recovery of from 75-100% of the herbicides and pesticides. Also much of the extraneous sample matter remained in the Boron trifluoride-methanol layer, giving a cleaner hexane extract.

Chromatograms were obtained for each sample extract and methylation product extract. These were compared to the standard chromatograms for both retention time of peaks and if they corresponded to any of the standards, for peak area. Chromatogram peak areas, as determined with a planimeter, were used to calculate the concentrations present.

The use of the dual flame ionization/electron capture system for sample component identification proved of considerable aid when analyzing extracts containing organic matter other than the chlorinated pesticides. The electron capture detector has a high affinity for the chlorinated compounds,as much as 5000 times compared to the flame ionization detector. But the unchlorinated organics from the samples showing flame ionization response usually have low electron capture capacity. The use of a dual system allows the additional determination of whether any particular components of a sample are probably chlorinated pesticides or just extraneous organic matter responding similarly to the pesticides.

The water was analyzed for the pesticides and herbicides listed in Table 2. 17.

A one liter sample in a one liter separatory funnel was acidified with dilute sulfuric acid. Diethyl ether (50 mL) was added and mixed with the sample by vigorous shaking. Then three 25 mL portions of n-hexane were added, shaken and withdrawn to provide quantitative extraction of the pesticides from the water. Residual water was removed from the extract by mixing it thoroughly with anhydrous sodium sulfate in a flask.

The ether -hexane extract was concentrated to a few milliliters by distillation. A Snyder distillation column (three unit) was employed to avoid any loss of pesticides. The concentrate was transferred to a 10 mL volumetric flask and made up to 10 mL with hexane. This solution was subsequently used for the GLC pesticide assay.

Half of the concentrated extract (5 mL) was pipetted to a 25 mL volumetric flask and the solvent evaporated by placing the flask in a hot water bath. Two mL of boron trifluoride in 14% methanol was added and the flask again heated for 2 minutes in the hot water bath. This procedure provided quantitative methylation of the 2, 4-D, 2, 4, 5-T and Silvex free acids. The cooled flask was made up to 25 mL with hexane, shaken vigorously for one minute and allowed to stand several minutes to separate the two solvent phases. The hexane solution was used for GLC analysis of the herbicides.

Distilled water and actual samples were "spiked" with standard pesticides and subjected to the above procedure. The GLC assays of the extracts showed good recoveries of both the pesticides and herbicides in the 1. 0 ng/L range and these recoveries were employed in quantitation of the water sample analyses.

The soil, grass, and tree leaf samples (approximately 10 grams) were placed in a small soxhlet extractor and extracted with diethy ether for 6 hours. The extracts were concentrated and methylated as described in the method for water samples then analyzed using the same techniques as the water analysis.

Five species of fish including the Coho, Lake Trout, Whitefish, White Sucker and the Dogfish, were obtained from a commercial fisherman and analyzed for pesticide and herbicide residues. Each fish had a 10 gm sample of flesh and skin removed and this sample was mascerated and thoroughly mixed with anhydrous magnesium sulphate in a glass mortar. The dry mix was transfered to a Soxhlet apparatus and extracted for 6 hours with diethyl ether. This extract was concentrated and methylated as described in the method for water samples prior to GLC assay.

c. Biological Examination

A biologic examination was made of the phytoplankton, zooplankton, and benthic organisms of the lakes and of the benthos of the streams. The organisms were identified to species where possible using standard biological examination techniques.

The benthic organisms were separated from the lake bottom sediment by means of washing and straining the sample. Two standard mesh screen sieves were used. One of these, a relatively coarse screen, was a U. S. Standard Sieve Series No. 50., with openings of 0.297 mm. The other was a No. 100, with openings of 0.149 mm.

The sediment sample was mixed with water and shaken vigorously to suspend the fine sediment. The cloudy supernatant liquid was then drained off quickly by pouring it through the No. 50 sieve into a 10 liter pail. This process was repeated several times. Organism and debris collected on the screen were removed and stored in glass containers for identification. The material in the 10 liter pail was later poured through the No. 100 sieve to concentrate any micro-benthos organism. These organisms are small enough to fall through the No. 50 sieve.

The residual remaining after the decanting process was further washed and screened by lowering the No. 50 sieve containing a portion of the sample into a tub of water. The sieve was moved vigorously in a circular pattern and at the same time it was raised and lowered slightly. When the water in the sieve was no longer cloudy the sieve was removed from the tub and any organisms were removed and stored with those already collected.

The stream benthos, was separated and concentrated at the time of collection and no further preparation was necessary before identification.

The equipment used for the collection of plankton also concentrates the sample in that very little water is collected with the plankton specimens. The specimens were mounted in polyvinyllactophenol after dissection in the case of the crustacea and water in the case of the algae before microscopic examination. The bacteriological examination of a water sample was performed as soon after collection as possible. In no case did the time elapsing between collection and examination exceed 24 hours.

The membrane filter method was used for the examination of water collected from the park in accordance with Standard Methods[1].

