ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF ENFORCEMENT

EPA-330/3-75-002

Remote Sensing Report
Lake Ontario

A study of thermal discharges from Ginna Nuclear Power Station, Oswego Steam Power Station, and Nine Mile Point Nuclear Power Station.

FEDERAL FIELD INVESTIGATIONS CENTER-DENVER

DENVER, COLORADO

APRIL 1975

ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF ENFORCEMENT

REMOTE SENSING REPORT

LAKE ONTARIO

A study of thermal discharges from Ginna Nuclear Power Station, Oswego Steam Power Station, and Nine Mile Point Nuclear Power Station

NATIONAL FIELD INVESTIGATIONS CENTER-DENVER
Denver, Colorado

April 1975

CONTENTS

TABLES

FIGURES

ABBREVIATIONS

BTU/hr	British Thermal Units per hour
EDT	Eastern Daylight Time
μ	micrometers (or microns)
MW	megawatts
mrad	milliradians

CONVERSIONS

	Metric Unit	*multiplied by*	*English Unit*
Length	millimeters (mm)	0.039 →	inches (in)
		← 25.4	
	centimeters (cm)	0.394 →	inches (in)
		← 2.54	
	micrometers (μm)	3.937×10^{-5} →	inches (in)
		← 2.54×10^{-4}	
	meters (m)	3.281 →	feet (ft)
		← 0.305	
		1.094 →	yards (yd)
		← 0.914	
	kilometers (km)	0.621 →	miles (mi)
		← 1.609	
Area	square centimeters (cm^2)	0.155 →	square inches (in^2)
		← 6.452	
	square meters (m^2)	10.76 →	square feet (ft^2)
		← 0.093	
		1.196 →	square yards (yd^2)
		← 0.836	
	square kilometers (km^2)	0.386 →	square miles (mi^2)
		← 2.590	
		247 →	acres
		← 4.047×10^{-3}	
	hectares (ha)	2.471 →	acres
		← 0.495	
Volume	cubic centimeters (cm^3)	0.061 →	cubic inches (in^3)
		← 16.39	
	cubic meters (m^3)	35.32 →	cubic feet (ft^3)
		← 0.028	
		1.307 →	cubic yards (yd^3)
		← 0.765	
	liters (1)	0.264 →	gallons (gal)
		← 3.785	
		0.035 →	cubic feet (ft^3)
		← 28.32	
Flow	meters/second (m/sec)	3.28 →	feet/second (ft/sec)
		← 0.305	
		2.237 →	miles/hour (mph)
		← 0.447	
	kilometers/hour (km/hr)	0.621 →	miles/hour (mph)
		← 1.609	
		0.540 →	knots (kn)
		← 1.852	
Velocity	cubic meters/second (m^3/sec)	1.58×10^{4} →	gallons/minute (gpm)
		← 6.31×10^{-5}	
		22.8 →	million gallons/day (mgd)
		← 0.044	
	cubic meters/day (m^3/day)	0.183 →	gallons/minute (gpm)
		← 5.42	
		2.64×10^{-4} →	million gallons/day (mgd)
		← 3770	
		4.09×10^{-4} →	cubic feet/second (cfs)
		← 2450	
		8.11×10^{-4} →	acre-feet/day (afd)
		← 1230	
Weight	grams (g)	0.035 →	ounces (oz)
		← 437.5	
		2.205×10^{-3} →	pounds (lb)
		← 454	
	metric tons (m. ton)	1.102 →	short tons (ton)
		← 0.907	
		2205 →	pounds (lb)
		← 4.54×10^{-4}	
Pressure	kilograms/sq. centimeter (kg/cm^2)	14.22 →	pounds/square inch (psi)
		← 0.0703	
Temperature	° Celcius (°C)	9/5 (°C) + 32 →	Fahrenheit (°F)
		← 5/9 (°F - 32)	
		5/9 °C (absolute) →	
		← 9/5 °F (absolute)	

Metric Prefixes

micro (u)	. ....	10^{-6}
milli (m)	....	10^{-3}
centi (c)	.....	10^{-2}
deci (d)	....	10^{-1}
deca (da)	....	10^{1}
hecto (h)	....	10^{2}
kilo (k)	....	10^{3}
mega (M)	....	10^{6}

Equivalents

1 hectare = 10,000 m^2
1 liter = 1,000 cm^3
1 knot = 1.151 mph
1 short ton = 2,000 lb
1 long ton = 2,240 lb
1 m^3/sec = 1,000 l/sec
= 8.46×10^{4} m^3/day

I. INTRODUCTION

An airborne remote sensing study of thermal discharges into Lake Ontario, from powerplants on its southeast shore, was conducted on 30 July and 1 Aug. 1974. The study was undertaken at the request of the Enforcement Division, Region II, Environmental Protection Agency, New York, N.Y.

The study area [Fig. I-1] covered the shore of Lake Ontario from Smoky Point 21 km (13 mi) east of Rochester, N.Y., to Mexico Bay in the southeast corner of the lake. Three existing powerplants, the R. E. Ginna Nuclear Power Station, the Oswego Steam Power Station, and the Nine Mile Point Nuclear Power Station, discharge cooling water into the southern part of the lake [Fig. I-2]. At Nine Mile Point, a second powerplant, the J. A. Fitzpatrick Nuclear Station, is under construction and a third plant, the Nine Mile Point Nuclear Station No. 2, is planned. The Oswego fossil-fueled station is being enlarged, and additional power stations are planned at Sterling, Russell, Morrison and Sommerset. Other much smaller thermal loads enter the lake from sewage treatment plants and an industrial facility in this geographical area.

Thermal infrared imagery of the lakeshore in the vicinity of the three existing plants was obtained with the thermal channel of an internally calibrated multispectral scanner mounted in a research aircraft. During each flight, water temperatures were measured at the three powerplants by ground crews. The airborne imagery and water temperature data were used to characterize the recorded thermal fields or plumes.

The purposes of this study were:

1. To document the presence of the thermal field resulting from each powerplant's thermal discharge

2. To document the surface area in each thermal field that has a surface temperature 1.7°C (3°F) or greater above ambient surface temperatures of Lake Ontario

3. To document, to the extent practicable, the encroachment of thermal fields into known inshore nursery areas of the many species of fish found in Lake Ontario.

The results of this study will be used in the preparation of the National Pollution Discharge Elimination System (NPDES) permits for these powerplants. These data will also provide a baseline for future compliance monitoring of these discharges.

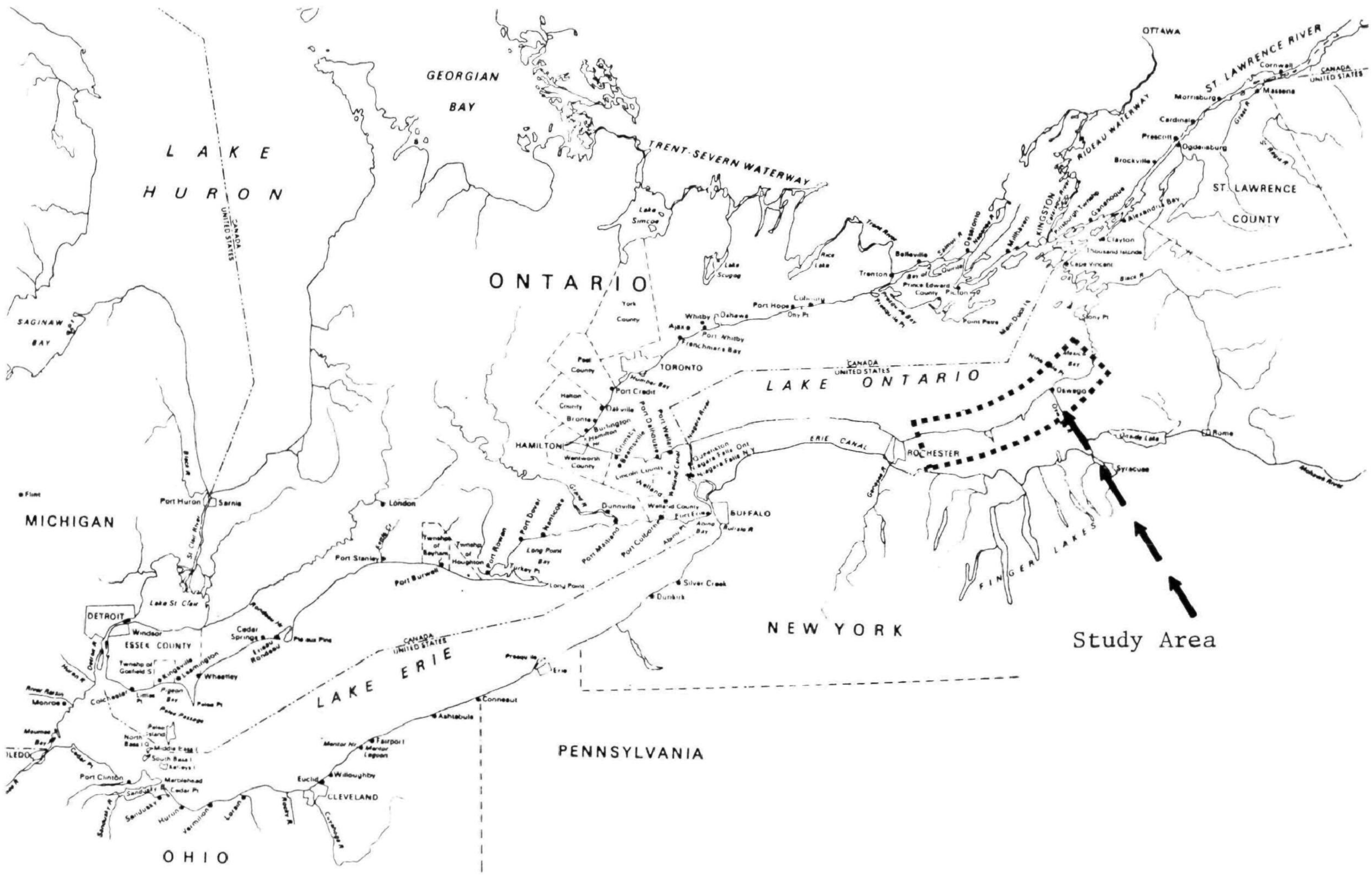


Figure I—1 Study Area, Southeast Shore of Lake Ontario

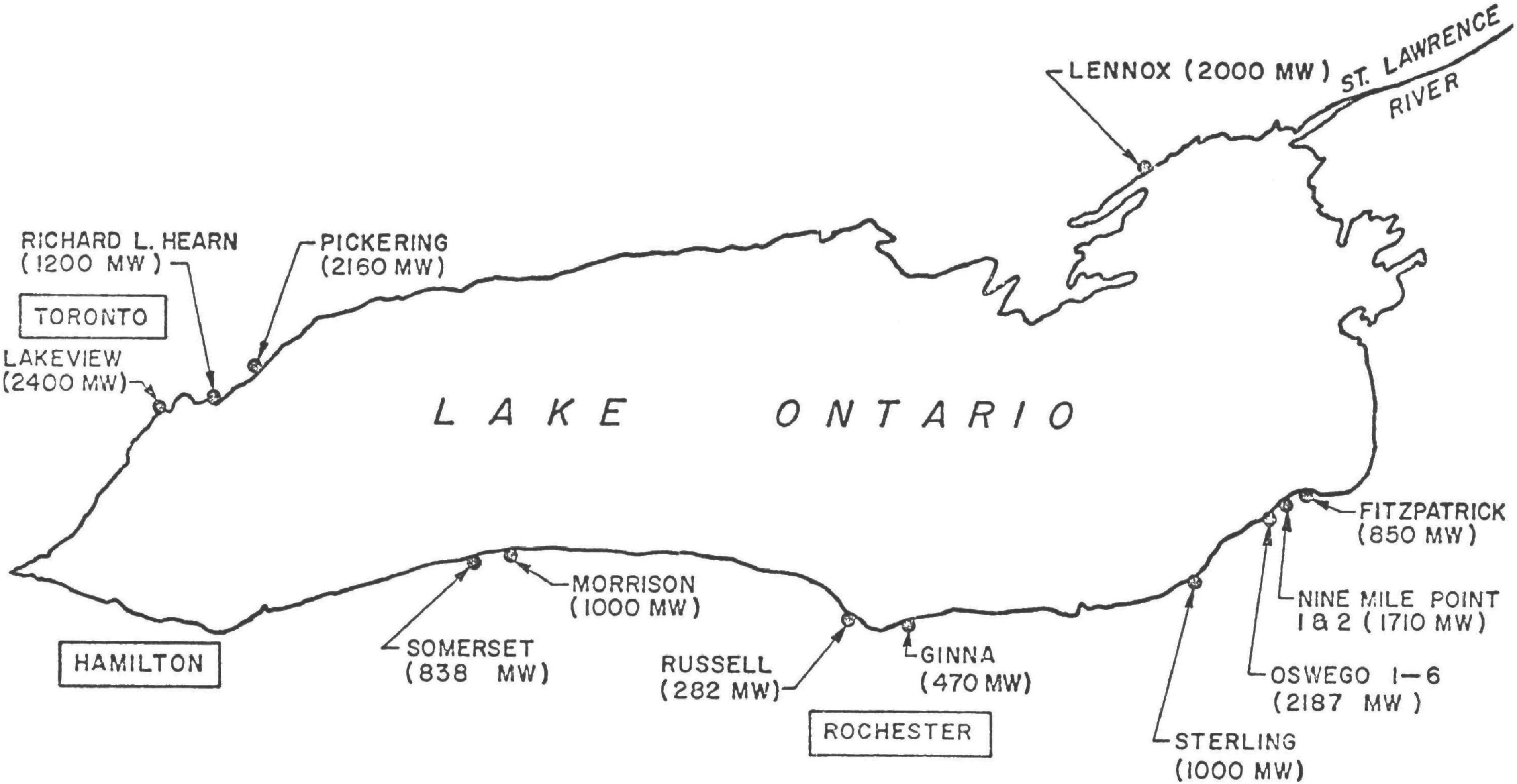


Figure I-2 Proposed and Installed Lake Ontario Powerplants

II. SUMMARY

On 30 July and 1 Aug. 1974, a remote sensing study was conducted over southeast Lake Ontario. An airborne thermal infrared sensor recorded the surface characteristics of the thermal discharges and resulting thermal fields from one fossil-fueled and two nuclear-fueled electric power stations along the lakeshore. The stations observed were the Oswego Steam Power Station, Oswego, N.Y., Ginna Nuclear Power Station Pultneyville, N.Y., and Nine Mile Point Nuclear Power Station, Unit No. 1, Scriba, N.Y.

The investigation was conducted in warm weather during a period of nearpeak power demand and warm receiving water temperatures. Surface water temperature measurements at various locations in the vicinity of each Station's thermal discharge constituted ground truth obtained by field crews at the time of flight.

Isarthermal* maps depicting areas of equal surface water temperatures were prepared from the infrared imagery which was digitally recorded on magnetic tape during the mission. The actual temperatures of the isartherms were determined by the internally calibrated infrared blackbodies in the multispectral scanner (thermal sensor). These temperatures were verified and/or normalized by comparison with the ground truth temperatures. The isarthermal maps characterize the behavior of the thermal fields under the weather conditions that existed at the time of flight.

---

* *Isarthermal indicates an area of the water's surface displaying an essentially constant temperature, in contrast to isothermal which is a line of constant temperature.*

Water temperature criteria proposed by the State of New York have not been approved by EPA. The present standard is given in Section III, and the proposed standard reads:

> The water temperature at the surface of a lake shall not be raised more than 1.7°C (3.0°F), except in designated mixing zones, over the temperature that existed before the addition of heat of artificial origin.

No mixing zones have been established in Lake Ontario as of Feb. 1975 for the thermal discharges discussed in this report.

The thermal fields of the Ginna and Nine Mile Point Nuclear Power Stations did not comply with the proposed standards [Table II-1]. The thermal fields from the Oswego Steam Power Station and the Oswego River combined in the Oswego Harbor, forming a thermal field. That field extended along shore eastward to the Nine Mile Point Nuclear Power Station field, a distance of 11 km (6.8 mi). The separate contributions to the overall field could not be determined.

Each of the three thermal fields was contiguous with a significant amount of the shoreline presumed to be spawning and nursery areas for the native fish of Lake Ontario.

Powerplants proposed or under construction will substantially increase the heat load rejected to this portion of Lake Ontario during the next 5-10 years. Completion of Units 5 and 6 at Oswego will increase the probability that warm surface waters from the Oswego vicinity will move along shore to Nine Mile Point as observed during this study. In addition, under predominant wind and lake current conditions, the thermal plume from the Nine Mile Point Nuclear Station will extend eastward over the discharge point of the Fitzpatrick Nuclear Plant, resulting in interaction of the plumes.

Table II-1
Summary of Power Station Characteristics

Thermal Discharge Characteristics†	Ginna Nuclear Power Station Pultneyville, N.Y.		Oswego Steam Power Station Oswego, N.Y.††		Nine Mile Point Nuclear Station Scriba, N.Y.	
Flight Date	7/30/74	8/1/74	7/30/74	8/1/74	7/30/74	8/1/74
Capacity (MW)	490	490	320	320	610	610
Cooling Water Use						
m^3/min	1,515	1,515	940	940	984	984
gpm	400,000	400,000	248,000	248,000	260,000	260,000
Temperature Difference						
°C	7.8	6.7	3.9	2.7	17.8	17.8
°F	14	12	7	5	32	32
Thermal Field Area (Total) ††† hectares	130	175	200	180	80	570
acres	265	355	400	360	165	1,160
Thermal Field Area Δt >2.2°C (3.9°F)						
hectares	40	99	45	160	25	150
acres	85	200	95	320	50	305
% of total	32	57	24	67	30	25
Thermal Field Area Δt >1.4°C (2.6°F)						
hectares	85	120	105	185	35	335
acres	175	250	215	375	70	680
% of total	66	71	53	79	41	58
Distance of Field Contiguous With Shoreline						
m	530	560	-	11,000	1,400	4,590
ft	1,740	1,840	-	36,000	4,200	13,780

† *Temperature Diff:* *Temperature difference between the thermal discharge and the ambient receiving water.*
Thermal Field Area: *Overall surface area of the thermal field.*
Δt >2.2°C or 1.4°C: *Area of the thermal field that was at least 2.2°C or 1.4°C warmer than the ambient receiving water temperature.*
Distance of Field: *Linear measure of thermal field touching shoreline.*

†† *The thermal field from Oswego Harbor was significantly affected by the Oswego River discharge.*

††† *1 hectare = 10,000 m^2 = 2.471 acres.*

RECOMMENDATIONS

After operations begin at the Oswego Power Station Unit 5 and the Fitzpatrick Nuclear Power Station, quarterly remote sensing flights should be performed over the section of shoreline from the Ginna Nuclear Power Station eastward through Mexico Bay. The area should be observed under various weather conditions. Such study would reveal the behavior of the overall thermal field resulting from the five discrete thermal discharges as a function of meteorological and hydrological conditions. This information would be useful to ascertain the physical and biological degradation imposed upon the southeastern reaches of Lake Ontario due to the thermal stress.

