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Cladophora Distribution in Lake Ontario (IFYGL)

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CLADOPHORA DISTRIBUTION IN LAKE ONTARIO (IFYGL)

By

C. T. Wezernak, D. R. Lyzenga, and F. C. Polcyn

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Project Officer

Michael D. Mullin
Grosse Ile Laboratory
National Environmental Research Center
Grosse Ile, Michigan 48138

NATIONAL ENVIRONMENTAL RESEARCH CENTER
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CORVALLIS, OREGON 97330

ABSTRACT

Multispectral remote sensing data were collected along the U.S. shoreline of Lake Ontario, under the sponsorship of the Environmental Protection Agency, as part of the International Field Year on the Great Lakes (IFYGL) program in Lake Ontario. Data were processed to show the distribution of Cladophora in the nearshore zone and to estimate the standing crop. Additionally, thermal data in the study area were displayed.

The results show an extensive growth and development of Cladophora in the study area. Approximately 66% of the nearshore zone in the western portion of the lake and 79% in the eastern portion is covered by Cladophora. Several major and minor thermal features and thermal discharges were evident at several locations along the U.S. shoreline.

This report was submitted by the Environmental Research Institute of Michigan in fulfillment of Grant No. 800778 under the sponsorship of the Environmental Protection Agency. Work was completed as of June 1974.

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ACKNOWLEDGMENTS

Several individuals at ERIM contributed to the project. In particular the efforts of Mr. Steve Stewart and Mr. Lewis Munford are acknowledged with sincere thanks. Mr. Stewart supervised airborne data collection and Mr. Munford produced the scanner ratio imagery and contoured separations.

SECTION I

CONCLUSIONS

The results of the airborne multispectral data collection program along the U.S. shoreline of Lake Ontario presented in this report led to the following conclusions:

(1) An extensive growth and development of Cladophora takes place in the nearshore zone on hard surfaces and other areas of "firm" bottom.

(2) Approximately 66% of the nearshore zone between Niagara and Rochester was covered by Cladophora. Expressed as dry weight, the standing crop was equal to 1.57×10^4 kg per kilometer of shoreline within a strip 350 meters wide. A shoreline strip of this width extends to approximately the 5 meter depth contour.

(3) Because of reduced transparency in the area east of Rochester, data processing extended out from shore only an average distance of 277 meters. The results show that 79% of the area of the nearshore zone was covered by Cladophora. Expressed as dry weight, the standing crop was equal to 2.6×10^4 kg per kilometer for an average strip-width of 277 meters. Extrapolating the results to a width of 350 meters, the standing crop is equal to 3.3×10^4 kg per kilometer of shoreline.

(4) Both major and minor thermal features, which can be expected to influence the biology and chemistry of the nearshore zone, were evident at several locations along the U.S. shoreline. Four power plants are presently located within the study area. An 8^oC difference was noted between the power plant discharge and offshore temperatures at Rochester.

(5) Several thermal fronts and boundaries were evident in the nearshore zone. A large thermal front, showing a 6^oC temperature differential between the warmest and coldest waters in the scene, was recorded in the vicinity of Olcott, New York.

(6) Remote sensing provides an effective technique for determining the distribution of benthic algae, thermal monitoring, surface chlorophyll determination, and other large-scale measurements dealing with the aquatic environment.

SECTION II

RECOMMENDATIONS

The potential of remote sensing technology to map aquatic communities, to estimate biomass, and to identify important changes in the life-history of the community should be further explored. A carefully controlled series of experiments is indicated as a logical extension of the work initiated in this program.

A wider use of remote sensing technology should be considered in large-scale studies such as the International Field Year of the Great Lakes (IFYGL) program in Lake Ontario. In particular, the use of remote sensing for surface chlorophyll measurement, suspended solids loading, and studies of thermal phenomena such as the thermal bar should be considered.

SECTION III

INTRODUCTION

The inflow of nutrient-rich waters from tributary sources together with nutrient loading from major population centers around Lake Ontario is sufficient to maintain a relatively high level of productivity in the lake. In the case of Lake Ontario, productivity is evidenced in part by an extensive growth and development of Cladophora.

The emergence of a dominant species of algae depends on a number of physical and chemical factors. In nearshore areas, benthic algae develop under suitable conditions on all hard surfaces. At one point in the life cycle, the algae become detached through wave and wind action and are normally deposited on the beach. For the shoreline property owner, subsequent decomposition of large masses of Cladophora produces highly objectionable conditions which detract from the aesthetic and recreational values of the nearshore zone.

Conventional methods of data acquisition to delineate the distribution (and estimate the standing crop) of benthic algae or aquatic macrophytes are totally inadequate, particularly when dealing with large environmental systems. The utilization of some form of remote sensing technology is clearly indicated for this purpose.

The work described in the sections which follow forms part of the U.S. Chemistry-Biology program in Lake Ontario as part of the International Field Year on the Great Lakes (IFYGL). The program described in this report was designed to exploit the capabilities of existing remote sensing technology for the following purposes:

(1) To delineate the distribution of Cladophora along the U.S. shoreline of Lake Ontario between Niagara and Stony Point, New York

(2) To provide an estimate of Cladophora standing crop by coupling remote sensing data with ground truth information

Concurrent with the above, temperature anomalies along the flight line were located. Additionally, the amount of surface chlorophyll in the Niagara vicinity was determined.

SECTION IV

METHODS

Data were collected using the Environmental Research Institute of Michigan (ERIM) remote sensing aircraft. Multispectral data collection was initiated along the U.S. shoreline on June 20, 1972 and completed on July 31, 1972 from altitudes of 397 m (1300 ft) and 610 m (2000 ft) respectively. Unfavorable field conditions in June 1972 along portions of the flight line necessitated another mission (in July) to complete the work.

MULTISPECTRAL SENSOR SYSTEM

The ERIM M-7 multispectral scanner was used for remote sensing data collection[1]. Use of this instrument permits simultaneous data collection in twelve narrow spectral bands over a wavelength range from 0.32 to 11.7 μm. The system includes a spectrometer for spectral dispersion of the radiation and filtered detector arrays placed at the focal points of a double-ended optical-mechanical scanner. Additional detector positions are used for spectral bands in the ultraviolet and the infrared.

Signals from the detectors are recorded on magnetic tape for later image reconstruction and data processing. As an integral feature of the system, reference lamps, an input proportional to the sun energy, and adjustable temperature reference plates are viewed each revolution of the scanner mirror. The basic configuration of the scanner is shown in Figure 1.

The scanner is positioned in the aircraft so as to provide continuous scanning perpendicular to the flight line as shown in Figure 2. As the aircraft advances, the rotating mirror scans the scene over a 90° field of view in a regular manner so that a continuous presentation is built up line by line. In addition to data collected by the multispectral scanner, photographic data are normally collected along the flight track. In this particular program, black-white and color photographic records were obtained.

REMOTE SENSING CONSIDERATIONS IN <u>CLADOPHORA</u> RECOGNITION

The radiant energy received by an optical remote sensing instrumental system oriented toward a water body consists of components of (1) scattered radiation from the intervening atmosphere and (2) reflected radiation from the scene. At depths (and wavelengths) where radiation

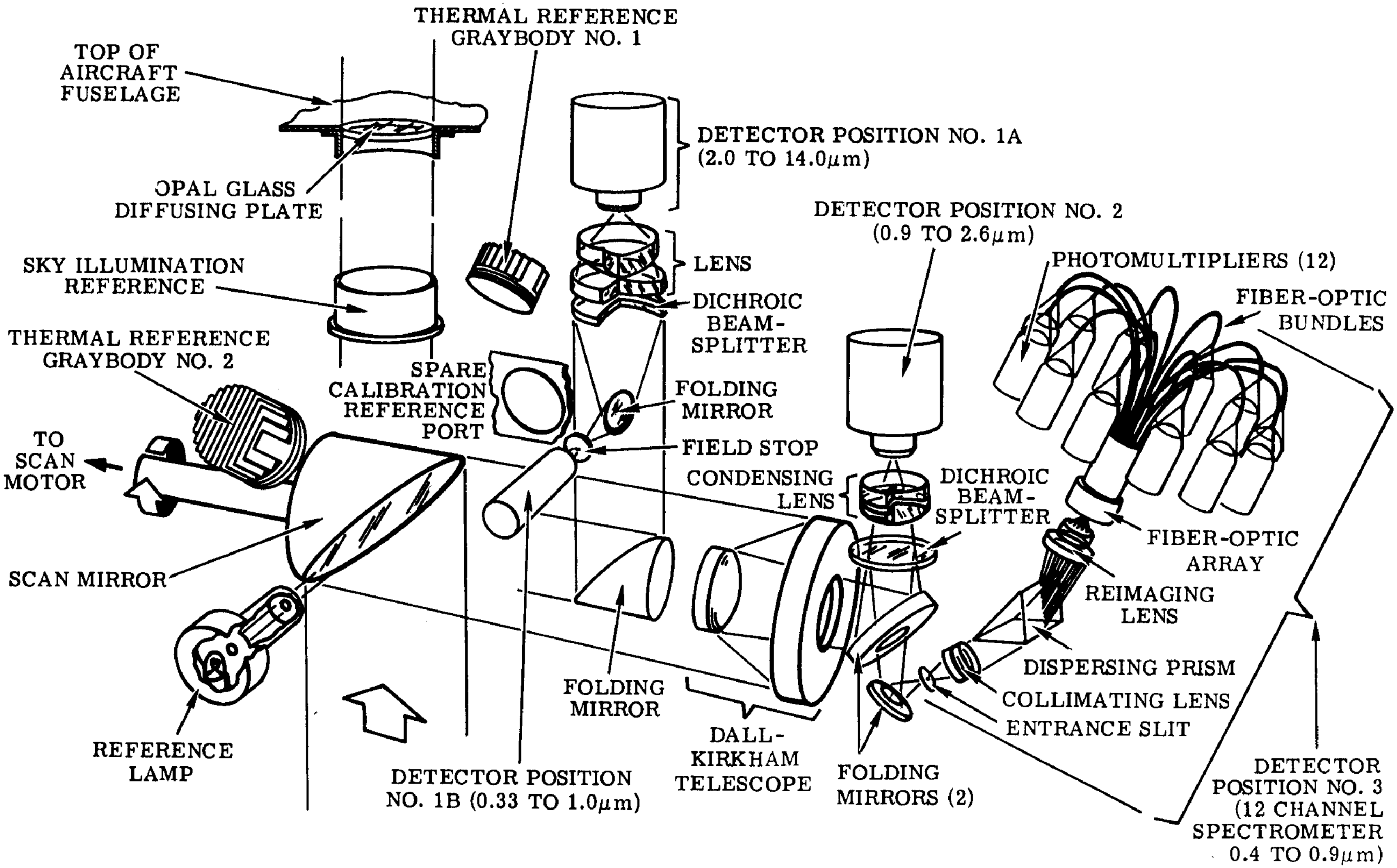


Figure 1. Schematic of ERIM multispectral scanner, M7

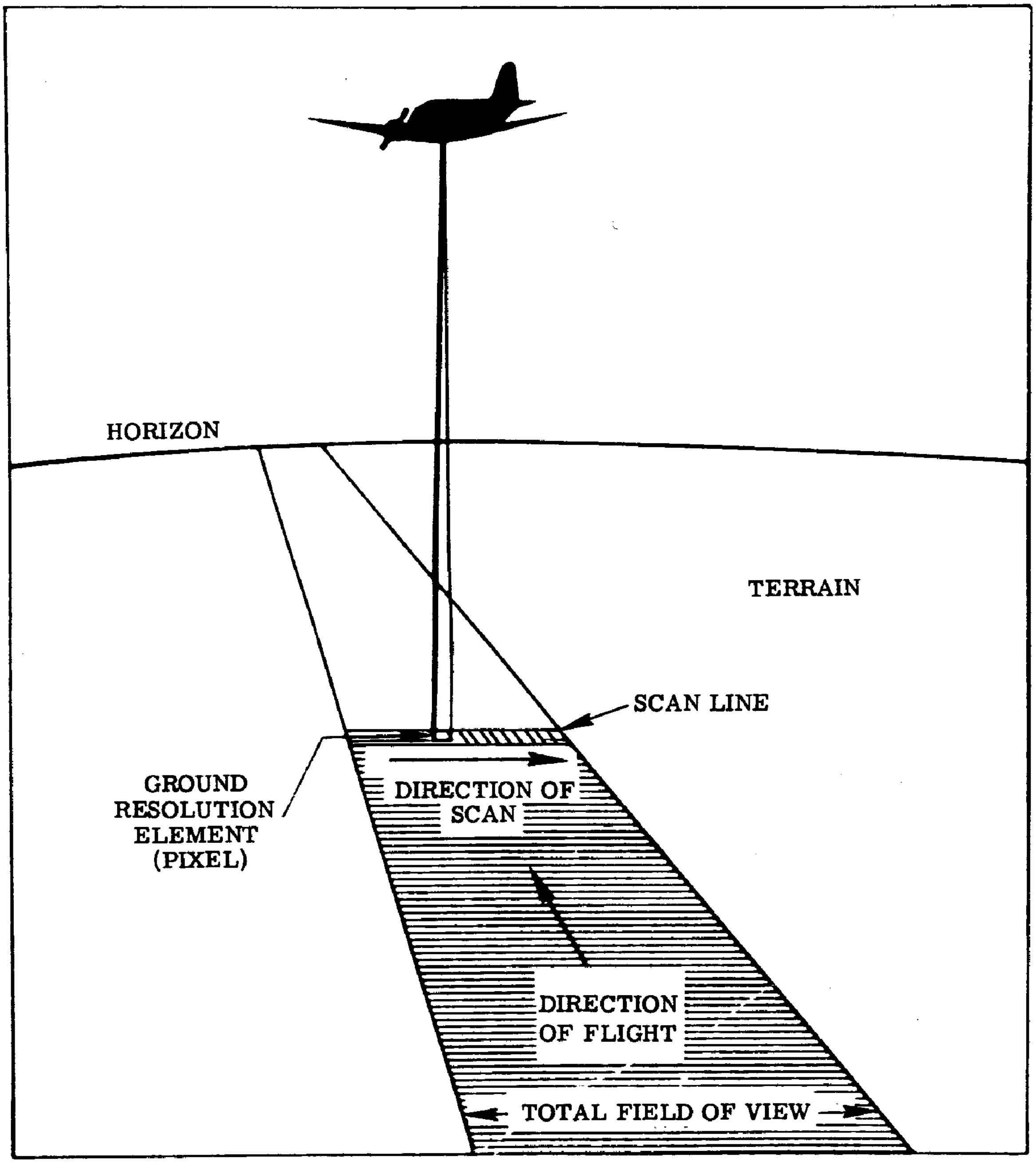


Figure 2. Airborne data collection

penetrates to the bottom, the latter component includes bottom reflectance, volume reflectance from the water column, and reflectance from the water surface. In the ERIM multispectral scanner, incident radiation is measured by a sun sensor and emanating radiation is measured by the scanner system. Utilization of this information to describe bottom features which result in radiation changes requires a model or models which account for the important interactions and their effects.

Since the radiation reflected by bottom features must pass through the intervening water column, the amount of radiation reaching the sensor at a given wavelength is dependent on the volume attenuation characteristics of the water. Attenuation is a function of the thickness of the water layer and the absorption and scattering properties of the water. These properties, in turn, are a function of water quality.

In practice, the sensor output is recorded as voltage (V) on magnetic tape. Neglecting atmospheric effects, the bottom-reflected signal in a given spectral channel may be written as:

$$V = V_s + k\rho e^{-(\sec\theta + \sec\phi)\alpha z}$$

where V = voltage received

V_s = surface reflectance

k = constant which incorporates solar irradiances and scanner characteristics

ρ = bottom reflectance

θ = viewing angle (from vertical)

ϕ = solar illumination angle (from vertical)

α = volume attenuation coefficient (absorption coefficient + scattering coefficient)

z = water depth

Since water depth is variable, the signal received from an identical bottom feature will vary with depth. From an operational standpoint, a depth-invariant model is required which in effect permits removal of the signal because of overlying waters and water surface effects. One possible approach to the problem is the use of a ratio of two spectral bands with similar water attenuation coefficients. Writing the above expression in terms of two spectral bands:

$$\frac{V_1 - V_{s1}}{V_2 - V_{s2}} = k_3\left(\frac{\rho_1}{\rho_2}\right)e^{-(\sec\theta + \sec\phi)(\alpha_1 - \alpha_2)z}$$

where $\frac{k_1}{k_2} = k_3$

In cases where α_1 is equal to α_2,

$$\frac{V_1 - V_{s1}}{V_2 - V_{s2}} = k_3\left(\frac{\rho_1}{\rho_2}\right)$$

Therefore, for a given bottom type, the signals received in two channels (when $\alpha_1 = \alpha_2$) are directly proportional to bottom reflectances and are depth invariant. This relationship applies over an area where water quality (volume attenuation coefficient) remains constant. Use of the above expression for differentiating between Cladophora and background features requires the selection of spectral bands which meet the following conditions:

(1) Attenuation coefficients are equal or may be assumed to be equal.

(2) Significant differences in reflectance occur in the two spectral bands between Cladophora and other bottom features.

Given the problem of differentiating between two different bottom features, the following expressions may be written, subject to the conditions stated above:

For material A,

$$\frac{V_{(A,\lambda_1)} - a_{(\lambda_1)}}{V_{(A,\lambda_2)} - b_{(\lambda_2)}} = R_A$$

For material B,

$$\frac{V_{(B,\lambda_1)} - a_{(\lambda_1)}}{V_{(B,\lambda_2)} - b_{(\lambda_2)}} = R_B$$

The constants "a" and "b" as well as the average values of R_A and R_B are determined from plots of the observed signals in the scene for materials A and B. An intermediate value R_X is then chosen as a "decision boundary" for separating the two materials. Classification of the materials in the scene is made using the criterion, $R_A > R_X > R_B$.

The use of a two-channel model was feasible in this particular case because of the fact that Cladophora was essentially the only aquatic growth present in the nearshore zone. The presence of mixed aquatic communities would have necessitated the use of a more complex multi-channel spectral signature approach.

PRINCIPLES OF THERMAL REMOTE SENSING

Remote sensing techniques for temperature measurement are based on the fact that all substances above absolute zero (0^oK) emit electromagnetic energy. The radiant emittance of a perfect radiator or blackbody is described by Planck's law:

$$L_\lambda = 2\pi c^2 h\lambda^{-5}\left[(e^{hc/\lambda kT})-1\right]^{-1}$$

where L = radiance at wavelength

c = speed of light

h = Planck's constant

λ = wavelength

T = absolute temperature

k = Stefan-Boltzmann constant

The above expression applies to a perfect blackbody, i.e., an object that absorbs all radiation. Since few objects even approximate a perfect blackbody, the factor ϵ (emissivity) is introduced. Blackbodies have an emissivity of 1, whereas other objects have an emissivity (less than 1) which varies with wavelength. Hence, the equation for a graybody is written

$$L_\lambda^g = (2\pi c^2 h)\epsilon_\lambda \lambda^{-5}\left[(e^{hc/\lambda kT})-1\right]^{-1}$$

Substituting

$$c_1 = 2\pi c^2 h$$

$$c_2 = \frac{hc}{k}$$

$$L_\lambda^g = \frac{c_1 \epsilon_\lambda}{\lambda^5\left[\left(e^{c_2/\lambda T}\right)-1\right]}$$

Therefore, Planck's law indicates that the radiation emitted by an object is a function of the object's absolute temperature and the wavelength of observation. However, before the above relationship is utilized for radiometric measurements from aircraft altitudes, several factors must be considered including selection of the operating spectral band. A region of the electromagnetic spectrum must be selected where both the water emissivity and atmospheric transmission are high.

The distribution of emitted energy over a broad wavelength band is temperature-dependent. The position of the peak of radiant emittance is defined by Wien's Displacement Law:

$$\lambda max = \frac{2898\ \mu^o K}{T}$$

From this relationship, it is evident that the wavelength (λ) of the energy peak decreases as the temperature (T) is increased. These relationships are illustrated for a blackbody in Figure 3. Therefore, for most earthbound objects (T = roughly 300^oK), the radiation peak occurs at approximately $10\mu m$. Atmospheric attenuation at this wavelength is not a serious problem. A good "atmospheric window" exists in this region, as shown in Figure 4.