References

1 Standard Methods for the Examination of Water and Waste Water 12th Ed. American Public Health Association Inc. (1965).

FIGURE I

ELECTRON CAPTURE GAS CHROMATOGRAM

CHLORINATED HYDROCARBON PESTICIDE STANDARDS

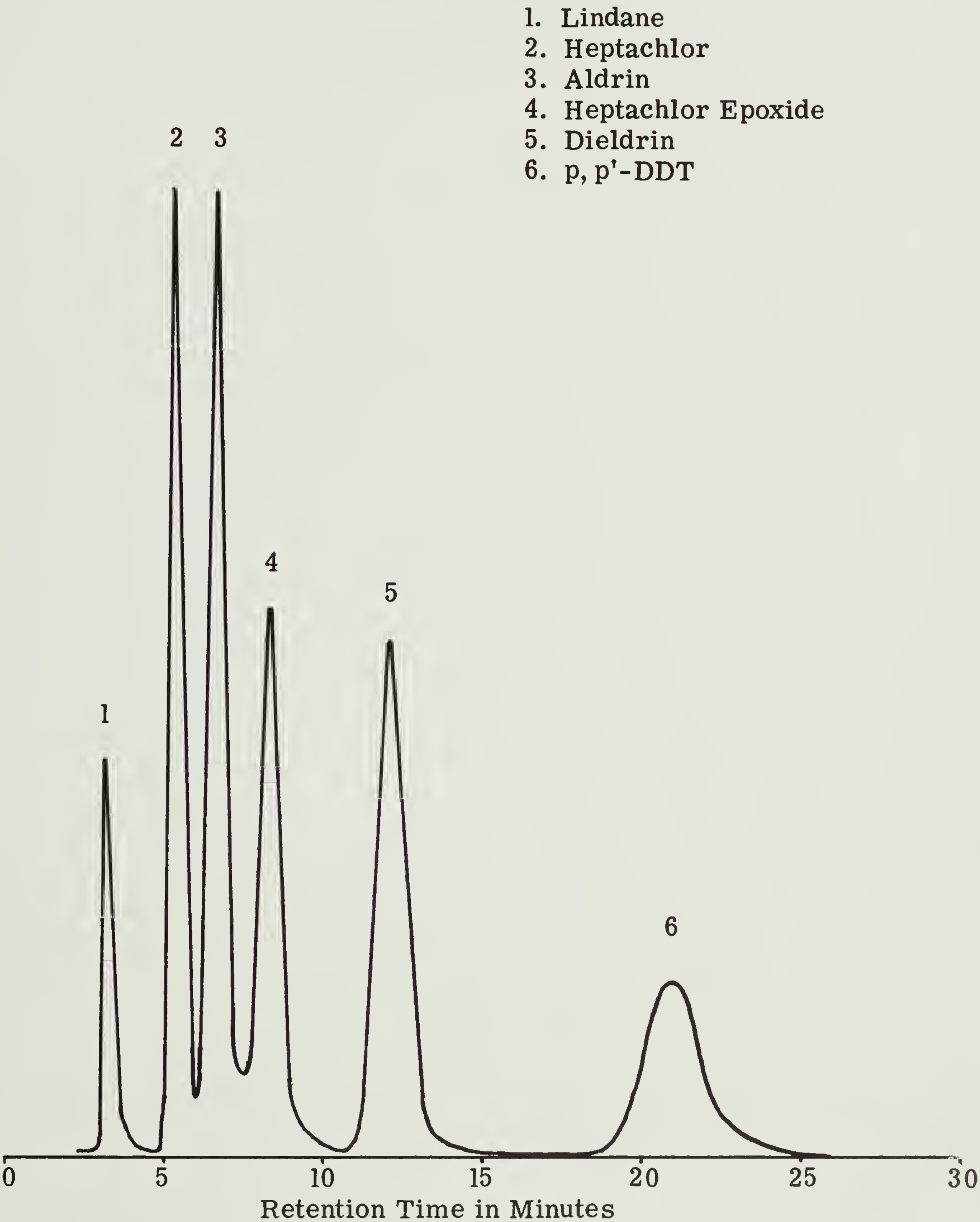


FIGURE 2

ELECTRON CAPTURE GAS CHROMATOGRAM

CHLORINATED HYDROCARBON PESTICIDE STANDARD

TOXAPHENE

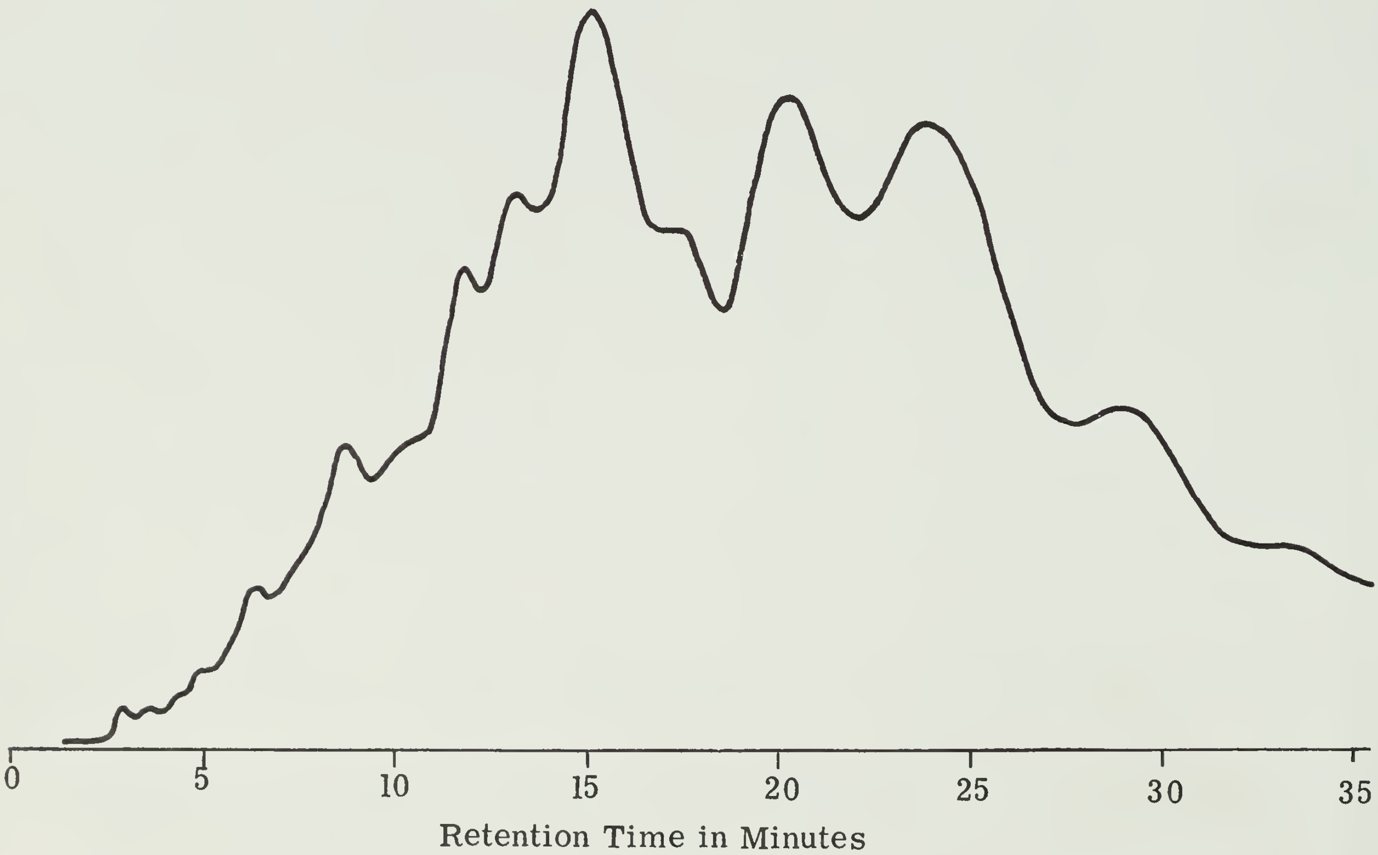


FIGURE 3

ELECTRON CAPTURE GAS CHROMATOGRAM

CHLORINATED HYDROCARBON PESTICIDE STANDARDS

RECOVERED FROM WATER BY EXTRACTION

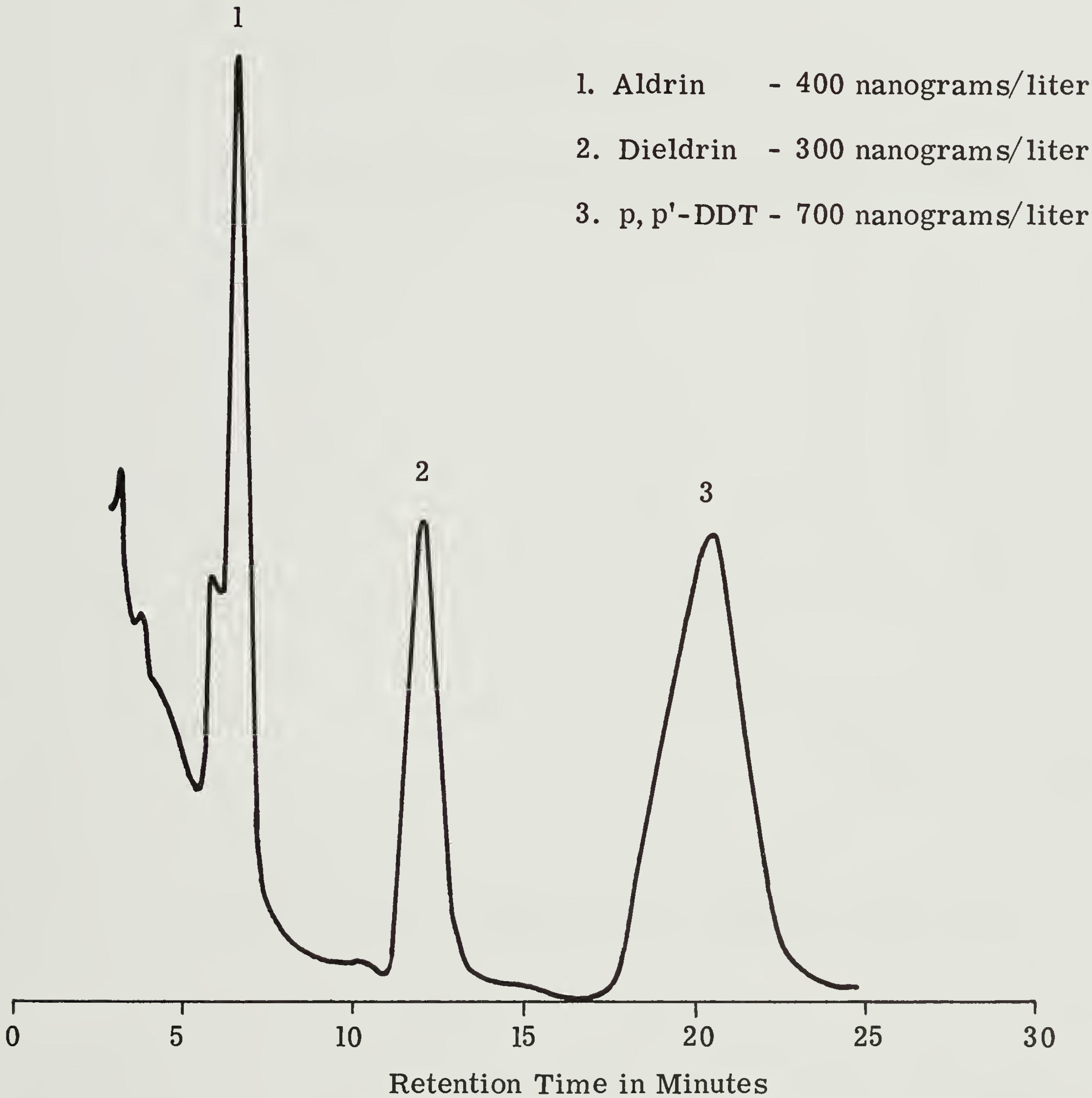


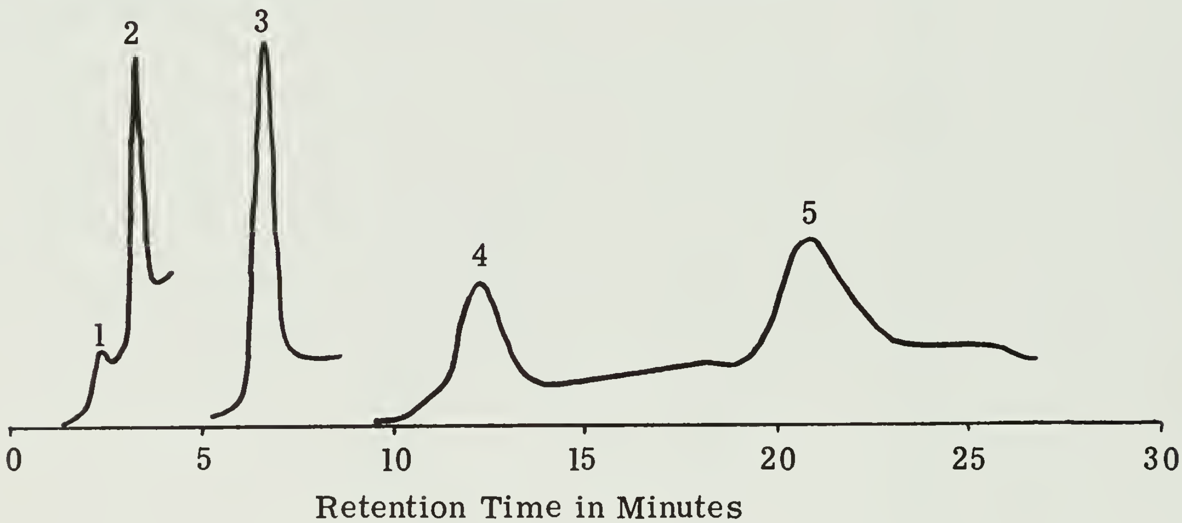
FIGURE 4

ELECTRON CAPTURE GAS CHROMATOGRAM

STANDARD PESTICIDES AND HERBICIDES

1. 2, 4-D - 80 nanograms/liter
2. Silvex - 60 nanograms/liter
3. Aldrin - 80 nanograms/liter
4. Dieldrin - 60 nanograms/liter
5. p, p'-DDT - 140 nanograms/liter