III. DESCRIPTION OF STUDY AREA

PHYSICAL CHARACTERISTICS

Ginna Nuclear Power Station, Nine Mile Point Nuclear Power Station, and Oswego Steam Power Station are in the northeast portion of the Lake Ontario Plain drainage basin. This basin varies in elevation from about 75-200 m (245-650 ft). Exclusive of lake surface area, the basin covers about 90,000 km^2 (34,800 mi^2) in New York and the Providence of Ontario. Physiographically it can be classified into two regions, Lake Plains and Appalachian Upland. The power generating stations are on the southeast lakeshore in the flat rolling plains area. This strip of land, varying in width from 8-50 km (5-31 mi) lies parallel to the lake shoreline and is dissected by many small streams.

Outside the Rochester and Syracuse urban centers, the study area is rural in population density and largely agricultural. The 1970 population in the study area was 1,555,000 (Oswego, Cayuga, Onondaga, Wayne, Monroe, Seneca, and Ontario counties). The two large urban areas, Rochester and Syracuse, have respective populations of 296,000 and 197,000. Manufacturing is centered in and around the urban areas. The land supports the production of fruits, field crops, dairy products, and livestock.

Lake Ontario is the smallest and easternmost lake of the Great Lakes. With a surface area of 19,000 km^2 (7,340 mi^2), the lake is 305 km (190 mi) long, 80 km (50 mi) wide at its widest point, and has a shoreline length of 1,170 km (726 mi). The average depth of the lake is 91 m (300 ft) with a maximum depth of 245 m (805 ft). Lake Ontario, with a large volume of water per unit of surface area, is the world's eleventh largest lake in volume. About 85% of its water mass is below the epilimnion.* Considering stratification, circulation, and mixing, the computed retention time for water in the lake is about 15 years.

CLIMATE

The climate in the area is controlled by the St. Lawrence Valley storm track, but it is moderated by Lake Ontario. The atmosphere circulation pattern is affected by the prevaling west to east winds and by storm systems moving from the other Great Lakes or the Mississippi Valley. A large portion of the rainfall and almost all of the major snowstorms result from cyclonic (counterclockwise) systems carrying moisture from the Gulf of Mexico. The systems move from the country's interior to the Atlantic Ocean through the St. Lawrence Valley. Occasionally the area is hit by coastal storms traveling northward up the Atlantic Coast. The moderating effect of Lake Ontario on the area climate is twofold. Heat stored in the lake during the summer is dissipated in the fall and early winter, extending the warm weather period later into the fall. The onset of spring is delayed when the lake absorbs heat and keeps temperatures at cooler levels. Hence, the net effect is cold, snowy winters and moderately wet, mild summers.

Winters are usually long with an average temperature of about -4°C (25°F), while summer temperatures average close to 21°C (70°F). Long-term records reveal extremes of 32°C (-25°F) and 38°C (100°F). The general delay in the onset of spring and vegetation development also create a good environment for growth of fruits and vegetables. The frost-free season is from 150-180 days (longest in New York), resulting in a growing season beginning about the last week of April and ending about the third week in October.

---

* *Epilimnion is the upper layer of warm water which contains more oxygen than the lower layers.*

Precipitation is moderate with a rather uniform distribution throughout the year. The average annual precipitation is about 915 cm (36 in), with most summertime moisture in the form of thundershowers. The average annual snowfall is about 2,030 mm (80 in) averaging 300-600 mm (1-2 ft) per month, December through March.

The prevailing winds during most of the year are from the southwest and approach the direction of the long axis of the lake. During winter months, the wind direction shifts to the west. High winds are usually associated with intense winter storms and severe thunderstorms.

HYDROLOGY

The inflow to Lake Ontario comes from the Niagara River at the west end, the Trent River from Canada, the Genesee, Oswego, Salmon, and Black Rivers along the southeast shore, and numerous small streams. The Niagara River carries the major portion of the inflow (about 85%) into Lake Ontario from the other Great Lakes. The average annual flow of the Niagara River is 5,800 m^3/sec (205,000 cfs). The Genesee River, which flows from the Applachian Front, and the Oswego, which drains the Finger Lakes area, have average annual flows of 79 m^3/sec (2,800 cfs) and 184 m^3/sec (6,500 cfs), respectively. The Salmon and Black Rivers flow from the Adirondacks, and the Trent River drains a portion of the Providence of Ontario. The St. Lawrence River carries the outflow (6,765 m^3/sec or 239,000 cfs) from Lake Ontario to the Atlantic Ocean, some 750 km (1,200 mi) away.

The lake surface elevation exhibits both periodic and random fluctuations over different time periods. Long term records reveal that the water surface averages about 85 m (250 ft) above mean sea level. Dams on the St. Lawrence River, controlled by the International St. Lawrence River Board of Control, regulate the lake level on a seasonal basis so that it does not drop below the 74.01 m (242.8 ft), agreed to in 1955 and in effect since 1960.

The circulation of the lake is generally in a counterclockwise direction. The predominant surface currents in Lake Ontario are from west to east, with a tendency to move toward the south shore. These currents, with a mean speed of about 0.03 m/sec (0.1 ft/sec), develop primarily from wind stress on the water surface and react rapidly to changes in wind speed and direction.

Tides in Lake Ontario are small, less than 25 mm (1 in.). Seiches generally have amplitudes of less than 2/3 m (2 ft). However, wind-driven surface waves 4.5 m (15 ft) high can occur.

Lake Ontario is a dimictic lake (both spring and fall turnover) with a large thermal gradient in the summer. Surface temperatures vary from about 0.5°C (33°F) in February when the lake is essentially isothermal to 22°C (72°F) in July when it is vertically stratified. During warm weather upwellings of cold, nutrient rich, bottom water (resulting from storm action) lead to rapid and sudden changes in inshore water temperature.

Lake Ontario is also oligotrophic (low production of organic matter) with a trend towards becoming eutrophic (rich in organic matter) inasmuch as most of the inflow, including nutrients, comes from Lake Erie. Changes in chemical characteristics over the last half century approximate those exhibited by Lake Erie with sodium, chloride, sulfate, and calcium concentrations increasing. High total dissolved solids and low transparency reflect a eutrophic trend. Since much of the lake is over 35 m (115 ft) deep with dissolved oxygen concentrations at 90-100% of saturation, full utilization of nutrients does not occur in this water; however, inshore waters are less oligotrophic than the offshore waters.

APPLICABLE WATER QUALITY REGULATIONS

Within New York's water quality criteria (amended 21 Feb. 1974), the south and east shores of Lake Ontario are under the jurisdiction of special classifications and standards developed by the Great Lakes Water Quality Agreement of 1972 for international boundary waters. The Official Compilation of the Codes, Rules, and Regulations of the State of New York, Part 702.1, Title 6 for "Class A-Special Waters" defines the best usage of these waters to be "for drinking, culinary or food processing purposes, primary contact recreation and any other uses." The standards include the following specifications regarding thermal discharges:

> No discharge which will be injurious to fish life or make the waters unsafe or unsuitable for any best usage determined for the specific waters which are assigned to this class.

Application of this standard to lakes is interpreted in Part 704.1 (Criteria Governing Thermal Discharges), which states:

> The water temperature at the surface of a lake shall not be raised more than 1.7°C (3°F) over the temperature that existed before the addition of heat of artificial origin, except that within a radius of 91 m (300 ft) or equivalent area* from the point of discharge, this temperature may be exceeded. In lakes subject to stratification, the thermal discharges shall be confined to the epilimnetic area.

Lake Ontario is, of course, stratified and subject to these criteria. The State of New York is, as of Jan. 1975, proposing to change, upon EPA approval, the thermal discharge standards which would modify Part 704.1 above to read:

---

* *Recognizing no flexibility to a fixed radius of 91 m (300 ft), provision is made to permit a greater or lesser area under exemption by the New York State Commissioner of Environment Conservation as long as "best usage" specifications are met.*

> The water temperature at the surface of a lake shall not be raised more than 1.7°C (3°F) over the temperature that existed before the addition of heat of artificial origin.

Mixing zones are not specified, but are to be developed later. And, the standards exclude powerplants built and in operation before 20 Oct. 1974, a point causing some controversy.

IV. STUDY TECHNIQUES FOR THERMAL DISCHARGES

AIRCRAFT AND FLIGHT DATA

This remote sensing mission was carried out by a research aircraft from the NASA-Lewis Research Center in Cleveland, Ohio. The aircraft was instrumented with a multispectral scanner and photographic equipment to perform environmental measurements.

The flight parameter data listed below provide the specific values of the aerial reconnaissance variables.

Dates of the flight: 30 July 1974 and 1 Aug. 1974

Times of flight: 12:46 p.m. to 4:13 p.m. and 11:42 a.m. to 3:48 p.m., respectively

Target areas: R. E. Ginna Nuclear Power Station; Oswego Steam Power Station, Units No. 1-4; the mouth of the Oswego River; and Nine Mile Point Nuclear Power Station, Number 1

Airspeed of aircraft: 200 km/hr (120 mph)

Average aircraft altitude above water level: 480 m (1,500 ft) and 760 m (2,500 ft)

Sensors used: Bendix Modular Multispectral Scanner

SENSOR DATA

A Bendix Modular Multispectral Scanner was the sensor used for this study. The sensor is mounted beneath the floor of a C-47 Research Aircraft. During flight, a rotating mirror scans through the instrument's field of view along cross track (a line at right angles to the flight direction of the aircraft) with a look-angle of 2.5 milliradians (mrad). The image is formed by successively recording the cross track data as the aircraft progresses along its flight path. A control sets the rotational speed of the mirror so that a contiguous scan is provided at a rate adjusted to the ratio of aircraft velocity to altitude above the ground level. In a single rotation the scanner mirror sweeps through the sensor's cross track look-angle, in a direction -50° and +50° to the aircraft nadir. Then, during the remainder of the complete rotation, the scan mirror/detector assembly views two calibrated blackbodies, which are a tungsten lamp calibration source, and a reference source to measure the incoming solar radiation. The blackbodies and reference source are mounted in the housing assembly of the scan mirror and are monitored after every scan line.

As illustrated in Figure IV-1, the incident light is directed from the rotating flat scanner mirror into a telescope where it is directed onto a beam splitter. The infrared radiation is reflected into a mercury-cadmium-telluride (Hg-Cd-Tl) liquid nitrogen cooled solid state detector. The visible radiation and near infrared between 0.4 and 1.0μ is passed through the beam splitter and into a grating spectrometer. There the radiation is dispersed and focused onto ten silicon detectors having spectral bands centered at the wavelengths given in Table IV-1. Band 11 in the thermal band is also included.

Table IV-1
Spectral Band Wavelengths

Band Number	Center Wavelength (μ)	Band Number	Center Wavelength (μ)
1	0.410	6	0.640
2	0.465	7	0.680
3	0.515	8	0.720
4	0.560	9	0.810
5	0.600	10	1.015
		11	†11.2

† *thermal band*

The infrared radiation incident upon the cryogenically cooled detector generates a small electrical signal which is amplified, processed and recorded on magnetic tape. (The amplifier is designed with a

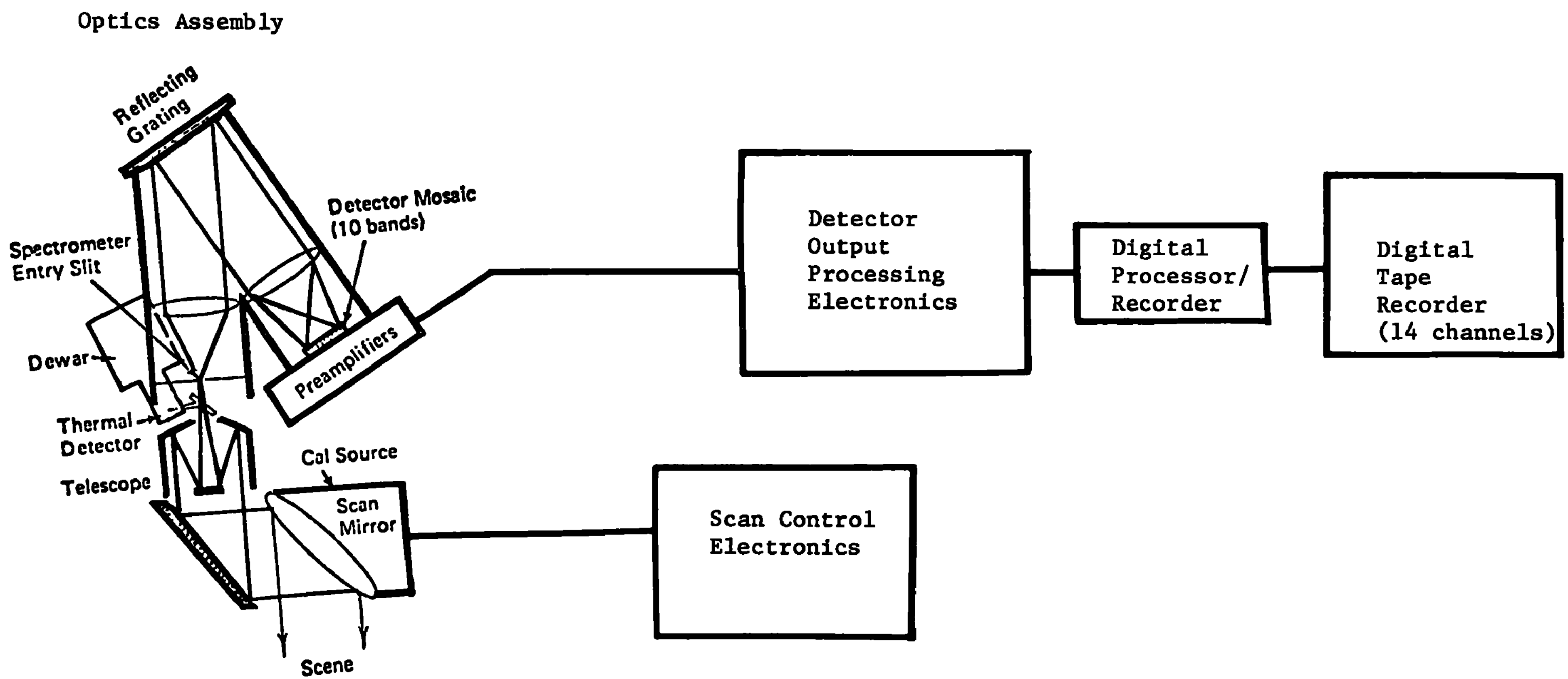


Figure IV—1 Simplified Block Diagram, Multispectral Scanner feedback loop controlling its gain so that a constant amplification factor is maintained.) The gain is adjusted with reference to the two calibration blackbodies viewed on each rotation of the scanning mirror. Due to the noise frequencies in the detector and the frequency response characteristics of the amplifier feedback loop, there is a low frequency variation in gain having a period of several seconds. This variation is viewed in the data as a periodic light and dark banding along crosstrack which is repeated every several hundred scan lines.

The ten visible/near infrared channel detector signals are also amplified, converted from analog to digital signals on a 0 to 256 numbers scale, and recorded on a 14-channel magnetic tape in a 10,000 bit per inch format. Housekeeping data such as blackbody temperatures, calibration lamp voltages, and synchronization signals are recorded in addition to the imagery from the eleven spectral channels.

Data reduction is accomplished in three major steps. The first step is to play back the high density digital tape to produce an analog photograph-like image that is used to qualitatively assess the value of the data and select the portions of the flight lines that will be used in computer processing. The second step is to convert the selected portions of each flight line from high density digital tape to a lower density computer compatible tape (format is 800 bits per inch, 9 track) that is used by the tape recorders on computers. The final step is to computer process the data on the computer compatible tape with the mathematical algorithm appropriate to the processing requirements. The thermal channel in the multispectral scanner has a sensitivity band width from 10.2 to 12.6μ the so-called thermal band of the electromagnetic spectrum. The system has an instantaneous field of view of 2.5 x 2.5 mrad. The total field of view on one scan line observed by the system is 100° by 2.5 mrad. The measured noise equivalent temperature (N E ΔT) of the scanner's thermal scanner is 0.2°C with 100 percent probability of target detection. This represents an effective measurement of the temperature resolution of the scanner.

GROUND TRUTH

The Rochester, N.Y., Field Station, EPA Region II, helped NFIC-Denver personnel obtain near-surface (surface to -10 cm (-3.9 in) depth) water temperature measurements simultaneously with the time-of-flight. The surface water temperatures were measured at discrete points in the vicinity of each thermal discharge, including each discharge point and ambient or background surface water locations within the lake.

The accuracy of the contact instrumentation used to obtain the surface water temperatures was ± 0.1°C (0.2°F). It is estimated that the precise location of the discrete water temperature data points were known to within ± 20 m (66 ft) with the exception of the locations of data points within each discharge and the inshore position. The positional accuracy of the latter was 1-3 m (3-10 ft).

DATA INTERPRETATION AND ANALYSIS

Data analysis was performed on the density sliced imagery produced from the computer compatible digital magnetic tapes. These images were processed into filmstrips on a mini-computer. Each gray level or step in the film corresponded to a particular step of thirteen digital numbers, representing the intensity of the detected infrared energy from the water. The relationship between the digital number steps and the water temperature level was determined from observations of the two calibrated blackbodies inside the instrument. The temperatures are derived from sensors embedded in each blackbody and recorded on the housekeeping channel of the magnetic tape as well as being displayed on the operator's console. By taking the difference between the digital number readings for the two scanner blackbody observations and dividing by the known blackbody temperature difference, the gain of the instrument in digital numbers per degree centigrade is obtained.

By relating the thermal channel digital number output to the temperature of one of the blackbodies, an absolute relationship is established between the level of the scanner output signal and the infrared radiance entering the instrument aperture from the target. This relationship does not precisely correspond to the absolute temperature of the water surface because of atmospheric correction and surface film evaporation effects. At the low altitudes in this mission, these corrections are small enough so that the scanner produces an accurate measurement of the temperature difference between the heated plume and background water and the absolute temperatures of the surface waters. However, the calibrated temperature data from the scanner was substantiated by reference to ground truth.

Because of absorption and reradiation in the 8-14 μ region of the spectrum by the carbon dioxide and water vapor, the absolute infrared radiance of the water surface is modified by passage through the intervening atmosphere between the aircraft and surface. The effect changes the absolute temperature level of the water surface when referenced to the scanner internal calibration blackbodies. Under normal conditions, the atmospheric temperature decreases with altitude. Since the radiation from the water is absorbed and reradiated by a colder atmosphere, the usual effect is to cause the scanner indicated temperature to be lower than the water temperature. If a temperature inversion or some other atmospheric effect occurs, however, the correction may go in the opposite direction. If the atmospheric temperature and humidity profiles are available from radio sound data, the correction may be calculated to a very few tenths of a degree centigrade accuracy. The more usual practice, however, is to measure the surface water temperature at a known location in the image and adjust the scanner temperature scale to coincide with the water surface temperature at that point.

Another reason that the scanner temperatures usually read lower than the measured surface temperature is evaporation (mass transport of heat from the water to the atmosphere) in the thin surface film. Since the infrared energy is irradiated from the top few hundred microns of the water's surface, evaporation slightly chills this layer below the temperature measured by a physical thermometer inserted into the water. The magnitude of this correction depends on the air and water temperatures, relative humidity, and wind velocity, but it is often about 0.2°C (0.4°F). Adjustment of the scanner temperature scale to match a known ground truth point is the most practical method of compensating for this effect. Any surface winds in the target area minimize this effect to a negligible level.