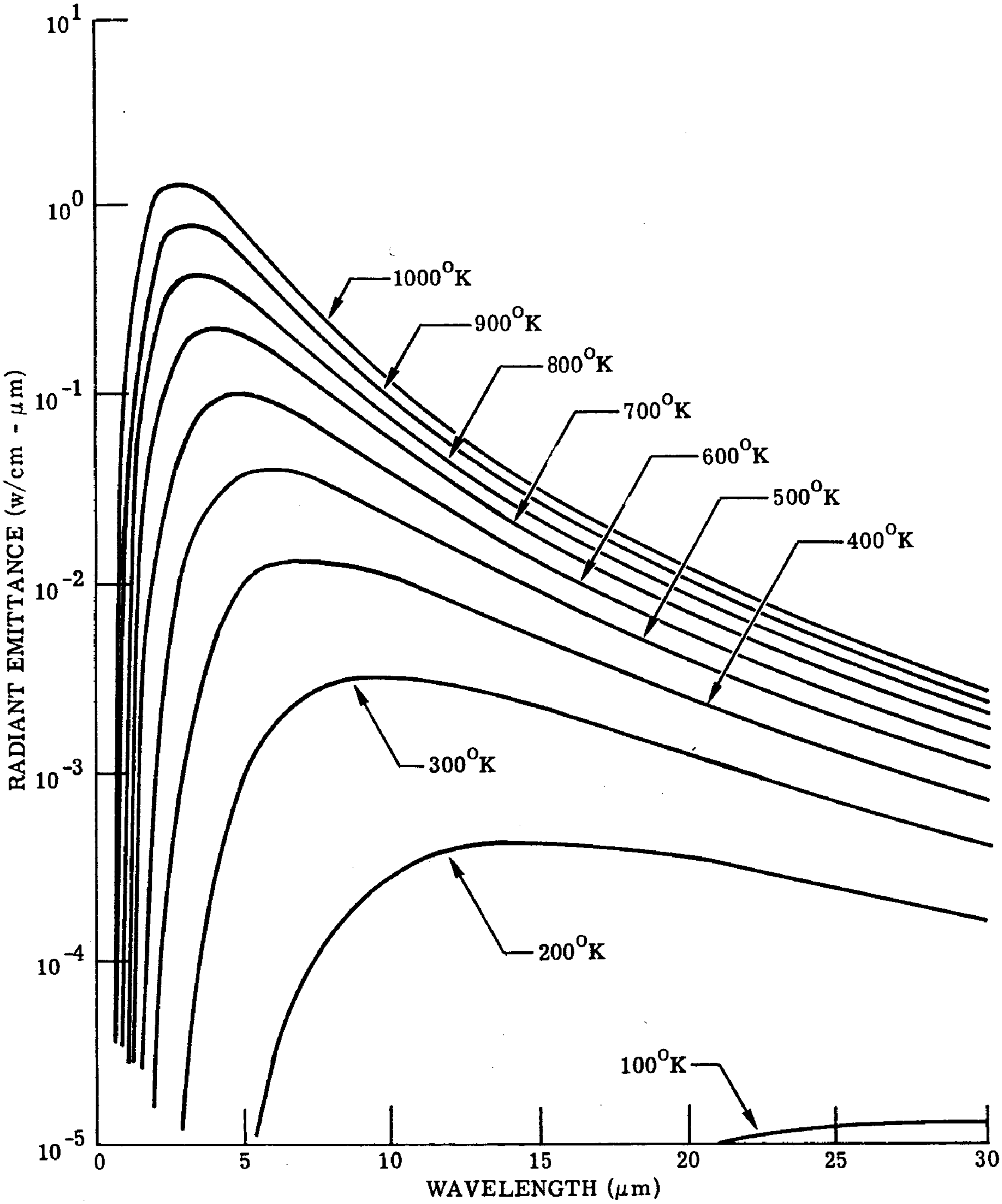


Figure 3. Blackbody radiation curves for 100°K to 1000°K

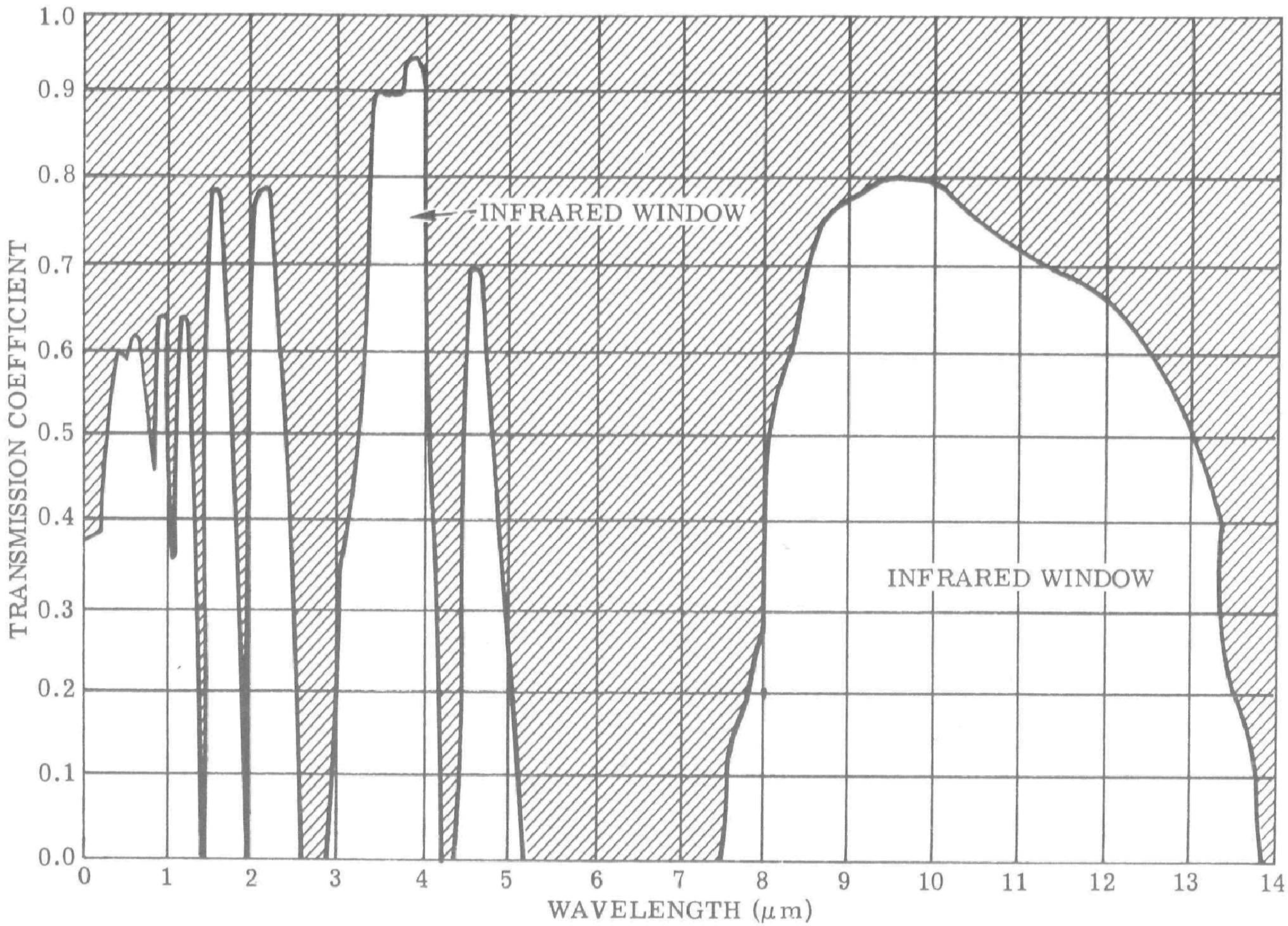


Figure 4. Atmospheric transmission

As indicated above, the observed radiation of any real object (graybody) is dependent in part on object emissivity. In the case of water, the emissivity in the 8 to 13.5 μm infrared range is very high. At 10μm, the emissivity of pure water is 0.993, and at any particular wavelength in the 8 to 13.5 μm range, the emissivity varies between 0.959 and 0.993. As a consequence of the high emissivity, it is frequently assumed that water may be treated as a blackbody. Although this assumption may at times be justified, accurate determinations of water temperature require that the "nonblackness" of water be considered in the analysis of data.

As a consequence of the various physical factors cited above—i.e., emissivity, atmospheric transmission, and wavelength peak—airborne infrared techniques for water temperature determination normally use the 8 to 13.5 μm spectral region, well beyond the photographic region of the electromagnetic spectrum. The infrared sensitivity of infrared film is limited to the portion of the reflective infrared region below 0.9μm. A 9.3 to 11.7 μm infrared channel was used in the thermal work described in this report.

As a general case, the radiation received by the detector will be modified to a small degree by the humidity of the intervening atmosphere, sky radiation, and other environmental factors. Corrections are applied to the radiometric temperatures as required.

CHLOROPHYLL

The technique adopted in this study for measuring chlorophyll in surface waters by means of remote sensing exploits the reflectance changes which occur in the red and blue regions of the spectrum due to phytoplankton. The basis for this approach is illustrated in Figure 5[2]. With increasing phytoplankton concentrations, an increase in reflectance in the red portion of the spectrum is accompanied by a decrease in the blue due to photosynthetic pigments and changes in scattering properties of the water column. Because of path radiance considerations in the blue region of the spectrum, the technique is best suited for low altitude aircraft operations. The sharp rise in reflectance near 0.7μm is another important feature which could be used in a chlorophyll model, particularly in an eutrophic situation. The expression used in this investigation took the form:

$$\log CH_{RS} = a + bR_1$$

where CH_{RS} = chlorophyll $\underline{a}$

a,b = constants

$$R_1 = \frac{\rho(0.62 \text{ to } 0.70\ \mu m)}{\rho(0.42 \text{ to } 0.48\ \mu m)}$$

In Figure 5, no special importance should be attached to the cross-over point at 0.51μm. The position of the cross-over point, the shape of the curve, and the position of the peak in the green region vary with various water quality factors and phytoplankton species differences.

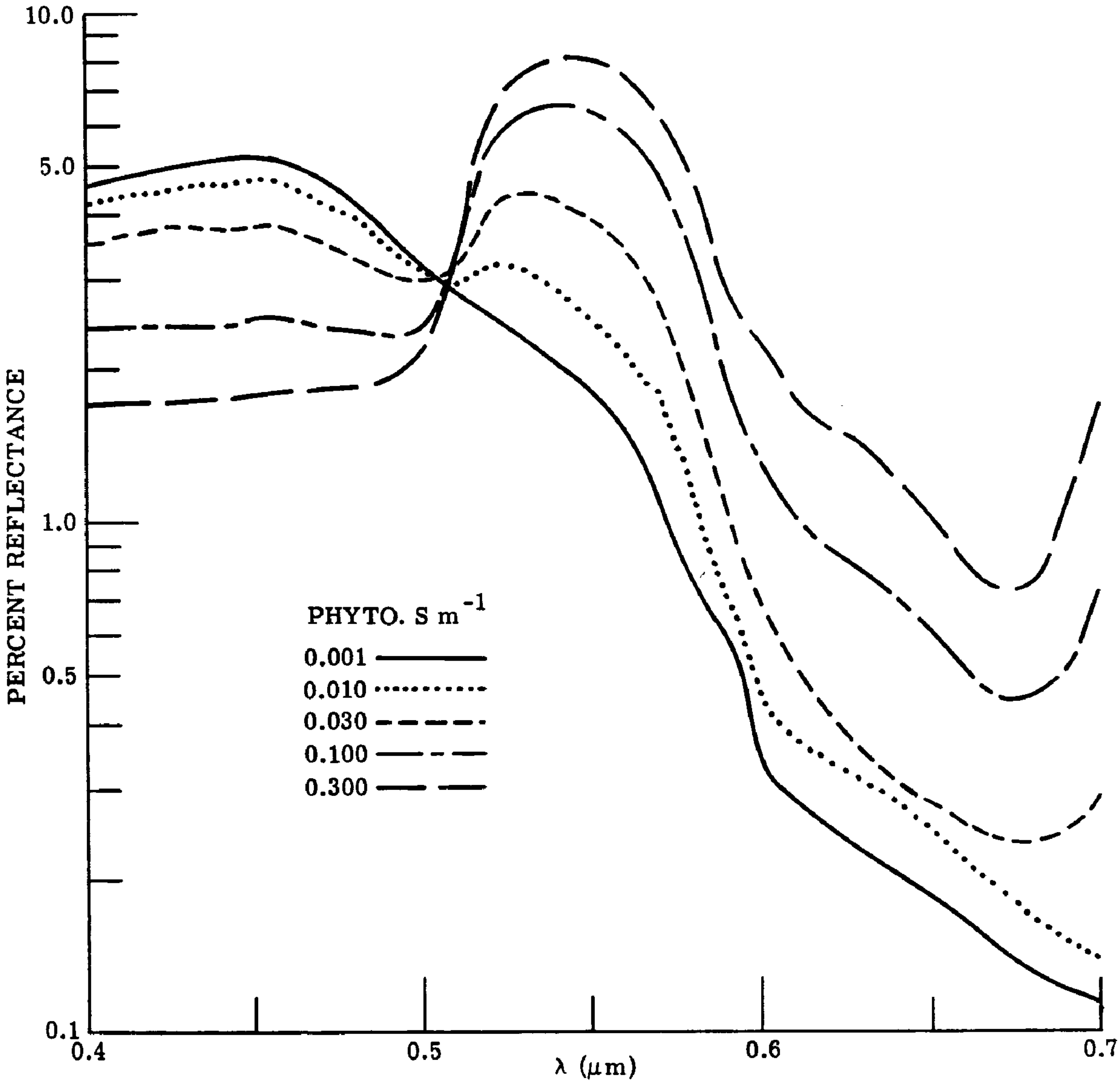


Figure 5. Calculated change in reflectance of water with increasing concentration of Phytoplankton (after G. Suits)

DATA PROCESSING PROCEDURES

Machine processing of multispectral scanner data for Cladophora recognition was accomplished by analog and digital processing techniques. The aircraft scanner analog data were converted to digital format. In the process, six original scan lines were smoothed for each line of digitized data. The smoothing factor employed was designed to produce a data set with the proper aspect ratio and to optimally use the redundant data produced by overscanning the scene. Data were also angle-corrected.

Within each site selected for digital processing, line prints were made through areas containing Cladophora and background. Scatter plots were made from selected pairs of channels to determine voltage offsets and the ratio values that separate Cladophora from background.

By means of the above procedures and with data from spectral bands 0.48 μm to 0.52 μm and 0.52 μm to 0.57 μm, digital maps were produced. A near-infrared band was used to delete land areas. An automatic point count of areas occupied by Cladophora was available for conversion into unit areas.

The ratio technique described above was also used with an analog processor to produce enhanced imagery. Although the preprocessing steps normal in digital processing were not included, the results demonstrated an improved Cladophora discrimination capability. The importance of setting the necessary offsets was also demonstrated by the results.

The amount of thermal processing performed in this investigation was limited to selected examples. The technique used was the standard analog procedure of contoured separations[1]. The temperature difference between the hot and cold reference plates was divided into equal intervals ($1^{o}C$). The areas occupied by each interval were recorded on photographic film. Once the separations have been made, temperature differences can be displayed either as individual temperature contours or as a color-coded composite. The former method was used in this report.

SECTION V

GROUND-TRUTH DATA

The Great Lakes Laboratory, State University College at Buffalo, furnished ground-truth information from five locations in the area between Niagara and Rochester. Remote sensing flights took place on 20 June 1972 and 31 July 1972. The available ground truth data were collected during the period 27 July 1972 to 1 August 1972.

The ground truth team reports that Cladophora was collected at 1, 2, 3, 4, 5, and 6 meter depths along five transects extending from the shore into the lake. Cladophora was collected from within randomly tossed hoops, each with a surface area of one square foot. The plant material was scraped from the bottom by divers, refrigerated at 4°C, and delivered to the laboratory for analysis of wet, dry, ash, and volatile weights[3,4]. The ground-truth information made available to ERIM is presented in Tables 1 through 5. The Decca coordinates shown in the tables indicate the location of stations 0.5 km from shore.

The nearshore investigators also report that Cladophora was not found at locations where sand constituted the bottom material. Additionally, the investigators report that growth and development at depths of 1 to 2 m was limited because of wave action.

Ground-truth information for the area east of Rochester was obtained from the Lake Ontario Environmental Laboratory, State University of New York at Oswego. The Cladophora data[5] made available to ERIM are shown in Table 6. Ground-truth information was collected during the period 18-21 July 1972.

Table 1. CLADOPHORA GROUND-TRUTH DATA, STATION 207

Date:	27 July 1972
Time:	15:00 hr
Decca Coordinates:	Red A-22; Green A-45
Max. Depth:	4.5 m

Distance from Shore, m	Water Depth, m	Description	Weight/3 sq ft Wet, g	Dry, g
600	6	Very sparse. Thin filaments scraped and stones. Rocks-included mud in sample	106.47	23.11
300	5	Solid cover; heavy growth	148.64	31.97
150	4	Solid cover; heavy growth	67.97	9.20
105	3	Sandy; no growth	------	-----
25	2	Sandy; no growth	------	-----
15	1	Sandy; no growth	------	-----

Table 2. CLADOPHORA GROUND-TRUTH DATA, STATION 216

Date:	27 July 1972
Time:	12:00 hr
Decca Coordinates:	Red I-8.50; Green B-31.3
Max. Depth:	4.5 m

Distance from Shore, m	Water Depth, m	Description	Weight/3 sq ft Wet, g	Dry, g
600	6	Growth sparse on rocks; thin filaments	73.35	16.80
140	5	Growth sparse on rocks; thin filaments	27.86	20.70
70	4	Moderate growth	25.63	17.81
35	3	Moderate growth	27.23	21.27
20	2	Clean bedrock	-----	-----
10	1	Clean bedrock	-----	-----

Table 3. CLADOPHORA GROUND-TRUTH DATA, STATION 222

Date: 27 July 1972

Time: 18:00 hr

Decca Coordinates: Red G-19.5; Green B-37.25

Max. Depth: 4.5 m

Distance from Shore, m	Water Depth, m	Description	Weight/3 sq ft Wet, g	Weight/3 sq ft Dry, g
600	6	Spotty; heavy, heavy patches-10-12' filaments-95% bare rock	527.94	118.47
350	5	Little growth only in depressions in rock	------	------
250	4	Sand; no Cladophora	------	------
100	3	Moderate-spotty	74.62	12.73
20	2	Heavy growth; dense	61.63	9.05
10	1	Heavy growth; dense	45.95	19.02

Table 4. CLADOPHORA GROUND-TRUTH DATA, STATION 228

Date: 31 July 1972

Time: 17:15 hr

Decca Coordinates: Red F-15.0; Green B-47.5

Max. Depth: 5.5 m

Distance from Shore, m	Water Depth, m	Description	Weight/3 sq ft Wet, g	Weight/3 sq ft Dry, g
500	6	Sparse; thin filaments on rocks	100.0	42.03
350	5	Sparse; rocks, sand and silt	72.92	31.17
200	4	Very sparse growth	15.57	1.87
50	3	Sandy; no Cladophora	------	-----
25	2	Scattered rocks in sand; growth heavy on rocks	61.63	11.2
10	1	Cover half rock, half sand	35.51	3.38

Table 5. CLADOPHORA GROUND-TRUTH DATA, STATION 237

Data:	1 August 1972
Time:	16.30 hr
Decca Coordinate:	Red E-11; Green 0-34.25
Max. Depth:	6.5 m

Distance from Shore, m	Water Depth, m	Description	Weight/3 sq ft Wet, g	Weight/3 sq ft Dry, g
550	6	Large rocks; growth uniform; 80-90% cover	60.26	8.34
350	5	Large rocks; growth uniform; 80-90% cover	91.87	26.28
150	4	Smaller rocks; growth uniform; 80-90% cover	108.15	27.65
40	3	Sand; no Cladophora	-----	-----
25	2	Sand; no Cladophora	-----	-----
10	1	Sand; no Cladophora	-----	-----

Table 6. GROUND-TRUTH DATA, EAST OF ROCHESTER

(Cladophora, Dry Weight, Grams Per 1,000 cm^2)

Depth (meters)	Location: Stations:	Sodus 424-429	Sterling 418-423	Lakeside-Oswego 412-417	Nine Mile Pt 406-411	Stony Pt 400-405
1		11.0150	18.2776	36.8439	33.9495	3.3198
2		29.0905	0.8652	64.6888	1.9615	3.4668
3		4.9543	7.9421	16.1619	8.8462	6.2667
4		5.3862	------	8.3855	8.2269	5.3632
5		2.7741	10.4277	24.6780	1.4483	8.7954
6		0.9838	26.8677	8.9294	0.3725	34.7932

NOTE: Data provided by State University of New York, Oswego. Collected 18-21 July 1972.

SECTION VI

RESULTS AND DISCUSSION

Data processing objectives of the program included processing of the data set on a sampled basis in order to provide an estimate of the area coverage of Cladophora. The original processing plan proposed sampling the data set on a 1/20th basis. As initially proposed, this requirement could be met either by processing every 20th scanline or by processing sections of the shoreline to provide an equivalent area coverage. In view of the wide variation in water quality in the study area, including highly turbid areas, the latter alternative proved to be the only practical solution to processing the data set.

Approximately 400 km of data were collected. Of this amount, 25.8 km of data were processed. The locations selected for processing are shown in Figure 6.

CLADOPHORA - NIAGARA TO ROCHESTER

Typical scenes showing the extent of development of Cladophora in the nearshore zone are shown in Figures 7 through 10. The dimensions of the areas displayed in the spectral ratio imagery are approximately 0.75 km by 3.5 km. The dark areas in the imagery (water areas) are occupied by Cladophora. From a purely physical standpoint, growth is determined by the availability of hard surfaces. The light areas in the imagery represent a loose, unconsolidated substrate—usually sand.

Analysis of the data indicates spectral variation within the Cladophora fields. This is particularly evident in Figure 9. The differences in tone may be due to differences in density of growth, differences in the length of the Cladophora, or other differences related to the life cycle of the algae. A demonstration and analysis of the capabilities of remote sensing technology to answer these and other questions related to benthic algae is outside the scope of this investigation. A carefully controlled series of experiments to answer the above questions is indicated as a logical extension of the work initiated in this program.

The results of processing of remote sensing data to estimate standing crop of Cladophora for the area Niagara to Rochester are summarized in Table 7. Imagery showing the location of each processing section is included in Appendix A. Individual digital maps for the various sites processed are included in Appendix B.