STANDARDS TREATED TO DETERMINE HERBICIDES



STANDARDS EXTRACTED FROM WATER AND TREATED

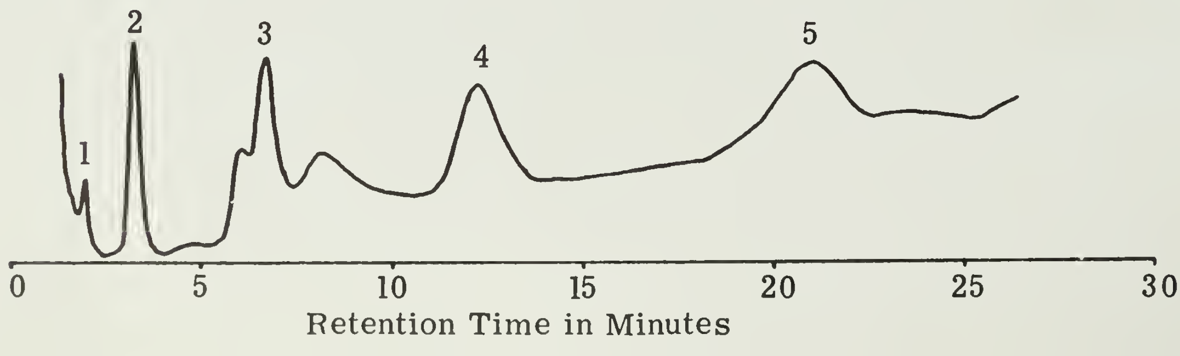


FIGURE 5

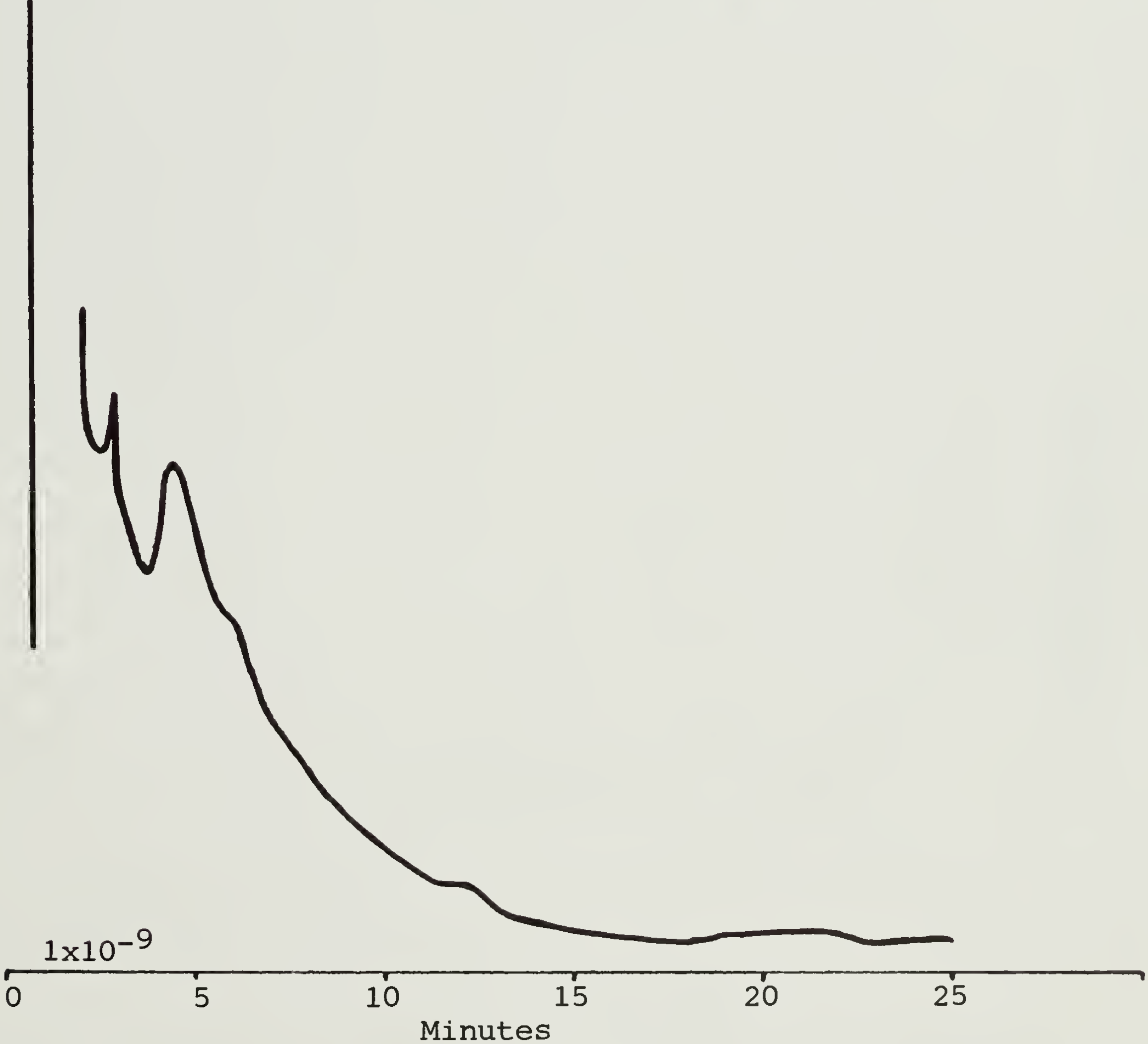
PESTICIDE RESIDUE ANALYSIS

Water Sample - Kingston Lake
Pictured Rocks Nat. Shoreline
Collected: 28 June, 1970

Packard 7400 Gas Chromatograph
Electron Capture Detection

Column: 2.6m x 4mm glass
2% SE-30 & PEG-20M TPA
on 60/80 mesh Chromosorb G

Column Temperature: 195°C.
Carrier gas: Nitrogen @ 73cc/min.



10ul. injection (equivalent to 10ml. original sample)

FIGURE 6

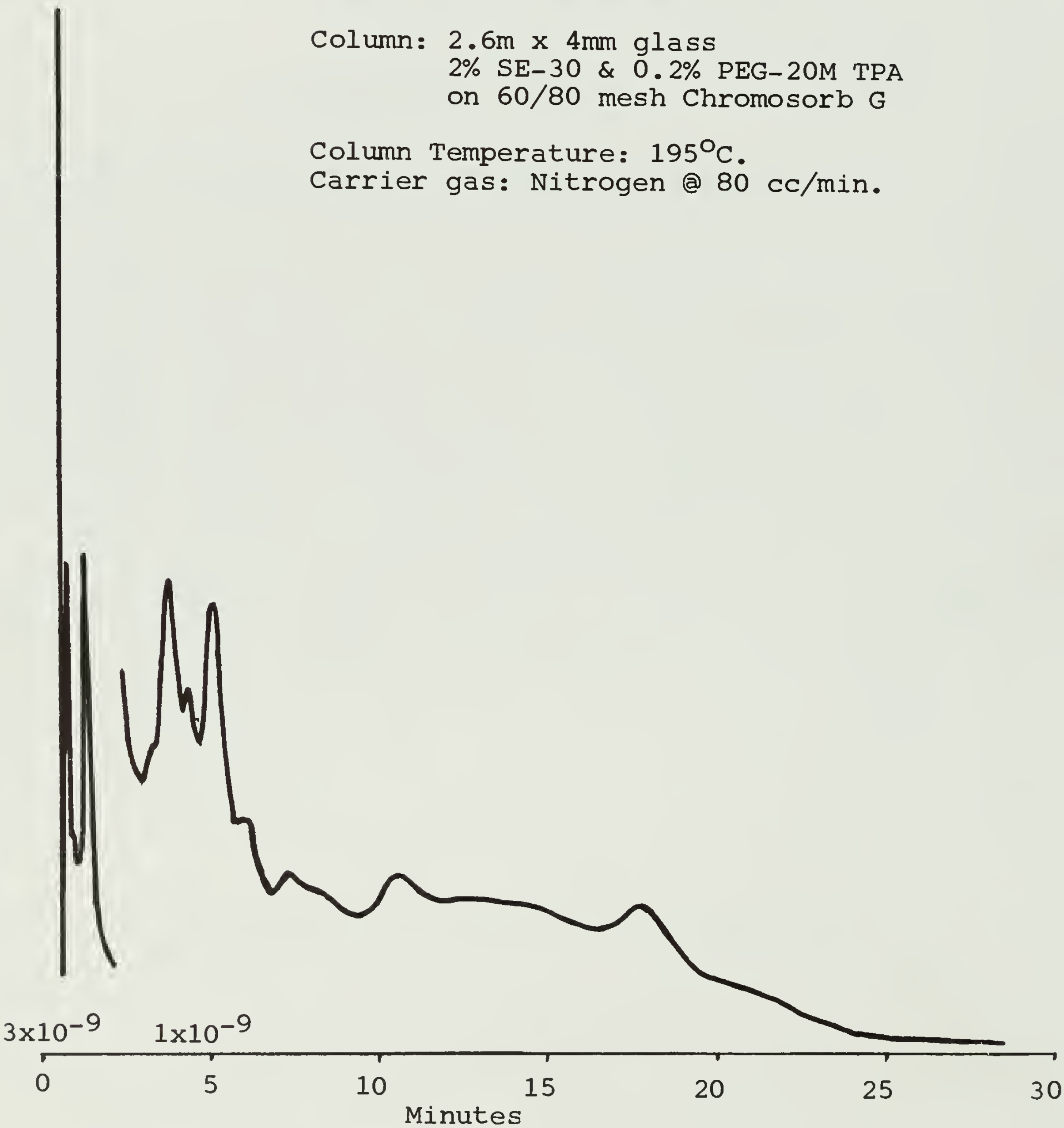
PESTICIDE RESIDUE ANALYSIS

Soil Sample - Kingston Lake Campsite
Pictured Rocks Nat. Shoreline
Collected: 6 Aug., 1970

Packard 7400 Gas Chromatograph
Electron Capture Detection

Column: 2.6m x 4mm glass
2% SE-30 & 0.2% PEG-20M TPA
on 60/80 mesh Chromosorb G

Column Temperature: 195°C.
Carrier gas: Nitrogen @ 80 cc/min.



10ul. injection (equivalent to 25mg. original sample)

FIGURE 7

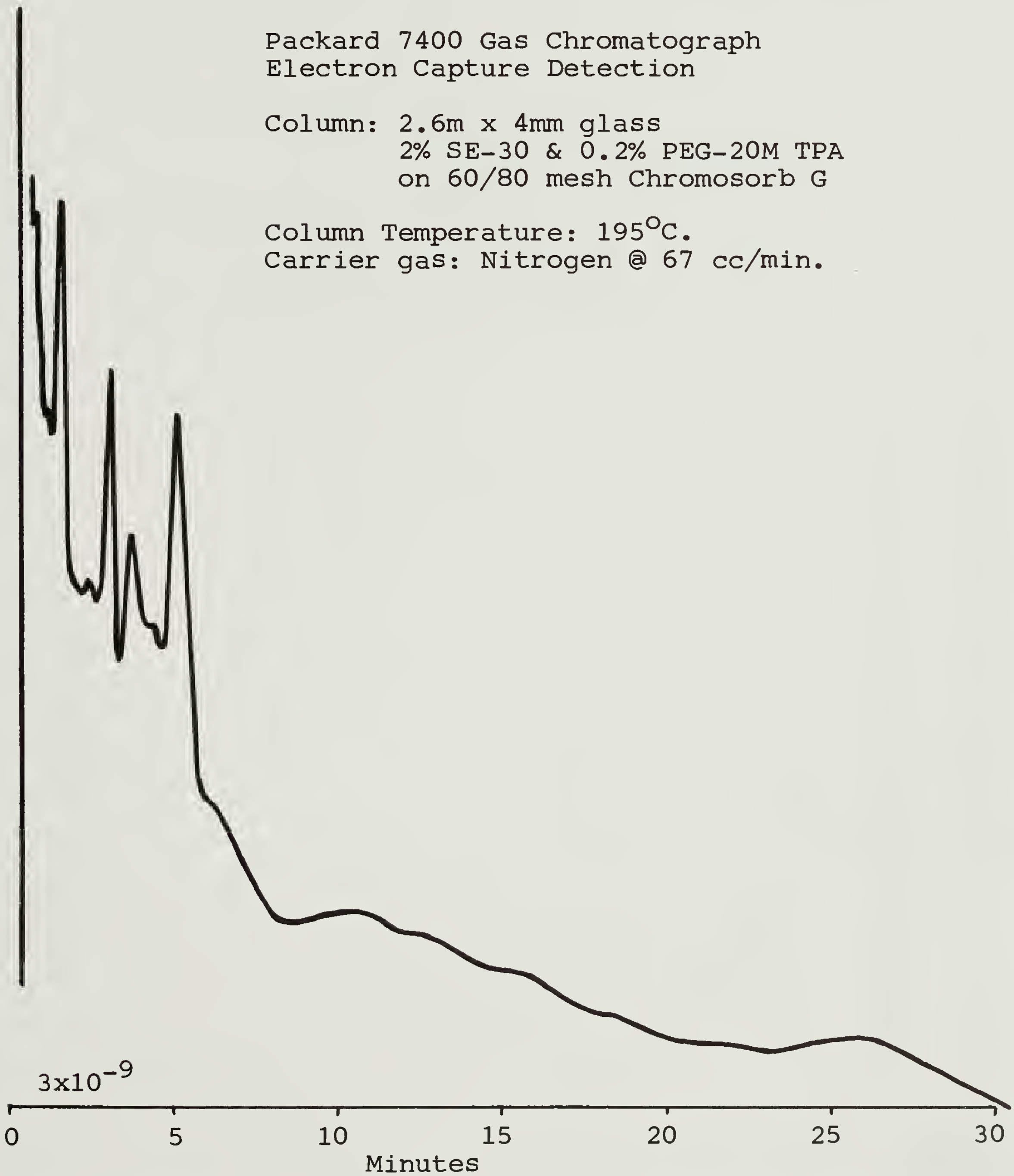
PESTICIDE RESIDUE ANALYSIS

Grass Sample - Kingston Lake Campsite
Pictured Rocks Nat. Shoreline
Collected: 6 Aug., 1970

Packard 7400 Gas Chromatograph
Electron Capture Detection

Column: 2.6m x 4mm glass
2% SE-30 & 0.2% PEG-20M TPA
on 60/80 mesh Chromosorb G

Column Temperature: 195°C.
Carrier gas: Nitrogen @ 67 cc/min.