A Spatial Data 704 image analyzer was used to convert the density sliced images into isarthermal maps. The image analyzer uses a technique called density slicing to divide the density range on a given infrared image into twelve increments. Each increment thus represents a particular density of gray on the image and a narrow temperature range closely approximating an isartherm. The density value of each increment is accurate to within 0.03 density units over a range of 0-2 density units. Each density increment is displayed on the image analyzer screen in a particular color. The actual temperature of each isartherm on the map was determined by referencing the density of the image to the density of a step wedge recorded immediately adjacent to the image on the photographic negative. The relation between image density and temperature is determined from the calibration blackbodies as described above. The temperature difference per density step is 0.71°C (1.28°F). The temperature scale determined from the densities is then adjusted to an absolute level by setting the temperature of a point on the image equal to the temperature determined by ground truth. The absolute temperatures of the entire scene are then adjusted to the same scale.

A scan angle effect (slant range) due to the intervening atmosphere is present in the data since the path length through the atmosphere varies with the slant range as a function of angle. This correction varies as 1/cos A, or varies from 1 to 1.55 as the scan angle varies from 0° to 50°. This effect is noticeable in the imagery as a cooling effect at the edge of the image relative to its center. The magnitude of this correction would be no larger than one difference in density level (0.71°; 1.28°F) between the middle and the far edge of the image.

An important factor must be mentioned at this point. The thermal scanner will only record water surface temperatures, since water is opaque in this region of the infrared spectrum. The maximum depth penetration in either freshwater or saltwater is 0.01 cm (0.004 in). Therefore, a submerged thermal discharge can be detected from an aircraft with a thermal scanner only if the warm wastewater reaches the surface of the receiving body of water. The isarthermal maps developed by this study represent surface temperatures only and not subsurface temperature distributions.

ERROR ANALYSIS

Limitations can be placed on the accuracy or uncertainty of the absolute value of water temperatures represented by the isarthermal maps developed by this study. The significant sources of error affecting the data are the two noise sources in the instrument and the accuracy of the instrumentation used in obtaining ground truth. These sources have the following error values:

1. *Scanner noise.* Each picture element in the scanner image contains a random noise component having a Gaussian spectral distribution with a noise equivalent temperature of ± 0.2°C (0.4°F). Also, the scanner image reveals a banding effect along the direction of the flightline that is due to the low frequency response of the elctronic amplifier used to record the infrared signal. This error source is systematic and can be compensated subjectively by the observer.

2. *Ground truth data.* The accuracy of the instrument used to record ground truth temperature is ± 0.1°C (0.2°F).

3. *Inherent error* in the processing of the digital data to form the density sliced image is as much as 0.2°C.

4. *Image analysis.* The image analyses contribute an error of ± 0.1°C due to the film density measurement accuracy.

By using the method of root-sum-squares, the magnitude of the total possible error range can be estimated as follows:

1. $\Delta t_1 = \Delta t_{scanner} = \pm 0.2°C$ (measured system noise equivalent temperature: NET)

2. $\Delta t_2 = \Delta t_{\text{ground truth instrumentation}} = \pm 0.1°C$ (accuracy of instrument)

3. $\Delta t_3 = \Delta t_{\text{computer digital processing}} = \pm 0.2°C$ (digital image slicing; ± 0.2°C is an extreme but ± 0.1°C is normal)

4. $\Delta t_4 = \Delta t_{\text{image analyzer}} = \pm 0.1°C$ (film density accuracy)

Finally, $$\Delta t_{total} = \pm \left[\sum_{i=1}^{4} (\Delta t_i)^2\right]^{1/2}$$

$$= \pm \left[(0.2)^2 + (0.1)^2 + (0.2)^2 + (0.1)^2\right]^{1/2}$$

$$\Delta t_{total} = + 0.32°C \ (\pm 0.6°F)$$

Reported temperature values are thus accurate to within ± 0.3 to ± 0.4°C (0.6 to 0.7°F) of those existing in the surface layer of the lake at the time of flight.

V. RESULTS AND EVALUATION OF THERMAL DATA ANALYSIS

This section presents the results of the analysis of the water temperature data obtained by aerial reconnaissance and ground surveys. Weather conditions existing at the time of flight are summarized. Powerplant descriptions and cooling water discharge characteristics obtained from information submitted by the power companies are also presented. The observed thermal plumes are evaluated with respect to the reported discharge characteristics and recorded weather conditions.

The powerplants are discussed by location, proceeding eastward along the southern shore of Lake Ontario [Fig. V-1, inside back cover].

GINNA NUCLEAR POWER STATION - PULTNEYVILLE, NEW YORK

Description of Power Station

The Rochester Gas and Electric Corporation operates this nuclear field power station with a generating capacity of 490 MW (net) at full output. The facility is about 380 m (1,250 ft) east of Smoky Point, a small land projection on the south shoreline of the lake. Cooling water supply is obtained from the lake through an intake about 940 m (3,100 ft) offshore at a depth of 10 m (33 ft) [Fig. V-2]. Heated water is returned to the lake through a short canal discharging at the surface and normal to the shoreline. Design conditions for the canal indicate that the heated layer would have an average depth at the canal outlet of 2.4 m (8 ft) and an average velocity normal to shore about 0.7 m/sec (2.3 fps) at full discharge rate.

Design capacity for the cooling water system is 2,180,000 m^3/day (400,000 gpm). As shown in Figure V-3, 104,000 m^3/day (19,000 gpm) is

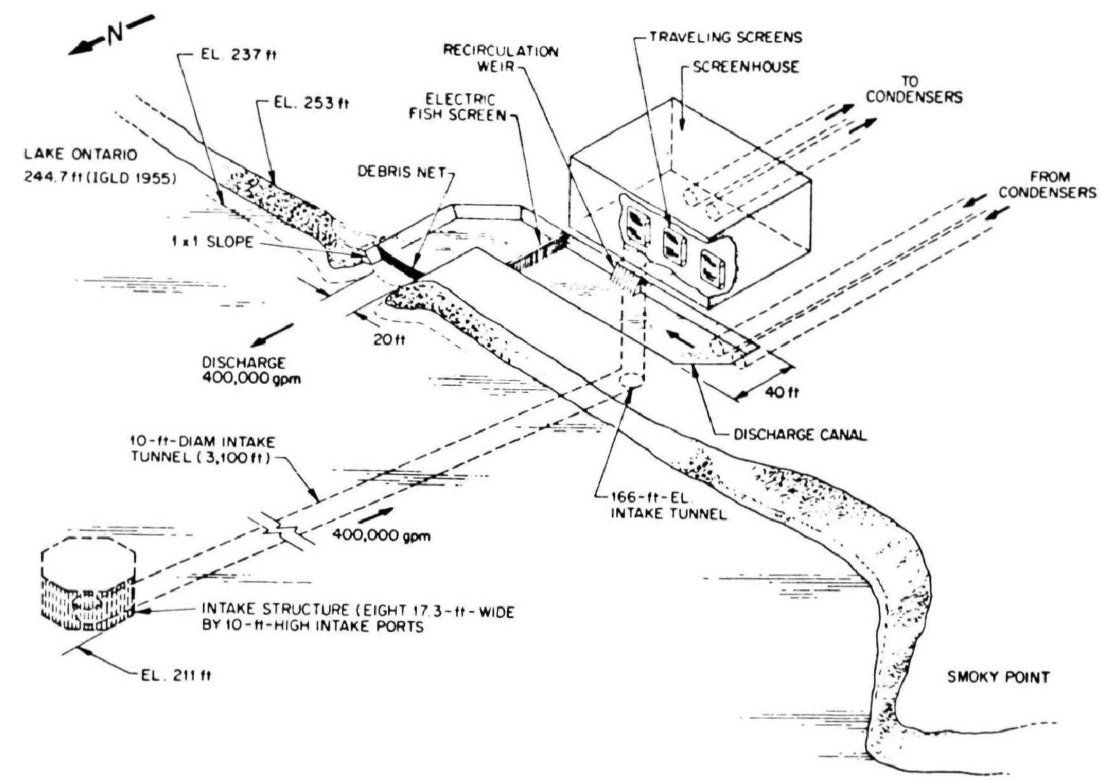


Figure V—2 Ginna Powerplant Intake and Discharge Structures

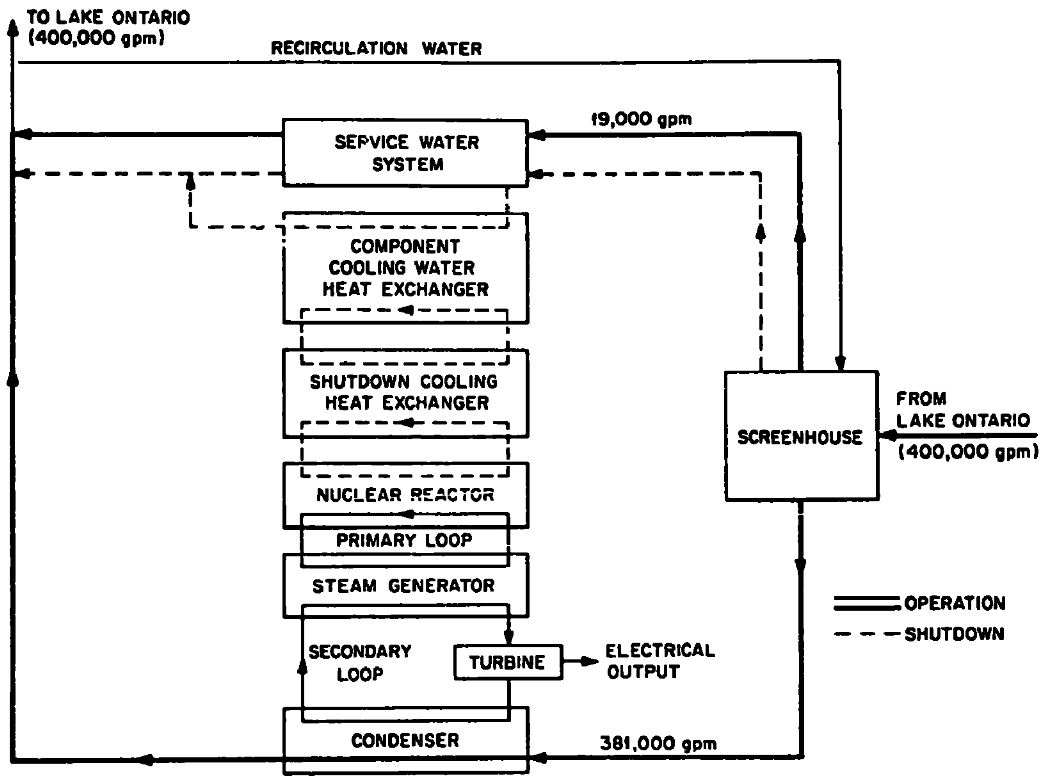


Figure V—3 Flow Diagram for Ginna Powerplant Cooling System used for service water and the remainder for condenser cooling water. Heated water can be recirculated from the discharge canal to the intake system for control of icing on the travelling screens.

The condenser is designed for a 10.9°C (19.6°F) temperature rise when operating at capacity. At full operating level, waste heat rejected to the environment through the condenser cooling water is 3 billion BTU/hr. At the time of data collection, the powerplant was operating at 70% of full capacity with condenser water flow at the design rate. Heat rejected to the cooling water was 2 billion BTU/hr. A temperature rise of 6.7-7.8°C (12-14°F) across the condenser was reported.

The Ginna reactor is a pressurized light water moderated and cooled system. Light water is used in the primary loop shown in Figure V-3. The condenser water is isolated from the radioactive system components. Small amounts of low level radioactive wastewaters along with boiler blowdown and water treatment wastewaters are discharged to the condenser water flow. Sanitary wastes go to a septic tank and leach fields.

Observed Thermal Conditions

Using the techniques discussed in Section IV, thermal imagery of Lake Ontario in the vicinity of the Ginna Nuclear Power Station was recorded at altitudes of 460 and 760 m (1,500 and 2,500 ft) above water level. The resultant thermal maps, presented as positive prints synthesized from the digital infrared data, are provided in Figures V-4 through V-6. Since these are positive prints, the darker areas depict cooler surface water temperatures while the light gray or white areas depict warm temperatures.

The station's surface discharge and resultant thermal field or plume are clearly shown in Figures V-4 and V-5, recorded on 30 July 1974 at about 1600 hours EDT. At the time of flight, the wind was blowing

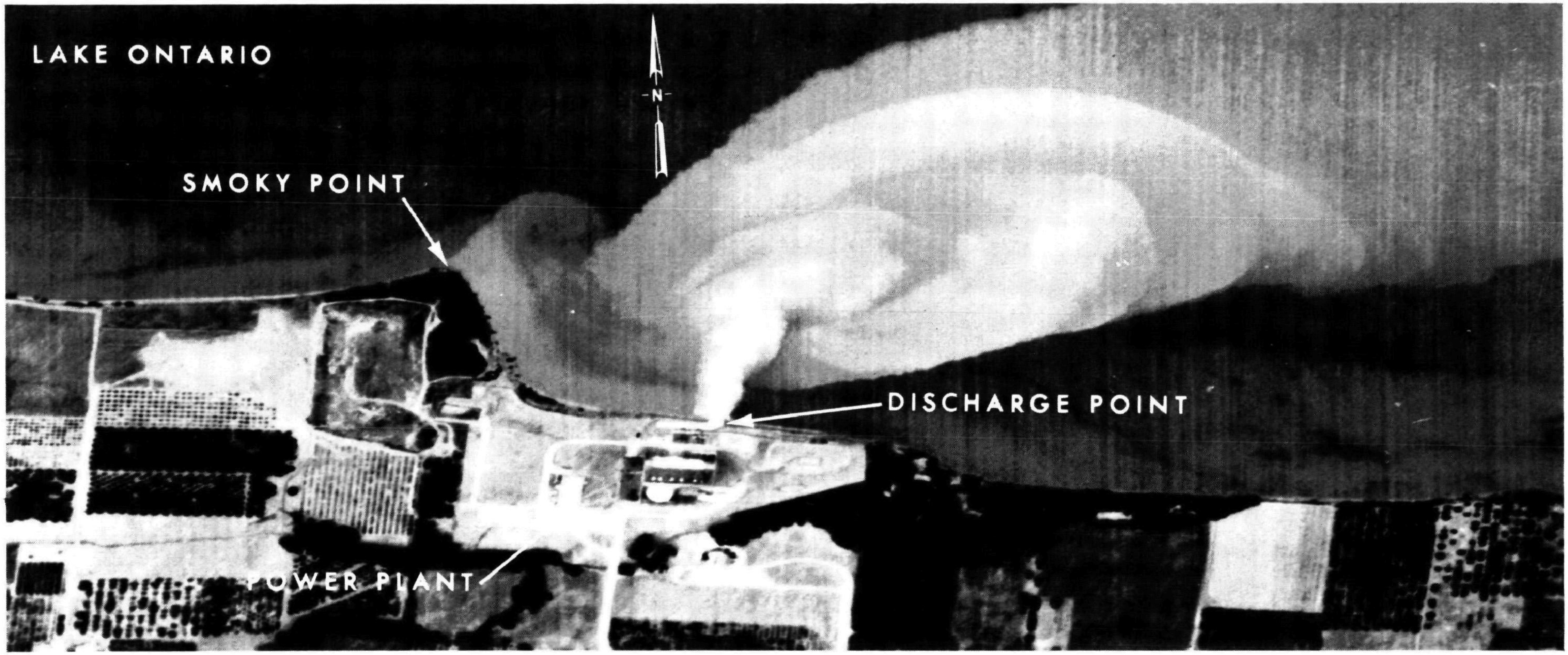


Figure V—4 Thermal Map of Nearshore Portion of Ginna Nuclear Power Station Thermal Plume
30 July 1974

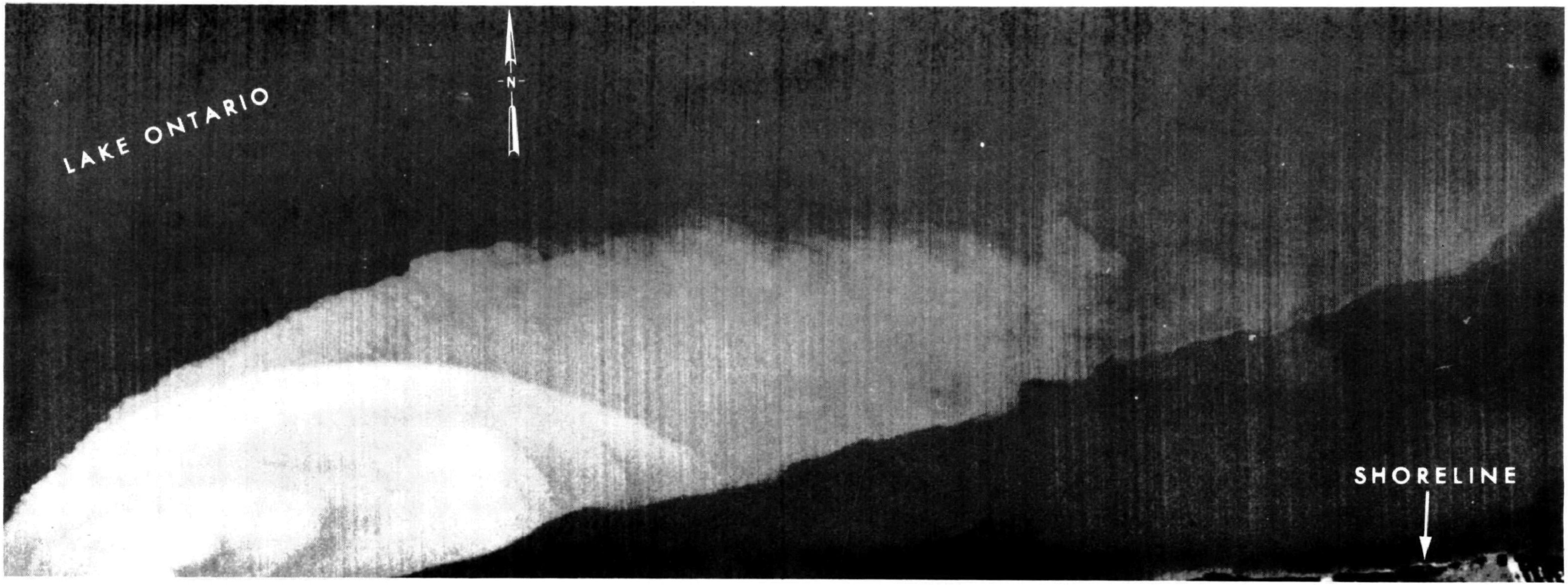


Figure V—5 Thermal Map of Offshore Portion of Ginna Nuclear Power Station Thermal Plume
30 July 1974