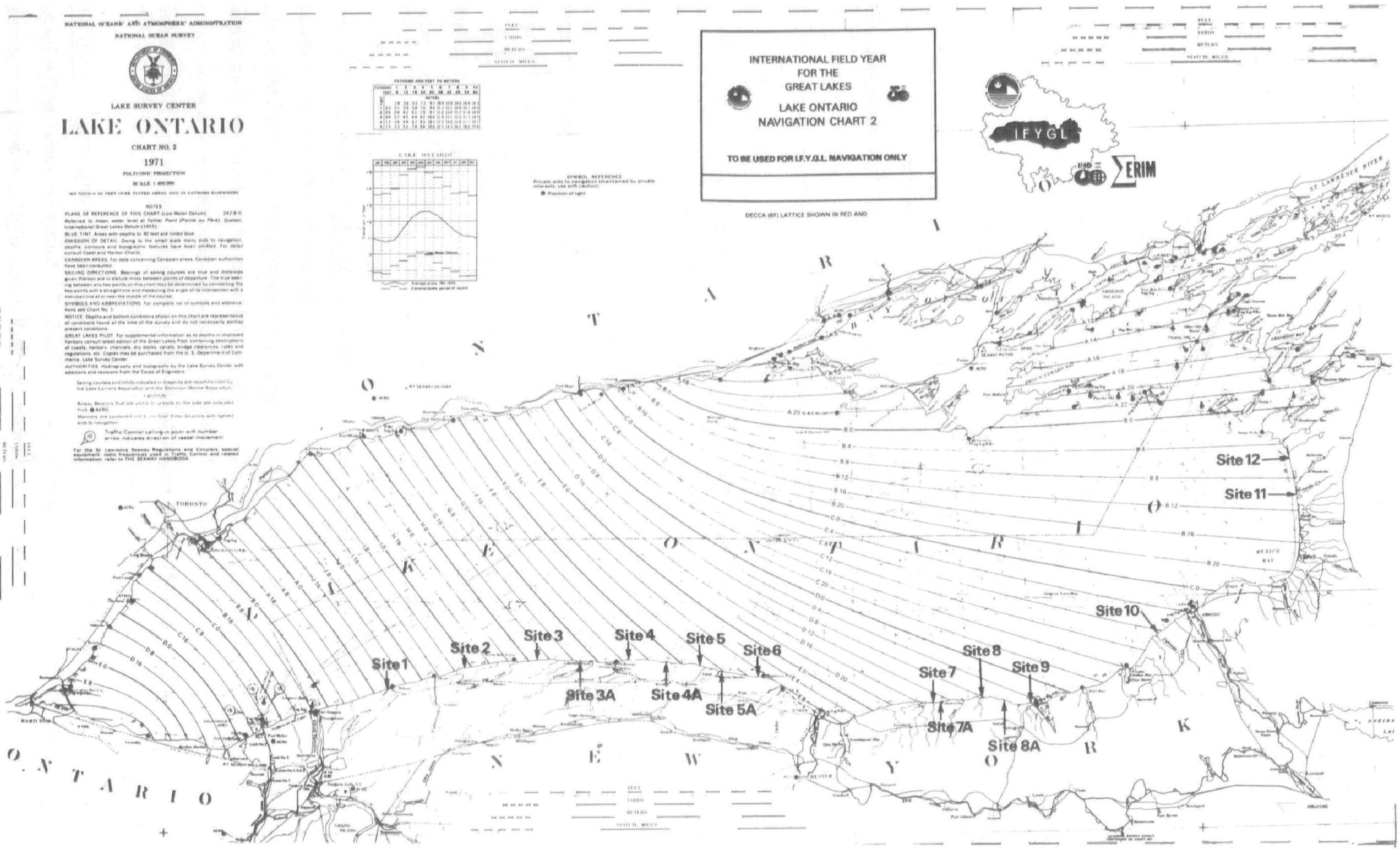


Figure 6. Data-processing locations

Figure 7. Ratio imagery, Site 3, Station 222. 20 June 1972

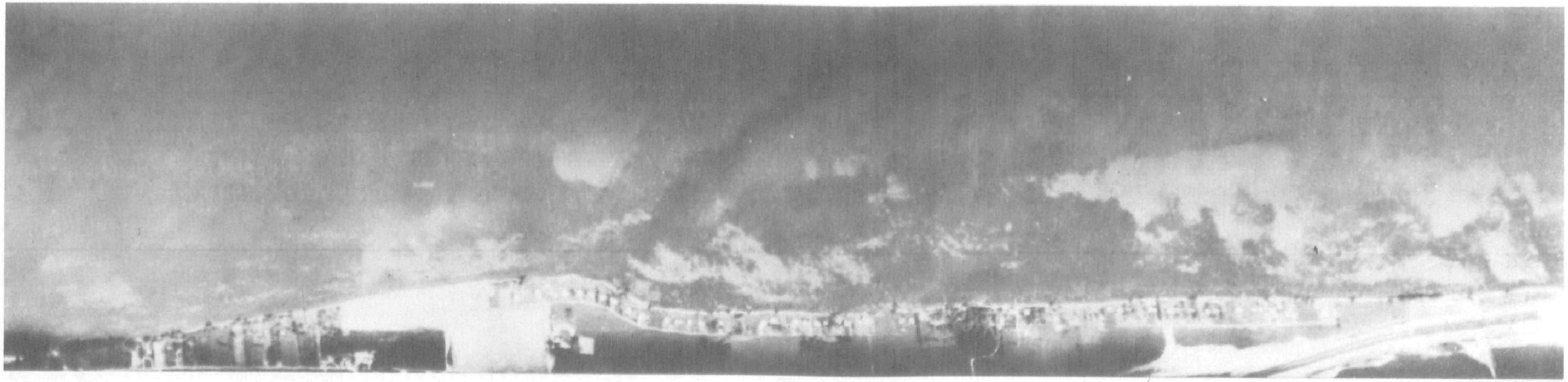


Figure 8. Ratio imagery, Site 4, Station 228. 20 June 1972

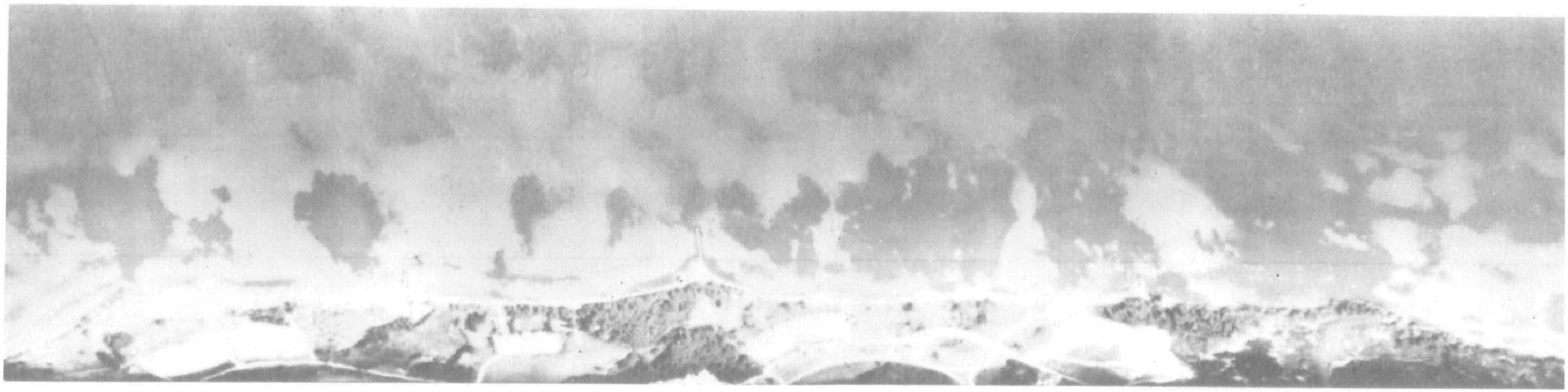


Figure 9. Ratio imagery, Site 5, North Hamlin. 20 June 1972

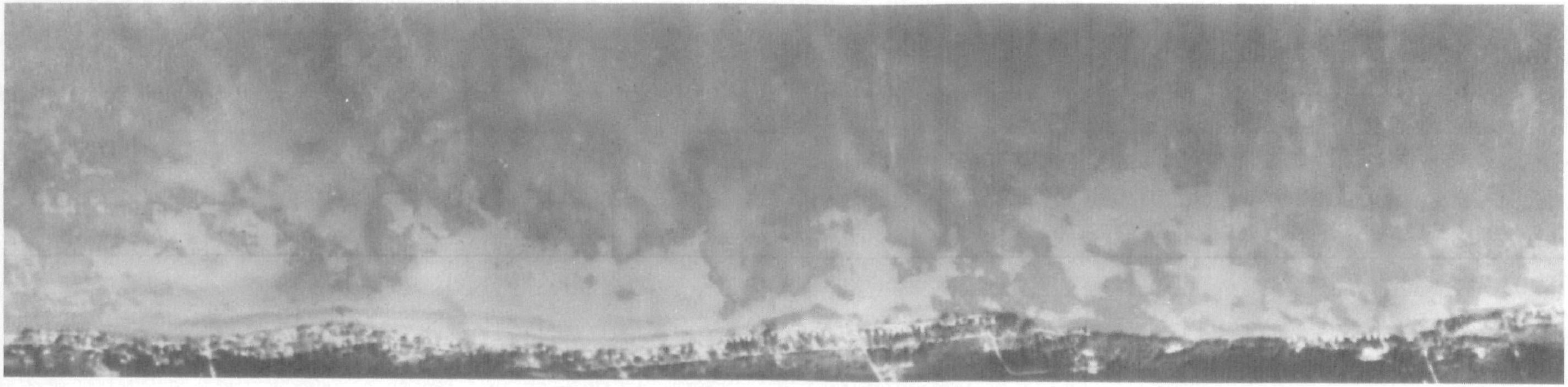


Figure 10. Ratio imagery, Site 6, Station 237. 20 June 1972

Table 7. *CLADOPHORA* DISTRIBUTION—NIAGARA TO ROCHESTER

Site	Date	Length, km	Max Dist from Shore, m	Ave Dist from Shore, m	*Cladophora*, %	Dry Wt[a] g/m^2	kg/km[b]
1	20 June 72	---	---	---	---	---	---
	31 July 72	1.0	400	354	75	74.1	1.97×10^4
2	20 June 72	---	---	---	---	---	---
	31 July 72	1.3	400	373	17	71.8	0.46×10^4
3	20 June 72	1.2	400	---	72.5	---	---
	31 July 72	1.2	400	353	72	49.0	1.17×10^4
3A	20 June 72	1.0	500	---	82	---	---
	31 July 72	---	---	---	---	---	---
4	20 June 72	1.2	400	---	82.5	---	---
	31 July 72	1.2	400	340	70	76.3	1.83×10^4
4A	20 June 72	1.8	500	---	66	---	---
	31 July 72	---	---	---	---	---	---
5	20 June 72	1.3	400	---	66	---	---
	31 July 72	1.3	400	345	67	97.1	2.23×10^4
5A	20 June 72	1.5	500	---	71	---	---
	31 July 72	---	---	---	---	---	---
6	20 June 72	1.2	400	---	59.5	---	---
	31 July 72	1.2	400	320	55	97.1	1.75×10^4
				Ave 348	65.8	77.56	1.57×10^4

[a]Average values for 0-5 meter depth range were derived from ground-truth data collected by State University College at Buffalo investigators, during the period 27 July—1 August 1972.

[b]kg dry wt per kilometer for strip-width shown.

Data processing extended out from shore an average distance of 348 m. At this distance from shore, water depth is reported to be 5 m or slightly greater. The data summarized in Table 7 show that approximately 66% of the nearshore zone was covered with Cladophora and that the standing crop expressed as dry weight was equal to 1.57×10^4 kg per kilometer of shoreline for a strip 350 m wide (5 m depth contour).

Studies of the nearshore zone conducted by other investigators extend to the 6 m depth contour. If desired, the above information can be extrapolated to this depth.

CLADOPHORA—ROCHESTER TO STONY POINT

The factors which govern the ability of a passive remote sensing system to map bottom features include: (1) the volume attenuation coefficient of the overlying waters, (2) "sea-state" at the time of the overflight, and (3) illumination conditions. Within the area between Rochester and Stony Point, field conditions at the time of the overflight were less than desirable. As a consequence, difficulties were experienced in processing the data for this region.

As indicated in Figure 6, eight processing sites were selected for this section of the lake. Imagery showing the location of these sites (sites 7-12) is included in Appendix A. Individual digital maps for the sites processed are included in Appendix B. Data processing results for the area east of Rochester are summarized in Table 8.

Due to a reduced transparency in the eastern section of the lake, data processing extended out from shore an average distance of 277 m as opposed to an average of 348 m in the area west of Rochester. The results summarized in Table 8 show that 79% of the area of the nearshore zone was covered by Cladophora and that standing crop expressed as dry weight was equal to 2.6×10^4 kg per kilometer for an average strip-width of 277 m. Extrapolating the results to a width of 350 m, the standing crop is equal to 3.3×10^4 kg per kilometer of shoreline.

THERMAL FEATURES

Temperature is an important environmental parameter and has a bearing on all chemical and biological processes in the lake. Although thermal monitoring was not the primary objective of the program described in this report, the use of a multispectral system provided the opportunity to document thermal features or anomalies in the nearshore zone. Both major and minor thermal features were noted at several locations along the U.S. shoreline.

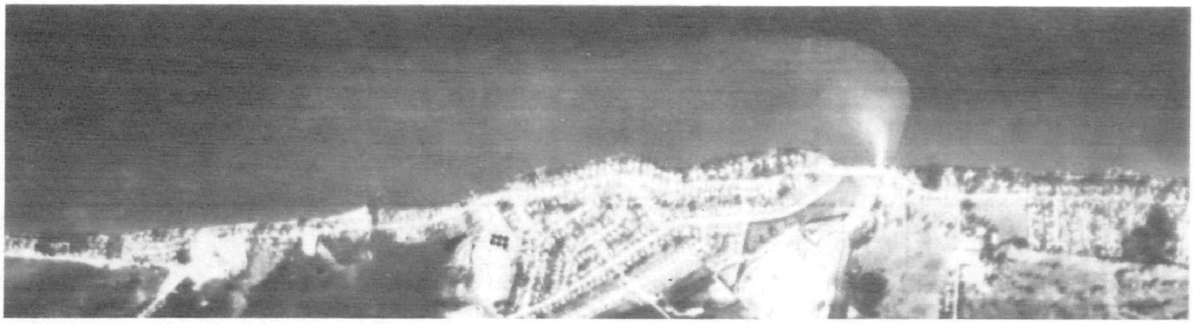
Four power plants are presently located within the study area. Cooling water discharges from these plants are displayed in the thermal imagery shown in Figure 11. The technique of contoured separations displays the temperature levels between ambient (offshore) and the discharge temperature (see Figure 12). The temperatures indicated correspond to the light areas in the separations. An $8^{\circ}C$ difference was noted between the discharge and offshore temperatures.

Table 8. CLADOPHORA DISTRIBUTION—ROCHESTER TO STONY POINT

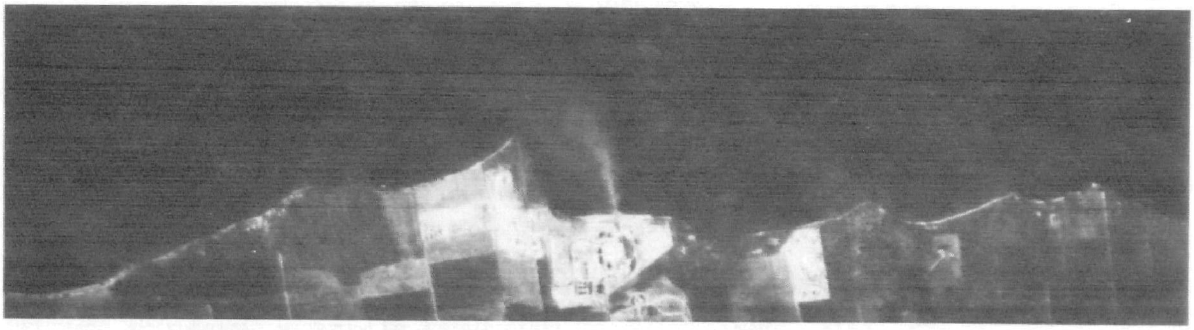
Site	Date	Length, km	Max Dist from Shore, m	Ave Dist from Shore, m	Cladophora, %	Dry Wt[a] g/m^2	kg/km[b]
7	31 July 72	1.5	380	279	89	106.4	2.65×10^4
7A	31 July 72	1.0	360	342	90	106.4	3.26×10^4
8	31 July 72	1.0	360	306	87	106.4	2.82×10^4
8A	31 July 72	1.0	360	294	81	106.4	2.55×10^4
9	31 July 72	1.2	360	291	12	106.4	0.38×10^4
10	31 July 72	1.0	360	249	93	301.5	6.95×10^4
11	31 July 72	1.2	300	209	90	54.4	1.02×10^4
12	31 July 72	1.0	300	244	86	54.4	1.14×10^4
				Ave = 277	79	117.8	2.60×10^4

[a]Average values for 0-5 meter depth range were derived from ground-truth data collected by State University of New York at Oswego investigators during period 18 July-21 July 1972.

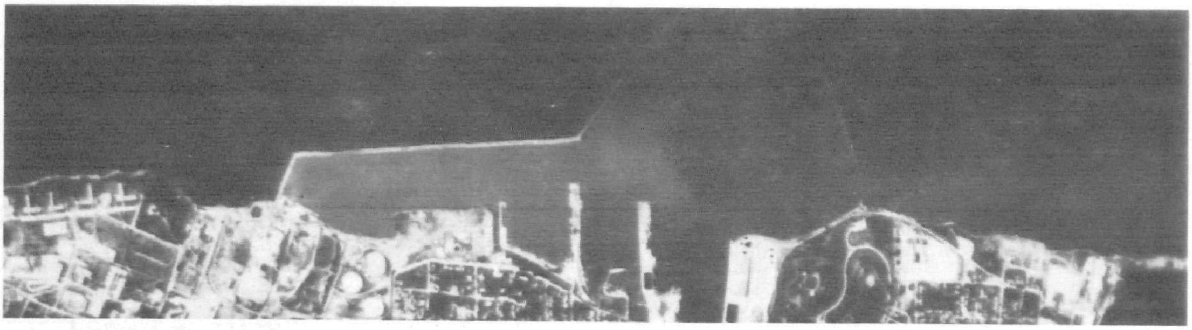
[b]kg dry wt per kilometer for strip-width indicated.



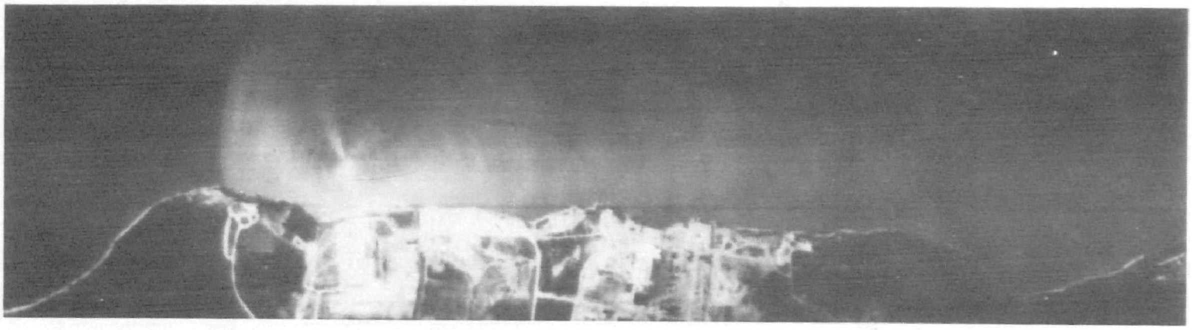
Rochester



Between Rochester and Oswego



Oswego



East of Oswego — Nine Mile Point

Figure 11. Power plant discharges, Lake Ontario, 31 July 1972, 9.3-11.7 μm

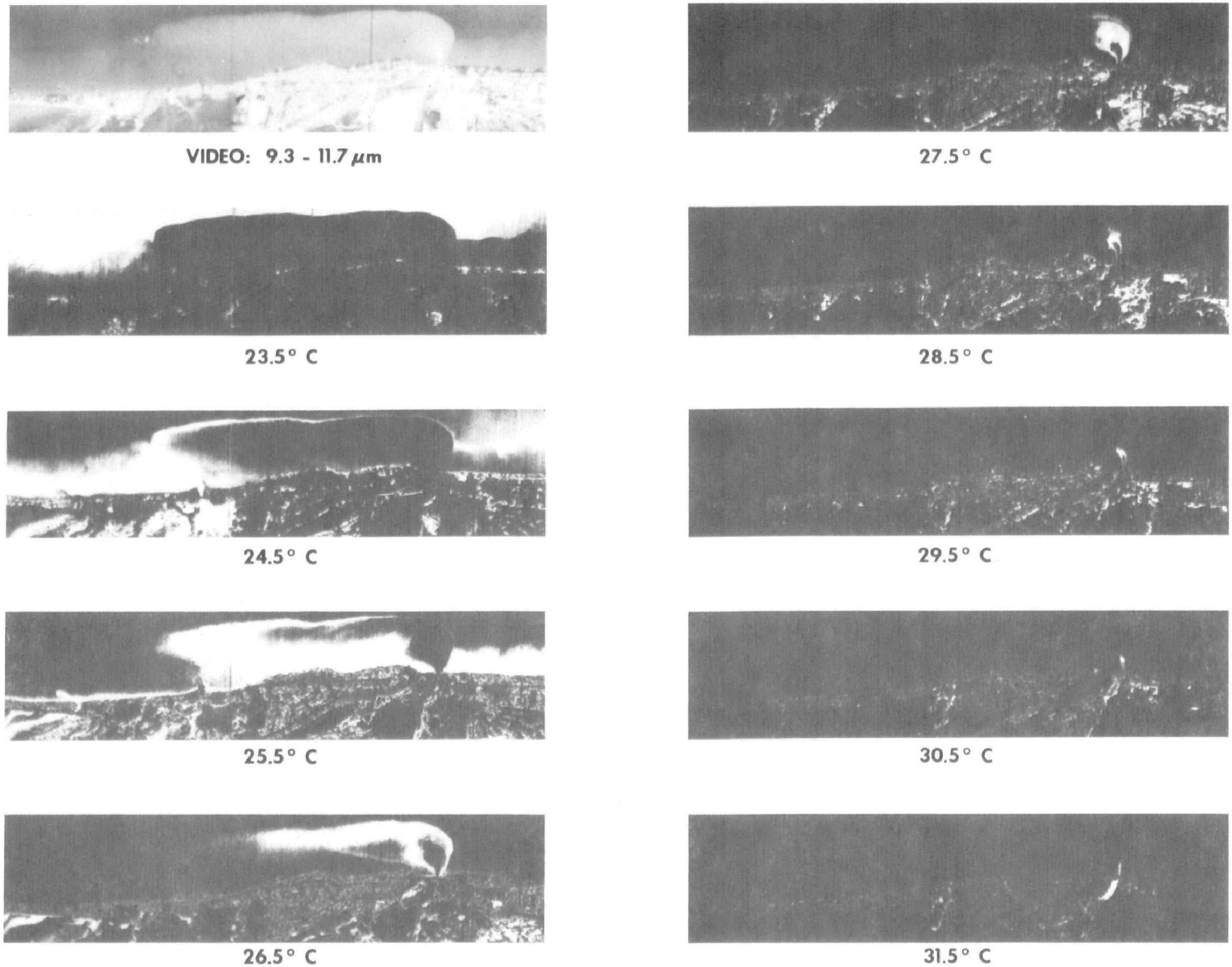


Figure 12. Power plant discharge temperatures, Rochester, 31 July 1972

On a much larger scale, a thermal front was recorded on 20 June 1972 in the vicinity of Olcott, New York, approximately 30 km east of Niagara (Figure 13). The thermal imagery shown is approximately 0.8 km wide. The temperature difference between the warm area (light tone) on the left and the cool water mass on the right (dark area) is 6°C.

Other thermal features of interest are shown in Figures 14 through 16. River discharges, seeps along the shore, and thermal boundaries in the lake are evident. All of these inputs can be expected to influence the biology and chemistry of the nearshore zone. The significance of these can only be interpreted by an analysis of the results obtained by the various nearshore investigators.

CHLOROPHYLL a

Processing of remote sensing data to determine surface chlorophyll a concentrations was performed at one location. Shown in Figure 17 is a portion of Lake Ontario in the vicinity of the Niagara River. Digital processing results show concentrations in the plume as high as 14.0 mg/m^3 on 31 July 1972. These results are presented primarily to illustrate the potential of remote sensing for this purpose. Results can be displayed as either (1) black-white or color-coded digital maps, or (2) as contoured separations.