10ul. injection (equivalent to 6.4mg. original sample)

FIGURE 8

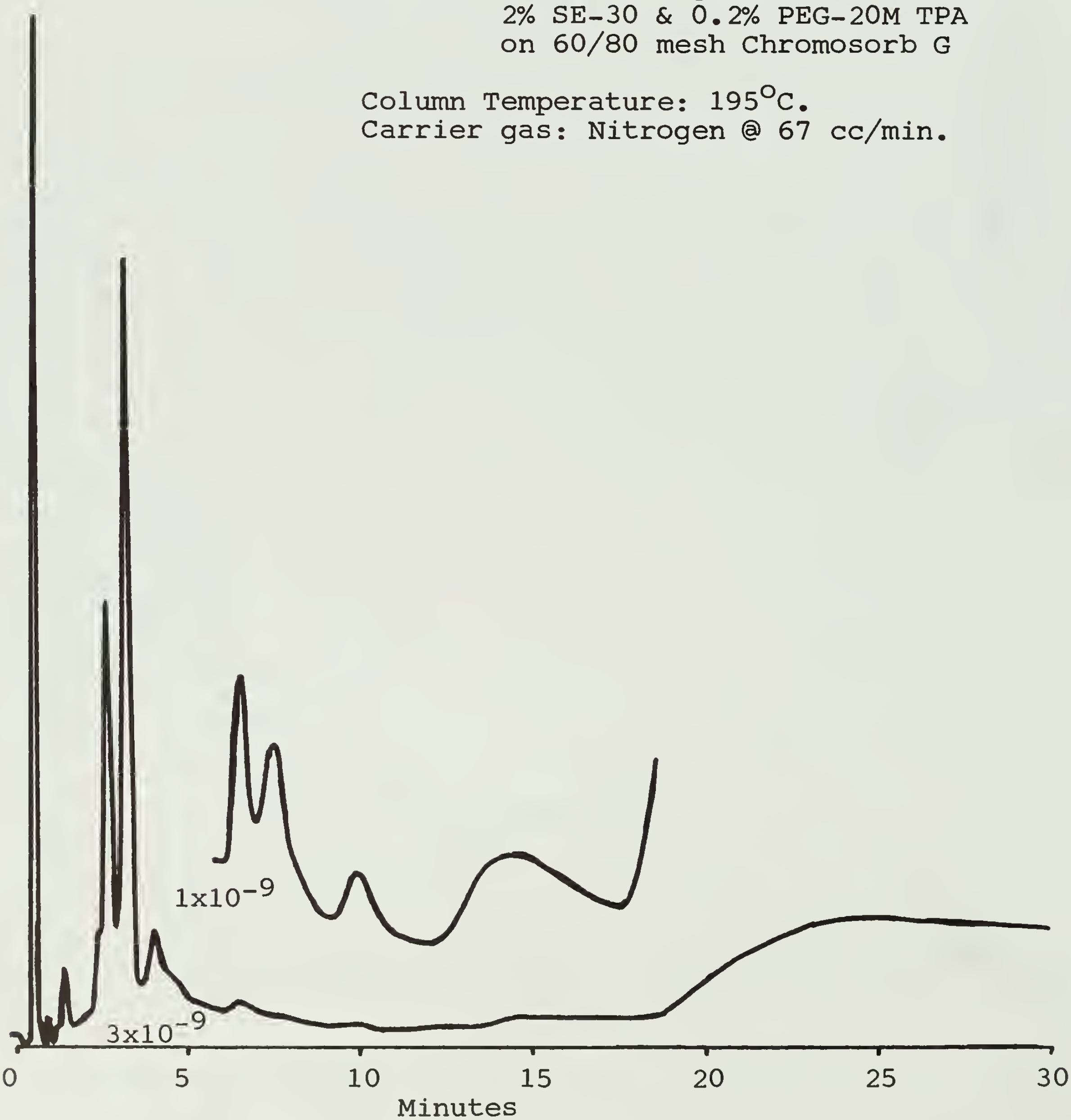
PESTICIDE RESIDUE ANALYSIS

Tree Leaves Sample - Kingston Lake Campsite
Pictured Rocks Nat. Lakeshore
Collected: 6 Aug., 1970
by: Mark D. Johansen

Packard 7400 Gas Chromatograph
Electron Capture Detection

Column: 2.6m x 4mm glass
2% SE-30 & 0.2% PEG-20M TPA
on 60/80 mesh Chromosorb G

Column Temperature: 195°C.
Carrier gas: Nitrogen @ 67 cc/min.



1.0 ul. injection (equivalent to 0.895mg. original sample)

FIGURE 9

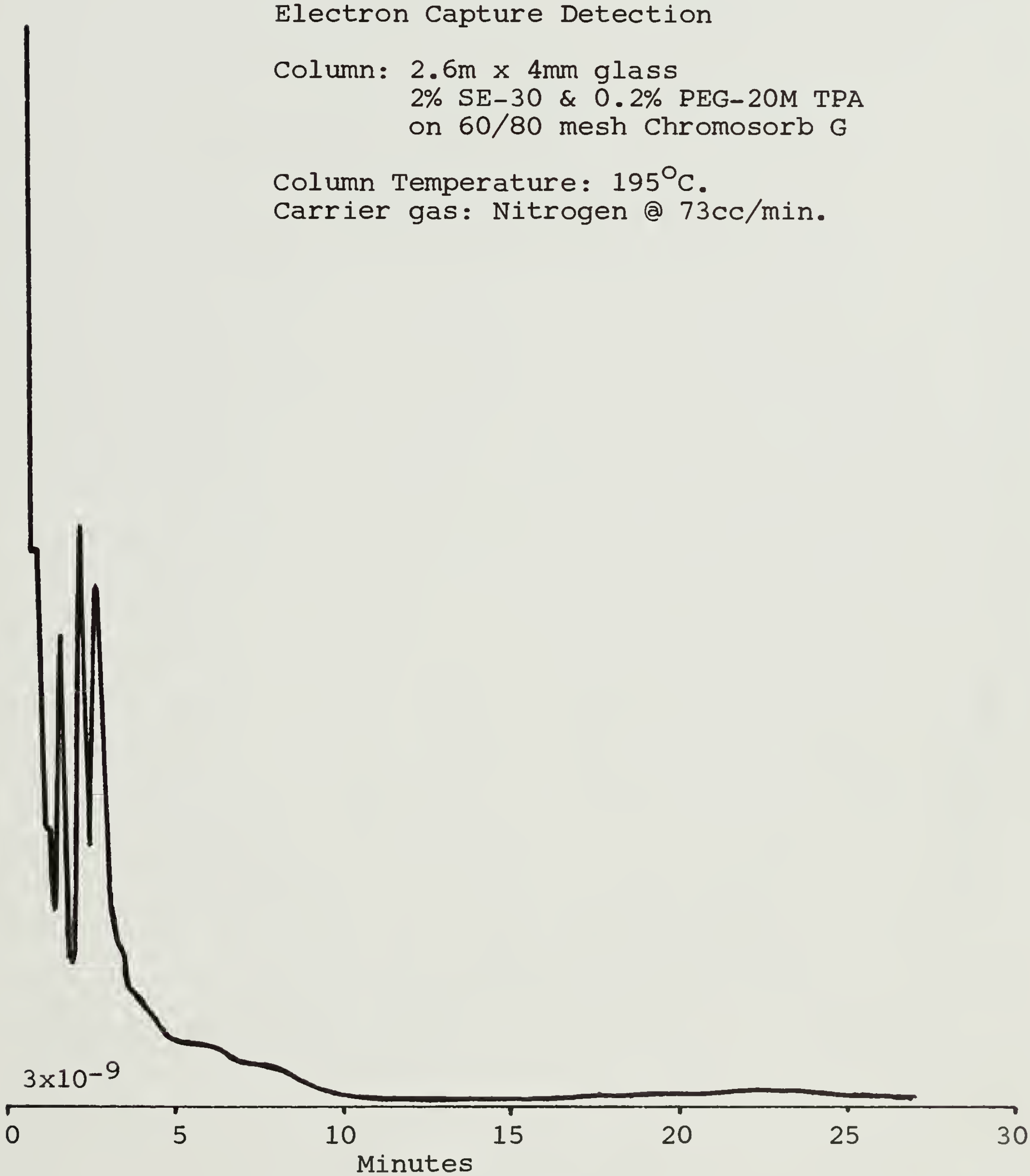
PESTICIDE RESIDUE ANALYSIS

Water Sample - Lake Superior
@ Spray Falls
Pictured Rocks Nat. Shoreline
Collected: 7 July, 1970

Packard 7400 Gas Chromatograph
Electron Capture Detection

Column: 2.6m x 4mm glass
2% SE-30 & 0.2% PEG-20M TPA
on 60/80 mesh Chromosorb G

Column Temperature: 195°C.
Carrier gas: Nitrogen @ 73cc/min.