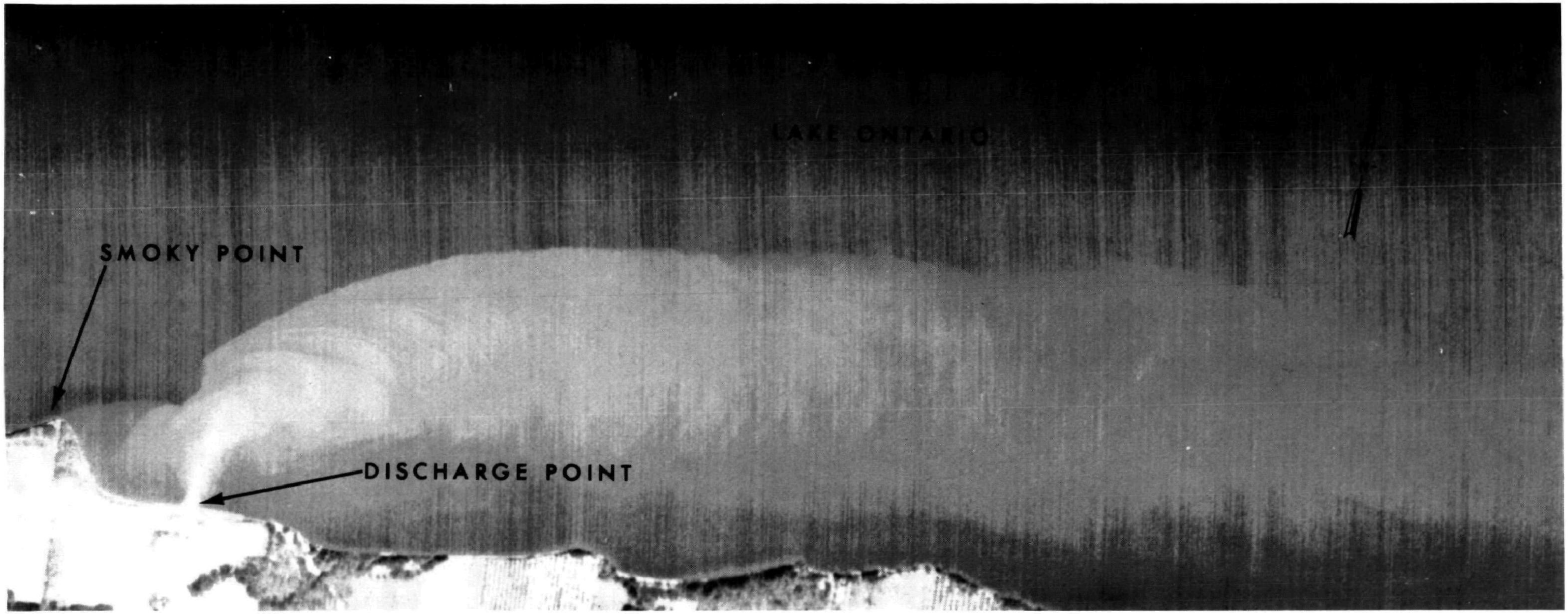


Figure V—6 Thermal Map of Ginna Nuclear Power Station
1 August 1974

from the west to northwest at 8-16 km/hr (5-10 mph) and was influencing the easterly movement of the field. An easterly internal lake circulation current, predominant along this segment of Lake Ontario's southern shoreline, was carrying the main body of the thermal field eastward in addition to the wind-induced currents. The field extended nearly 3.1 km (1.9 mi) northeastward from the discharge before completely dispersing and moved away from the shore [Fig. V-5]. It maintained an average width of 0.5 km (0.3 mi) until dispersal. The discontinuity in the shore at Smoky Point offers more quiescent hydrodynamic conditions for the first 200 m (650 ft) of the field adjacent to the discharge.

With the aid of the digital thermal imagery [Fig. V-4] and the ground truth obtained at the time of flight, the thermal field was computer analyzed for areas of equal surface temperature and an isarthermal map was prepared using the analytical techniques discussed in Section IV. In the isarthermal map [Fig. V-7], areas with surface water temperatures falling within a given temperature interval are depicted by a particular color. The color scheme goes from dark red, representing the warmest surface temperature, through several lighter shades of red and several light shades of blue to a dark blue color representing the coolest temperature.

The total surface area of the thermal field measured about 108 hectares* (266 acres). The surface area for each isartherm [Fig. V-7] which had a surface temperature greater than 1.5°C (2.7°F) above that of the background water is given in Table V-1. About 2-3% of the total surface area of the thermal field was at least 3.6°C (6.5°F) warmer than the ambient waters, 32% averaged at least 2.2°C (4.0°F) above ambient, and 66% of the field had an average surface temperature at least 1.5°C (2.7°F) above that of the background surface waters. The maximum temperature at the discharge point was 27.8°C (82°F).

---

* *1 hectare = 10,000 m^2 = 2.471 acres.*

PAGE NOT

AVAILABLE

DIGITALLY

Table V-1

Summary of Isarthermal Data, Ginna Nuclear Power Station, 3 July 1974†

Isartherm Number	Average Temperature of the Isartherm (°C)	(°F)	Δt Above Background†† (°C)	(°F)	Surface Area††† (Hectares)	(Acres)	Percentage of Total Field Surface Area
0	>25.7	>78.2	>5.4	>9.7	0.01	0.02	~0.01
1	>25.7	>78.2	>5.4	>9.7	0.39	0.97	0.36
2	25.3	77.6	5.1	9.1	0.44	1.08	0.41
3	24.6	76.3	4.3	7.8	0.44	1.08	0.41
4	23.9	75.0	3.6	6.5	1.43	3.54	1.3
5	23.2	73.8	2.9	5.3	13.97	34.53	13
6	22.5	72.5	2.2	4.0	17.42	43.05	16
7	21.8	71.2	1.5	2.7	36.23	89.53	~34
Total					70.33	173.80	~66

† *The temperatures of the intake and discharge water were 20 and 27.8°C (68 and 82°F), respectively, at the time of flight with a discharge flow rate of 2,180,000 m^3/day (400,000 gpm).*

†† *Surface temperatures of the background Lake Ontario waters in this vicinity averaged 20.3°C (68.5°F).*

††† *1 hectare = 10,000 m^2 = 2.471 acres.*

The thermal field was contiguous along 530 m (1,740 ft) of shoreline between the discharge canal and Smoky Point [Fig. V-7]. Surface temperatures in this quiescent area ranged from 0.8-1.5°C (1.4-2.7°F) above ambient lake temperatures. For the wind and current conditions observed, it would appear that only a small subsurface temperature increase above ambient would be present in the shallow nearshore waters around Smoky Point.

A second thermal map [Fig. V-6] was recorded on 1 Aug. 1974 at about 1250 hours EDT. At that time the wind was out of the northwest at 3-11 km/hr (2-7 mph). The observed thermal field was proceeding outward from the shore about 230 m (760 ft) and then moving in an easterly direction parallel to shore due to the aforementioned easterly lake current and the westerly wind. The field maintained a width of 0.5 km (0.3 mi) until dispersal. It extended nearly 3.1 km (1.9 mi) eastward with the south edge averaging about 120 m (380 ft) offshore. The field was contiguous along 560 m (1,840 ft) of shoreline from just east of the discharge canal to Smoky Point. This nearshore area was 2.2°C (4°F) warmer than the ambient lake surface temperature.

The thermal field's total surface area was about 144 hectares (356 acres). The surface areas of isartherms [Fig. V-8] that had a surface temperature greater than 1.5°C (2.7°F) above that of the background water are given in Table V-2. These data show that over 7% of the total surface area of the thermal field was at least 3.6°C (6.5°F) warmer than the ambient waters, 57% had an average surface temperature that was at least 2.2°C (4.0°F) above ambient, and a minimum of 71% of the field had an average surface temperature of 1.5°C (2.7°F) above that of the background surface waters. The warm areas of this field were significantly larger (1.5 to 2.5 times) than observed on 30 July. Plume dispersal was not as rapid on 1 Aug. as on 30 July.

As stated in Section III, the proposed New York State thermal discharge standards for Lake Ontario (subject to EPA approval) dictate

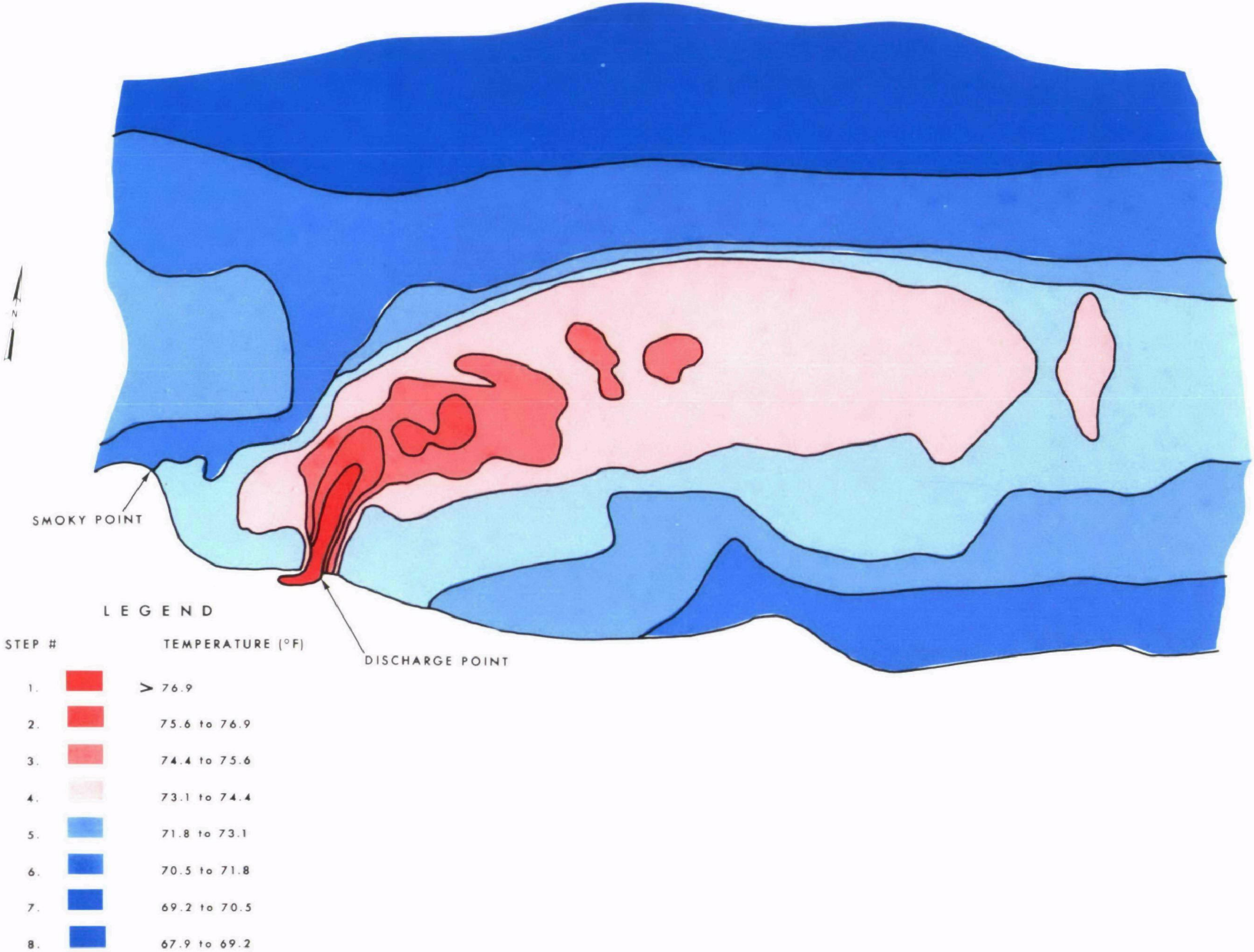


Figure V—8 Isarthermal Map of Ginna Nuclear Power Station Discharge
1 August 1974

Table V-2

Summary of Isarthermal Data, Ginna Nuclear Power Station, 1 Aug. 1974†

Isartherm Number	Average Temperature of the Isartherm (°C)	Average Temperature of the Isartherm (°F)	Δt Above Background†† (°C)	Δt Above Background†† (°F)	Surface Area††† (Hectares)	Surface Area††† (Acres)	Percentage of Total Field Surface Area
1	>24.9	>76.9	>4.7	>8.4	0.73	1.79	0.5
2	24.6	76.3	4.3	7.8	2.36	5.82	1.6
3	23.9	75.0	3.6	6.5	7.29	18.00	5.1
4	23.2	73.8	2.9	5.3	32.46	80.21	23.0
5} ††††	22.5	72.5	2.2	4.0	39.02	96.42	27.0
6	21.8	71.2	1.5	2.7	19.93	49.27	14.0
Total					101.79	251.51	∿71

† *The temperatures of the intake and discharge water were 21.1 and 27.8°C (70 and 82°F), respectively, at the time of flight with discharge flow rate of 2,180,000 m^3/day (400,000 gpm).*

†† *Surface temperatures of the background Lake Ontario waters in this vicinity averaged 20.3°C (68.5°F).*

††† *1 hectare = 10,000 m^2 = 2.471 acres.*

†††† *Isartherm numbers 5 and 6 are only shown in Fig. V-8, to the extent they relate to the main region of the thermal field. The outer extremities of these regions are not included in Fig. V-8.*

that the surface temperature of a thermal field shall not exceed a level of 1.7°C (3.0°F) above the surface temperature of the background receiving waters except in designated mixing zones. To date no mixing zones have been established in Lake Ontario. On 30 July, 32% of the field did not comply with this recommendation while a significant portion of isartherm 7 (34% of the total) also exceeded the 1.7°C (3.0°F) value as average values of the temperature interval of each established isartherm were used during laboratory analysis of the thermal data. On 1 Aug., 57% of the field did not fall within the 1.7°C (3.0°F) limit, while a significant part of isartherm 6 also exceeds this proposed value which cannot be precisely quantified due to the reasons stated above.

OSWEGO STEAM POWER STATION - OSWEGO, NEW YORK

Description of Power Station

The Niagara Mohawk Power Corporation operates this fossil-fueled steam power station at Oswego [Fig. V-1]. It has four 80 MW oil-fired units presently in operation (Units 1 through 4). Unit 5, rated at 850 MW, will be in operation during the spring of 1975. Another 850 MW unit (No. 6) will be placed in operation in 1977.

Cooling water for the existing units is obtained from Lake Ontario through an intake located about 168 m (550 ft) offshore outside the Oswego Harbor breakwater [Fig. V-9]. Heated water averaging 1,810,000 m^3/day (332,000 gpm) is discharged to the turning basin at the west end of Oswego Harbor inside the breakwater. Small amounts of boiler blowdown and water treatment backwash are also discharged to the Harbor. No sluice water is discharged as bottom, and fly ash are sold for vanadium recovery. As indicated in Figure V-9, intake and discharge points for the new Units 5 and 6 will be substantially different. Each of these units will use about 1,550,000 m^3/day (285,000 gpm) of cooling water.

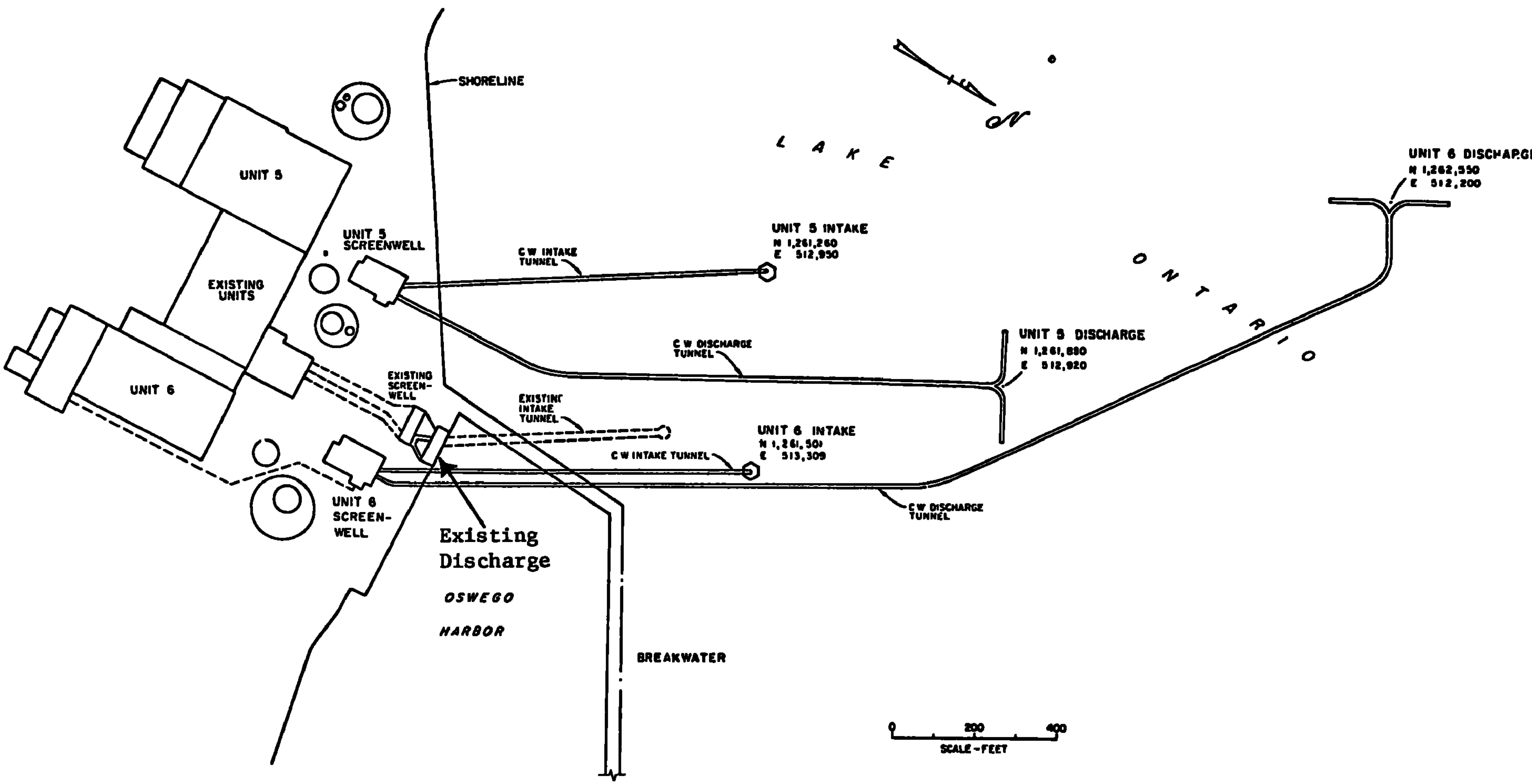


Figure V—9 Oswego Steam Power Station Intake and Discharge Structures

In addition to the powerplant discharge, effluent from the Oswego municipal waste treatment facility is discharged to the west portion of the Harbor. Streamflow from the Oswego River also enters the Harbor. The cooling water discharge is about 12% of the average river flow and about equal to the 7-day low flow occurring once in 10 years. The mixed river and cooling waters flow out of the Harbor entrance into Lake Ontario.

Observed Thermal Conditions

Thermal imagery of Lake Ontario and Oswego Harbor in the vicinity of the Oswego Steam Power Station was recorded at altitudes of 460 m (1,500 ft) and 760 m (2,500 ft) above water level. Thermal maps (positive prints) of this immediate area are provided as Figures V-10 and V-11. Figure V-10 was recorded on 30 July 1974 at about 1246 hours EDT. Only the entrance and the thermal field entering Lake Ontario in an easterly direction are shown in this map. There was an easterly lake circulation current, predominant along this segment of shoreline, that was carrying the warm water from the harbor eastward. A northwesterly wind (precise speed not available) aided the transport of warm water eastward. The resultant thermal field extended at least 1.1 km (0.7 mi) east of the harbor breakwaters, with measurement being precluded by the edge of the thermal map.