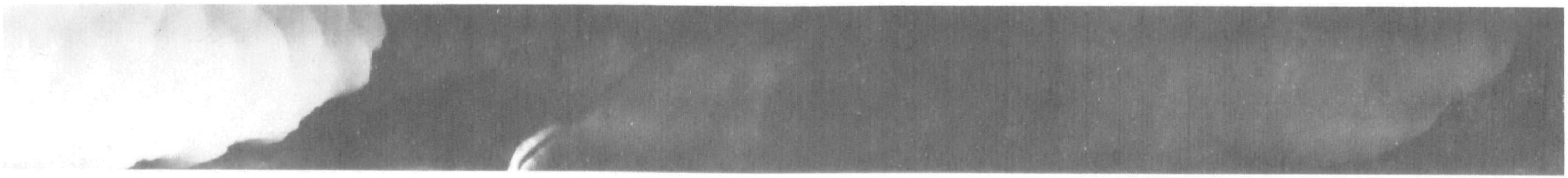
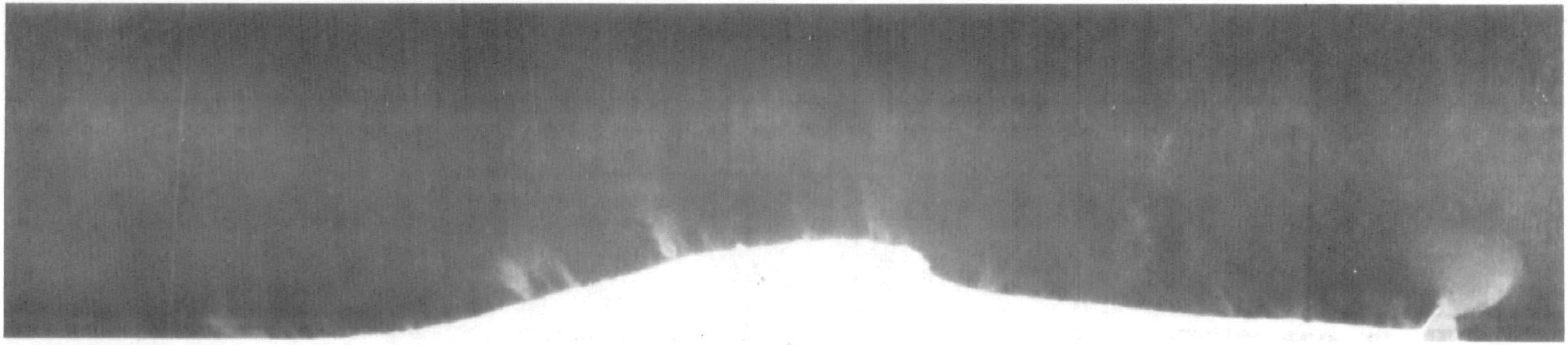


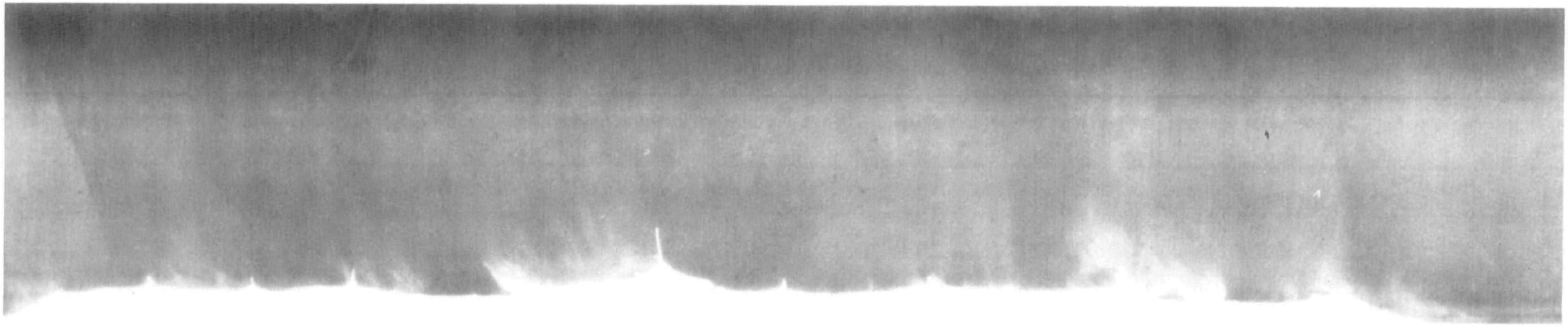
Figure 13. Lake Ontario at Olcott, 20 June 1972, 9.3-11.7 μm



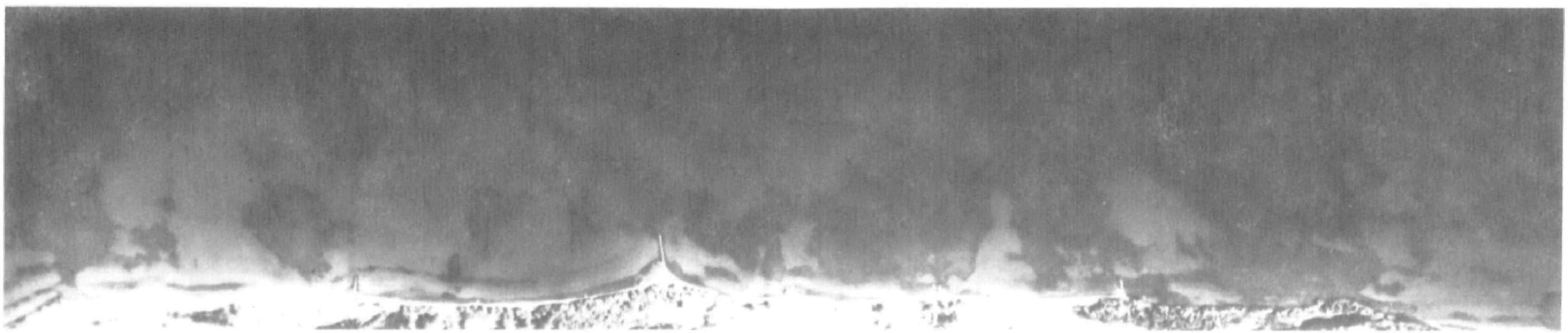
9.3-11.7 μm

0.52-0.57 μm

Figure 14. Multispectral imagery—Lake Ontario near North Hamlin, 20 June 1972

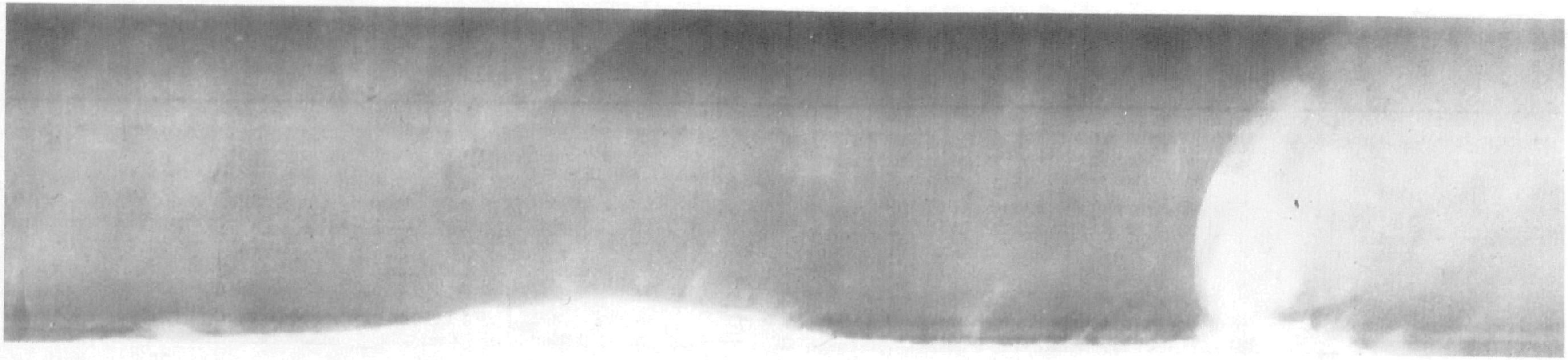


9.3-11.7 μm



0.52-0.57 μm

Figure 15. Multispectral imagery—Lake Ontario near North Hamlin, 20 June 1972



9.3-11.7 μm

0.52-0.57 μm

Figure 16. Multispectral imagery — Lake Ontario at Point Breeze, 20 June 1972

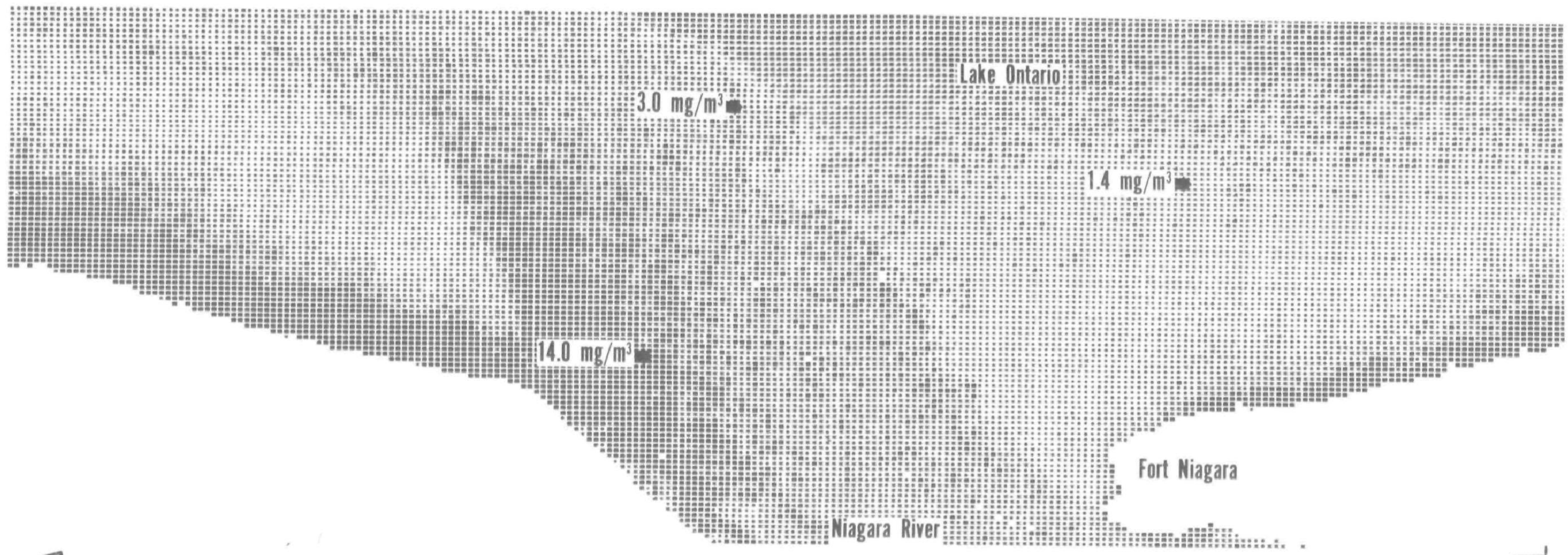


Figure 17. Chlorophyll a, Lake Ontario at Niagara

SECTION VII

REFERENCES

1. Hasell, P. G., Jr., et al. Michigan Experimental Multispectral Mapping System — A Description of the M7 Airborne Sensor and Its Performance. Environmental Research Institute of Michigan, Ann Arbor, Michigan. Report 190900-10-T. January 1974. 148 pp.

2. Suits, G. Preliminary Results of Water Reflectance Calculations Using AQUACAN. Environmental Research Institute of Michigan, Ann Arbor, Michigan. Unpublished Memo. January 1973.

3. Sweeney, R. A. Ground Truth-U.S. Shoreline, Western Lake Ontario (IFYGL). Personal Communication. Great Lakes Laboratory, State University College at Buffalo, Buffalo, New York. November 1972.

4. Great Lakes Laboratory, State University College at Buffalo. Annual Report, Analysis and Model of Impact of Discharge From Niagara and Genesee Rivers of the Nearshore Zone. In: First Annual Reports of the EPA IFYGL Projects. Environmental Protection Agency, Corvallis, Oregon. Report EPA 660/3-73-021. December 1972. pp. 218-329.

5. Moore, R. B. Personal Communication. Lake Ontario Environmental Laboratory, State University of New York at Oswego. October 1972.