10 ul injection (equivalent to 10ml. original sample)

FIGURE 10

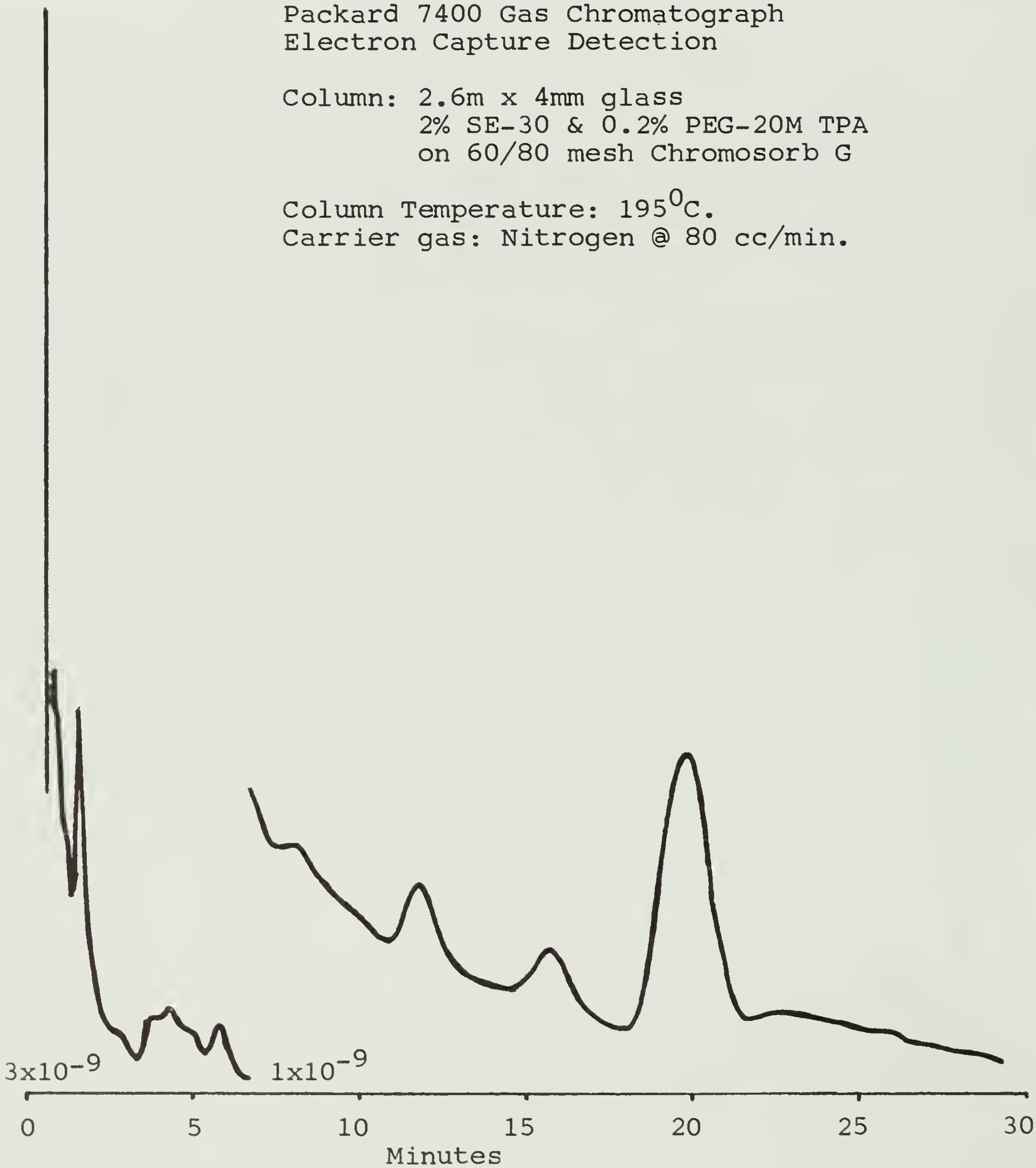
PESTICIDE RESIDUE ANALYSIS

Soil Sample - Au Sable Point Campsite
Pictured Rocks Nat. Shoreline
Collected: 5 Aug., 1970

Packard 7400 Gas Chromatograph
Electron Capture Detection

Column: 2.6m x 4mm glass
2% SE-30 & 0.2% PEG-20M TPA
on 60/80 mesh Chromosorb G

Column Temperature: 195^{0}C.
Carrier gas: Nitrogen @ 80 cc/min.



10ul. injection (equivalent to 25mg. original sample)

FIGURE 11

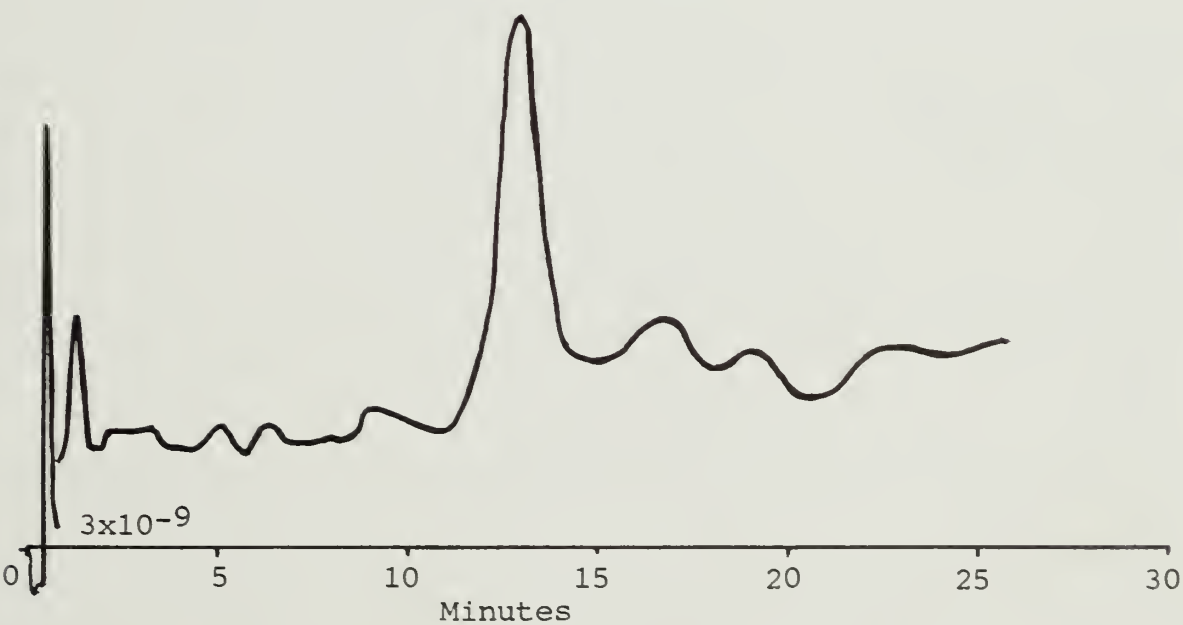
PESTICIDE RESIDUE ANALYSIS

Fish Sample - Coho Salmon
(Oncorhynchus kisutch)
Pictured Rocks Nat. Lakeshore

Packard 7400 Gas Chromatograph
Electron Capture Detection

Column: 2.6m x 4mm glass
2% SE-30 & PEG-20M TPA
on 60/80 mesh Chromosorb G

Column Temperature: 195°C.
Carrier gas: Nitrogen @ 67 cc/min.



10ul. injection (equivalent to 2.0mg. original sample)

FIGURE 12

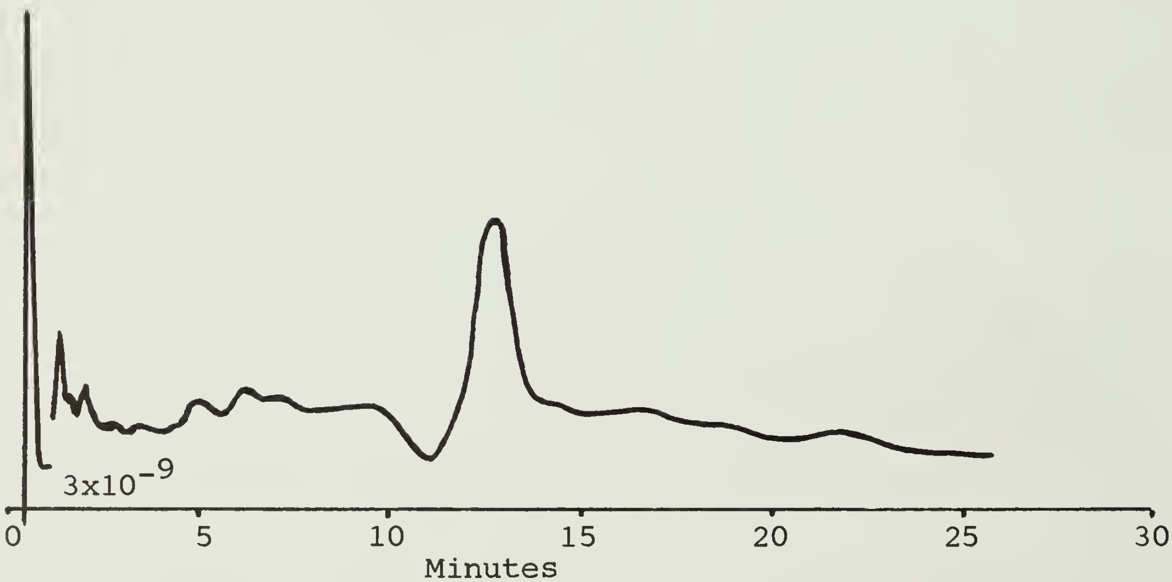
PESTICIDE RESIDUE ANALYSIS

Fish Sample - White Sucker
(Catostomus commersoni)
Pictured Rocks Nat. Lakeshore

Packard 7400 Gas Chromatograph
Electron Capture Detection

Column: 2.6m x 4mm glass
2% SE-30 & 0.2% PEG-20M TPA
on 60/80 mesh Chromosorb G

Column Temperature: 195°C.
Carrier gas: Nitrogen @ 67 cc/min.



10ul. injection (equivalent to 2.0mg. original sample)

APPENDIX B

AIR QUALITY MONITORING METHODS

1. Short Term Monitoring

The short term air sampling consisted of two hour periods (one hour at two sites) and the test objective was to simultaneously determine particulate matter and sulfur compounds.

The choice of a monitor for this particular purpose was based upon the need for portability and self-contained power supply. Most of the available equipment, including the high volume air sampler have high power requirements necessitating the use of either line voltage, heavy-duty batteries or generating equipment. A small, dry cell battery operated, air sampler was chosen.

The Telmatic 150A Automatic Air Sampler (Unico Environmental Instruments, Inc.) can be operated for up to 8 hours on one nickel/cadmium battery (rechargeable), and has a capacity to pump up to 5 liters/minute of air. As purchased, the kit contains the air sampler, filters and filter paper for particulate matter, midget liquid impinger tuber for trapping airborn chemicals and a battery recharger. Plate B1 below illustrates the portable air monitor. (see next page).

a. Particulate Matter Determination

Filter paper pads (Whatman #41, 37 mm dia.) were preweighed in the laboratory after being sealed in small plastic disposable petri dishes. A Mettler H20 semi-micro balance, reading to ± 0.02 mg., was used. The papers were inserted in the plastic filter holder as needed and connected to the air sampler inlet. After the sampling the papers were carefully returned to the petri dishes and reweighed using the laboratory balance.