The isarthermal map corresponding to Figure V-10 is provided as Figure V-12. The total surface area of the thermal field contained in this map was 163 hectares (402 acres). Because the temperature of the Oswego River was warmer than the lake, it cannot be ascertained what relative contributions to the total field were made by the Oswego River and the power station. However, of the area shown in Figure V-12, 6% was 2.8°C (5.1°F) warmer than the ambient waters, 24% was 2.2°C (3.9°F) warmer, and 53% was 1.4°C (2.6°F) warmer [Table V-3]. Of the 29% included in isartherm 5, a large portion was 1.7°C (3.0°F) above ambient

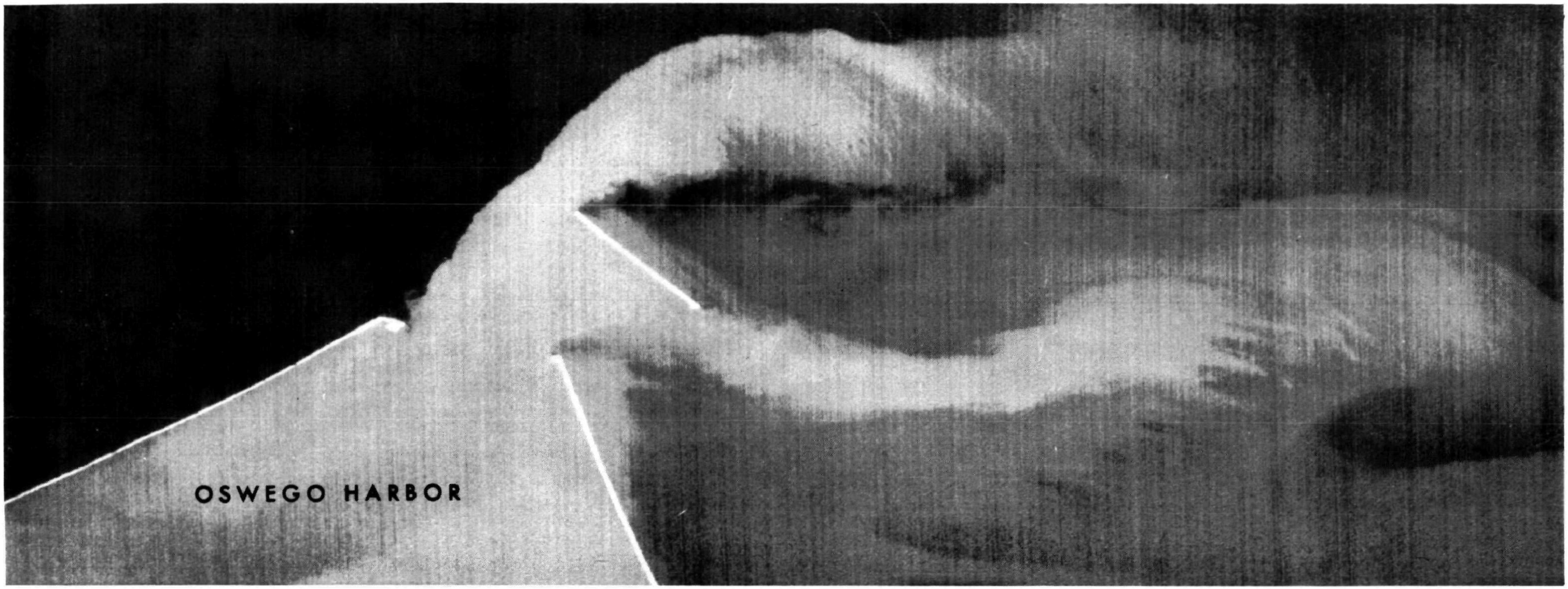


Figure V—10 Thermal Map of Outflow from Oswego Harbor
30 July 1974

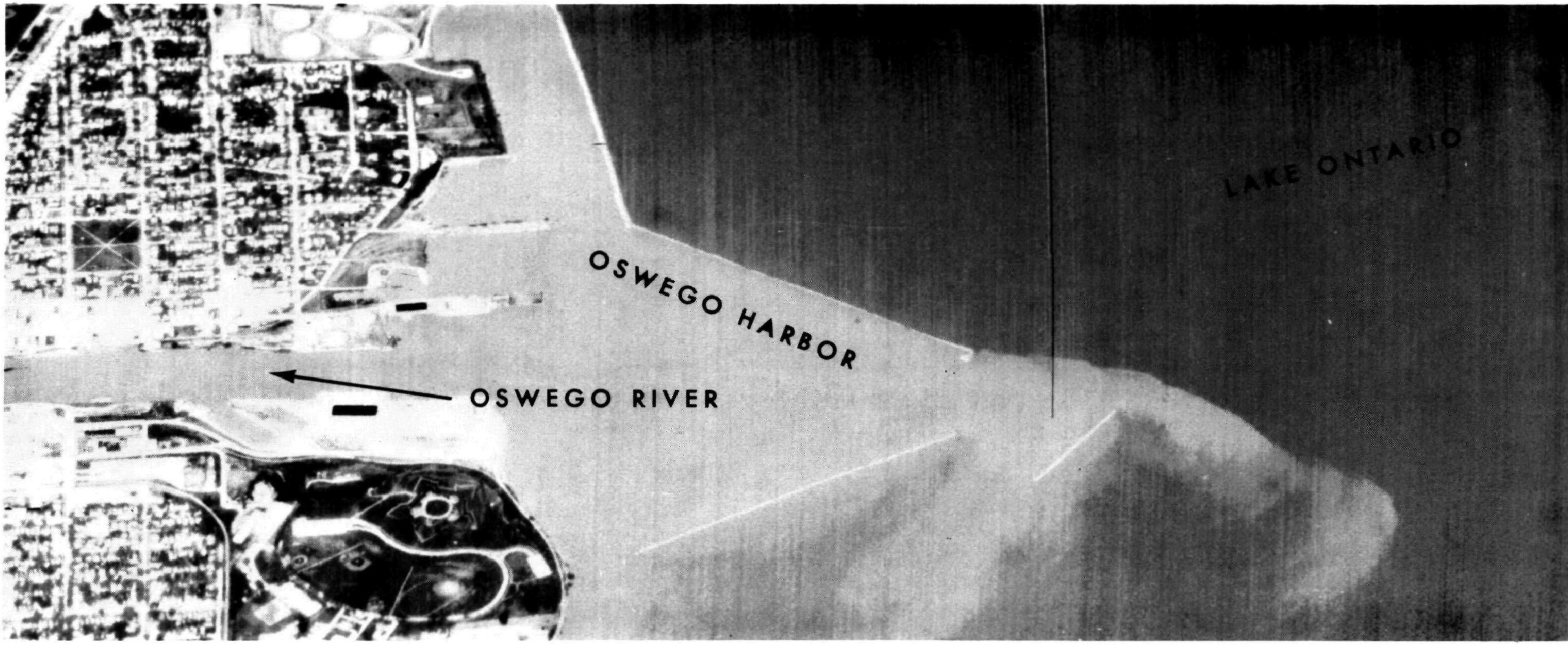


Figure V—11 Thermal Map of Oswego Harbor
1 August 1974

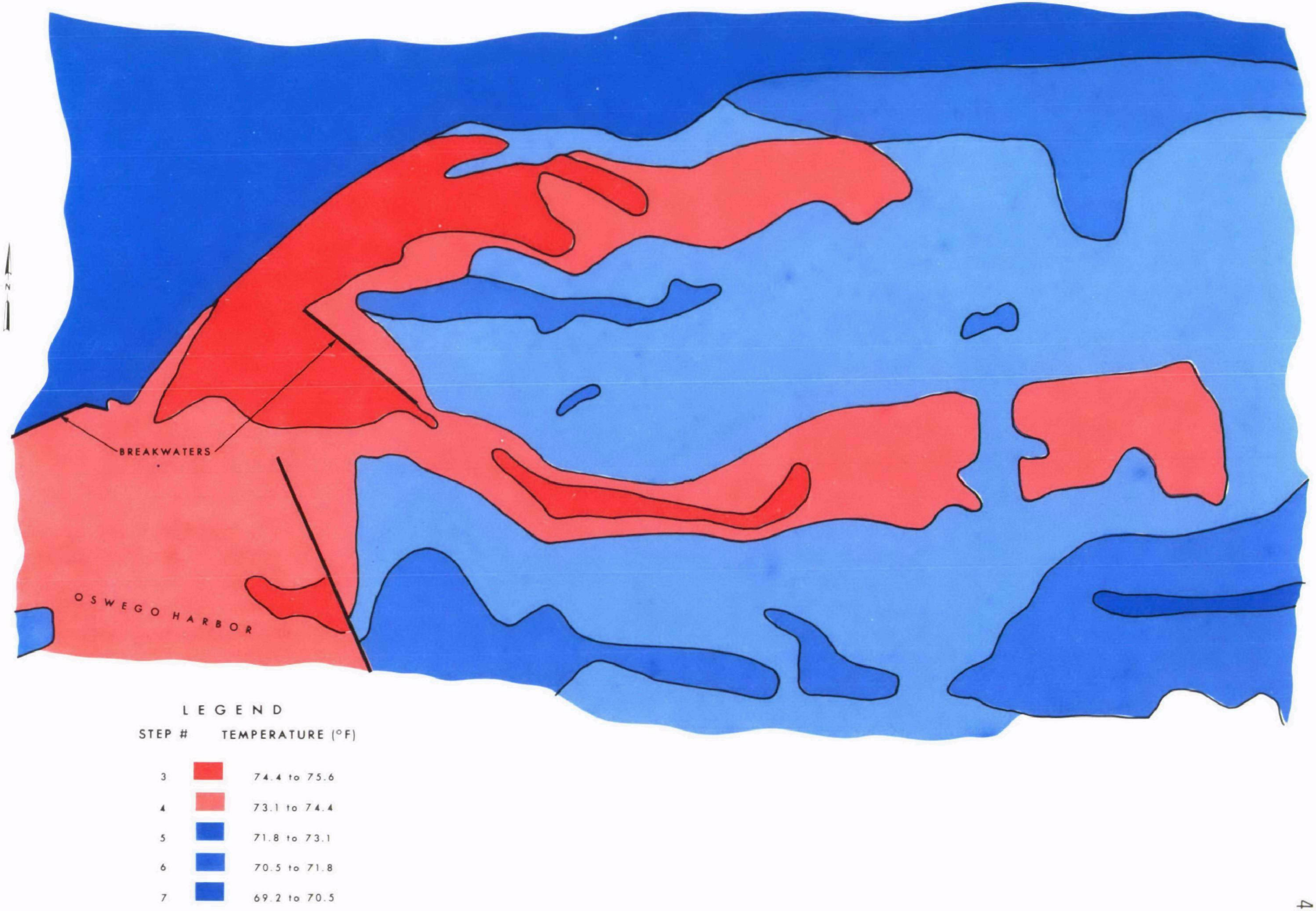


Figure V—12 Isarthermal Map of Oswego Steam Power Station/ Oswego River Thermal Discharge to Lake Ontario 30 July 1974

Table V-3

Summary of Isarthermal Data, Oswego Harbor, 30 July 1974[†]

Isartherm Number	Average Temperature of the Isartherm (°C)	Average Temperature of the Isartherm (°F)	Δt Above Background[††] (°C)	Δt Above Background[††] (°F)	Surface Area[†††] (Hectares)	Surface Area[†††] (Acres)	Percentage of Total Field Surface Area
1	>24.9	>76.9	>3.9	>7.0	--	--	--
2	24.6	76.3	3.6	6.4	--	--	--
3	23.9	75.0	2.8	5.1	10	24	6
4	23.2	73.8	2.2	3.9	29	73	18
5	22.5	72.5	1.4	2.6	47	114	29
6	21.8	71.2	0.7	1.3	--	--	--
7	20.8	69.9	--	--	--	--	--
Total					86	211	53

† *The temperatures of the intake and discharge waters were 21.1 and 25.0°C (70 and 77°F), respectively, at the time of flight with a discharge flow rate of 1,350,000 m^3/day (248,000 gpm).*

†† *The average value of the surface temperature of the background waters in this vicinity of Lake Ontario was 20.8°C (69.9°F).*

††† *1 hectare = 10,000 m^2 = 2.471 acres.*

because averages of the isarthermal temperature intervals were used in the data analysis.

The thermal field extended into the lake to the east of the Oswego Harbor. However, from the thermal data along this flight line it cannot be determined if the warm water was contiguous with the adjacent shoreline.

On 1 Aug. 1974, two sets of thermal imagery were recorded over the Oswego Steam Power Station and the Oswego Harbor at an altitude of 760 m (2,500 ft). Figure V-11 shows the thermal map recorded along a flight line parallel to the Oswego River and perpendicular to the lake shoreline (1445 hours EDT). The warm water from the power station and the Oswego River were flowing into Lake Ontario and moving in an easterly direction forming a thermal field. The easterly motion of the field was induced by the natural easterly lake currents and by a 16-24 km/hr (10-15 mph) northwesterly wind at the time of flight. The isarthermal map corresponding to Figure V-11 is Figure V-13. The total surface area of the thermal field from the mouth of the Oswego River out into the lake measured 146 hectares (360 acres). Again, it could not be determined what percentage of the total field was directly attributable to the Oswego River was in isartherm 3 with an average temperature of 23.9°C (75.0°F) [Fig. V-13]. The surface temperature of the harbor near the power station's discharge was in isartherm 2 with an average temperature of 24.6°C (76.3°F). The station's discharge flow rate is constant while the river experiences a large variation in flow rate during the summer months. River flow during the study, measured at a point 1.3 km (0.8 mi) upstream of the harbor, was as follows:

Oswego River Streamflow

Date (1974)	m^3/sec	cfs
30 July	125	4,420
31 July	160	5,660
1 Aug.	178	6,250
2 Aug.	221	7,810

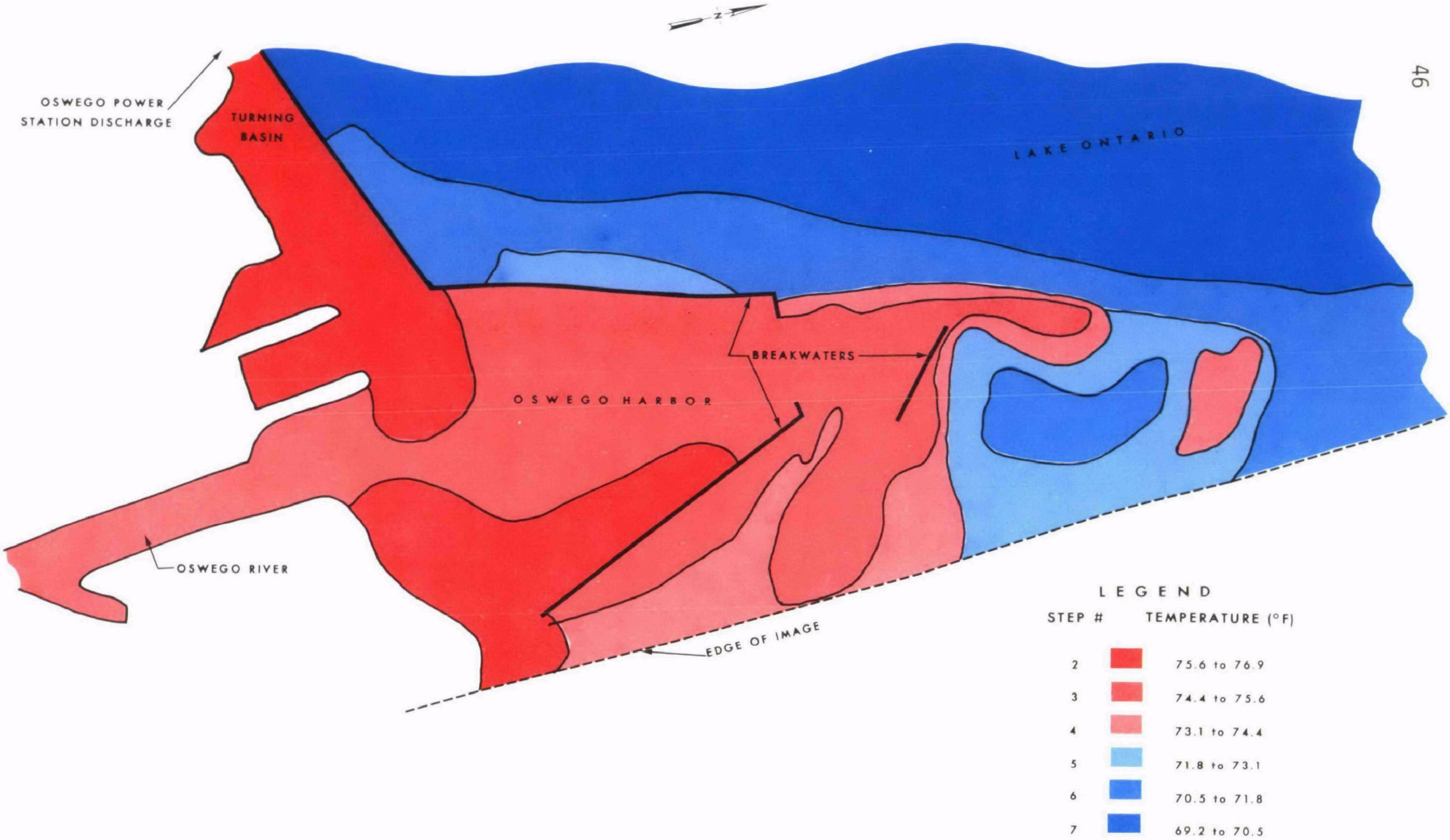


Figure V—13 Isarthermal Map of Oswego Steam Power Station/ Oswego River Thermal Discharge to Lake Ontario
1 August 1974

The power station flow rate was 16 m^3/sec (553 cfs), about 7-12% of the river flow during this period. However, the river flow has at times been significantly lower. For example, in 1971 the river flow rates varied from 105 m^3/sec (3,700 cfs) on 1 Aug. to 42 m^3/sec (1,500 cfs) on 15 Aug., and back to 71 m^3/sec (2,500 cfs) at the end of that month. At mid-month the power station discharge was 37% of the river flow and would have contributed a major portion of the resultant thermal field.

As given in Table V-4, 22% of the total field surface areas was 3.6°C (6.4°F) warmer than the average surface temperature of Lake Ontario, 67% was 2.2°C (3.9°F) warmer, and 79% was 1.4°C (2.6°F) warmer. Determination of how the proposed New York State Standards apply to this thermal field could not be made due to the influence of the Oswego River.

On 2 Aug. 1974, the Oswego Harbor was flown with an uncalibrated infrared (thermal) scanner. The thermal map obtained from that flight [Fig. V-14] is a photonegative of those presented earlier in this section; the warm areas in the water are dark gray while the colder areas are white. The influent from the Oswego River was cooler than the power station's thermal field moving into the Harbor (no ground truth was obtained during this flight, it was a target of opportunity). The river discharge was flowing between the easternmost breakwater and shore. The station's discharge was moving out into the Harbor and subsequently northward into Lake Ontario. It is also seen that the warm water from the Harbor was seeping through the west breakwater.