SECTION VIII

APPENDICES

APPENDIX A

DATA PROCESSING LOCATIONS

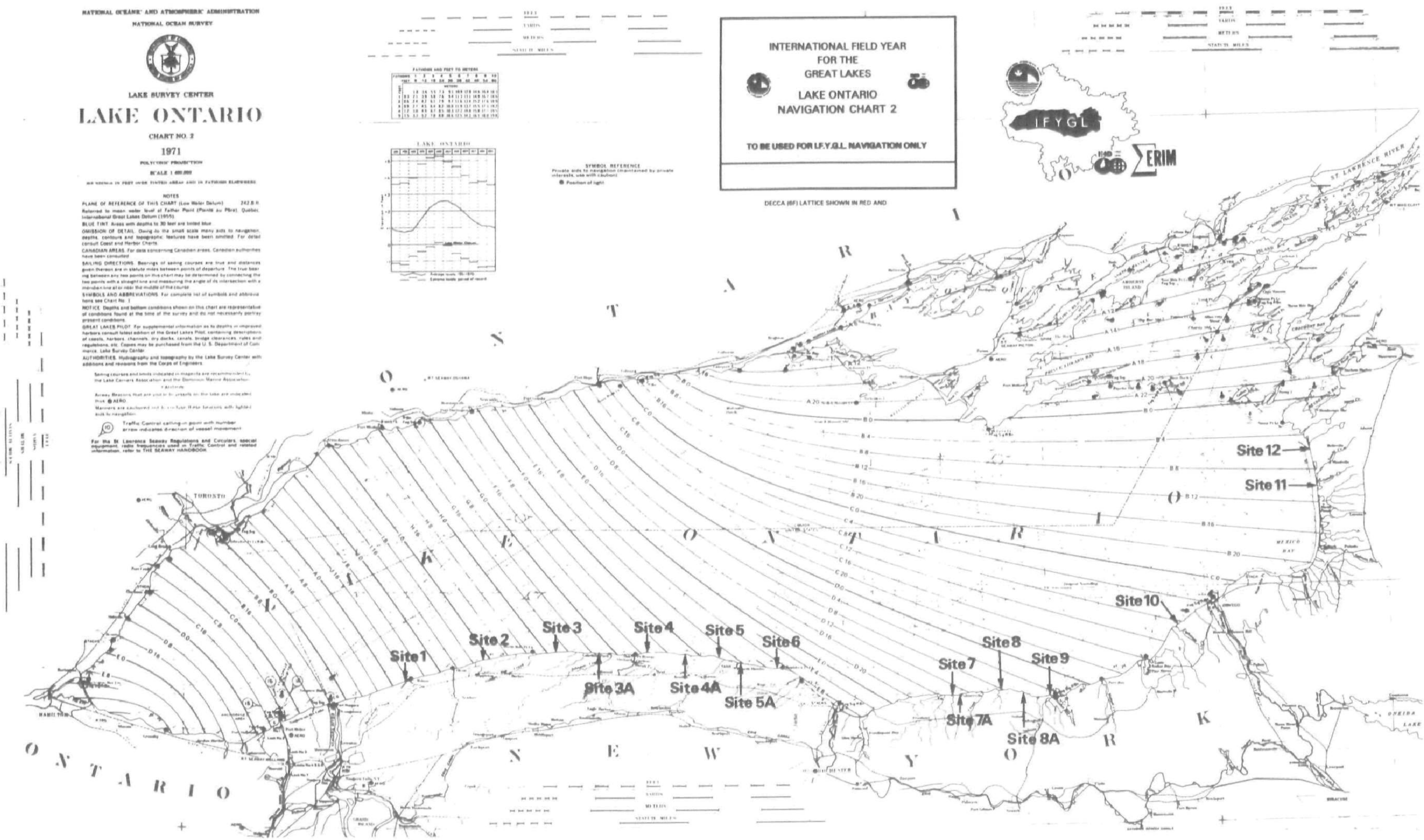


Figure A-1. Data-processing locations

Figure A-2. Site 1, near Wilson, 31 July 1972

KEY CREEK STATION 216 ← SITE 2 →

Figure A-3. Site 2, near Station 216, 31 July 1972

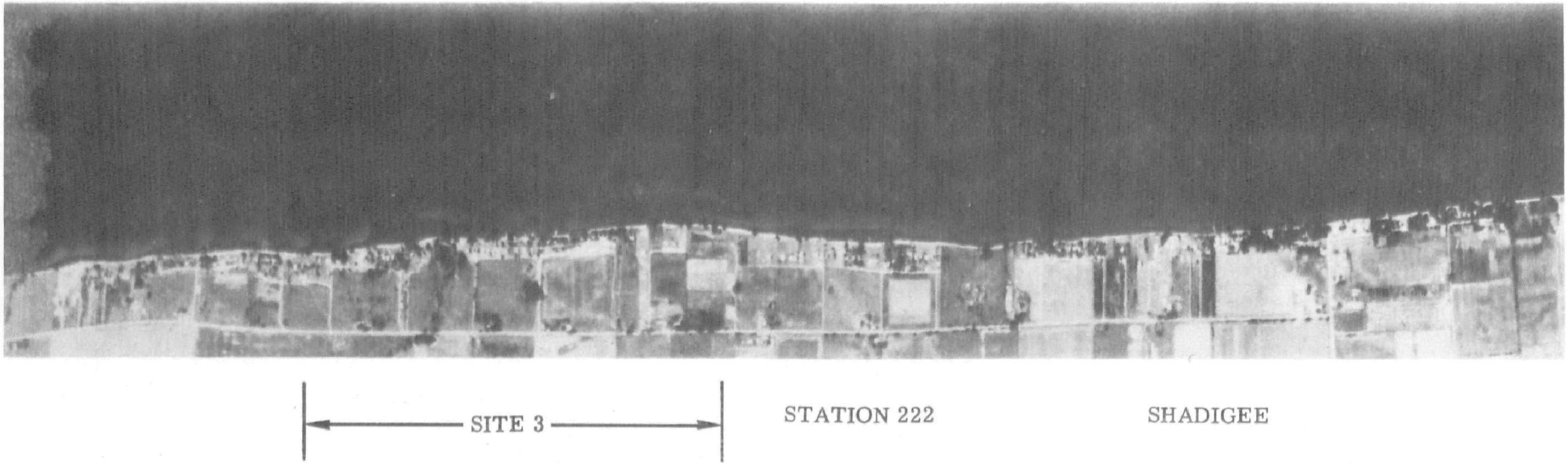


Figure A-4. Site 3, near Station 222, 31 July 1972

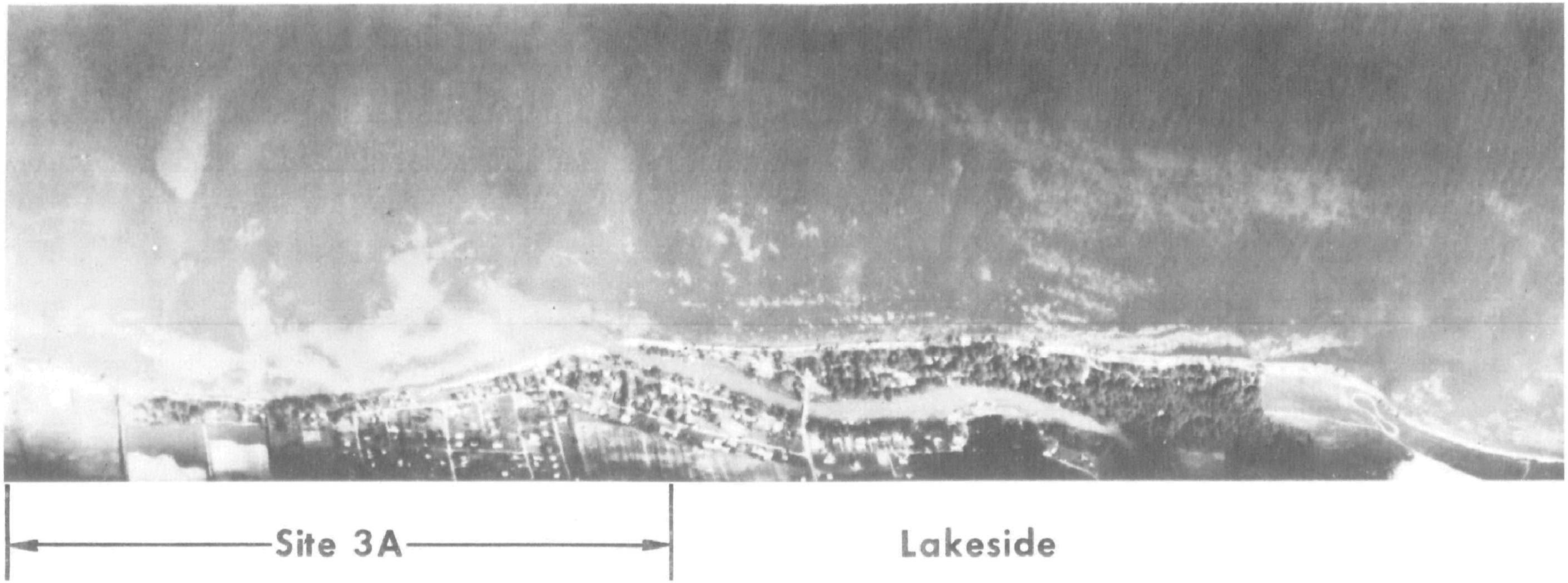


Figure A-5. Site 3A, near Lakeside, 20 June 1972

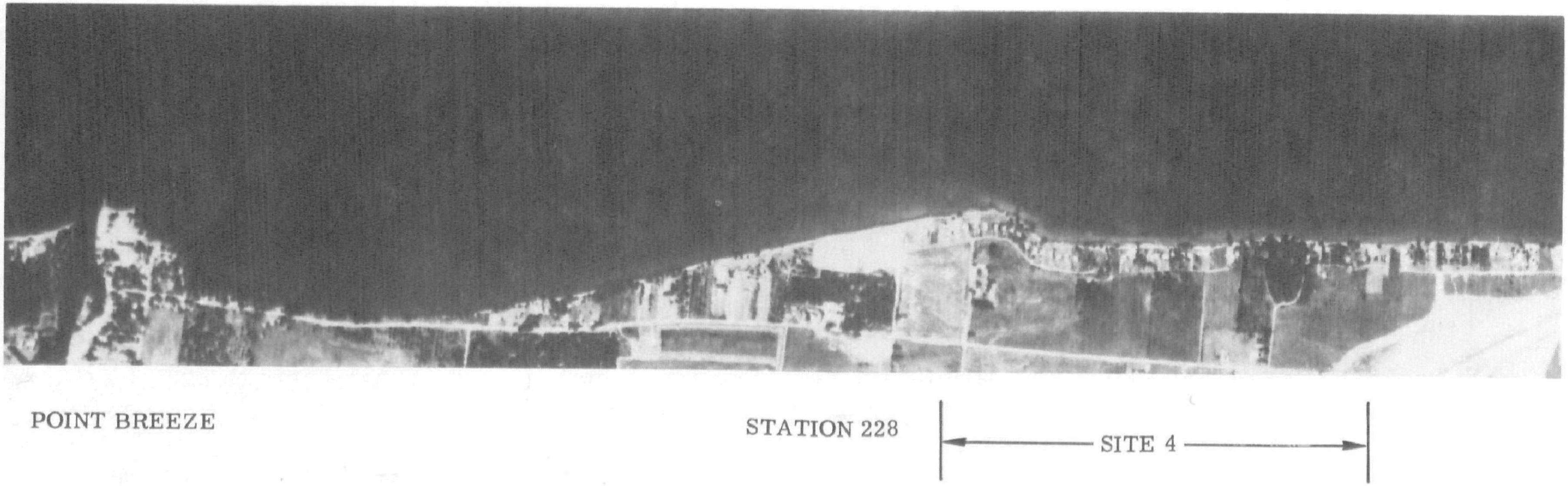


Figure A-6. Site 4, near Station 228, 31 July 1972

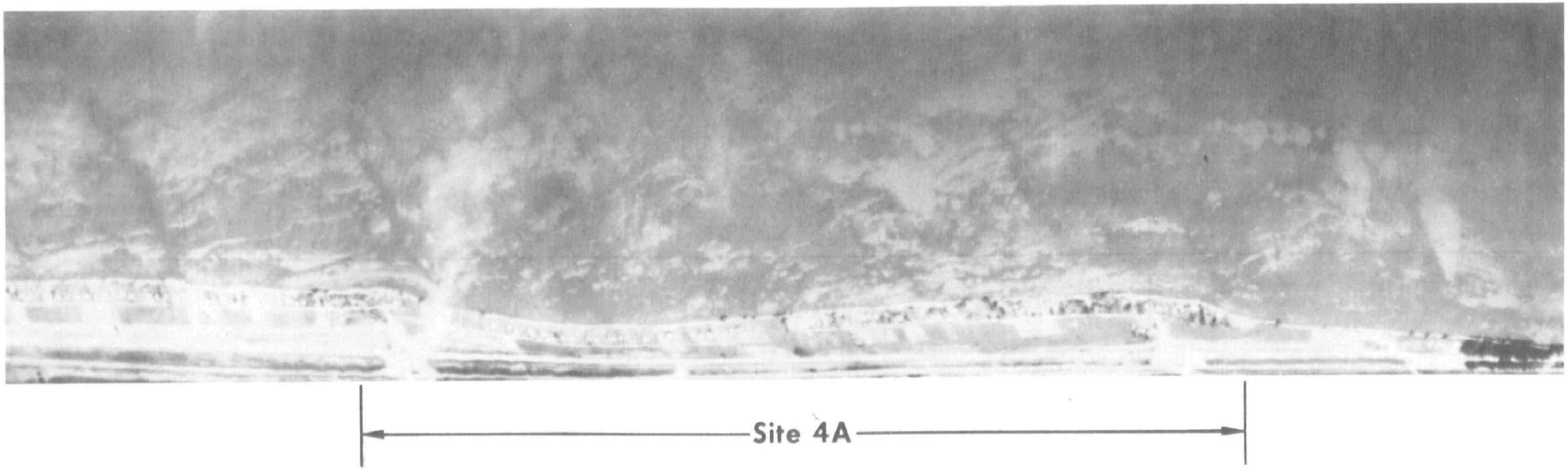


Figure A-7. Site 4A, Lomond Shore, 20 June 1972

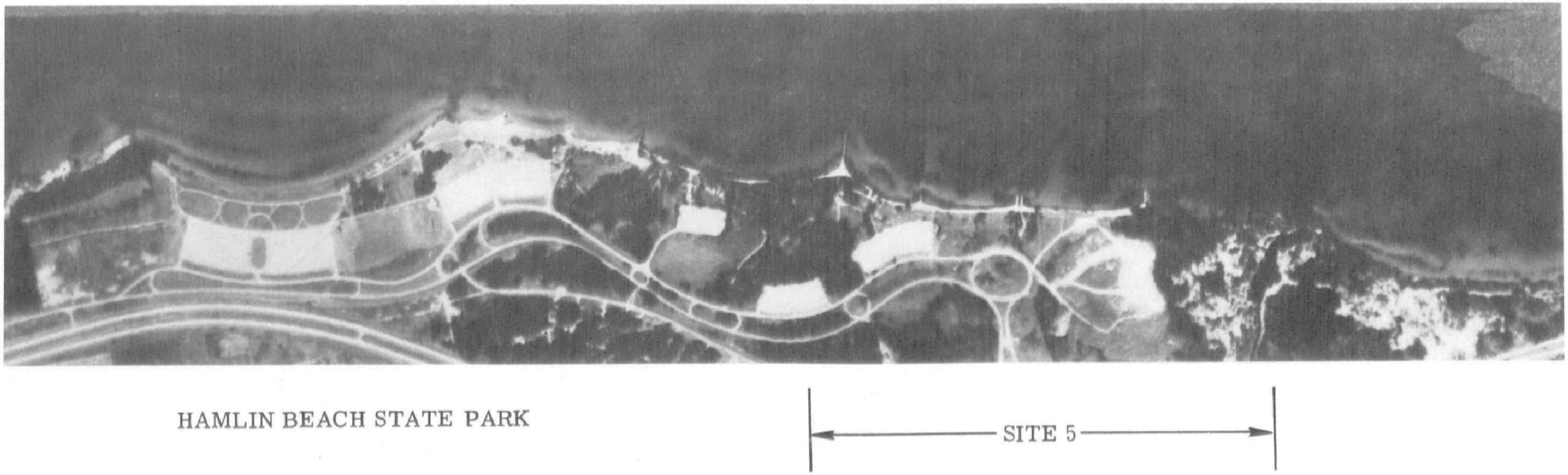


Figure A-8. Site 5, near North Hamlin, 31 July 1972

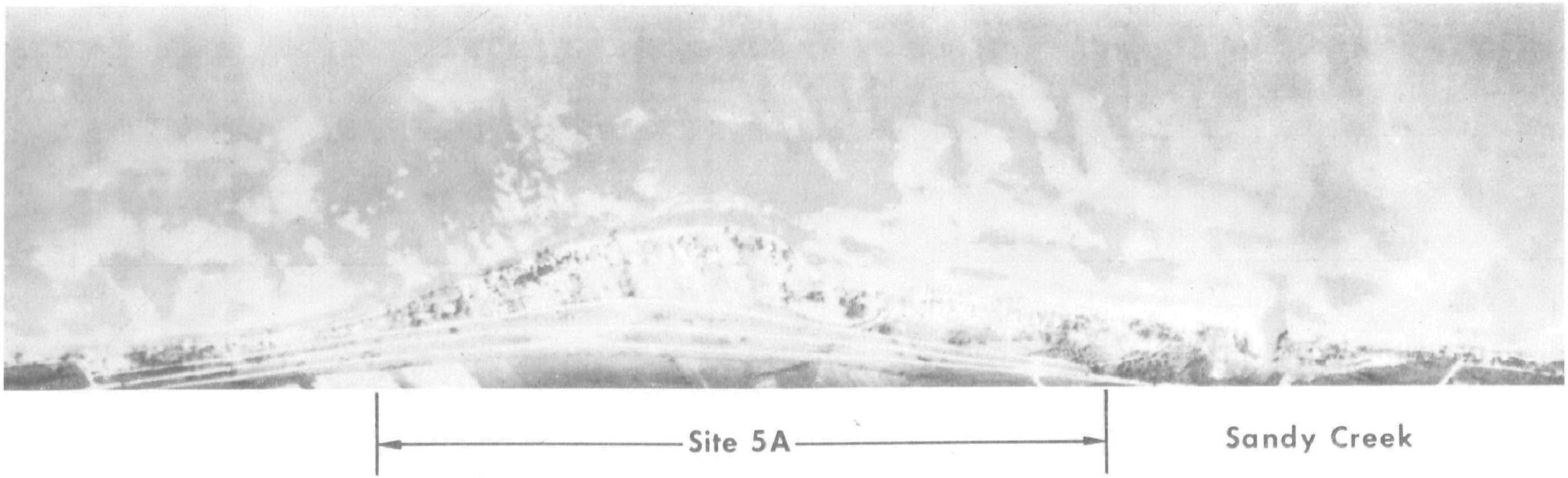


Figure A-9. Site 5A, Onteo Beach, 20 June 1972

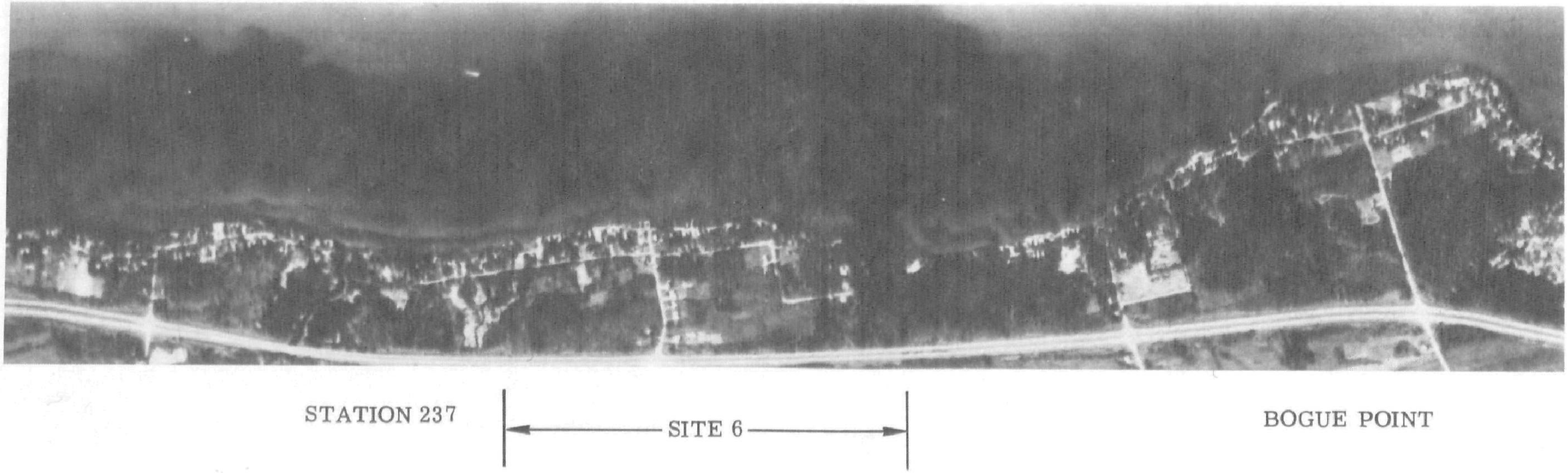


Figure A-10. Site 6, near Station 237, 31 July 1972

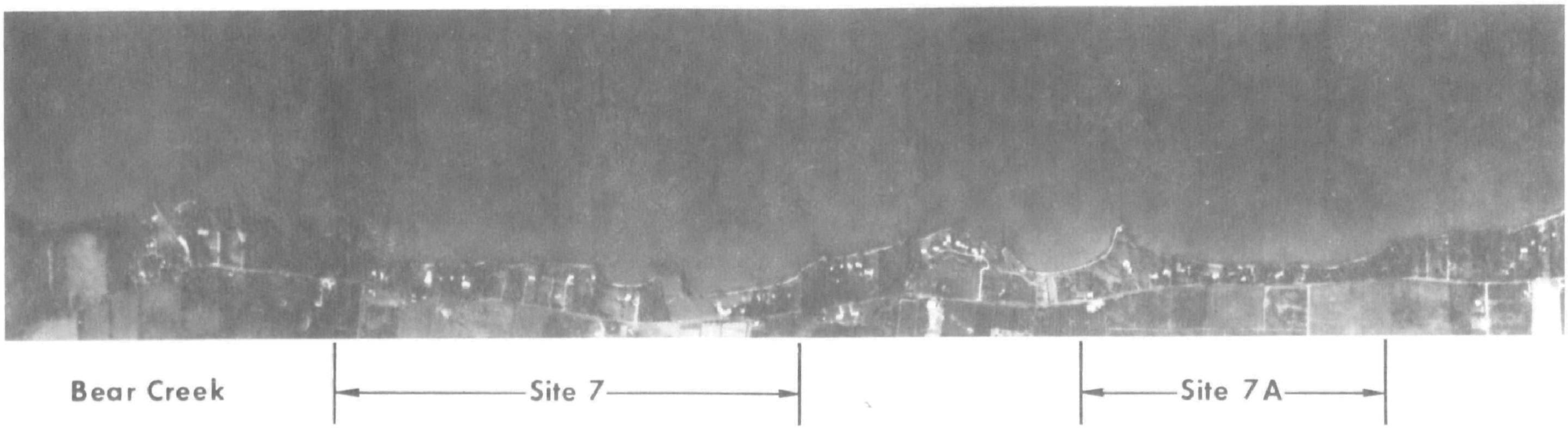


Figure A-11. Site 7, west of Pultneyville, 31 July 1972

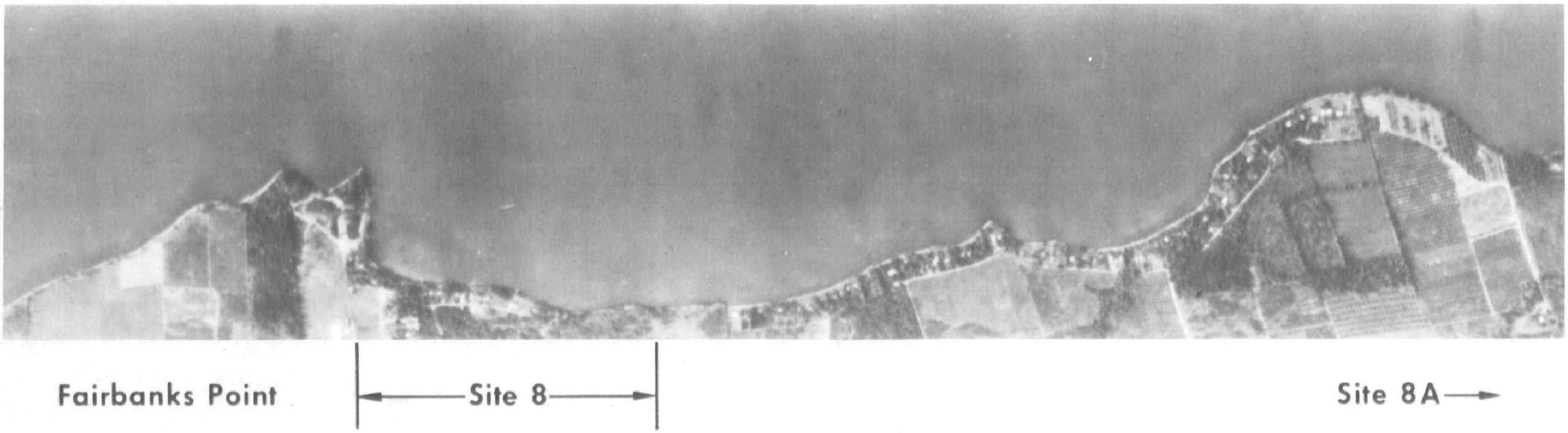


Figure A-12. Site 8, east of Pultneyville, 31 July 1972

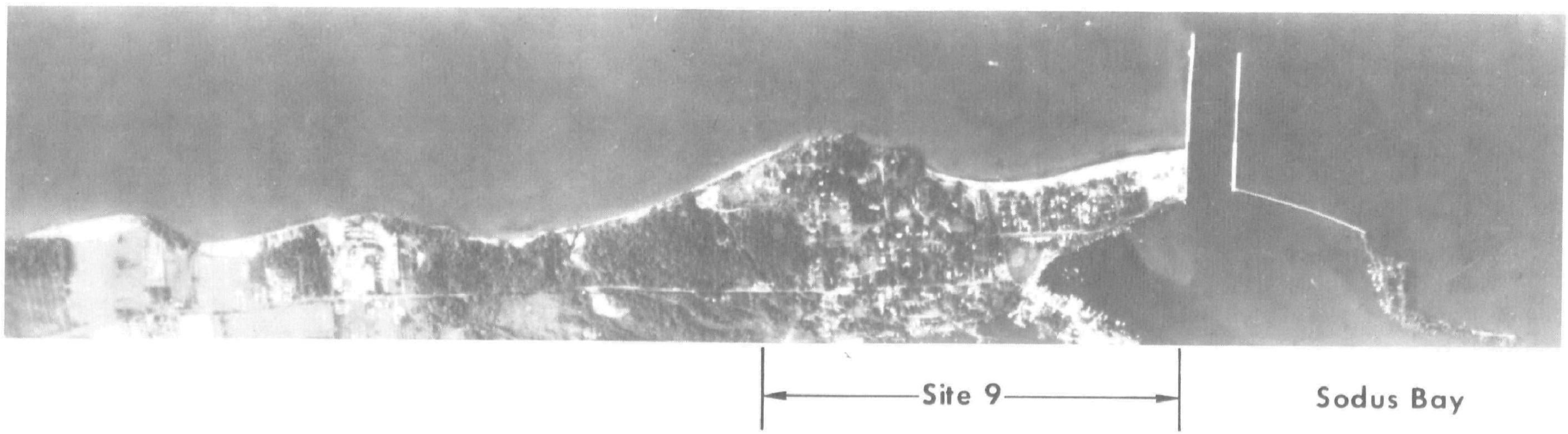


Figure A-13. Site 9, west of Sodus Bay, 31 July 1972

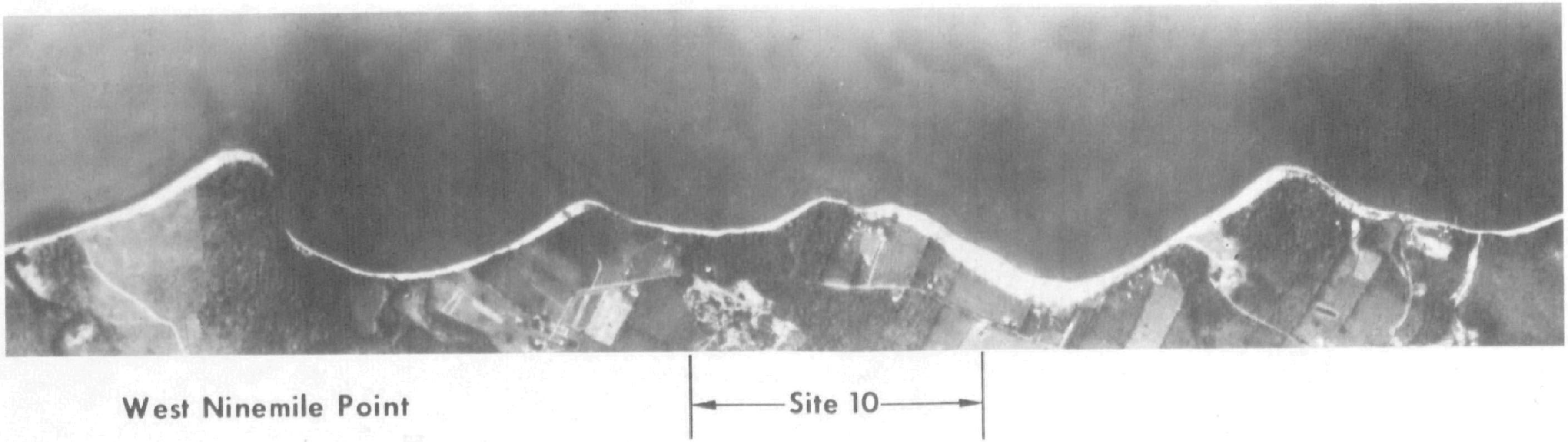


Figure A-14. Site 10, west of Oswego, 31 July 1972

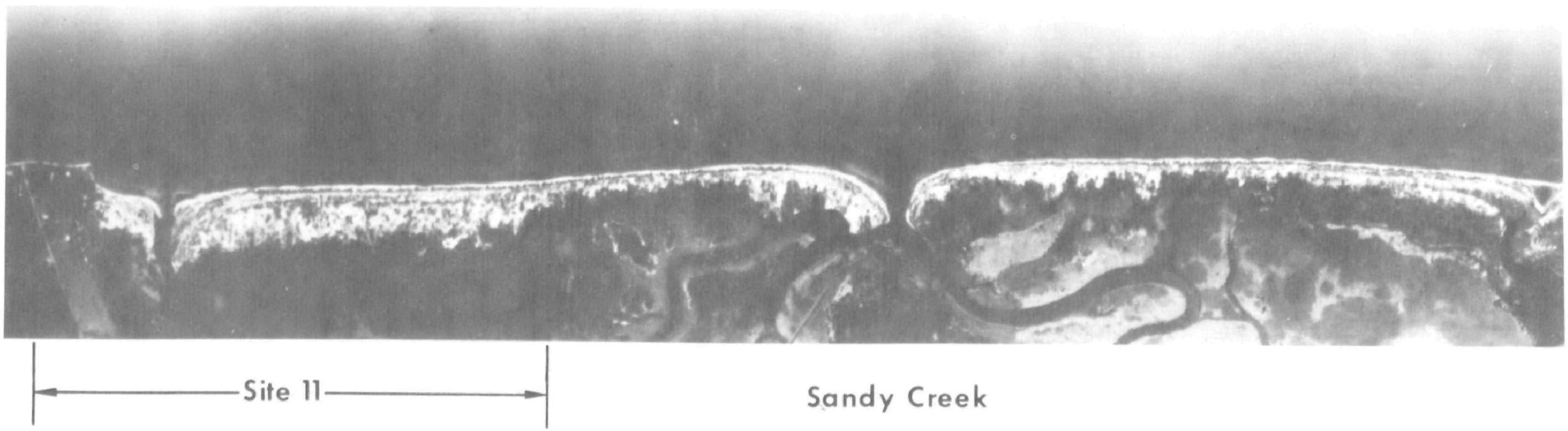