PLATE B1. PORTABLE AIR MONITOR

Due, apparently, to changes in moisture content (relative humidity variances) of the paper filters, it was determined that the standard deviation for the filter paper weights alone was 0.16 mg. The airflow rate used in these tests was 2 liters/minute, limited by the liquid impinger apparatus capacity which is required for collecting sulfur compounds. Therefore, with the two hour sampling, only 240 liters of air were sampled. Using 95% confidence limits for accuracy, the minimum significant test level was 1 ug/L. Several established air quality particulate matter standards have been established and are generally below .2 ug/L. The sampling as done in this study, using the semi-micro balance, should have a theoretical sensitivity of at least .17 ug/L. But applying the determined actual error, the air volume sampled in 2 hours would have to be at least $2M^3$ or 15 liters/minute, to confidently determine .2 ug/L. Consequently, future particulate matter surveys should be conducted at an air sampling rate of at least 5 liters/minute over a full 8 hour period. This sampling rate is possible with the Telmatic 150A Sampler, but a different liquid impinger apparatus would have to be designed to allow collection of reduced sulfur compounds at the same time that particulate matter was being collected.

b. Sulfur Compounds

A general test for reduced sulfur compounds (i. e. hydrogen sulfide, sulfur dioxide) was obtained by bubbling the air samples into an alkaline solution of one Normal sodium hydroxide, using the micro-impinger apparatus connected to the air sampler, after the particulate matter filter. The solution containing any trapped material was sealed in glass and the presence of the reduced sulfur compounds was determined in the laboratory by iodometric titration. The titration was sensitive to 0. 02 mg. as sulfur dioxide, so the minimum detection limit for 240 liters of air was 0. 085 ug/L, or 0. 028 ppm.

2. Long Term Monitoring

The long term air monitoring was performed with the AERON Automatic Tape Sampler to continuously collect particulate matter and the AERON Tape Spot Evaluator, which is used to analyze the collected matter. This equipment and method conform with the American Society for Testing and Materials Standard Method of Test for Particulate Matter in the Atmosphere (ASTM Designation D-1704-61).

The Automatic Tape Sampler unit was installed at the Park Ranger Headquarters at Sand Point on August 20, 1970 and adjusted for continuous air filtration and collection periods of four hours. This device utilizes an automatically advanced paper tape roll to trap particulate matter from air continuously drawn through the tape by a vacum pump, adjusted to a flow rate of 15 cubic feet per hour. The paper tape roll was collected at the end of the test period on September 29, 1970 and sent to the laboratory for analysis. The analysis was performed by the Tape Spot Evaluator which uses a photovoltaic cell to record percent of light transmittance. The Automatic Tape Sampler and the Tape Spot Evaluator are illustrated in Plates B2 and B3.

a. Optical Density

Optical Density may be calculated by readings taken directly from the tape spot evaluator.

$$\text{Optical Density} = \frac{\log I^{o}}{\log I^{o}}$$

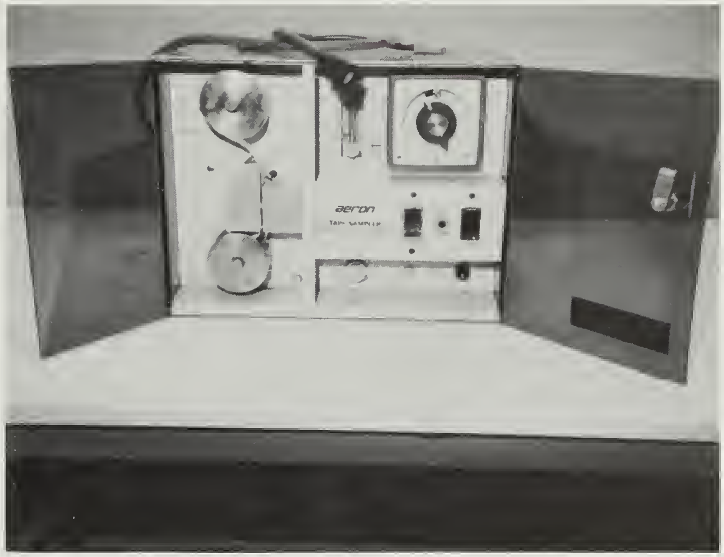


PLATE B2. AUTOMATIC TAPE SAMPLER

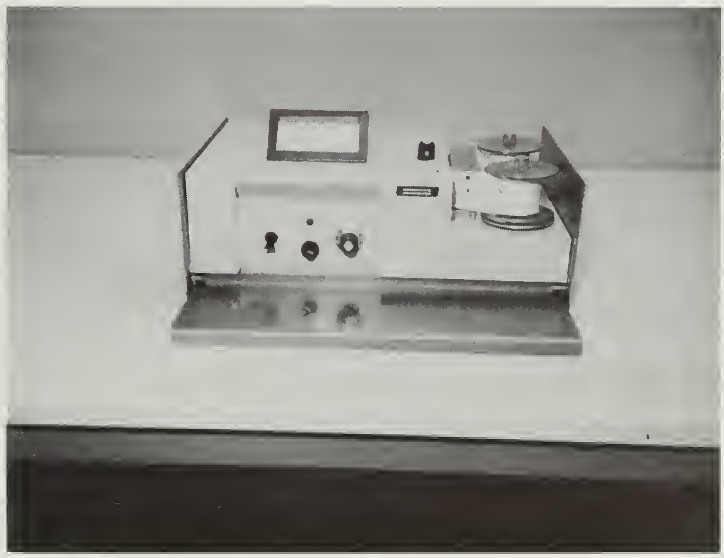


PLATE B3. TAPE SPOT EVALUATOR

Where I_o = the intensity of transmitted light through clean paper and

I = the intensity of transmitted light through the sample

log = logarithm to the base 10

b. Coefficient of Haze

For comparison purposes with similar samples collected in other sampling areas and under sampling conditions where the area of paper exposed and the volume flow rate may be different, the optical density values for transmittance are converted to a unit scale called the Coh unit (Coefficient of Haze). The Coh unit is defined as 100 times the optical density of the deposit so that an optical density of 0. 051 is 5. 1 Coh units.

Since the intensity of the filter paper stain is determined by the total volume of air aspirated through the filter and the area of the exposed filter, the size of the air sample is properly expressed in linear units of air, i. e., the volume of air aspirated divided by the area of the filter.

c. Lineal Air Flow Rate

For convenience, the results are reduced to multiples of 1000 linear feet of air sample so that the soiling for any time period is described in terms of Coh units per 1000 feet of air.

If the quantity of air sampled during each spot sample is equal to L, in thousands of linear feet, then

$$L = \frac{(\text{flow in cu. ft./hr.})\,(\text{sampling time in hrs.})}{(1000)\,(\text{circular area of spot in sq. ft.})}$$

$$\text{Coh per 1000 ft.} = \frac{(\text{optical density}) \times (100)}{L}$$

The air flow rate for this sampling was adjusted to 15 CFH and the sampling period was set at 4 hours. The area of the paper filter exposed is 5.45×10^{3} sq. ft. (1"diameter circle) therefore, the linear flow rate L is:

$$L = \frac{(15\ \text{CFH})\ (4\ \text{hrs.})}{(1000)\ 5.45 \times 10^{-3}\ \text{sq. ft.})}$$

$$= \frac{60}{5.45} \qquad \text{(thousands ft. of air)}$$

$$L = 11 \qquad \text{(thousands ft. of air)}$$

APPENDIX C

NOISE QUALITY MONITORING METHODS

1. Sample Noise

15 to 30 minute tape records were made of the background noise at the 14 air and noise sampling sites (see figure 4. 1). The recordings were made on a random basis between the early morning and late evening hours. The tape recorder used was the AIWA TP-728 tape recorder which is portable and battered operated. The purpose of the sample noise recordings was to characterize the nature of the noise levels at the various sites and to provide data for long term monitoring programs.

The location of the microphone was selected to record normal noises heard by visitors. The microphone was positioned approximately at ear level facing upward.

Noise levels are commonly expressed in decibels (db) above some reference or threshold level. The db scale is logarithmic and allows a very wide range of noise power to be expressed in a compact, but non-linear scale. For example, a frequently used noise level scale sets the 0 db reference point to correspond with the approximate threshold of hearing for young male adults (at 1000 Hz). Some typical noise levels using this scale are:

1) 103 db for a jet aircraft 1000 ft. away

2) 90 db for a motorcycle 25 ft. away

3) 70 db for busy street traffic

4) 60 db for normal conversation

5) 40 db for a quiet room

6) 20 db for a broadcasting studio

The noise level records were made by playing back the tape records in the laboratory while recording the noise levels with the General Radio type 1565-A Sound Level Meter. The A scale, which is a weighted scale to correspond with the human ear response was used for these recordings. The A scale is the most widely used sound level scale.

2. <u>24 Hour Recording</u>

Three sound recordings of 24 hours duration each, were taken at the three campground sites within the park. These recordings were made with the Soundscriber Model S-124, 24 hour Magnetic Tape Recorder-Reproducer.

The recordings are made on a special magnetic tape 2 1/4" wide which has reference numbers in minutes imprinted on the tape for time referencing. One magnetic tape roll (300 feet of tape) will continuously record sound for a 24 hour period through a unique revolving head mechanism that records both laterally and longitudinally along the tape. In addition, a very slow recording speed is used to provide the long duration recording storage on one compact roll of tape.

The recordings were made at remote sites by usind a 12 vdc to 120 vac, 60 hz power inverter. Six heavy duty, 85 ampere hour 12 vdc batteries connected in parallel were used as the power source. The microphone used for these recordings was an Electrovoice Model 635A Dynamic Omni-directional, low impedance microphone equipped with wind blast filters. The equipment is illustrated in Plate C1.

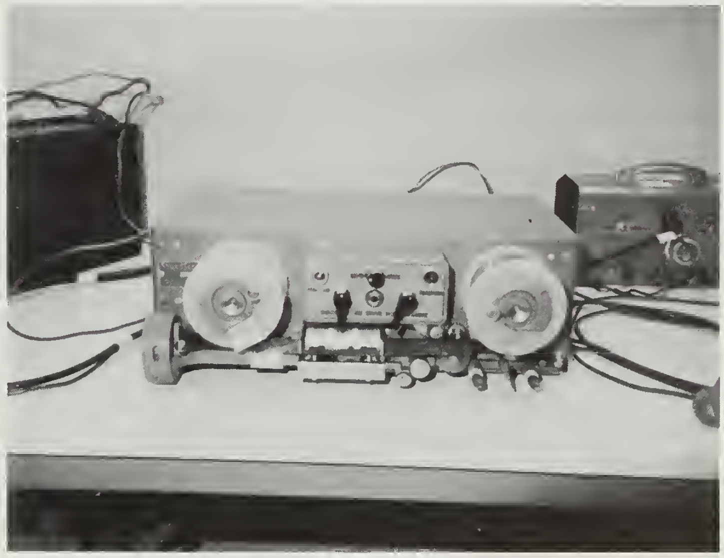


PLATE C1. 24 HOUR TAPE RECORDER

Again, the noise level records were made by playing back the tape in the laboratory and using the General Radio type 1565-A Sound Level Recording Meter on the A scale.