The entire shoreline from the Oswego Harbor to the Nine Mile Point area, about 13 km (8 mi), was also flown on 1 Aug. 1974 at 1436 hours EDT at an altitude of 760 m (2,500 ft). The thermal map for this area is divided into four segments and presented as Figures V-15 through V-18. The corresponding isarthermal maps are Figures V-19 through V-22. There is a continuous thermal field extending from Oswego Harbor through

Table V-4

Summary of Isarthermal Data, Oswego Harbor, 1 Aug. 1974†

Isartherm Number	Average Temperature of the Isartherm (°C)	Average Temperature of the Isartherm (°F)	Δt Above Background†† (°C)	Δt Above Background†† (°F)	Surface Area††† (Hectares)	Surface Area††† (Acres)	Percentage of Total Field Surface Area
1	>24.9	>76.9	>3.9	>7.0	--	--	--
2	24.6	76.3	3.6	6.4	43.4	107	22
3	23.9	75.0	2.8	5.1	71.1	176	37
4	23.2	73.8	2.2	3.9	15.0	37	8
5	22.5	72.5	1.4	2.6	22.3	55	12
6	21.8	71.2	0.7	1.3	--	--	--
7	20.8	69.9	--	--	--	--	--
Total					151.8	375	79

† *The temperatures of the intake and discharge waters were 21.7°C (71°F) and 24.4°C (76°F), respectively, at the time of flight with a discharge flow rate of 1,350,000 m^3/day (248,000 gpm).*

†† *The average value of the surface temperature of the background waters in this vicinity of Lake Ontario was 20.8°C (69.9°F).*

††† *1 hectare = 10,000 m^2 = 2.471 acres.*

PAGE NOT

AVAILABLE

DIGITALLY

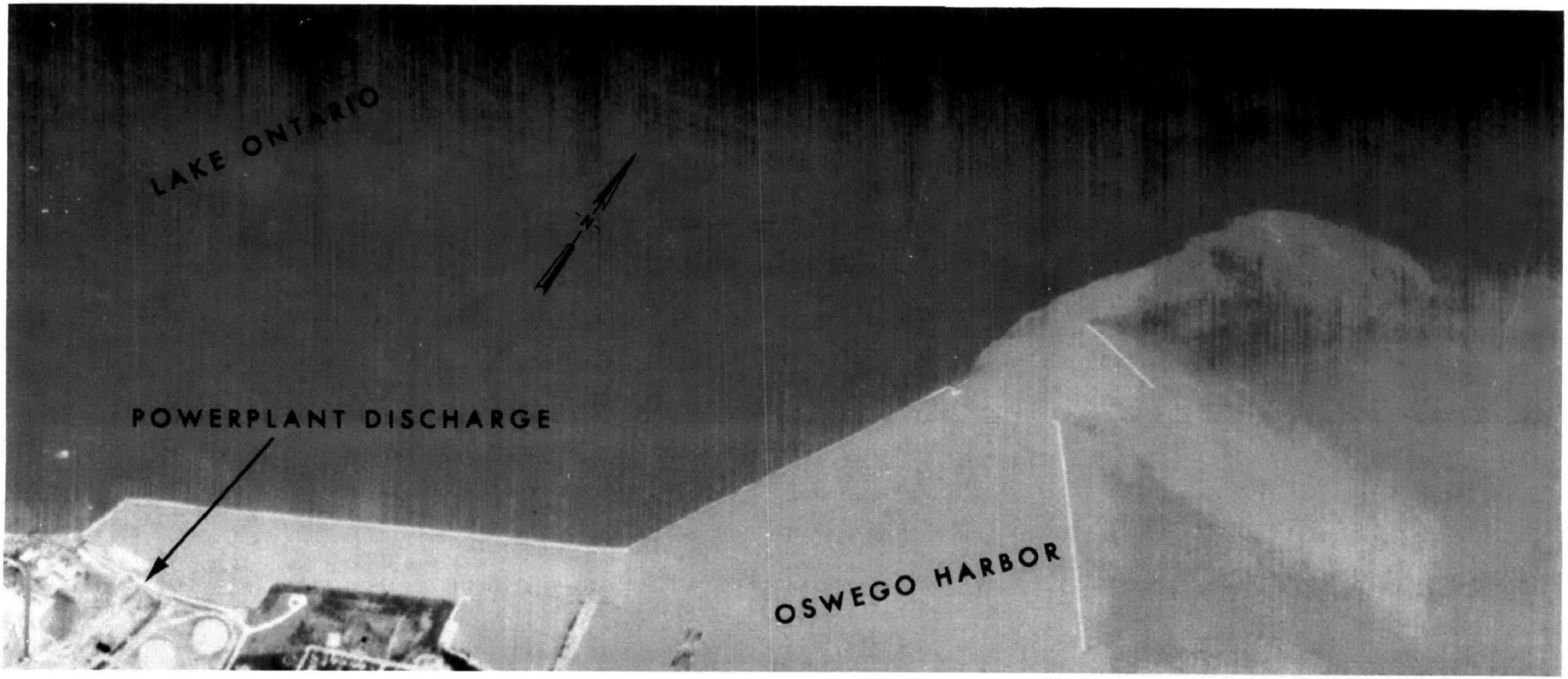


Figure V—15 Thermal Map of Lake Ontario Shoreline
(Section I: Oswego Harbor)

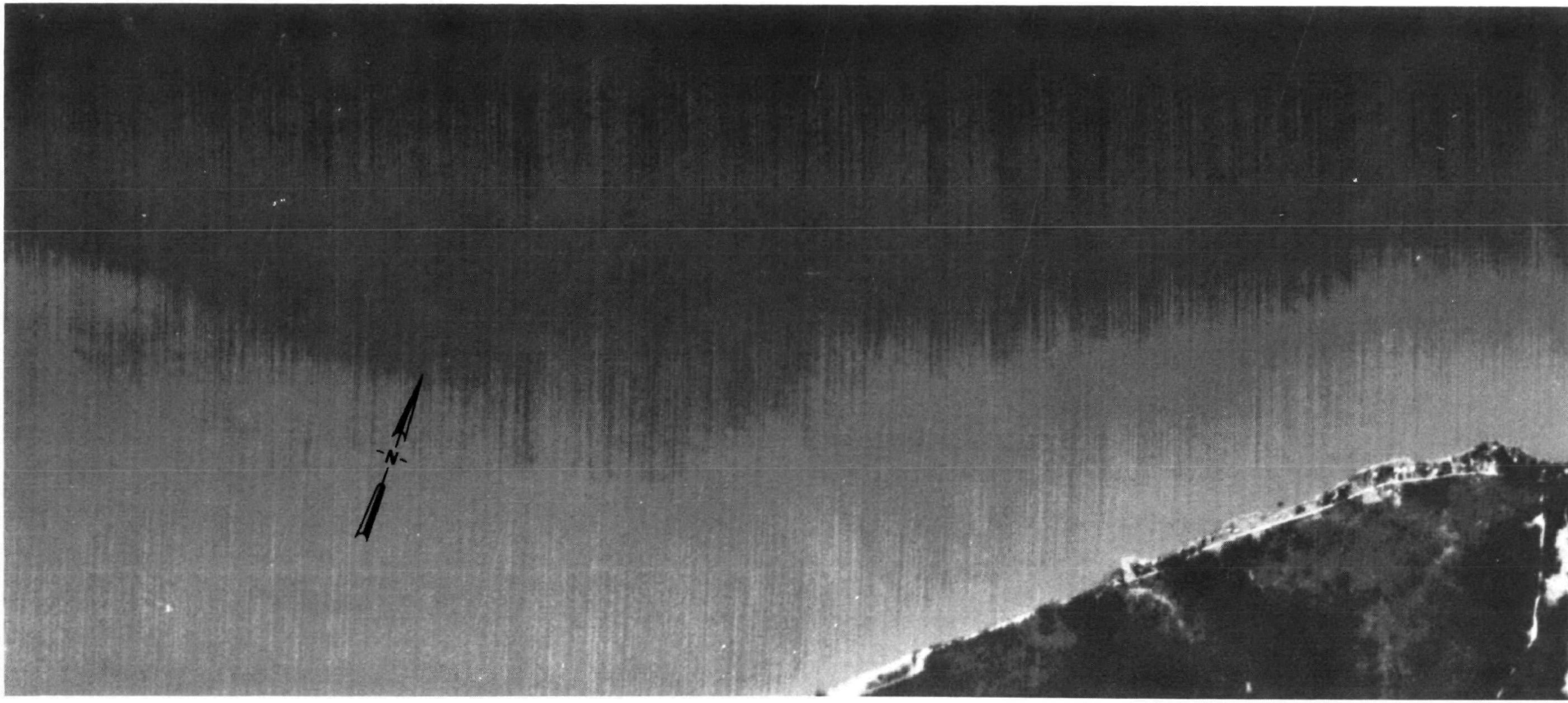


Figure V—16 Thermal Map of Lake Ontario Shoreline
(Section II)

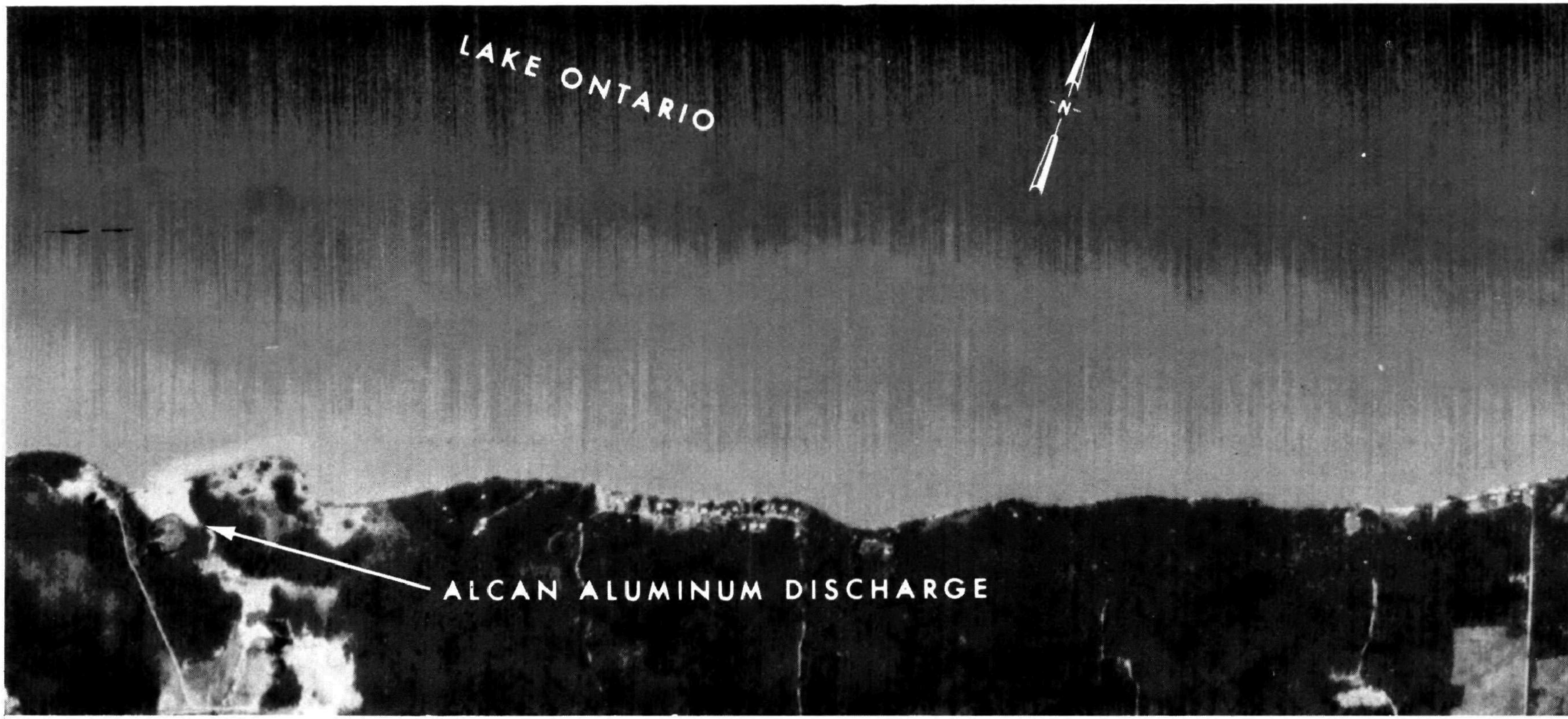


Figure V—17 Thermal Map of Lake Ontario Shoreline
(Section III: Alcan Aluminum Company)

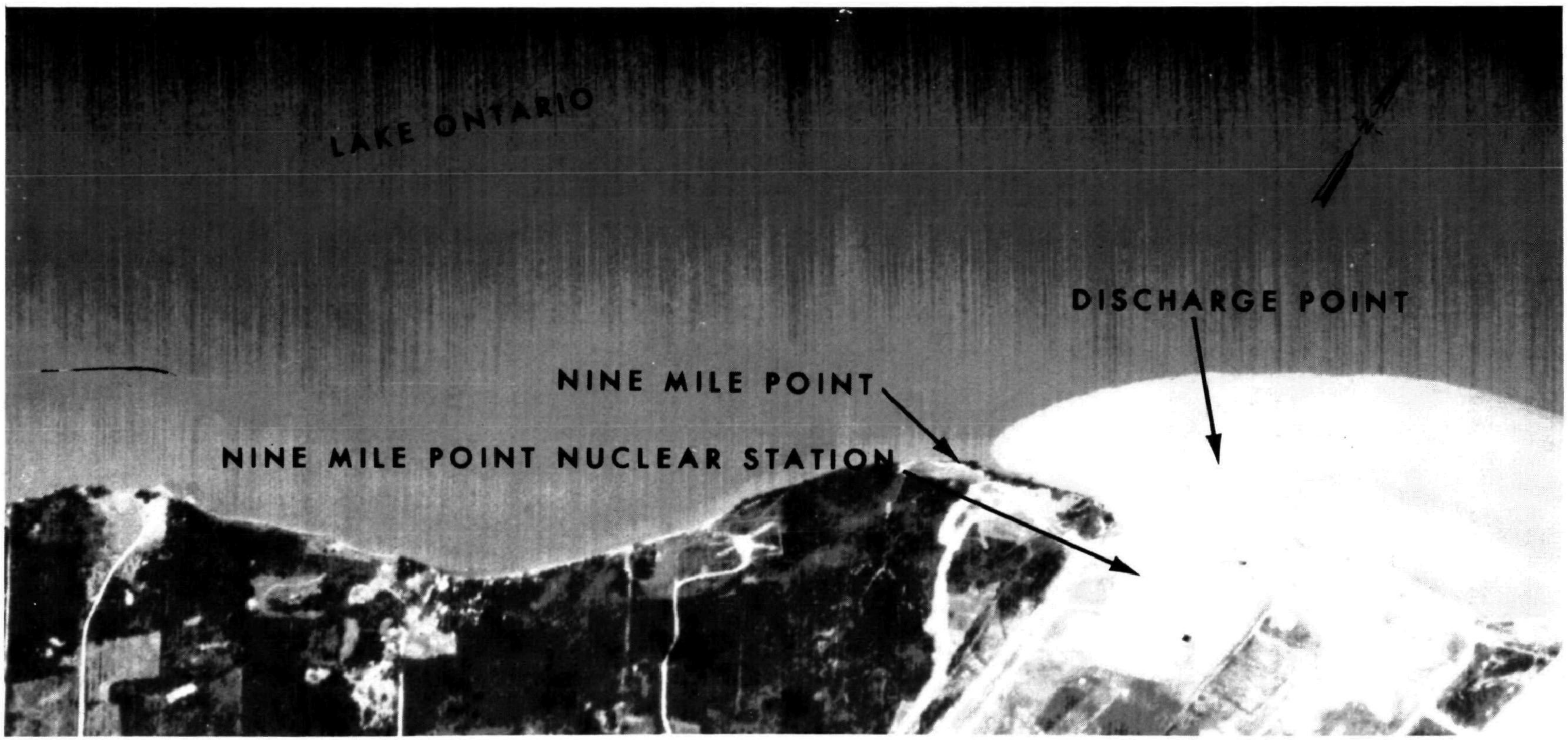
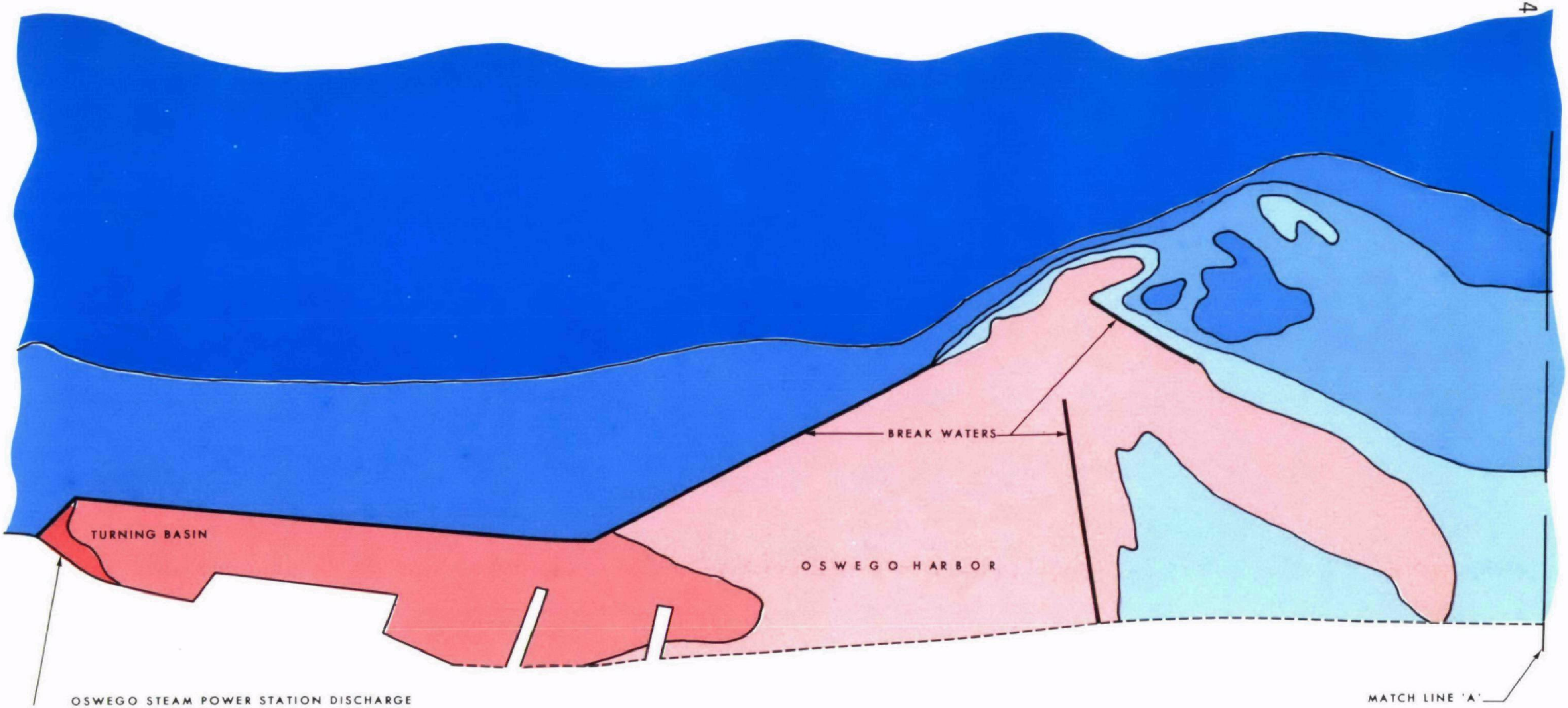