Figure A-15. Site 11, south of Sandy Creek, 31 July 1972

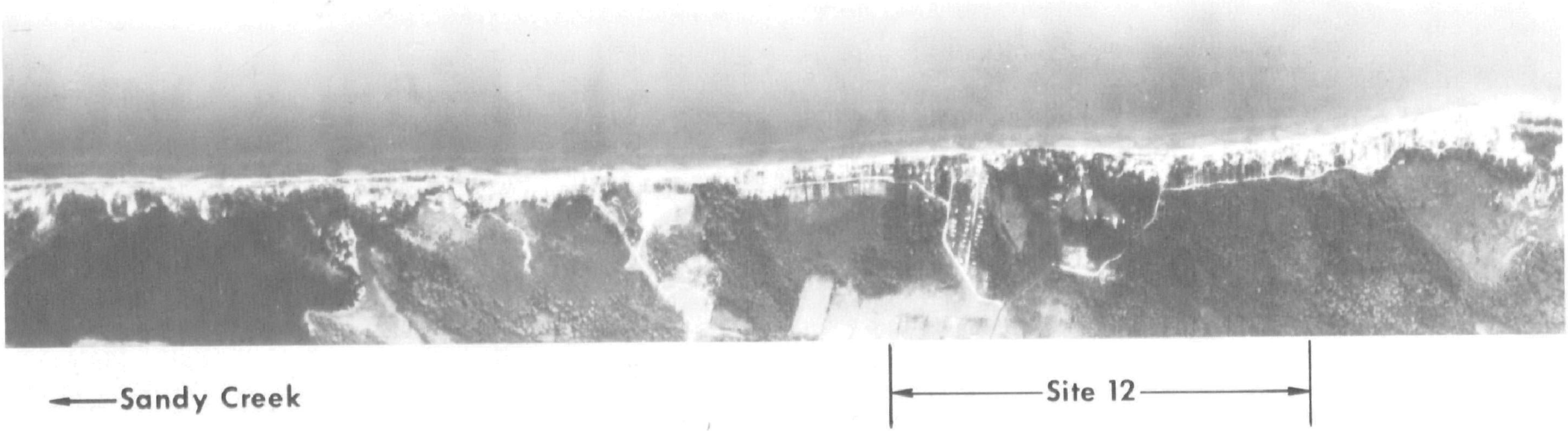


Figure A-16. Site 12, north of Sandy Creek, 31 July 1972

APPENDIX B

CLADOPHORA DISTRIBUTION DIGITAL MAPS

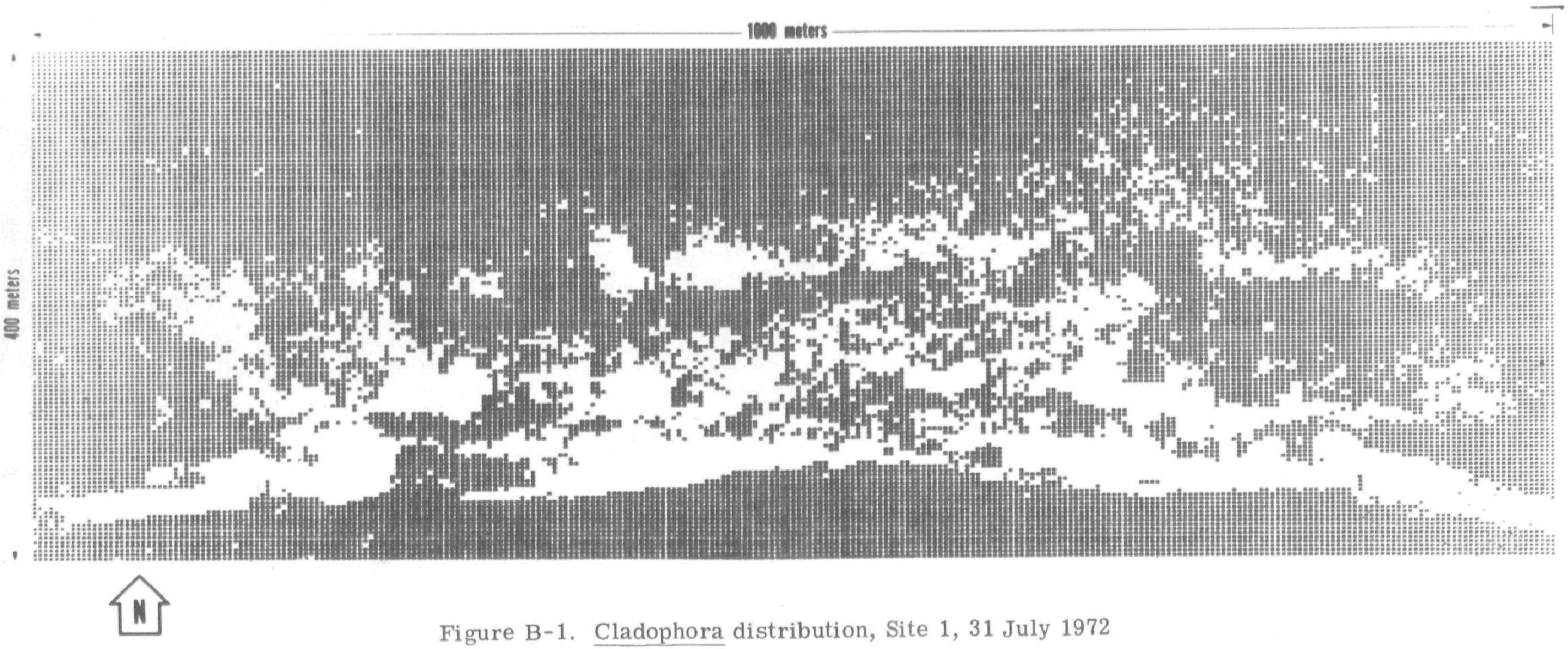


Figure B-1. Cladophora distribution, Site 1, 31 July 1972

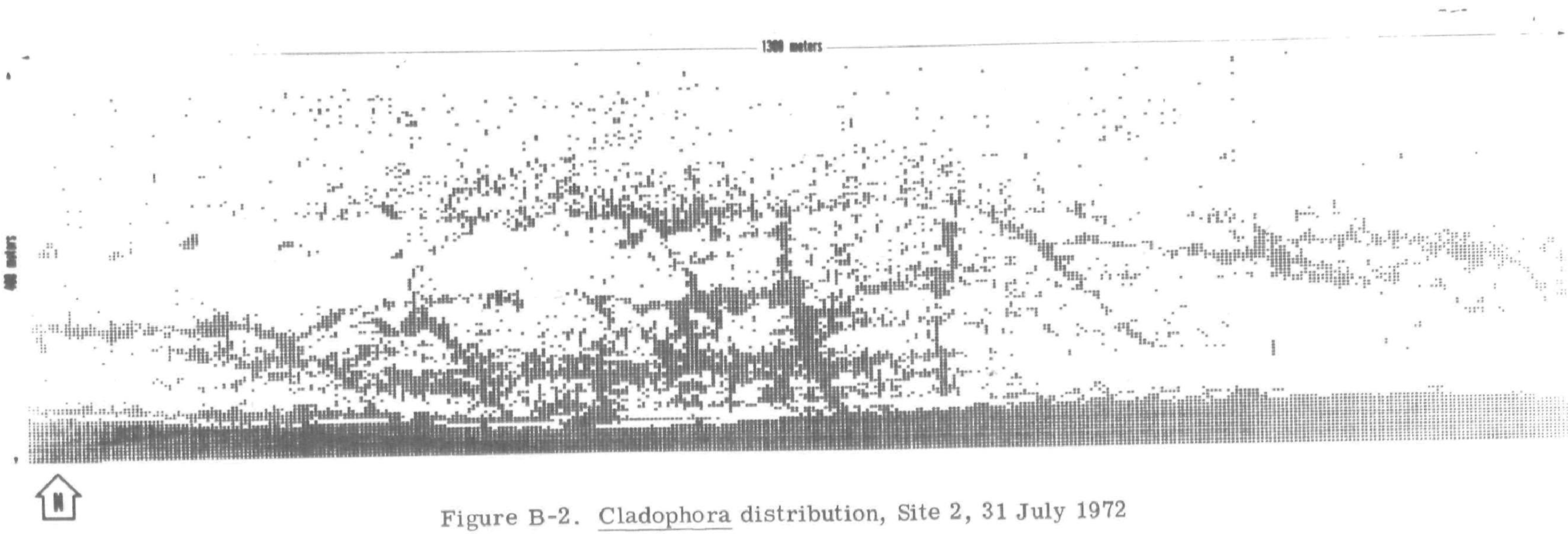


Figure B-2. Cladophora distribution, Site 2, 31 July 1972

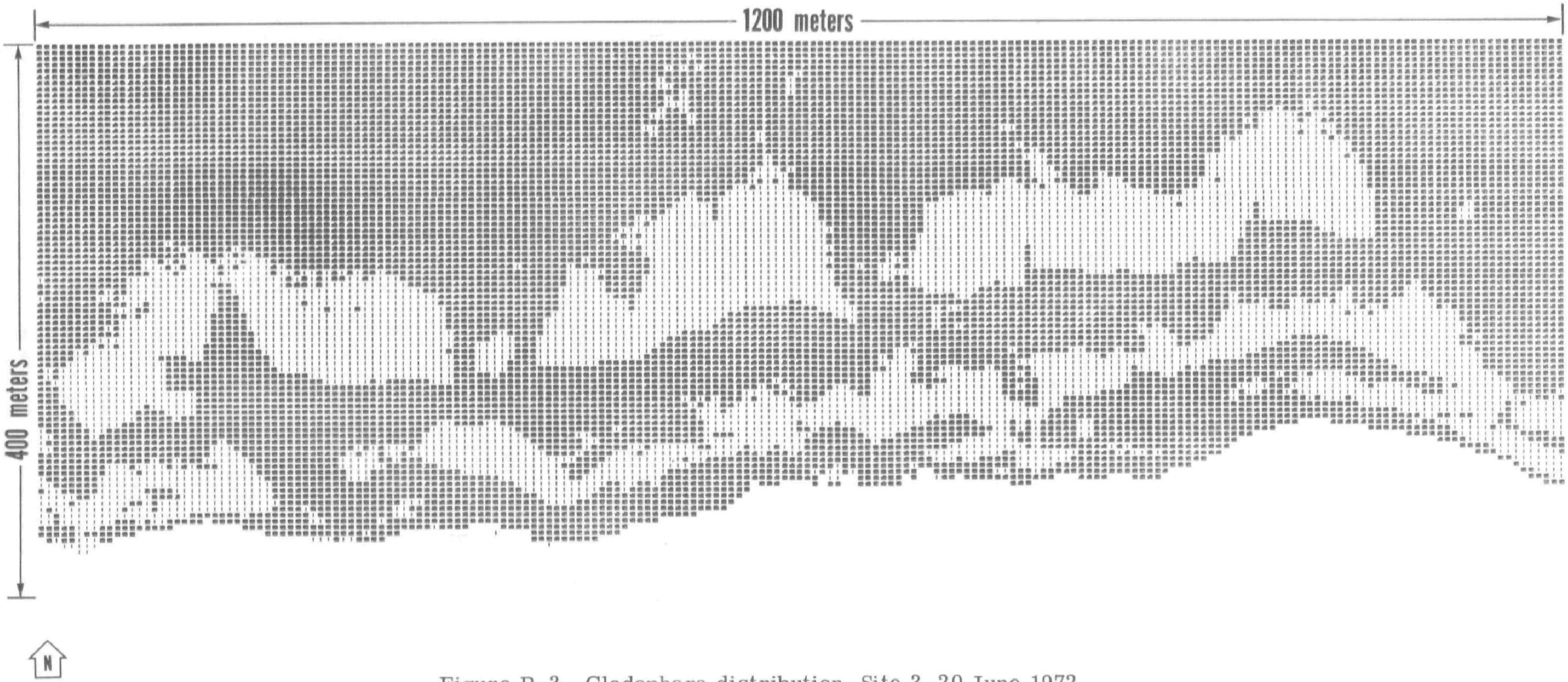


Figure B-3. Cladophora distribution, Site 3, 20 June 1972

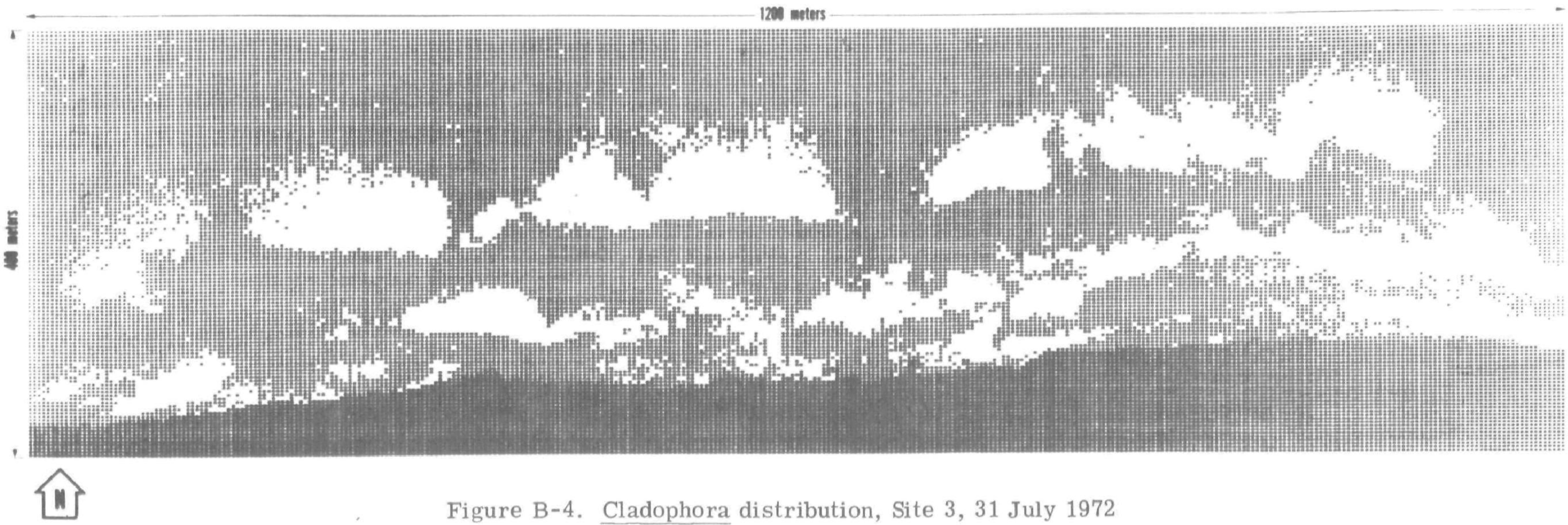


Figure B-4. Cladophora distribution, Site 3, 31 July 1972

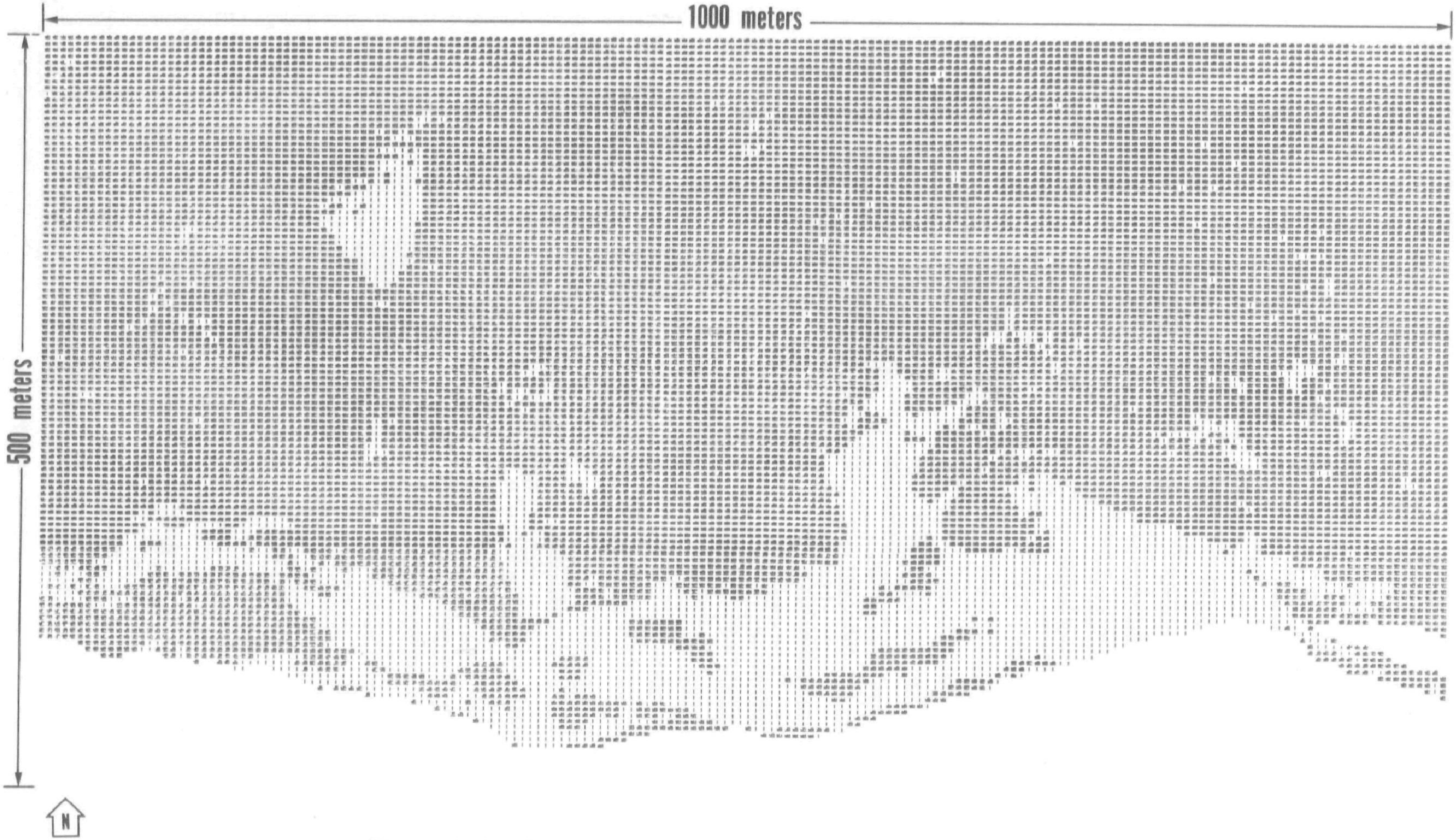


Figure B-5. Cladophora distribution, Site 3A, 20 June 1972

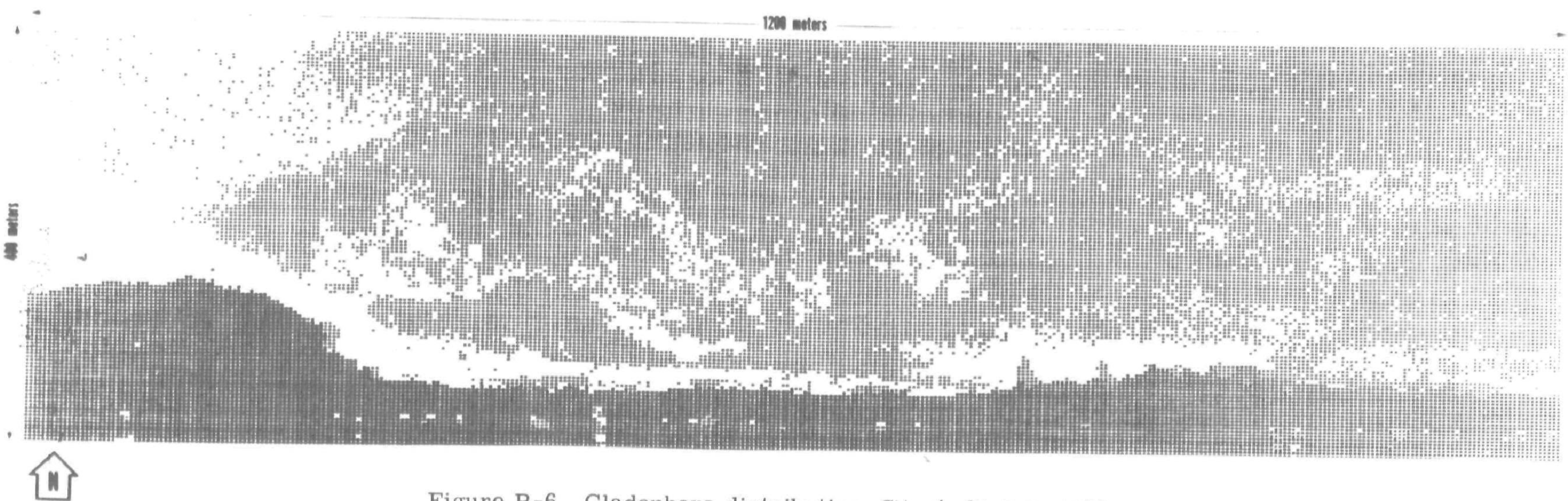


Figure B-6. Cladophora distribution, Site 4, 31 July 1972

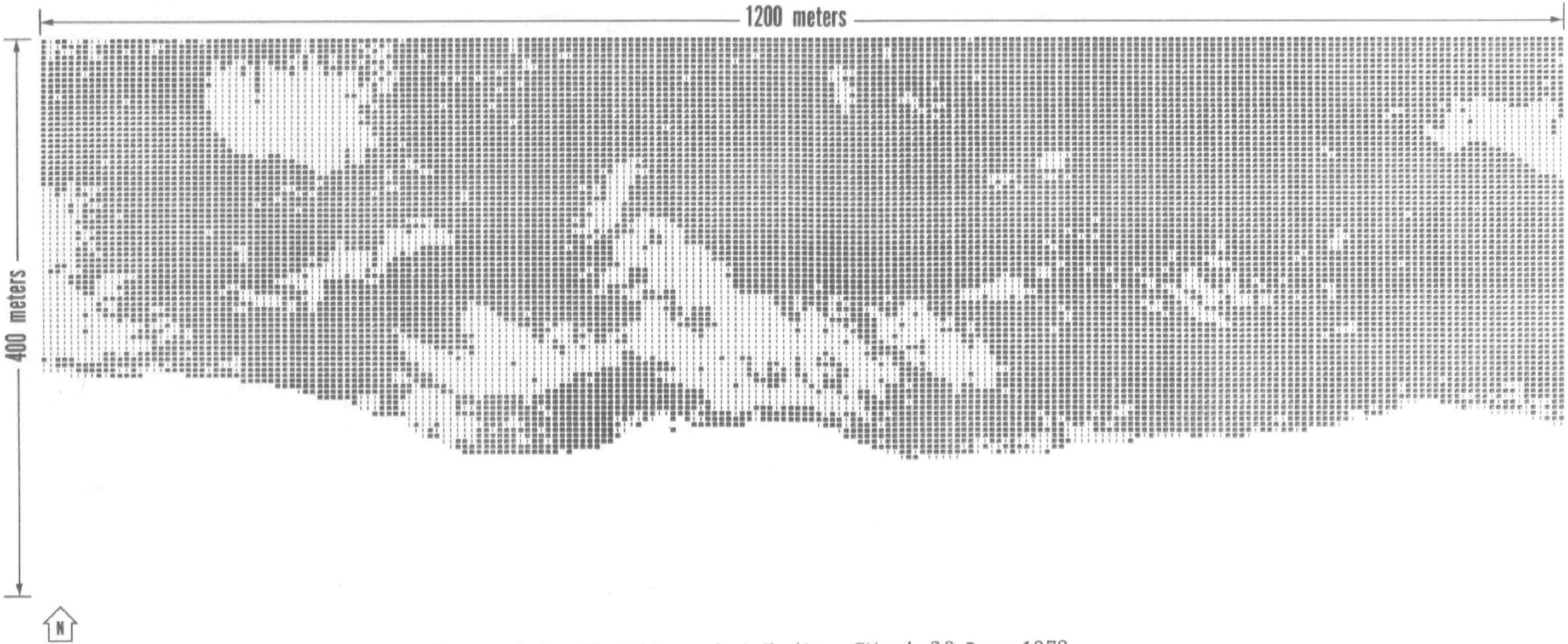


Figure B-7. Cladophora distribution, Site 4, 20 June 1972

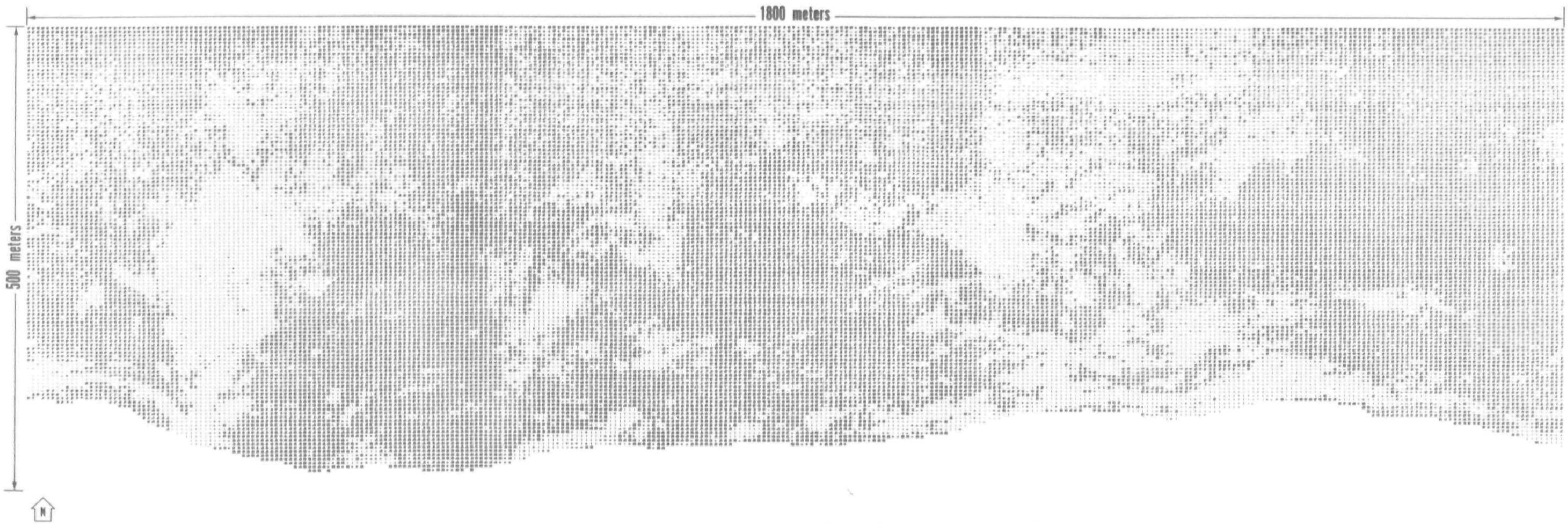


Figure B-8. Cladophora distribution, Site 4A, 20 June 1972

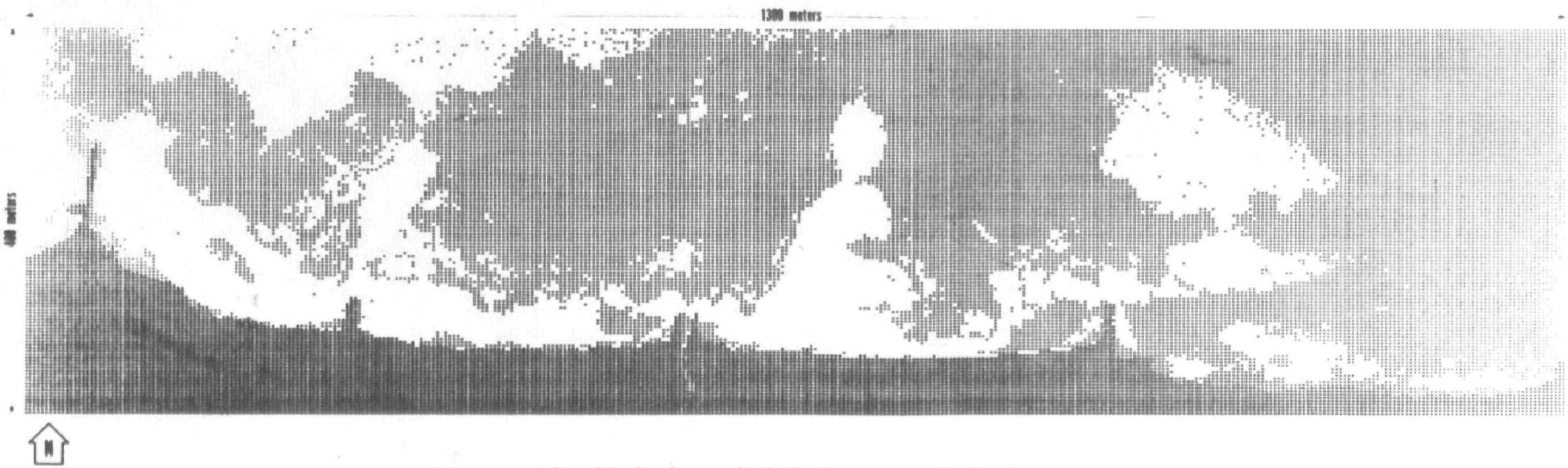


Figure B-9. Cladophora distribution, Site 5, 31 July 1972

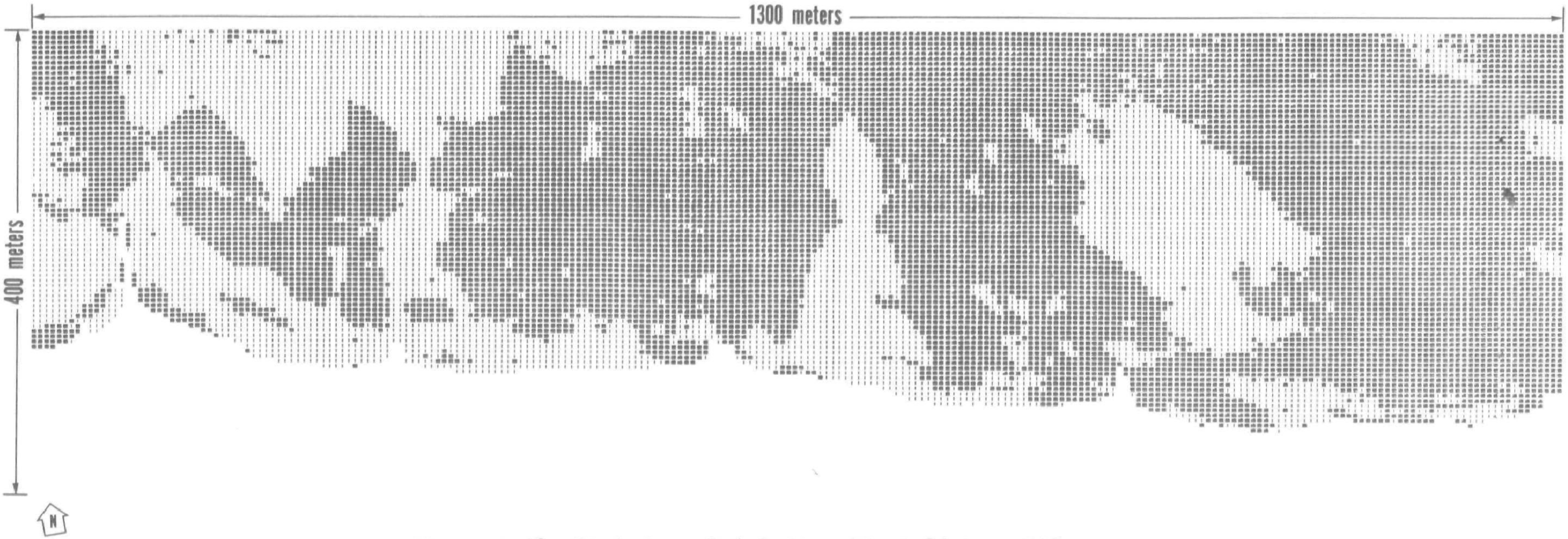


Figure B-10. *Cladophora* distribution, Site 5, 20 June 1972

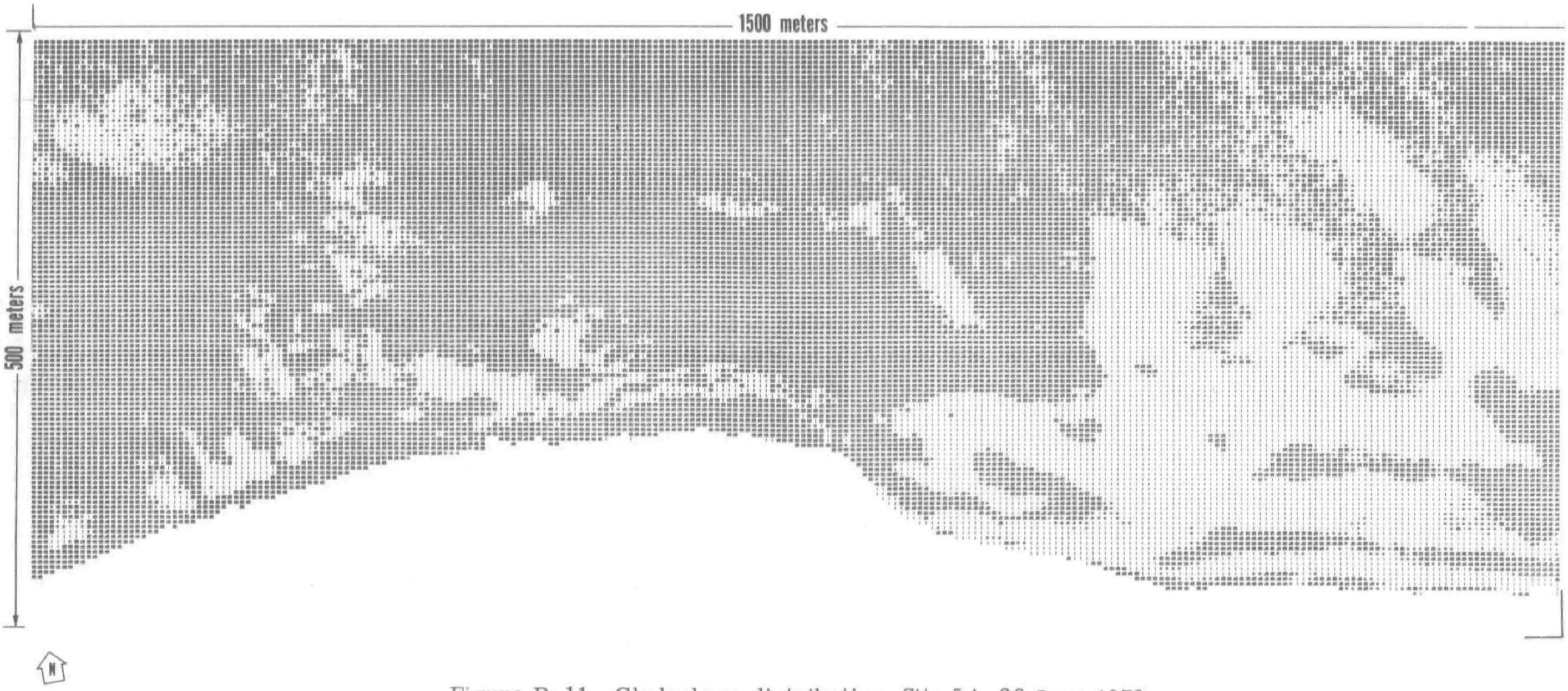


Figure B-11. Cladophora distribution, Site 5A, 20 June 1972