3. Long Term Integrated Noise Recording

Continuous, long term noise data at two representative remote locations within the park was performed by a unique proprietary method developed by Limnetics Incorporated. This method employs an amplifier, integrator and strip chart recorder to record the accumulated value of noise continuously monitored over a 15 minute period. The "noise information" is actually separated into three distinct frequency ranges by filter techniques and then recorded separately on the chart paper. The integrated noise recording equipment is shown in plate C2 below:

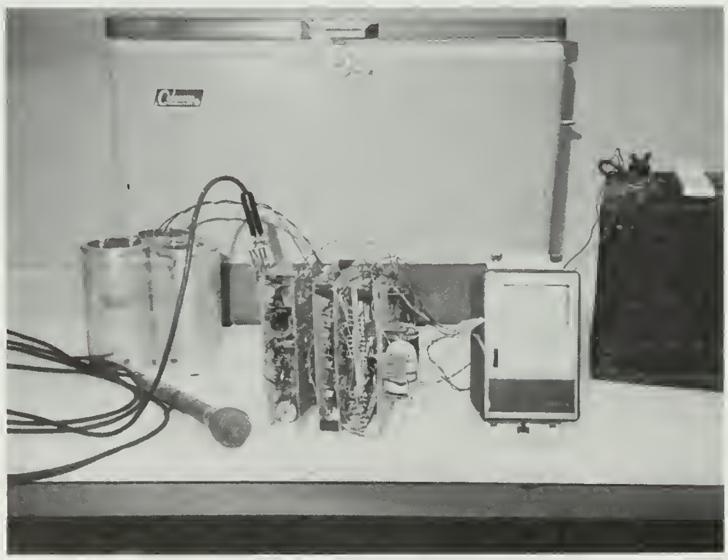


PLATE C2. INTEGRATED NOISE RECORDER

The Limnetics Integrated Noise Recorder is battery operated by a 12 vdc battery and is entirely self-contained within an insulated unit which houses all components except the microphone. During this program the unit was physically buried at the recording sites (Beaver Lake and Little Beaver Lake Campground) and the microphone was attached to a nearby tree at ear level height. The microphone had to be positioned downward to avoid rain damage.

a. Integrated Noise

The Limnetics Integrated Noise Recorder produces an output at the end of 15 minute intervals which represents the "average noise" generated during that period. If the noise environment was continually "very loud" during the previous period, then a "very loud" record would be produced. If the noise environment was "very loud" during half of the period and quiet during the other half, then a "moderately loud" record would be produced.

The noise output is developed by integrating or summing up the total noise signals produced during the 15 minute period. However, the data is presented herein as hourly averages of 15 minute period records. This was done to more clearly illustrate the data over a 24 hour period.

b. Frequency Response of System

The range of audible sound frequencies monitored was from 80 to 13, 000 Hz, and was primarily a function of the microphone's bandwidth. The three frequency ranges of noise separation were 80 to 1000 Hz (low), 150 to 8000 Hz (mid) and 2400 to 13, 000 Hz (high). Figure C1 illustrates the frequency responses and bandwidths of the major components in the Limnetics Integrated Noise Recording System.

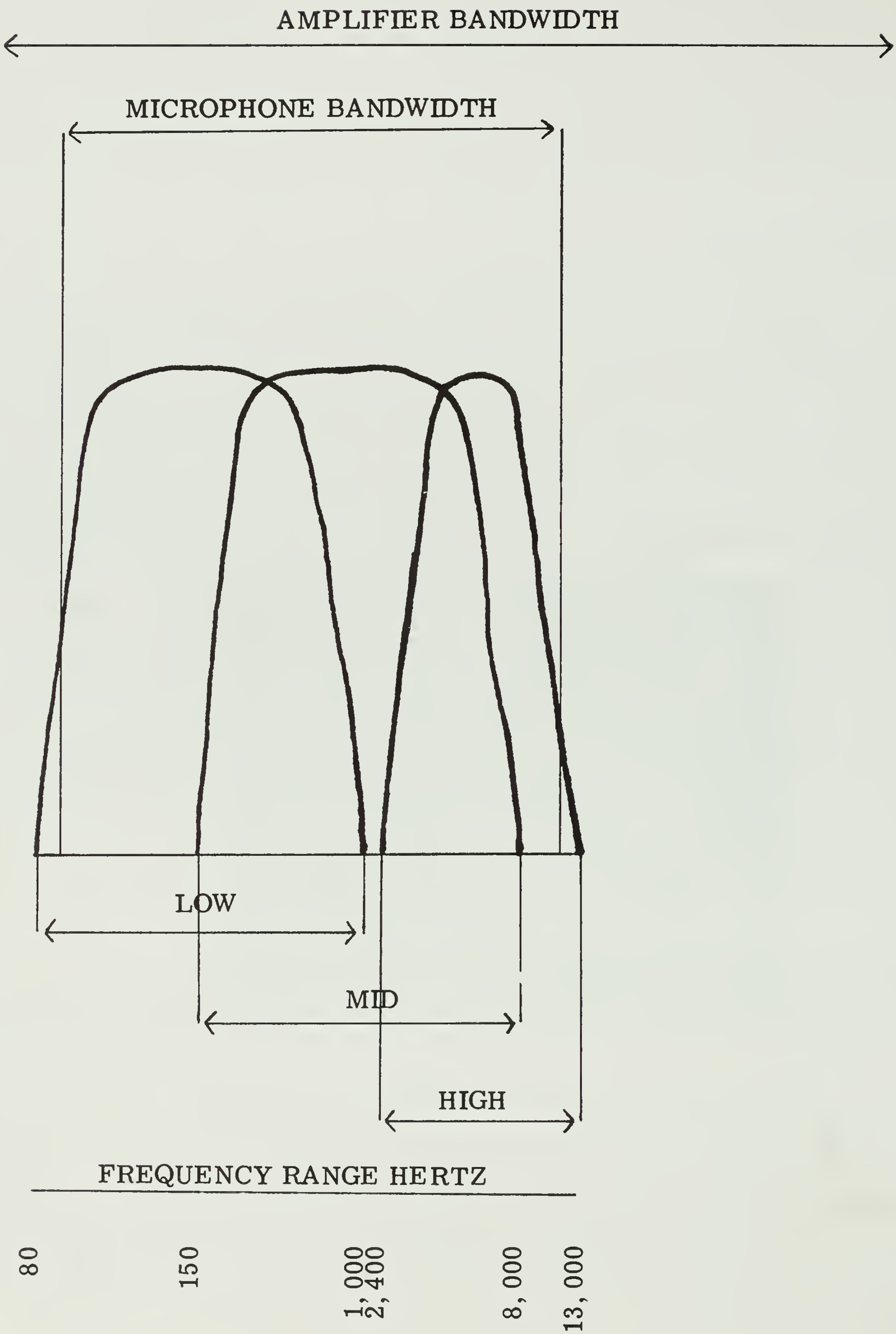


FIGURE C1

AUDIBLE SOUND FREQUENCY RANGE

c. Output Loudness Scale

The original noise data was recorded on a small recording strip chart as a series of dots on a 0 to 1 milliampere full scale deflection chart. The recorder input impedance is 100 ohms therefore the voltage input to the recorder ranged from 0 to .1 volt. The relative range of sound intensity was determined as 40 db over the entire chart scalewidth (0 to 10 units). The threshold level of the integrator's output was established as 1 millivolt (.01 scale units).

The noise level N above the threshold limit is derived below:

$$N\,(db) = 20 \log_{10} \left[\frac{E_{out}}{E_{threshold}} \right]$$

where E_{out} = Integrator voltage out

$E_{threshold}$ = Minimum voltage sensitivity

For example, a full scale (10 units) recorded noise level of .1 volt output (N_{FS}) represents average integrated noise 40 db above the threshold level.

$$N_{FS}(db) = 20 \log_{10} \left[\frac{.1}{.001} \right]$$

$$= 20 \log_{10} \quad (100)$$

$$N_{FS} = 40 \text{ db above threshold}$$

The average noise level for a very quiet remote environment outdoors is estimated to be 40 db above the threshold of hearing. This approximation is made from an analogy to extensive noise measurements made in quiet indoor areas such as a library. Actually, a very quiet outdoors area is rare since there is usually some wind or other natural sounds unless the air is extremely calm and no animal activity is occurring. The noise levels recorded in this program varied widely between 30 to 80 dBA.

The graphical noise records of the Pictured Rocks environment should represent integrated noise levels from approximately 40 to 80 db above the threshold of hearing. This range, in qualitative loudness terms, is from a quiet through a moderately loud range.

APPENDIX D: METEOROLOGICAL DATA

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

Address reply to:
Officer in Charge
U.S. Coast Guard
Munising Station
Munising, Michigan

December 29, 1970

Mr. Richard A. Wehland
Limnetics, Inc.
6132 West Fond du Lac Avenue
Milwaukee, Wisconsin 53218

As per your request of December 23rd, find below the data you need. I trust the temperature you need is the air temperature and not the water temperature.

	JULY		AUGUST		SEPTEMBER		OCTOBER	
1	SW 5 kts	63-78	NW 5 kts	64-72	S 3 kts	45-72	E 12 kts	40-60
2	Calm	70-74	Var 8 kts	61-73	E 4 kts	58-64	NW 10 kts	46-54
3	NW 2 kts	56-70	N 12 kts	53-58	Var 4 kts	64-72	Var 8 kts	37-42
4	NW 15 kts	44-52	Calm	46-64	NW 3 kts	59-68	NW 3 kts	39-50
5	Calm	48-72	S 4 kts	58-74	S 3 kts	56-65	S 8 kts	42-64
6	SE 5 kts	60-86	S 3 kts	64-76	E 6 kts	58-78	SE 8 kts	57-68
7	SE 12 kts	60-75	Calm	66-80	E 8 kts	68-75	E 5 kts	58-67
8	NW 5 kts	48-54	Calm	66-82	NW 5 kts	56-62	SE 6 kts	60-70
9	W 3 kts	48-65	Calm	66-80	E 8 kts	56-67	SE 10 kts	60-65
10	Calm	52-68	Calm	68-84	Var 5 kts	50-65	S 4 kts	38-50
11	NW 3 kts	58-68	Calm	64-80	S 2 kts	50-60	S 4 kts	36-56
12	Calm	58-76	Var 2 kts	64-80	N 6 kts	46-66	Calm	46-54
13	Calm	62-77	Var 6 kts	70-82	Calm	46-47	Calm	48-55
14	Calm	62-68	S 10 kts	70-80	N 2 kts	46-54	N 3 kts	36-48
15	NW 6 kts	57-78	E 12 kts	68-84	NE 5 kts	48-53	Var 4 kts	35-37
16	E 10 kts	60-82	Var 4 kts	62-72	Calm	49-56	Calm	34-48
17	W 3 kts	52-78	Calm	57-64	Var 3 kts	52-62	Calm	36-63
18	NW 3 kts	50-58	S 6 kts	60-70	SE 3 kts	56-60	N 4 kts	38-50
19	N 14 kts	50-58	Calm	64-78	SE 6 kts	54-74	Calm	32-60
20	NW 6 kts	52-68	W 4 kts	56-70	E 6 kts	61-76	Calm	36-50
21	Calm	48-75	E 2 kts	50-70	E 6 kts	60-83	Calm	42-54
22	Calm	58-74	Calm	60-74	Calm	54-60	Calm	42-60
23	Calm	62-72	N 2 kts	57-63	Calm	50-52	Var 2 kts	50-62
24	SE 5 kts	63-84	NW 2 kts	57-63	Calm	52-70	E 3 kts	52-55
25	E 7 kts	68-94	NW 3 kts	54-68	Var 2 kts	52-60	Calm	50-54
26	S 5 kts	74-90	NW 3 kts	55-68	W 4 kts	43-54	E 3 kts	48-52
27	SE 8 kts	70-79	SE 5 kts	54-76	Calm	42-45	SE 6 kts	50-55
28	Calm	64-76	NW 5 kts	52-64	NW 4 kts	38-46	E 10 kts	46-52
29	SE 2 kts	68-90	E 5 kts	51-70	E 6 kts	40-58	Calm	38-48
30	Calm	66-76	NW 9 kts	58-64	NW 8 kts	39-47	SE 8 kts	40-54
31	SE 6 kts	72-88	Var 3 kts	50-64			Calm	36-42