Figure V—18 Thermal Map of Lake Ontario Shoreline
(Section IV: Nine Mile Point)



LEGEND

STEP #	TEMPERATURE (°F)
1	76.9
2	75.6 to 76.9
3	74.4 to 75.6
4	73.1 to 74.4
5	71.8 to 73.1
6	70.5 to 71.8
7	69.2 to 70.5

Figure V—19 Isarthermal Map of Nearshore Waters of Lake Ontario
(Section I: Oswego Harbor)

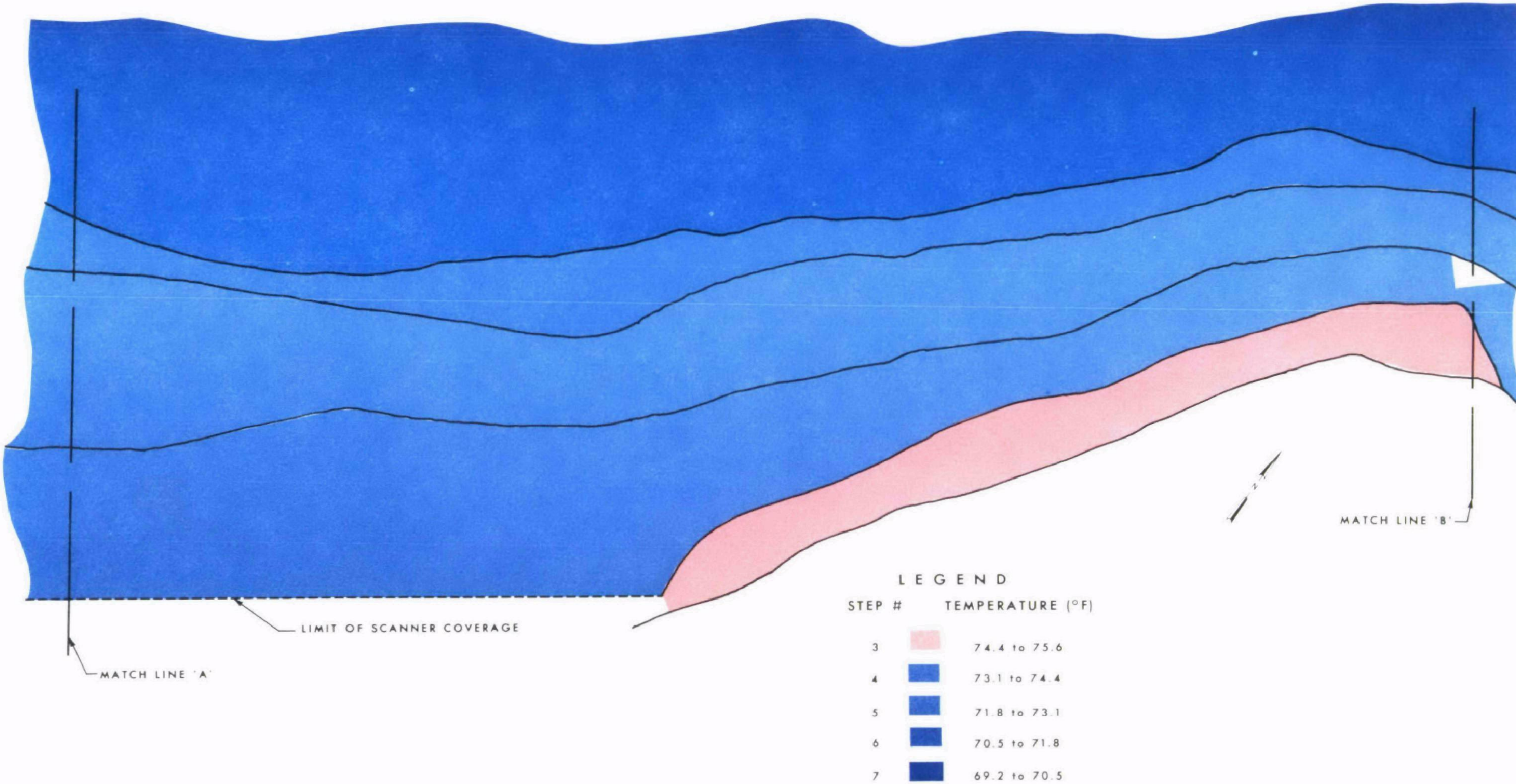


Figure V—20 Isarthermal Map of Nearshore Waters of Lake Ontario (Section II)

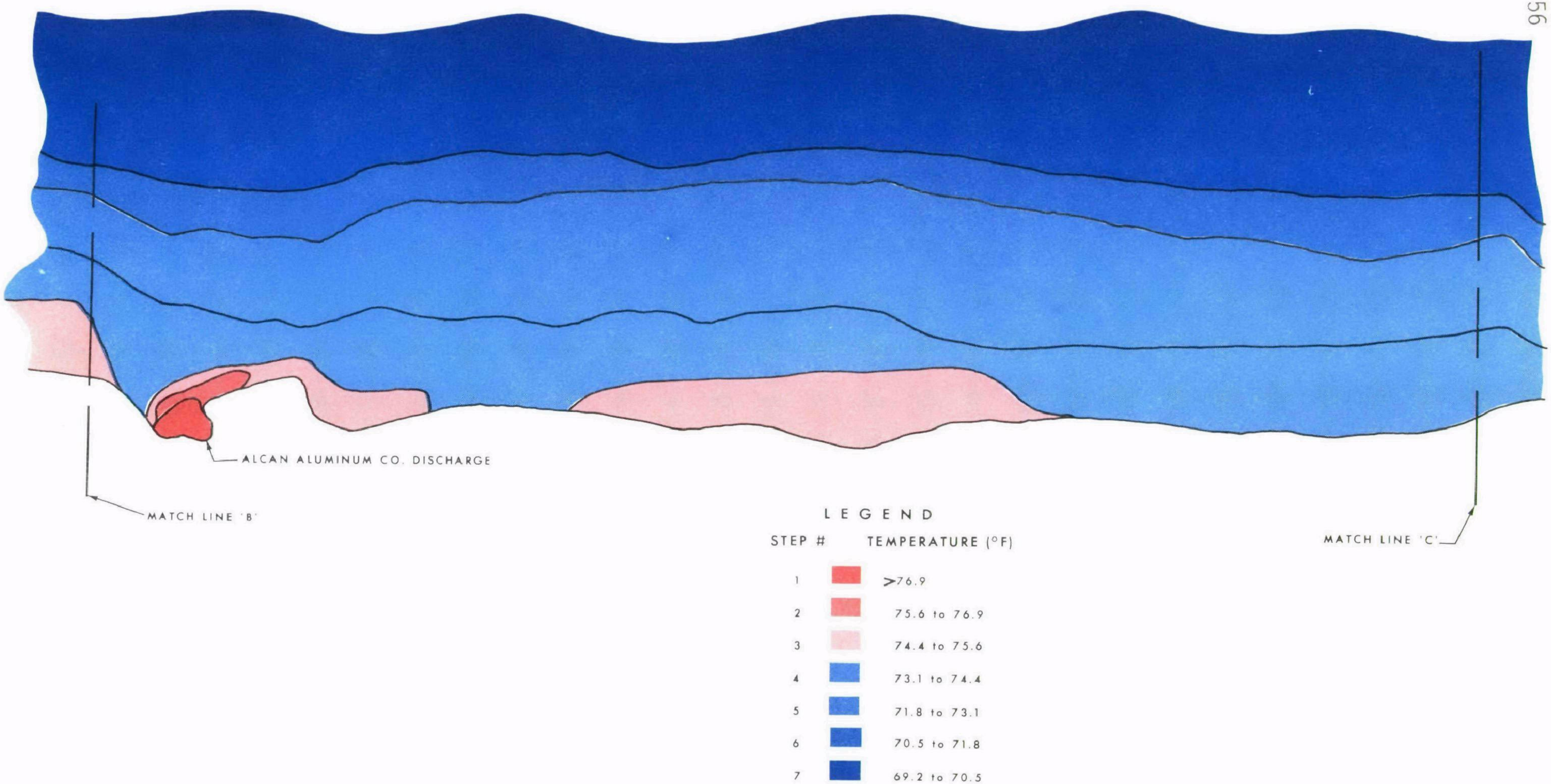


Figure V—21 Isarthermal Map of Nearshore Waters of Lake Ontario
(Section III: Alcan Aluminum Company)

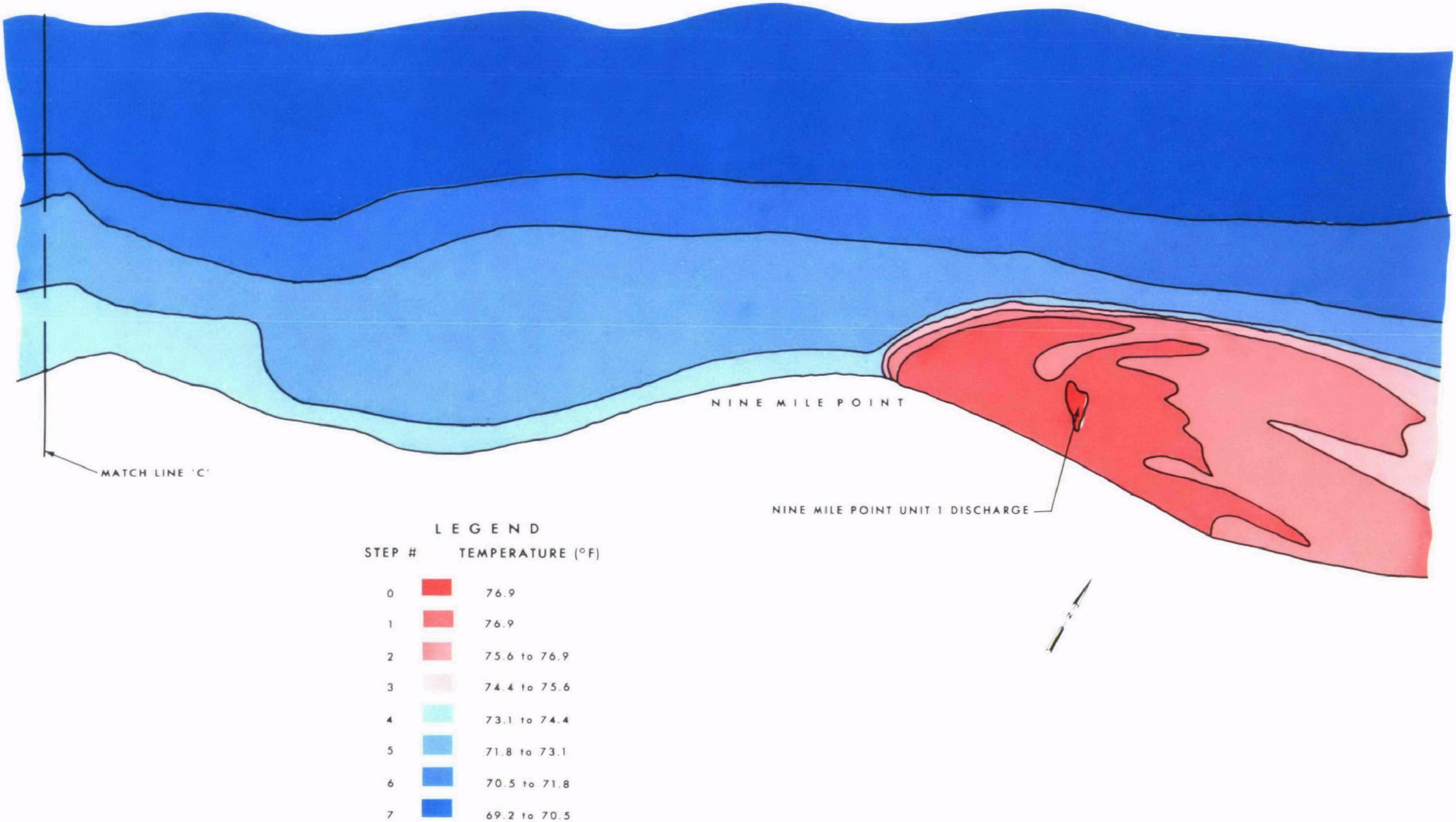


Figure V—22 Isarthermal Map of Nearshore Waters of Lake Ontario
(Section IV: Nine Mile Point)

the location of the Nine Mile Point Station. The surface temperature of the waters adjacent to shore mostly fall within isartherm 3 or 4, having average temperatures of 23.9°C (75.0°F) and 23.2°C (73.8°F), respectively. The average surface temperature of the background water was 21.1°C (69.9°F). The Oswego Steam Power Station's discharge is shown in Figures V-15 and V-19.

At the other end of this strip, the Nine Mile Point Nuclear Power Station discharge is shown in Figures V-18 and V-22. About in the center of this strip [Figs. V-17 and V-21], a thermal discharge was recorded which originated within the Alcan Aluminum Company facility. This discharge appeared to have a minor effect on the larger thermal field along shore. It is well known that nearshore waters are somewhat warmer than the ambient waters further out into a body of water. However, the average surface temperature of these nearshore waters ranges from 2.4-3.1°C (4.3-5.6°F) above the ambient lake temperature of 20.8°C (69.9°F).

This region is suspected to contain spawning and nursery areas for the fish of Lake Ontario. It is important to note that when Oswego Station's Unit 5 goes into operation later this year (spring 1975), the discharge of warm water from this facility could have significant impact on the warming of these nearshore waters to higher temperatures.

NINE MILE POINT NUCLEAR STATION - SCRIBA, NEW YORK

Description of Power Station

The Niagara Mohawk Power Corporation operates this nuclear-fueled steam power station at Nine Mile Point [Fig. V-1]. The plant is about 12 km (7.5 mi) east of the Oswego Steam Power Station, previously discussed, and is 910 m (3,000 ft) west of the Fitzpatrick Nuclear Plant, under construction. The Nine Mile Point Nuclear Station currently has one 610 MW (net) unit operating. Unit 2, with a generating capacity of 1,100 MW, is planned for construction about 1977.

Condenser cooling water use for Unit 1 is about 16 m^3/day (260,000 gpm). Cooling water supply is obtained from the lake through a submerged intake located about 370 m (1,200 ft) offshore in 8 m (25 ft) of water [Fig. V-23]. Heated water is returned to the lake through a submerged jet diffuser about 300 m (1,000 ft) offshore in 5 m (16 ft) of water. The cooling system is designed for a temperature rise of 17.8°C (32°F) across the condenser. At low ambient temperatures, some heated water is recirculated to the intake to prevent icing.

A second cooling water intake has been proposed for Unit 2 [Fig. V-23]. The heated effluents from both Units 1 and 2 with a flow rate of 50 m^3/day (803,000 gpm) would be discharged through a single large diffuser about 520 m (1,700 ft) offshore, eliminating the present discharge in shallower water.

This station's reactor is a boiling water type. The boiler water is radioactive and must be treated appropriately. All potential radioactive waste streams are filtered, demineralized, sampled and then discharged slowly into Lake Ontario. Boiler make-up water from the lake is demineralized and then treated with sulfuric acid and sodium hydroxide. The backwash is discharged into the lake.

The power station is shut down annually for refueling, usually in April or May.

The Fitzpatrick Nuclear Power Station using a boiling water reactor will go into operation by mid-1975. The location of its intake and discharge diffuser are shown in Figure V-23. This facility will provide a net generating capacity of 820 MW with a discharge (once-through cooling) flow rate of 23 m^3/day (370,000 gpm).

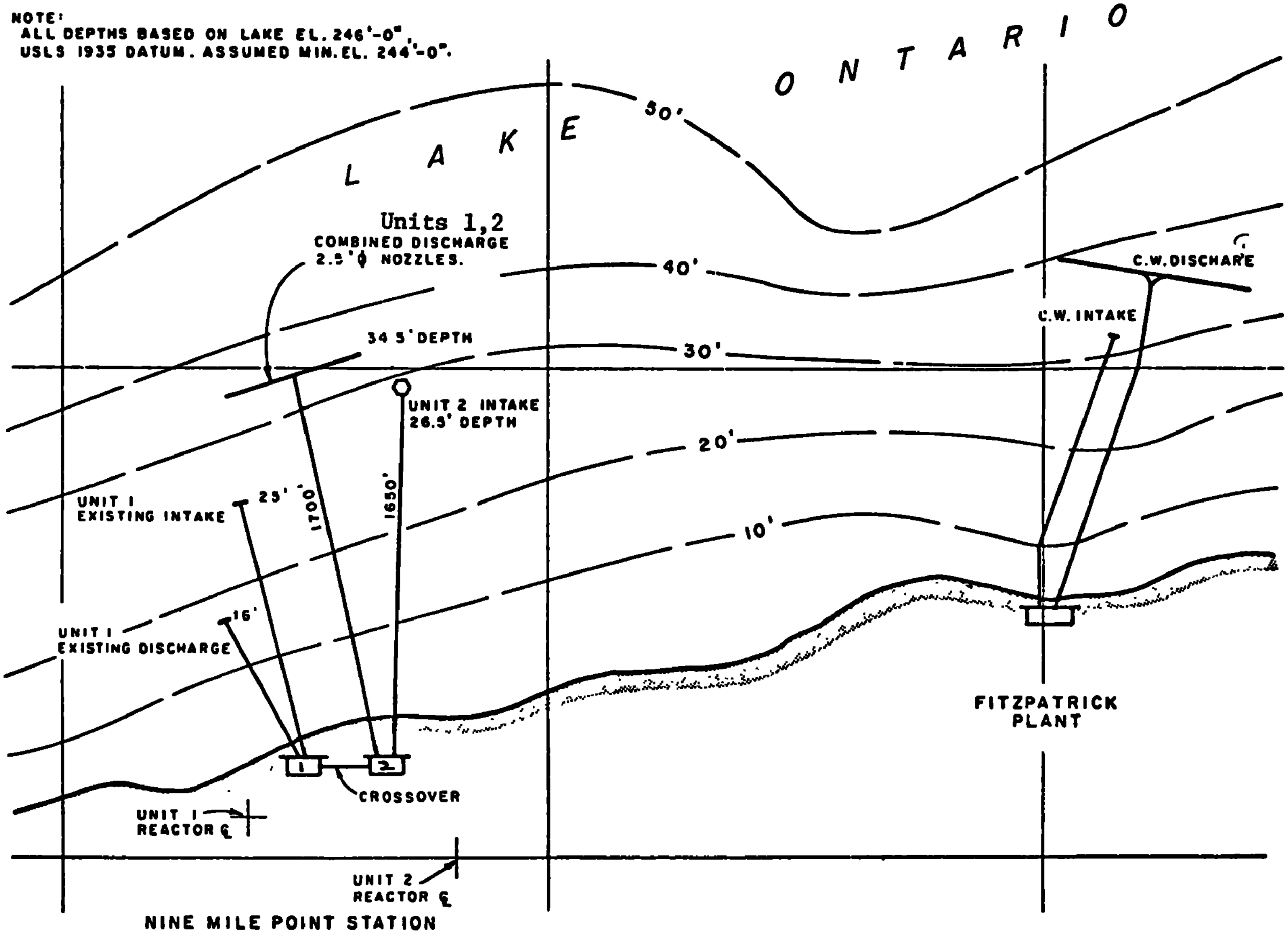


Figure V–23 Intake and Discharge Points for Nine Mile Point Nuclear Power Station

Observed Thermal Conditions

Thermal imagery of the nearshore waters at Nine Mile Point was recorded on 30 July 1974 and 1 Aug. 1974 at altitudes of 460 m (1,500 ft) and 760 m (2,500 ft) above water level. Thermal maps of this immediate area are provided as Figures V-24 and V-25.