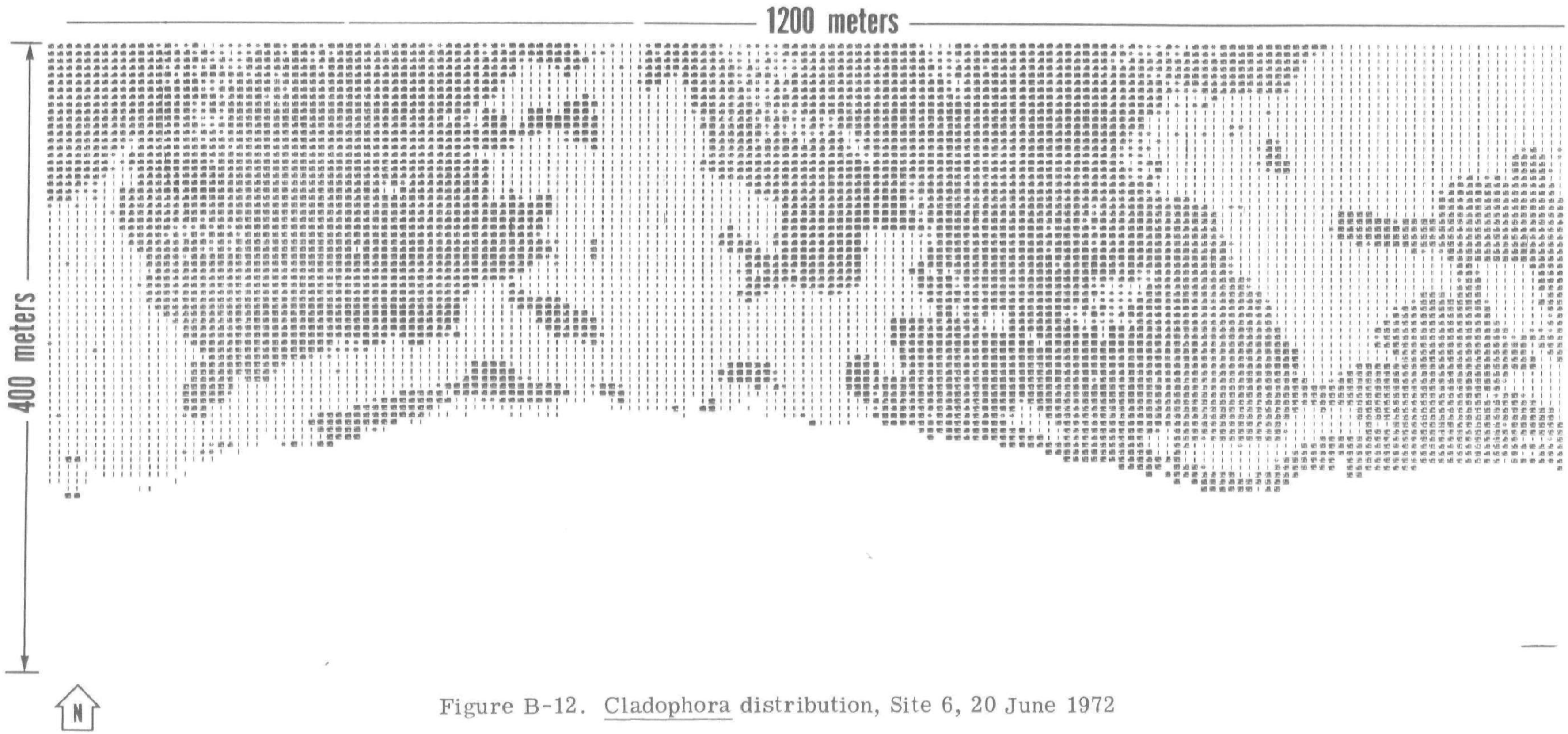


Figure B-12. Cladophora distribution, Site 6, 20 June 1972

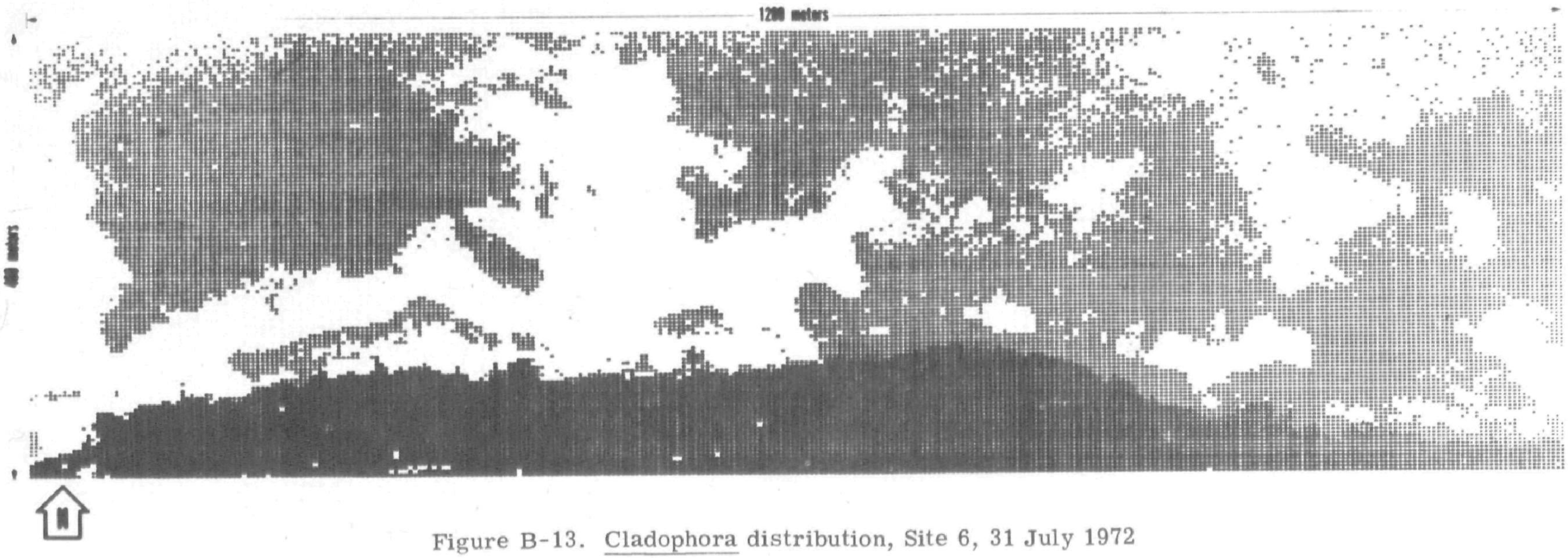


Figure B-13. Cladophora distribution, Site 6, 31 July 1972

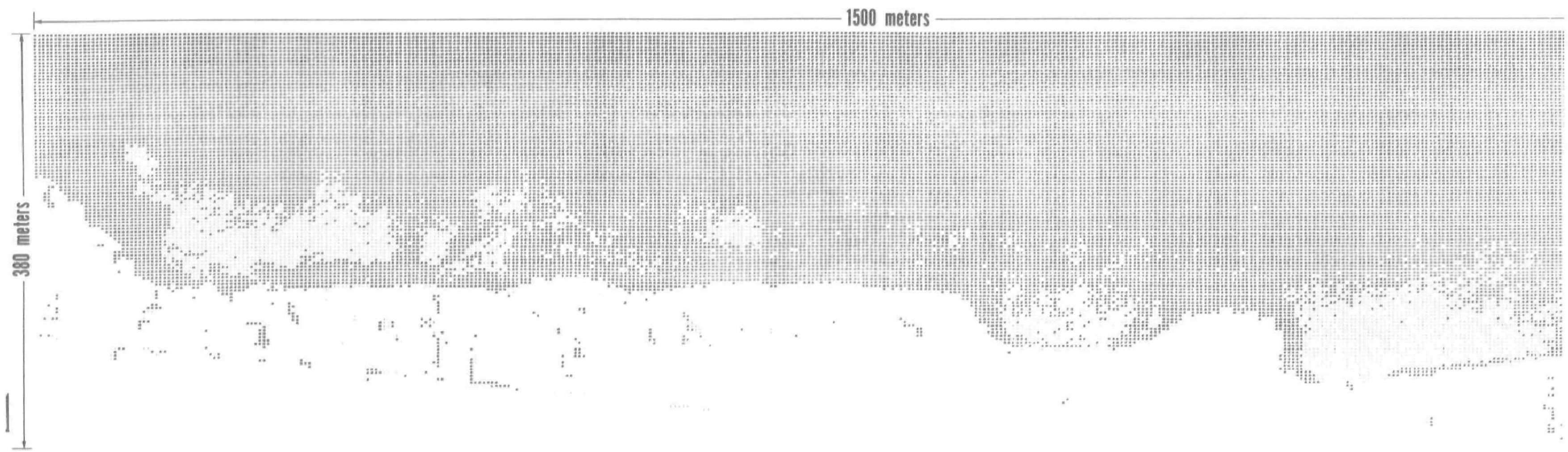


Figure B-14. Cladophora distribution, Site 7, 31 July 1972

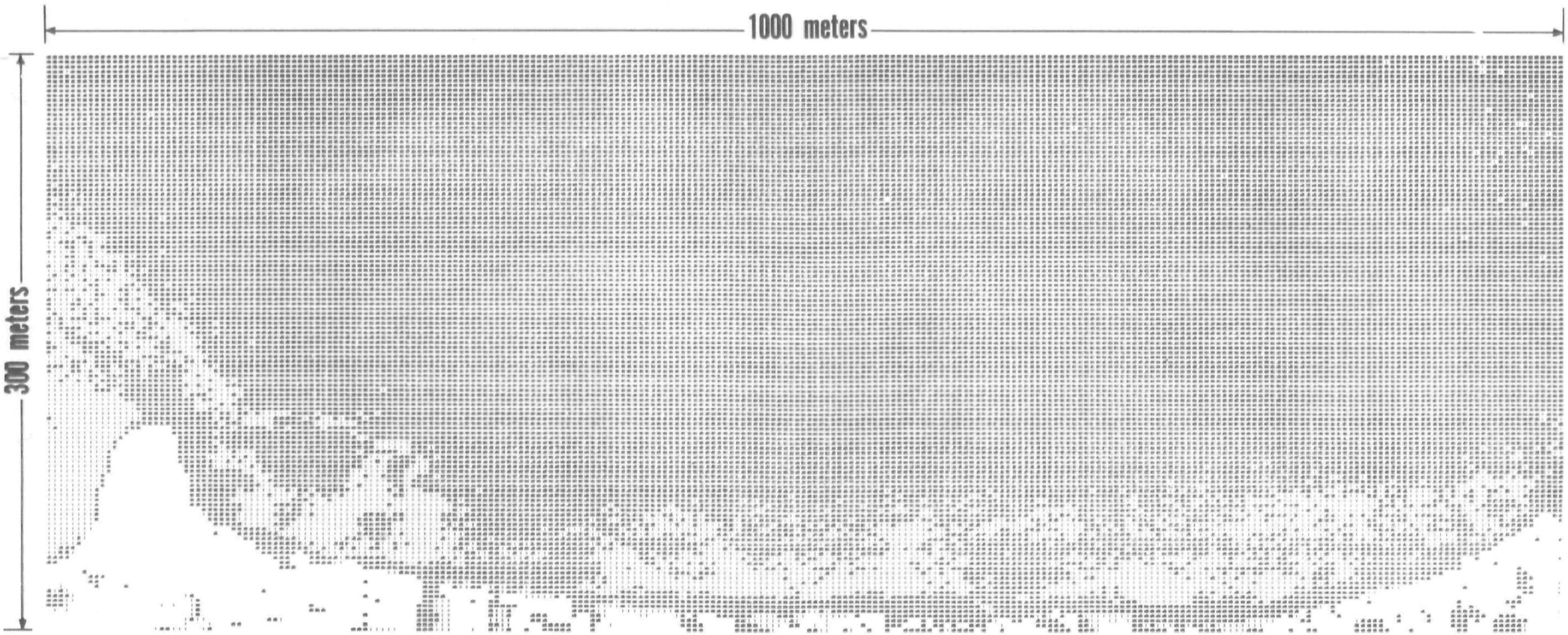


Figure B-15. Cladophora distribution, Site 7A, 31 July 1972

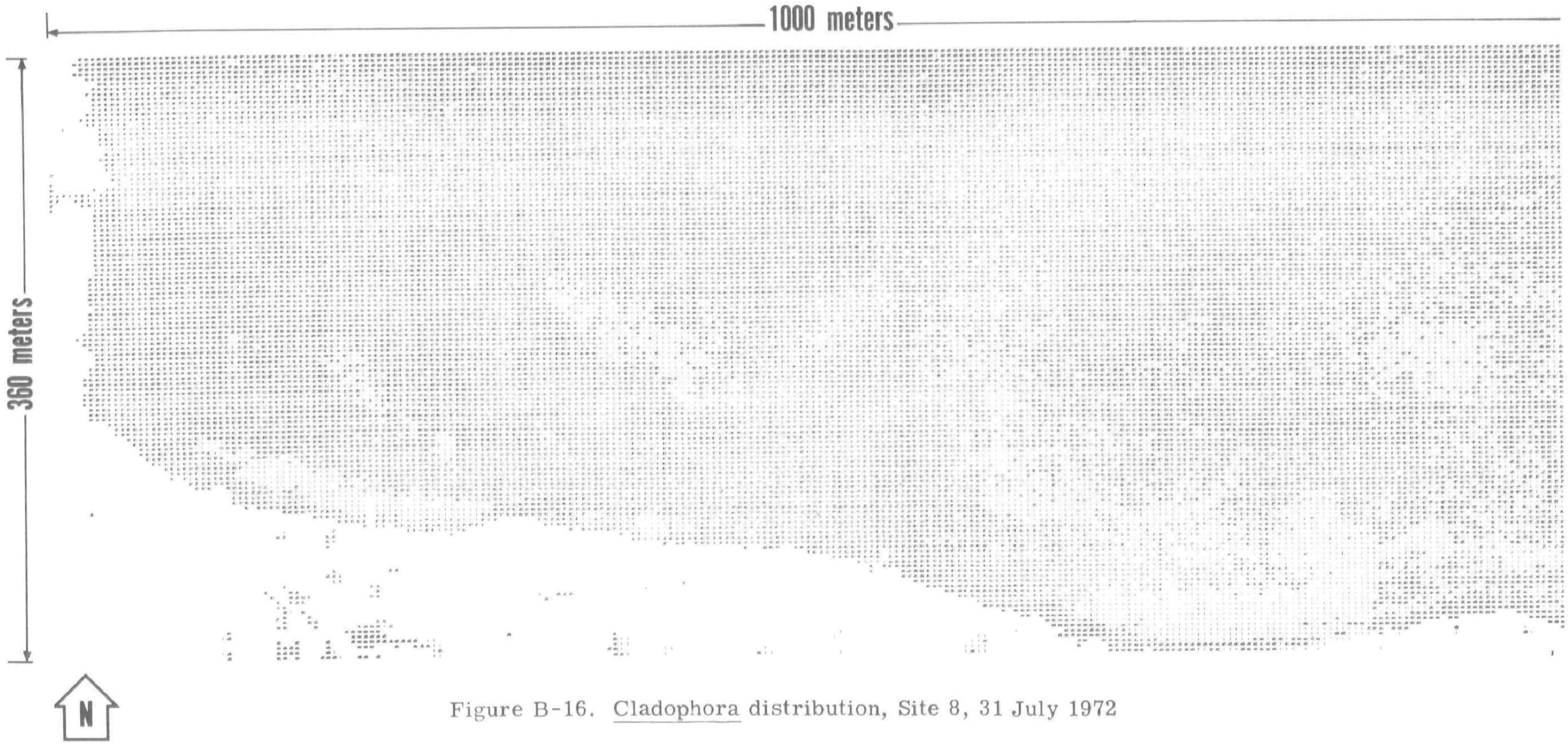


Figure B-16. Cladophora distribution, Site 8, 31 July 1972

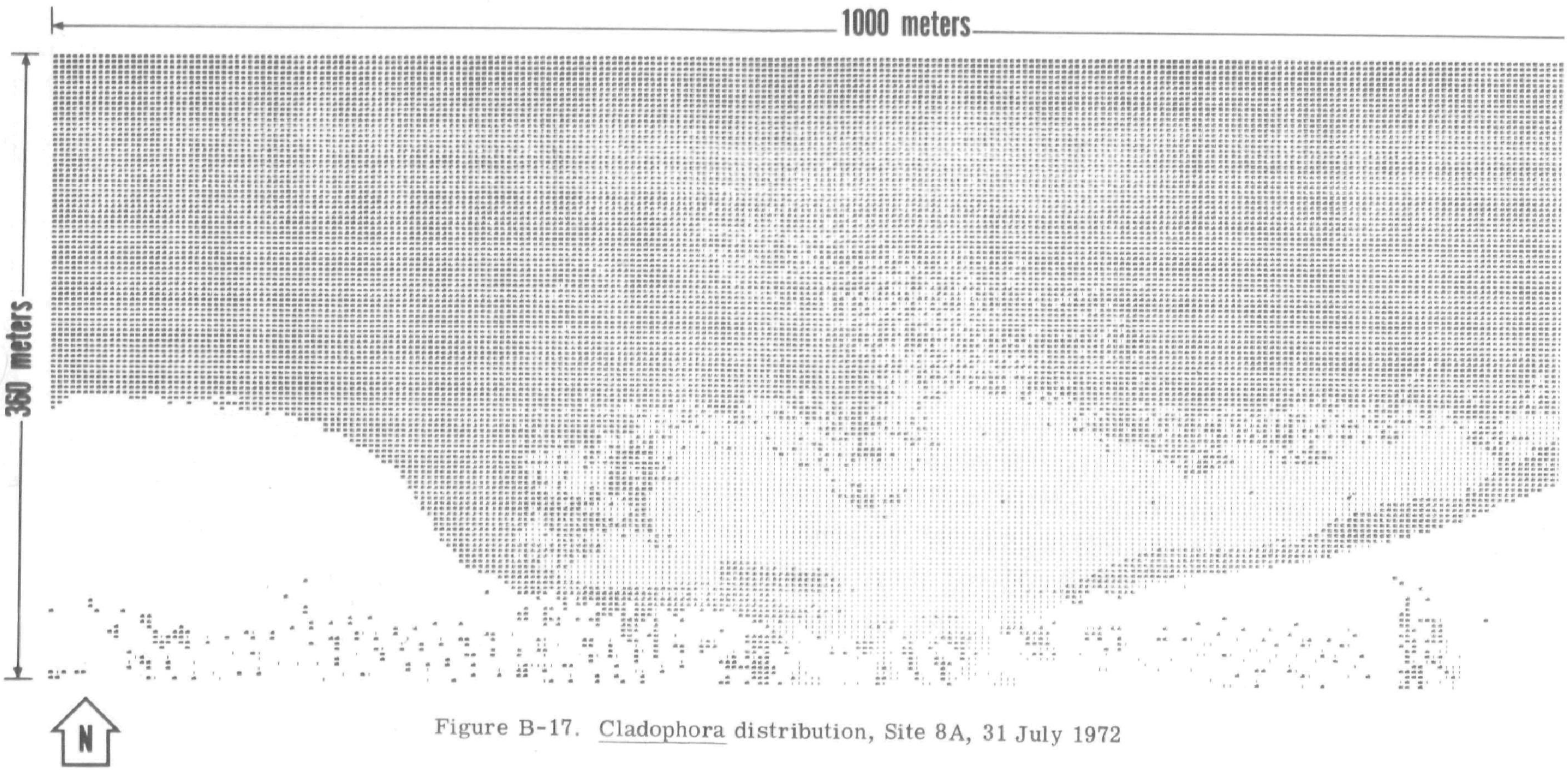


Figure B-17. Cladophora distribution, Site 8A, 31 July 1972

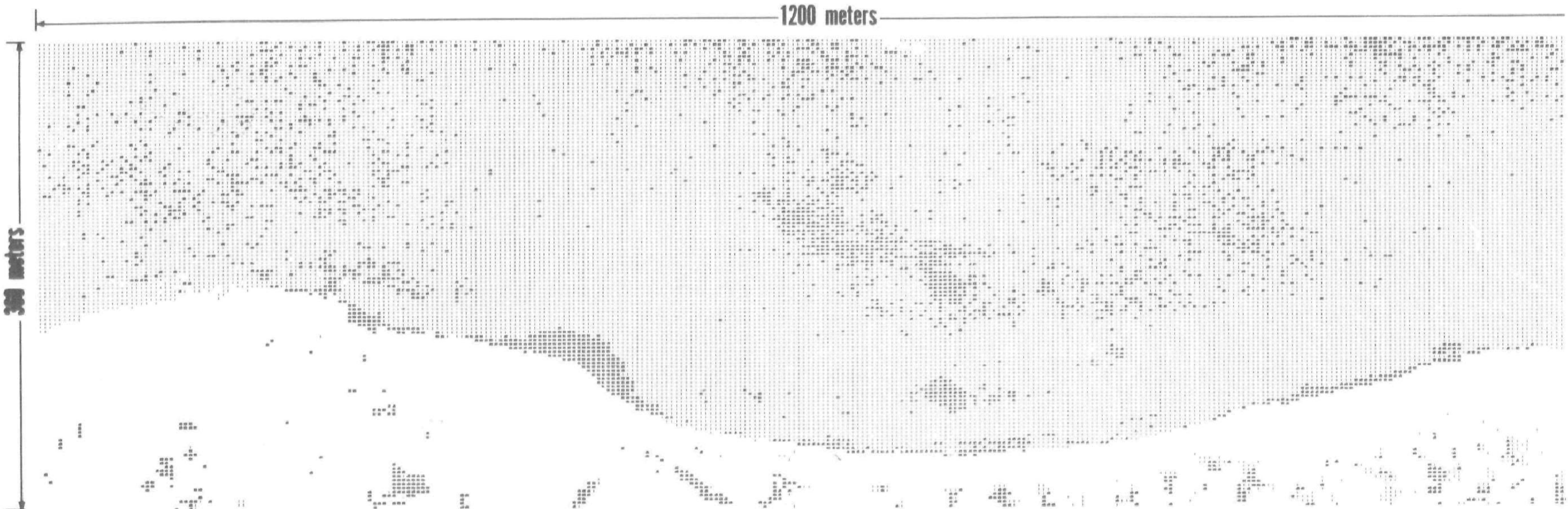


Figure B-18. Cladophora distribution, Site 9, 31 July 1972

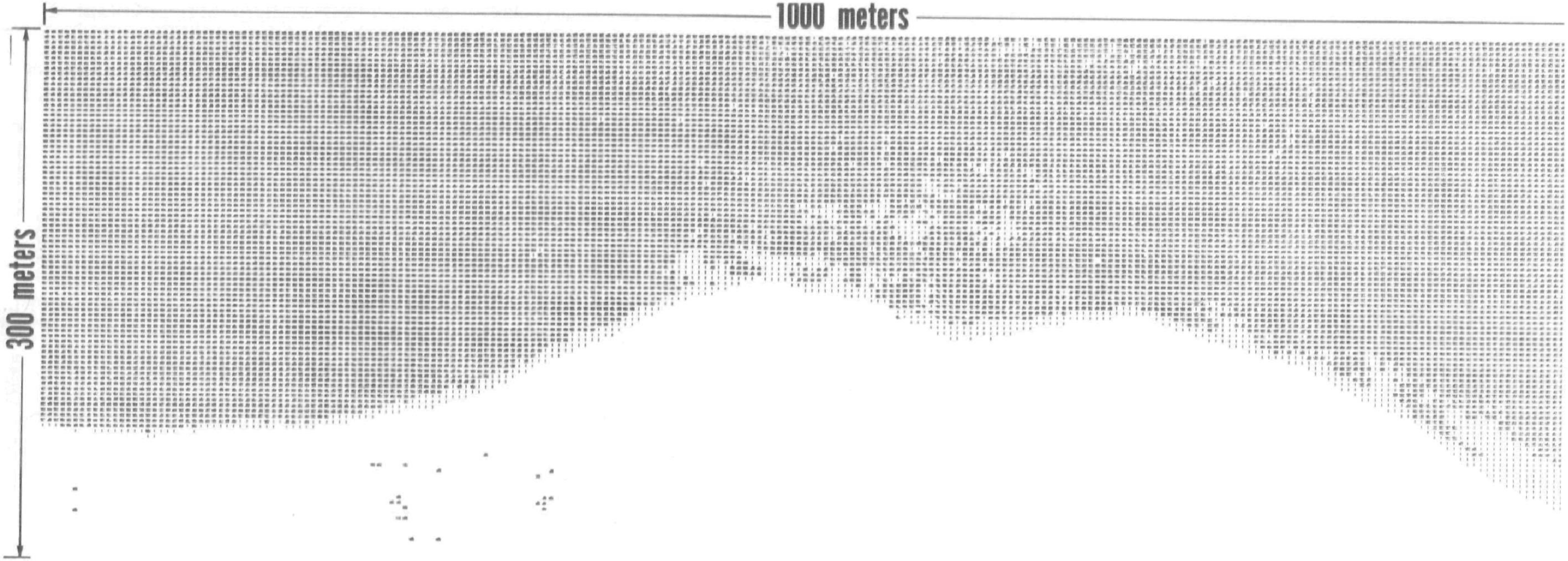


Figure B-19. Cladophora distribution, Site 10, 31 July 1972

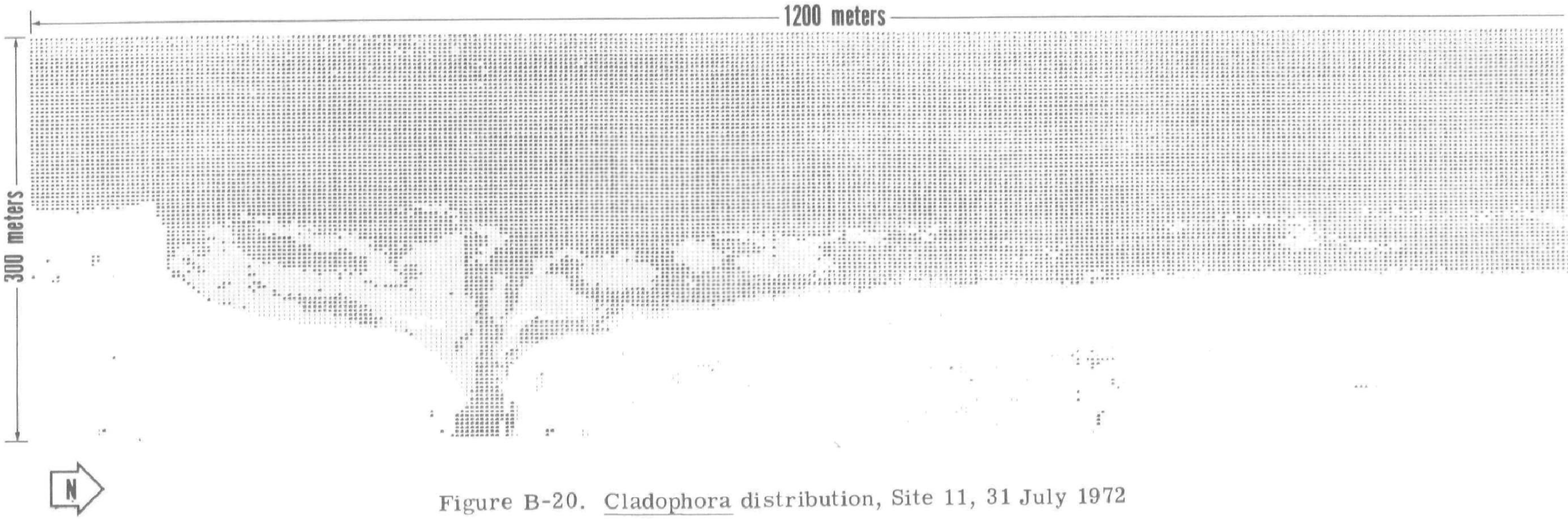


Figure B-20. Cladophora distribution, Site 11, 31 July 1972

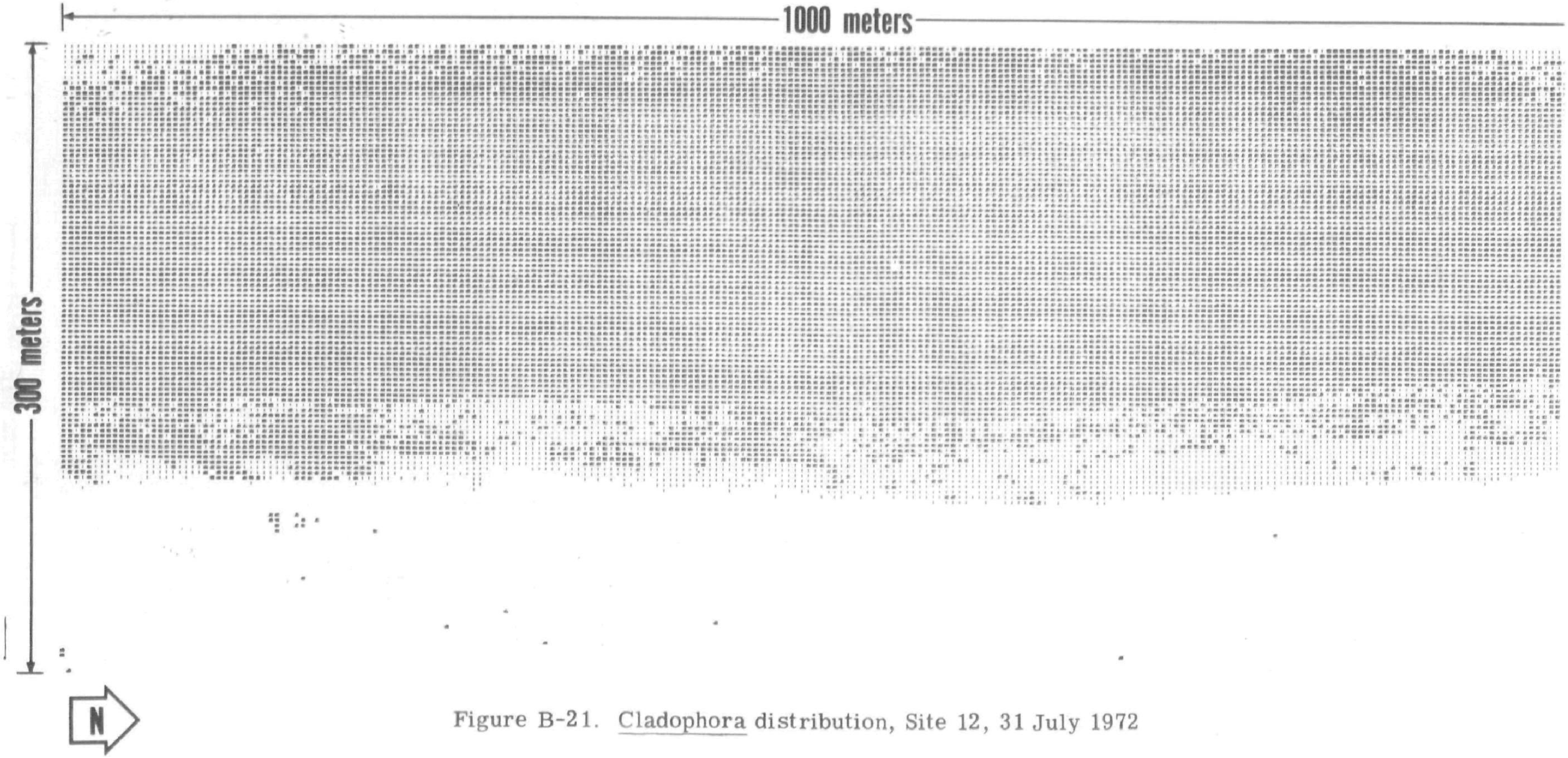


Figure B-21. Cladophora distribution, Site 12, 31 July 1972

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA 660/3 -74-028		

4. TITLE AND SUBTITLE	5. REPORT DATE
CLADOPHORA DISTRIBUTION IN LAKE ONTARIO (IFYGL)	December 1974
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
C. T. Wezernak, D. R. Lyzenga, and F. C. Polcyn	102600-04-F
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
Environmental Research Institute of Michigan P. O. Box 618 Ann Arbor, MI 48107	1B1026
	11. CONTRACT/GRANT NO.
	800778
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Environmental Protection Agency National Environmental Research Center Grosse Ile Laboratory Grosse Ile, MI 48138	Final Report
	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Multispectral remote sensing data were collected along the U.S. shoreline of Lake Ontario, under the sponsorship of the Environmental Protection Agency, as part of the International Field Year on the Great Lakes (IFYGL) program in Lake Ontario. Data were processed to show the distribution of Cladophora in the nearshore zone and to estimate the standing crop. Additionally, thermal data in the study area were displayed.

The results show an extensive growth and development of Cladophora in the study area. Approximately 66% of the nearshore zone in the western portion of the lake and 79% in the eastern portion, is covered by Cladophora. Several major and minor thermal features and thermal discharges were evident at several locations along the U.S. shoreline.

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17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Cladophora remote sensing Lake Ontario	IFYGL (Lake Ontario)	

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