David H. Spencer
DAVID H. SPENCER

GLOSSARY OF TERMS

Aerobic	Pertaining to the presence of oxygen.
Algae	A group of plants some of which are free floating in lakes.
Aliquot	A portion of a sample.
Anaerobic	Indicating little or no oxygen.
Aquatic Vegetation	Group of plants which live in the water.
Atomic Absorption Spectrometry	Analytical method for analysis of elements utilizing the characteristic of spectral radiation absorption by specific atoms.
Audible Sound Frequencies	The group of sounds which can be heard by the unaided ear.
Bacteria	Microscopic organisms most of which are beneficial to man and some of which are harmful.
Benthos	Organisms living in or on the bottom sediment of lakes and streams.
Biota	Pertaining to animal and plant life.
Caudal Peduncle	The part of a fish between the anal fin and the tail.

Centimeter (cm)	The metric unit of measurement equivalent to 0.394 inches.
Chromatogram	The recorded output of the gas chromatograph.
Cladocera	An order of Crustacea, "water fleas".
Coefficient of Haze	A relative unit for establishing particulate matter concentrations per foot of air sample using an optical measurement procedure.
Comminution	The process of reducing matter to minute particles.
Conductance	A water quality parameter indicating the presence of dissolved salts.
Correlation	The degree of relationship of two or more measurements.
Crustacea	A group of animals containing the crabs, lobsters, shrimps, beach hoppers, sow bugs, barnacles, and water fleas.
Cubic Meters Per Second	The metric unit of expressing discharge. 1 cubic meter per second (cms) is equivalent to 35.315 cubic feet per second (cfs).
Decibels	The standard unit for measuring sound level intensity.
Deciduous Trees	Trees which lose their leaves in the fall.

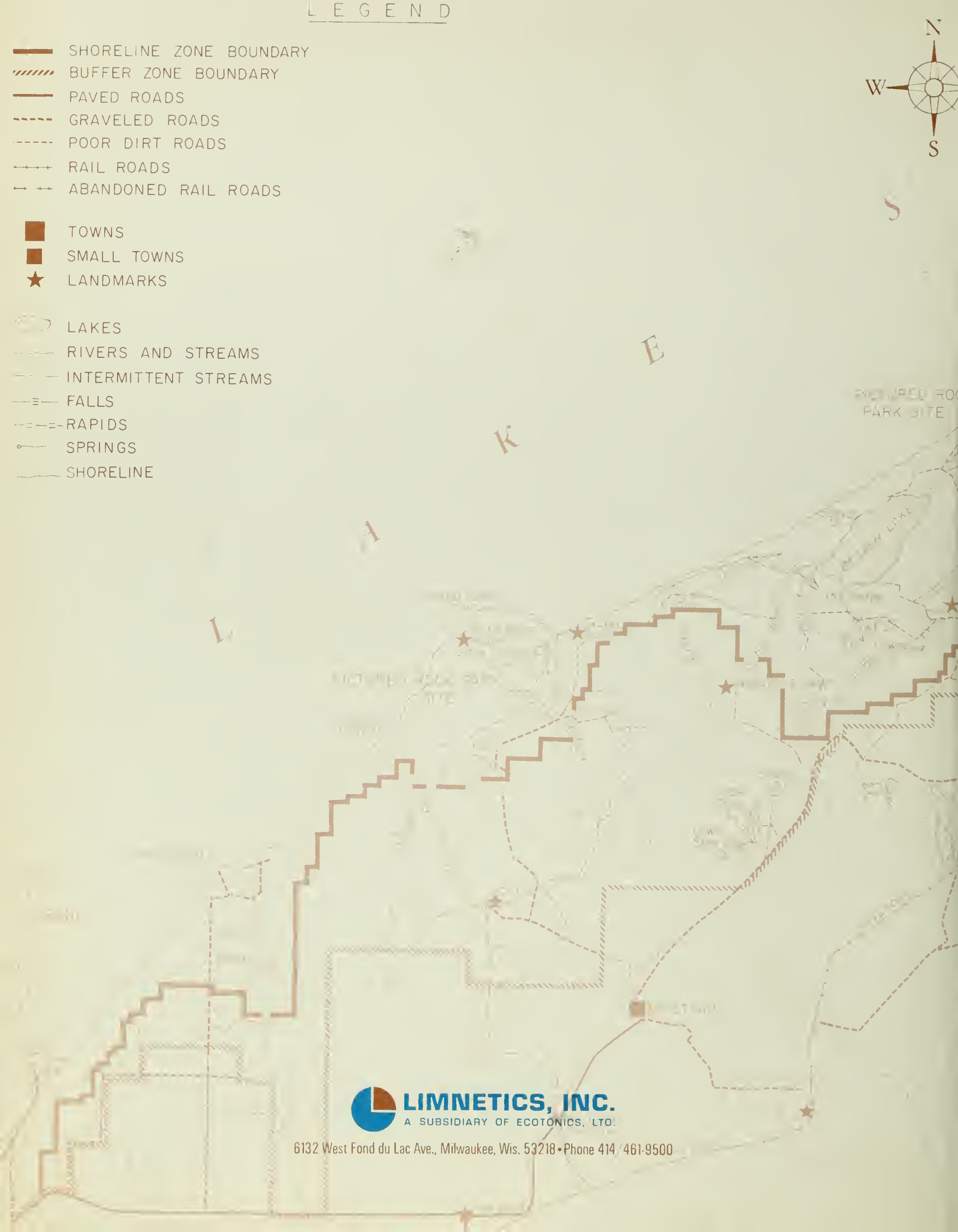
Detection Limits	Minimum significant quantity of a substance which can be detected as governed by the particular method used.
Diatom	A group of algae.
Dissolved Oxygen	The oxygen which is dissolved in water and which can be used by fish and other aquatic organisms.
Dissolved Solids	Substances and minerals dissolved in water.
Diurnal	Pertaining to daily changes.
D. O.	Dissolved Oxygen
Dystrophic	Brown-water lakes often characterized by low nutrient content.
Ecology	Study of organisms in relation to each other and to their environment.
Environment	The surrounding in which an organism lives.
Environmental Benchmark	The set of all measurements pertaining to the quality of the environment at a particular period of time.
Epilimnion	The warmer less dense layer of water above the thermocline.
Eutrophic	Pertaining to waters with a large supply of nutrients and hence highly fertile.

Fauna	Animal life.
Fecal Coliform Bacteria	A group of bacteria which are mainly found in both human and animal excreta.
Flora	Plant life.
Gas Chromatograph	An analytical instrument often used for measuring pesticides.
Hectare	A metric unit of area equivalent to 2.471 acres.
Herbicide	A group of chemical agents used to kill weeds.
Hydrologic Cycle	The circulation of water by evaporation from the sea and lakes to the atmosphere and return to the earth.
Hypolimnion	The cold dense layer of water at the bottom of a lake.
Integrated Noise	The net noise energy accumulated over a period of time.
Isothermal	Having the same temperature throughout.
Kilometer	The metric unit of measurement equal to 1000 meters and equivalent to 0.621 statue miles.
Lacustrine	Pertaining to lakes.

Limnology	The scientific study of inland waters such as lakes and streams with reference to their physical, chemical, biological features.
Lineal Air Flow	The number of feet of air drawn through a specified surface area per unit of time.
Littoral	The shoreward region of a body of water.
Metabolic	The physical and chemical processes of an organism.
Metalimnion	See thermocline.
Meter	The metric unit of distance equivalent to 3.28 feet.
Mg/L	Milligrams per liter.
Microfilter	Filters of cloth or stainless steel wire densely woven so that the openings are very small.
Mollusca	The group of animals which includes snails and clams.
Nannoplankton	Those microscopic plankton, which because of their small size cannot be collected by nets.
Nekton	Swimming organisms sufficiently strong to be independent of water currents in which they live e. g. fish.

Nutrient	Any chemical substance which is utilized by plants for food e. g., phosphate, nitrate.
Oligochaetes	The group of animals which includes the earthworms.
Oligotrophic	Waters with a small supply of nutrients and hence with a low fertility.
Optical Density	Pertaining to a method for measuring particulate matter through light transmission.
Particulate Matter	The solid materials found in the atmosphere.
Pathogenic	Pertaining to a disease-producing organism.
Pesticide	A group of chemical agents used to kill insects.
pH	The degree of acidity or alkalinity.
Phytoplankton	The plant constituent of the plankton.
Plankton	Organisms living in lakes which drift with the current.
Poly Chlorinated Biphenyls	(PCB's) A series of chemical plasticizing agents used in industry. Sometimes interfer with chlorinated hydrocarbon pesticide analysis.

ppm	Parts Per Million.
Primary Production	Pertaining to algal productions.
Rotifera	A group of microscopic animals found in the plankton.
Stratification	The process by which lakes form separate layers of water with different densities.
Sub Fossil	The remains of an animal which has not yet been fossilized.
Thermocline	The zone of density transition between the epilimnion and hypolimnion of a lake.
Threshold Level	Refering to sound, the minimum audible sound level percieved.
Topography	Detailed description of the relief features of the surface area of land.
Turbidity	Property of opaqueness in water resulting from particulate matter causing a muddy appearance.
Turn Over	The process taking place when the epilimnion and hypolimnion mix together. This happens during spring and fall when the lake becomes isothermal and the thermocline disappears.
Tychoplankton	Planktonic forms, particularly algae, which become entangled among the vegetation near the shore.
Zooplankton	The animal part of the plankton.


LEGEND
SHORELINE ZONE BOUNDARY
BUFFER ZONE BOUNDARY
PAVED ROADS
GRAVELED ROADS
POOR DIRT ROADS
RAIL ROADS
ABANDONED RAIL ROADS
TOWNS
SMALL TOWNS
LANDMARKS
LAKES
RIVERS AND STREAMS
INTERMITTENT STREAMS
FALLS
RAPIDS
SPRINGS
SHORELINE
N
W
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