Figure V-24 was recorded on 30 July 1974 at about 1348 hr EDT. The flight line was nearly centered over the submerged discharge and extended perpendicularly out from shore. This low-altitude flight path revealed that the thermal field, resulting from the star-shaped jet discharge pattern, moved away from shore about 0.5 km (1,600 ft) before being carried in an easterly direction toward Mexico Bay in the southeast corner of Lake Ontario. The wind ranging from 5 to 10 mph out of the northwest at flight time induced a current in the near surface waters that carried the field eastward. The thermal pattern in this immediate area, resulting from the jet diffuser, reveals five projections or fingers characteristic of this discharge.

The isarthermal map corresponding to Figure V-24 is provided as Figure V-26. The total surface area of the thermal field contained in this map was 666,900 m^2 (7,179,000 ft^2). The surface areas of each isartherm which have an average Δt of 1.4°C (2.6°F) minimum above ambient are provided in Table V-5. Of this section of the thermal field, 6% was at least 3.9°C (7.0°F) warmer than the ambient waters while 41% was 1.4°C (2.6°F) above ambient. Nearly 30% of the field in this map was 2.2°C (3.9°F) warmer than the ambient waters, which is in noncompliance with the proposed New York State Thermal Standards. No mixing zone has been established for the discharge. The warm water in this section of the overall thermal field was contiguous with the shoreline for a distance of 1.4 km (0.9 mi), which may be a spawning and nursery area for native fish.

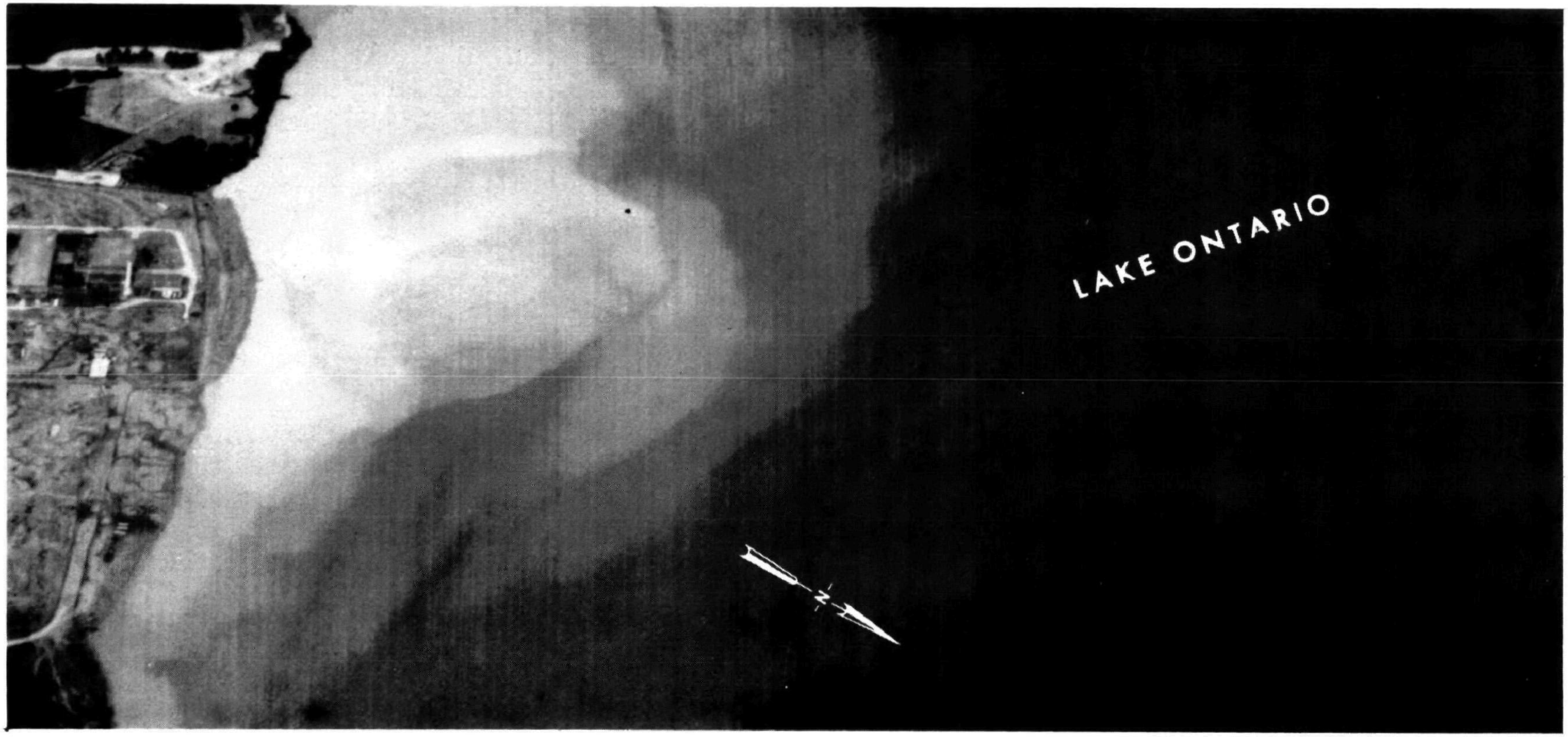


Figure V—24 Thermal Map of Nine Mile Point Nuclear Power Station Effluent
30 July 1974

PAGE NOT

AVAILABLE

DIGITALLY

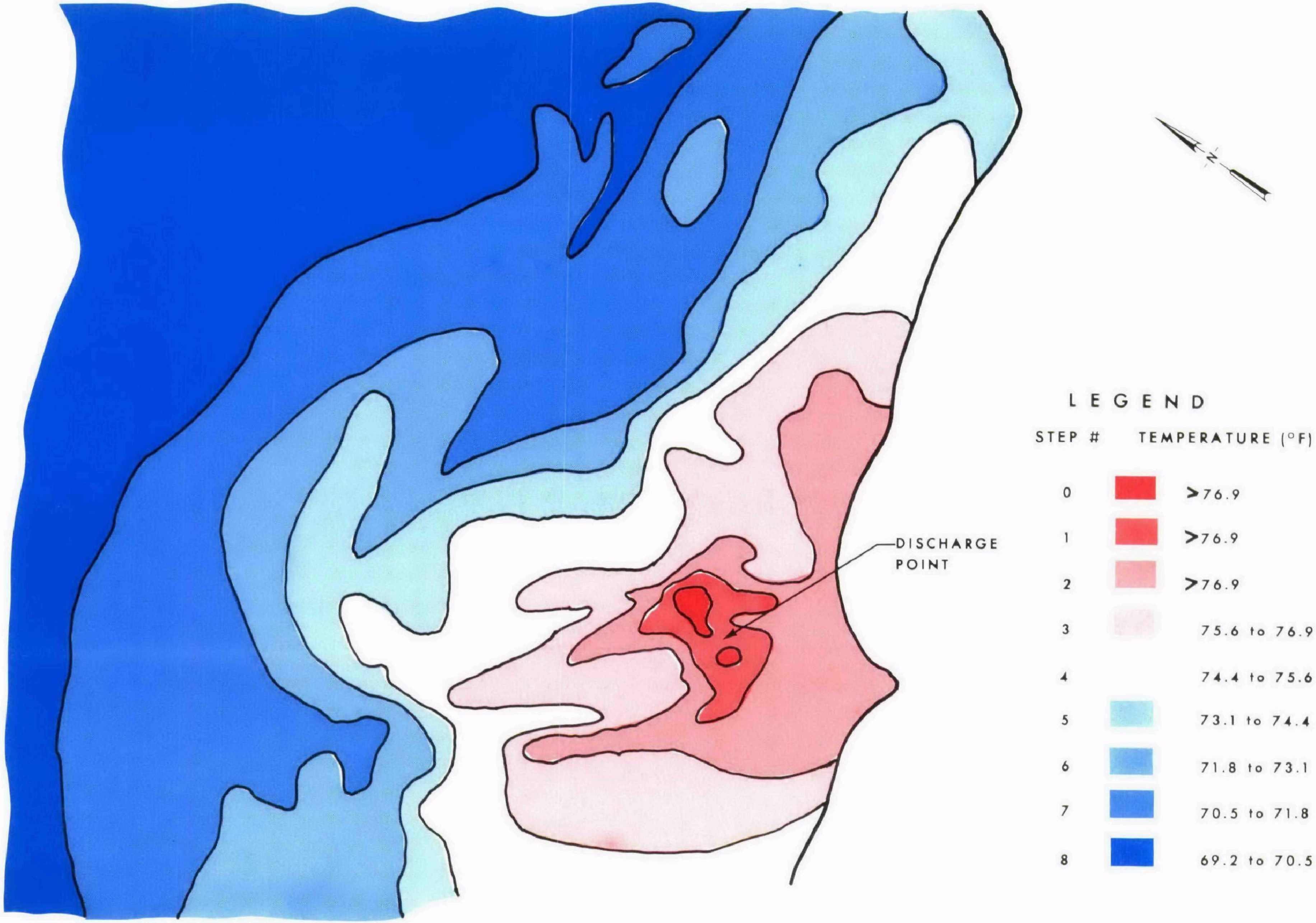


Figure V—26 Isarthermal Map of Nine Mile Point Unit 1 Discharge
30 July 1974

Table V-5

Summary of Isarthermal Data, Nine Mile Point, 30 July 1974†

Isartherm Number	Average Temperature of the Isartherm (°C)	(°F)	Δt Above Background†† (°C)	(°F)	Surface Area††† (Hectares)	(Acres)	Percentage of Total Field Surface Area
0	24.9	76.9	3.9	7.0	0.2	0.4	0.3
1	24.9	76.9	3.9	7.0	0.6	1.3	0.8
2	24.9	76.9	3.9	7.0	4	8	4.9
3	24.6	76.3	3.6	6.4	6	13	7.6
4	23.9	75.0	2.8	5.1	7	15	9.1
5	23.2	73.8	2.2	3.9	6	12	7.3
6	22.5	72.5	1.4	2.6	9	18	11.2
Total					33	68	∿41

† *The temperatures of the intake and discharge water were 19.4°C (67°F) and 37.2°C (99°F), respectively, at mission time with a discharge flow rate of 16.41 m^3/sec. (260,000 gpm).*

†† *The average value of the surface temperature of the background waters in this vicinity of Lake Ontario was 20.8°C (69.9°F).*

††† *1 hectare = 10,000 m^2 = 2.471 acres.*

On 1 Aug. 1974 (1509 EDT), thermal imagery was recorded along a flight line parallel to shore at Nine Mile Point and centered over the discharge [Fig. V-25]. These data were recorded at 760 m (2,500 ft) above water level. The thermal map [Fig. V-25] shows the fingerlike structure of the discharge pattern and the thermal field extending eastward alongshore. The field extended only 340 m (1,115 ft) into the lake but was carried eastward toward Mexico Bay parallel to shore for a minimum (due to image cutoff) distance of 5.5 km (3.4 mi). The field was moving in an easterly direction due for the most part to wind induced currents. The wind at the time of flight was from the northwest at a velocity of 24 km/h (15 mph). The isarthermal map derived from Figure V-25 is shown in Figure V-27.

The total surface area of the thermal field measured about 575 hectares (1,165 acres), excluding that to the left of isartherm 2, adjacent to the discharge which was due to the Oswego River/Oswego Steam Power Station thermal field [Fig. V-27]. The surface areas of each isartherm of Figure V-27, which have an average Δt of 1.4°C (2.6°F) minimum above the ambient waters, are given in Table V-6. Of the total thermal field, 6% was at least 3.9°C (7.0°F) warmer than the ambient surface waters, and about 25% of the total field was 2.2°C (3.9°F) above ambient; isartherm 5, being 33% of the total field, was 1.4°C (2.6°F). Since the analysis of the thermal data employed the average surface temperatures, it follows that a significant portion of this isartherm would have been 1.7°C (3.0°F) warmer than the ambient waters. About 58% of the total surface area of the thermal field was 1.4°C (2.6°F) warmer than ambient, most of which exceeded the 1.7°C (3.0°F) thermal limit of the New York State Proposed Thermal Standards.

During this mission, the thermal field was contiguous with about 4.2 km (2.6 mi) of shoreline which are presumed spawning and nursery areas for various species of native fish of Lake Ontario.

PAGE NOT

AVAILABLE

DIGITALLY

Table V-6

Summary of Isarthermal Data, Oswego Station, 1 Aug. 1974†

Isartherm Number	Average Temperature of the Isartherm		Δt Above Background††		Surface Area†††		Percentage of Total Field Surface Area
	(°C)	(°F)	(°C)	(°F)	(Hectares)	(Acres)	
0	>24.9	>76.9	>3.9	>7.0	1	2	0.2
1	>24.9	>76.9	>3.9	>7.0	34	68	5.9
2	24.6	76.3	3.6	6.4	45	90	6.7
3	23.9	75.0	2.8	5.1	21	43	3.7
4	23.2	73.8	2.2	3.9	49	100	8.7
5	22.5	72.5	1.4	2.6	188	380	33.0
Total					338	683	~58

† *The temperatures of the intake and discharge water were 19.4°C (67°F) and 37.2°C (99°F), respectively, at mission time with a discharge flow rate of 260,000 gpm.*

†† *The average value of the surface temperature of the background waters in this vicinity of Lake Ontario was 20.8°C (69.9°F).*

††† *1 hectare = 10,000 m^2 = 2.471 acres.*

Thermal imagery of the Nine Mile Point area recorded by other investigators was obtained for this report to provide additional data on thermal field behavior. Figure V-28 is a thermal map recorded on 22 June 1971. This shows a basic field movement/dispersion pattern similar to that of 1 Aug. 1974 [Fig. V-25]. The large thermal field to the left or west of Nine Mile Point Unit 1 was most probably from the combined warm waters of the Oswego River and the Oswego Steam Power Station. The general movement of the thermal field along shore [Fig. V-29] was in an easterly direction into Mexico Bay.

An isarthermal map derived from thermal imagery recorded on 22 July 1970 is shown in Figure V-29. The observed thermal plume was also similar to the plumes observed in this study. Figure V-30 is a thermal map of the area recorded on 2 Aug. 1974. In this map, black is warm and white is cold. This imagery is unique in that it shows the field resulting from the Nine Mile Point Unit 1 jet discharge moving directly northward out into the lake. At the time this imagery was recorded (1300 hr EDT), the winds were calm; thus no wind-induced currents in the near-surface waters were carrying the field eastward. Earlier in the day the winds were light and variable from the south.

In summary, the thermal images show that when the wind is blowing from the west, northwest, or north (predominant direction) the warm waters from the discharge are carried eastward into Mexico Bay, a known fish spawning and nursery area. During calm conditions or southerly winds, the field extends out into the lake.

When the Fitzpatrick Nuclear Power Station (spring 1975) and the Nine Mile Nuclear Power Station Unit 2 (1977-79) discharges go into operation, the warm water input into Lake Ontario at Nine Mile Point will be greatly increased. During the conditions of west to northwesterly winds, the thermal heating effect in Mexico Bay will be significantly increased. Also, warm surface waters from the Oswego area will probably move along shore to the Nine Mile Point vicinity. Under

PAGE NOT

AVAILABLE

DIGITALLY

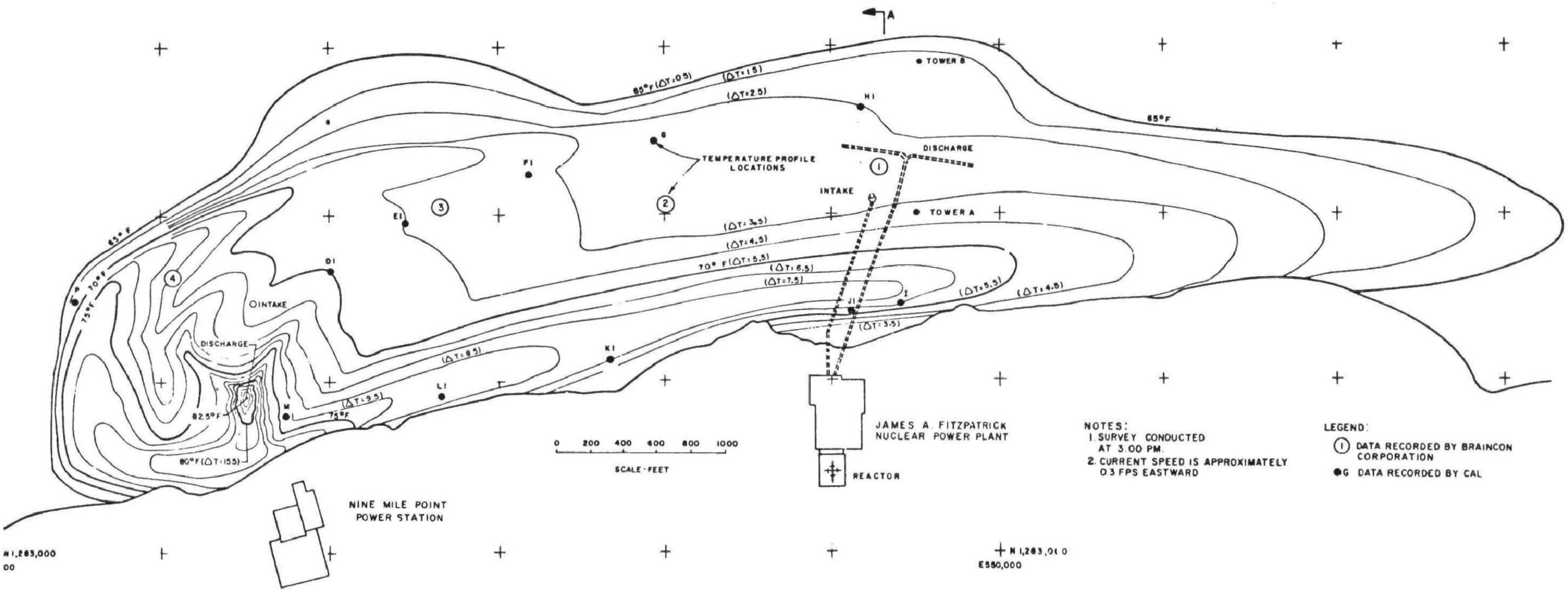


Figure V—29 Water Surface Temperatures Recorded from Infrared Radiation, 22 July 1970

PAGE NOT

AVAILABLE

DIGITALLY

predominant wind and current conditions, the thermal plume from the Nine Mile Point Nuclear Station will extend across the discharge point of the Fitzpatrick Nuclear Plant, and some interaction of plumes can be expected.

PAGE NOT

AVAILABLE

DIGITALLY